An Annotated Flood Risk Management Bibliography Focusing On Flood-Related CBA and MCA Literature

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In this bibliography each reference is annotated by means of an abstract which explains the content of the reference. The references are organised in the alphabetical order of the surname of the first author within discrete sections which structure the bibliography. These sections group together references addressing similar areas of benefit or impact as well as grouping together those references which address a general overview and theory. Where a reference covers more than one area of impact, a judgement has been about the predominant content so that the reference has been allocated to the grouping which represents this predominance. Users may need to consult one or more sections of the bibliography.

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FLOOD RISK MANAGEMENT

Climate change adaptations

Filatova, T. (2014) Market-based instruments for flood risk management: A review of theory, practice and perspectives for climate adaptation policy, Environmental Science and Policy, Vol 37, 227-242

Dynamic adaptation under spatial externalities, path-dependency and time lag are vital. Market-based instruments stimulate autonomous climate adaptation. International experience of MBIs provides positive and negative lessons. MBIs that are unattractive today may become feasible in the future. Climate change creates challenges for developments in coastal and delta areas. The risks are reduced more effectively if both planned and autonomous adaptations take place. Flood risk management is dominated by planned adaptation, which is primarily command-and-control in nature, e.g. spatial planning and engineered flood defences. If autonomous adaptation is downplayed people are more likely to make land-use choices that collectively lead to increasing flood risks while leaving the costs of adaptation and land scarcity with governments. Unless governments provide stimuli, autonomous adaptation in flood-prone areas is unlikely to happen due to spatial externalities, path-dependency and time lag between private investment decisions and consequences. This paper reviews the theory and practice of using market-based instruments (MBIs) for flood-risk management as means for autonomous climate change adaptation. While the use of MBIs for climate change mitigation is widely discussed, systematized reviews of various MBIs for climate change adaptation are rare. Yet, international experience shows that such measures as preferential taxes, non-perverse subsidies, flood insurance, marketable permits and transferable development rights can engage local stakeholders and provide price signals that stimulate individual adaptation. MBIs combined with command-based instruments help policy-makers to guide developments in flood-prone zone by affecting individual behaviour via market forces. As adverse consequences of climate change become more pronounced locally, quantity-based MBIs unfeasible at present should become more attractive. Price-based MBIs that are currently employed could be designed to strategically account for increasing climate-induced flood and erosion probabilities in coastal and delta areas.

Fratiniab, C.F., Geldofac, G.D., Kluckd, J. and P.S. Mikkelsen (2012) Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality, Urban Water Journal, Vol 9, 5, 317-331

Urban flood risk is increasing as a consequence of climate change and growing impervious surfaces. Increasing complexity of the urban context, gradual loss of tacit knowledge and decreasing social awareness are at the same time leading to inadequate choices with respect to urban flood risk management (UFRM). The European Flood Risk Directive emphasises the need for non-structural measures aimed at urban resilience and social preparedness. The Three Points Approach (3PA) provides a structure facilitating the decision making processes dealing with UFRM. It helps to accept the complexity of the urban context and promotes transdisciplinarity and multifunctionality. The 3PA introduces three domains wherein water professionals may act and where aspects valued by different stakeholders come into play: (1) technical optimisation, dealing with standards and guidelines for urban drainage systems; (2) spatial planning, making the urban area more resilient to future changing conditions; and (3) day-to-day values, enhancing awareness, acceptance and participation among stakeholders. Based on in-depth interviews conducted in The Netherlands and Denmark, we describe the complexity of decision making in practical UFRM and explain how the 3PA can be used when organising participatory processes. We introduce a theoretical framework characterising the large range of aspects involved in decision making related to UFRM and evaluate the usefulness of the 3PA in dealing with it. We conclude that the 3PA offers water managers and operators an efficient communication tool and thinking system, which helps to reduce complexity to a level suitable when organising strategy plans for UFRM and urban adaptation to climate change.

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Harries, T. (2012) The anticipated emotional consequences of adaptive behaviour – impacts on the take-up of household flood-protection protective measures, Environment and Planning, A 44, 649-668

Interviews were conducted with risk managers in a case-study area in England to determine the factors influencing the choice between more traditional, engineering based, adaptation to flood risk and those focussing on vulnerability reduction. The findings of in-depth analysis of these interviews have implications for climate change adaptation as a whole. They suggest that government policies to implement a broader range of adaptation measures might be hampered by institutional cultures formed when structural, engineered approaches were the norm. Political decentralisation and the fashion for public consultation exacerbate this effect, leaving decision-makers more responsive to the influence of those directly affected by natural hazards than they are to the needs of the wider population or to policy pronouncements by government.

Harries, T and E.C. Penning-Rowsell (2011) Victim pressure, institutional inertia and climate change adaptation: The case of flood risk, Global Environmental Change, 21, 1, 188-197

To follow

Merz, B., Aerts, J., Arnbjerg-Nielsen, K., Baldi, M., Becker, A., Bichet, A., Blöschl, G., Bouwer, L.M., Brauer, A., Cioffi, F., Delgado, J.M., Gocht, M., Guzzetti, F., Harrigan, S., Hirschboeck, K., Kilsby, C., Kron, W., Kwon, H-H., Lall, U., Merz, R., Nissen, K., Salvatti, P., Swierczynski, T., Ulbrich, U., Viglione, A., Ward, P.J., Weiler, M., Wilhelm, B. and M. Nied (2014) Floods and climate: emerging perspectives for flood risk assessment and management, Nat. Hazards Earth Syst. Sci., 14, 1921–1942

Flood estimation and flood management have traditionally been the domain of hydrologists, water resources engineers and statisticians, and disciplinary approaches abound. Dominant views have shaped; one example is the catchment perspective: floods are formed and influenced by the interaction of local catchment-specific characteristics, such as meteorology, topography and geology. These traditional views have been beneficial, but they have a narrow framing. In this paper we contrast traditional vies with broader perspectives that are emerging from an improved understanding of the climatic context of floods. We come to the following conclusions. (1) Extending the traditional, system boundaries (local catchment, recent decades, hydrological/hydraulic processes) opens up exciting possibilities for better understanding and improved tools for flood risk assessment and management. (2) Statistical approaches in flood estimation need to be complemented by the search for the causal mechanisms and dominant processes in the atmosphere, catchment and river system that leaves their fingerprints on flood characteristics. (3) Natural climatic variability leads to time-varying flood characteristics, and this variation may be partially quantifiable and predictable, with the perspective of dynamic, climate-informed flood risk management. (4) Efforts are needed to fully account for factors that contribute to changes in all three risk components (hazard, exposure and vulnerability) and to better understand the interactions between society and floods. (5) Given the global scale and societal importance, we call for the organisation of an international multi-disciplinary collaboration and data-sharing initiative to further understand the links between climate and flooding and to advance flood research.

Munaretto, S., Vellinga, P. and T. Hilde (2012) Flood Protection in Venice under Conditions of Sea-Level Rise: An Analysis of Institutional and Technical Measures, Coastal Management, Vol 40, 4, 355-380

It is widely acknowledged that in times of climate change loss of coastal resources and risk for human life can be minimized by implementing adaptation strategies. Such strategies need to encompass a balanced mix of non-structural (institutional) and structural (technical) measures based on sound scientific knowledge. This article discusses measures carried out to protect the city of Venice, Italy from flooding (locally known as “high water”), and reflects on their ability to anticipate a possible acceleration of sea-level rise as induced by climate change. It is based on scientific literature, legislative and policy documents of key institutions, reports and documents of organizations working on Venice issues, newspaper articles, and interviews. Our analysis shows that the synergic action of the hydraulic defense infrastructure under construction is in principle adequate to withstand a broad range of sea-level rise scenarios for the next 100 years. However, when the goal is to use these investments effectively major changes in the existing institutional arrangements will be required in the years to come. The

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Venice findings point out the difficulties and yet the importance of identifying and implementing both non-structural and structural measures to adapt to climate change.

Ojha, H. R., Sulaiman, V. R., Parvin, S., Dahal, K., Thapa, D., Mittal, N., Thompson, P., Bhatta, G., Duttl, G., Ghimire, L., and P. Aggarwal (2014) South Asian Agriculture Adapting to Climate Change? Evidence from the Indo-Gangetic Plains, Agroecology and Sustainable Food Systems, Vol 38, 5, 505-53

Despite growing scientific consensus that agriculture is affected by climate change and variability, there is still limited knowledge on how agricultural systems respond to climate risks under different circumstances. Drawing on three case studies conducted in the Indo-Gangetic Plains, covering Nepal, Bangladesh, and the Indian state of Punjab, this article analyzes agricultural adaptation practices to climate change. In particular, we examine how farmers and other agricultural actors understand and respond to climate change. We identify a variety of adaptation practices related to changes in cropping system, technological innovations, and institutional changes. We also explore key challenges related to such emerging adaptive innovation processes in the region.

Richards. T., Bohn, J. M., Downing, T., Guillerminet, M-L., Hizsnyik, E., Kasperson, R., Lonsdale, K., Mays, C., Nicholls, R., Olsthoorn, A., Pfeifle, G., Poumadere, M., Toth, F., Vafeidis, A., Van Der Werff, P. Yetkiner, I. (2006) Adaptation to Five Metres of Sea Level Rise, Journal of Risk Research, Vol 9, 5, 467-482

There is an unknown but probably small probability that the West-Antarctic Ice Sheet (WAIS) will collapse because of anthropogenic climate change. A WAIS collapse could cause a 5–6 metre global sea level rise within centuries. In three case studies, we investigate the response of society to the most extreme yet not implausible scenario, a five-metre sea level rise within a century, starting in 2030. The case studies combine a series of interviews with experts and stakeholders with a gaming workshop. In the Rhone delta, the most likely option would be retreat, with economic losses, perhaps social losses, and maybe ecological gains. In the Thames estuary, the probable outcome is less clear, but would probably be a mix of protection, accommodation and retreat, with parts of the city centre turned into a Venice of London. A massive downstream barrier is an alternative response. In the Rhine delta (the Netherlands), the initial response would be protection, followed by retreat from the economically less important parts of the country and, probably, from Amsterdam–Rotterdam metropolitan region as well. These impacts are large compared to other climate change impacts, but probably small compared to the impacts of the same scenario in other parts of the world. This suggests that the possibility of a anthropogenic-climate-change-induced WAIS collapse would strengthen the case for greenhouse gas emission reduction.

Vanderlinden, J-P., Batzan, J., Coates, T., Gonzales, D., Hissel, F., Kane, I., Koundouri, P., McFadden, L., Parker, D.J., Penning-Rowsell, E.C., Pietrantoni, L., Pescaroli, G., Gabriele, P., Bénédicte, R., Stithou, M. and N. Touili (2015) Non-structural approaches to coastal risk mitigation, in Coastal risk management in a changing climate, 1st edition edited by Barbara Zanuttigh, Robert Nicholls, Jean-Paul Vanderlinden, Richard Thompson, Hans Burcharth, 01/2015: chapter 5: pages 237-274 Elsevier.

Non-structural coastal risk mitigation options that deal with society-centered instruments have the potential to contribute jointly to coastal settlement safety through vulnerability reduction and resilience enhancement. The paradigmatic characteristics of vulnerability reduction approaches and resilience enhancement approaches are described. Thereafter, vulnerability reduction measures associated with the use of insurance-based, land use planning-based, business recovery plan-based, communication plan-based, post-flood management-based, and evacuation plan-based approaches are presented in terms of guidelines for implementation. Resiliency analysis of these approaches is conducted in parallel. This analysis leads to additional recommendations for implementing specific risk-reducing measures. The authors conclude by stressing the importance of three overarching characteristics of non-structural mitigation options. The first element that is central to all options lies in the need to adopt approaches that mobilize stakeholders in the implementation process. The second element that is central to all non-structural mitigation options is the fact that they increase safety through a direct reduction in the consequences of flooding. A third element that non-structural mitigation options share is the obvious fact that they interact strongly, showing the potential to transcend the sum of their individual contributions.

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Woodward, M., Kapelan, Z., and B. Gouldby (2014) Adaptive Flood Risk Management Under Climate Change Uncertainty Using Real Options and Optimization, Risk Analysis, Vol 34, 1, 75–92

It is well recognized that adaptive and flexible flood risk strategies are required to account for future uncertainties. Development of such strategies is, however, a challenge. Climate change alone is a significant complication, but, in addition, complexities exist trying to identify the most appropriate set of mitigation measures, or interventions. There are a range of economic and environmental performance measures that require consideration, and the spatial and temporal aspects of evaluating the performance of these is complex. All these elements pose severe difficulties to decision-makers. This article describes a decision support methodology that has the capability to assess the most appropriate set of interventions to make in a flood system and the opportune time to make these interventions, given the future uncertainties. The flood risk strategies have been explicitly designed to allow for flexible adaptive measures by capturing the concepts of real options and multi-objective optimization to evaluate potential flood risk management opportunities. A state-of-the-art flood risk analysis tool is employed to evaluate the risk associated to each strategy over future points in time and a multi-objective genetic algorithm is utilized to search for the optimal adaptive strategies. The modeling system has been applied to a reach on the Thames Estuary (London, England), and initial results show the inclusion of flexibility is advantageous, while the outputs provide decision-makers with supplementary knowledge that previously has not been considered.

Coastal flood risk

Chan, F., Adekola, O., Mitchell, G., Ng, C. and Mcdonald, A. (2013) Towards sustainable flood risk management in the Chinese coastal megacities. a case study of practice in the Pearl River delta, Irrigation and Drainage, Vol 62, 4, 501

This article analyses the current flood risk management practices in the Pearl River Delta (PRD), China. In the next four decades, 120 million people are expected to live in the region, which currently covers 11 major cities, and includes the coastal megacities formed by Hong Kong and Shenzhen. These populous low-lying coastal cities experience emerging flood risk from (i) intense precipitation, (ii) storm surges, (iii) global sea level rise and (iv) rapid urbanization in the flood-prone areas. These have major economic, social and ecological impacts and have made it imperative to adopt a sustainable flood risk management strategy to mitigate these risks. This research uses the case study in Tai O and Shenzhen River sites from Hong Kong and Shenzhen where in-depth discussions were held with various stakeholders to overview and understand current constraints to realizing sustainable flood risk management (SFRM). The outcome shows the authorities have realized the importance of SFRM and climate change adaptation strategies. They seek further improvement in managing flood risk and preparing for unpredictable climatic regimes in both megacities, and by extension comparable urbanizing coastal cities in the PRD and East Asia.

Dawson, R. J., Hall, J. W., Bates, P. D. and Nicholls, R. J. (2005) Quantified Analysis of the Probability of Flooding in the Thames Estuary under Imaginable Worst-case Sea Level Rise Scenarios, International Journal of Water Resources Development, Vol 21, 4, 577-591

Most studies of the impacts of sea level rise (SLR) have explored scenarios of < 1 m during the 21st century, even though larger rises are possible. This paper takes a different approach and explores and quantifies the likely flood impacts in the Thames estuary for a number of plausible, but unlikely, SLR scenarios. The collapse of the Western Antarctic Ice Sheet (WAIS) could cause global mean sea level to rise by 5–6 m; here a time-scale for such an event of 100 years is assumed to create a worst-case scenario. Combined with the 1 in 1000 storm surge event, this would result in 1000 km 2 of land being frequently inundated. This area currently contains 1 million properties and their inundation would result in direct damage of at least £97.8 billion at 2003 prices. Smaller SLR scenarios, resulting from a partial collapse of the WAIS over 100 years, also have significant potential impacts, demonstrating the vulnerability of the Thames estuary to SLR. Construction of a new storm surge barrier in the outer Thames estuary is shown to provide greater resilience to unexpectedly high SLR because of the additional large flood storage capacity that the barrier would provide. This analysis has, for the first time, connected

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mechanisms of abrupt climate change and SLR with hydrodynamic modelling used to quantify impacts. In particular, it is recognized that future management strategies need to be adaptive and robust in order to manage the uncertainty associated with climate change.

Fagherazzi, S., Fosser, G., D' Alpaos, L. and P. D' Odorico (2005) Climatic oscillations influence the flooding of Venice, Geophysical Research Letters, Vol 32, 19

A detailed analysis of the tidal regime in Venice, Italy, during the last century shows that the frequency and magnitude of high tides are correlated to interdecadal climatic oscillations. The monthly high tide maxima and the average elevation of all high tides are negatively correlated to the North Atlantic Oscillation (NAO), to the Arctic Oscillation (AO), to the East Atlantic – West Russian oscillation (EA-WR), and to the Polar Eurasia teleconnection (POL). The correlation is high during winter months for all four indices, whereas in the fall, when most of the city floods occur, the AO and the EA-WR exert a stronger influence on the tidal regime. During negative phases of the climate indices both the average elevation of high tides and the frequency of flooding increase consistently, with negative effects on the city and its monuments.

Galloway, J. A. (2009) Storm flooding, coastal defence and land use around the Thames estuary and tidal river c.1250–1450, Journal of Medieval History, Vol 35, 2, 171-188

Climatic deterioration in the later middle ages was associated with an increasing frequency of marine storm surges affecting the coasts of the southern North Sea. This paper investigates the impact of storm surges upon the lands bordering the Thames estuary and tidal river between the mid-thirteenth and mid-fifteenth centuries. Land use in the coastal and riverine marshes is reviewed, and the means and costs of defence against marine flooding explored. The impact of flooding upon human use of the marshlands, upon the suburbs of medieval London and upon the Thames fisheries are all investigated. Stress is placed upon the complex interaction of economic and environmental factors in determining the response to the threat of marine flooding. 1 This paper is a product of ongoing research, funded from January to June 2006 by the Crown Estate–Caird Fellowship scheme at the National Maritime Museum, Greenwich, and from March 2008–February 2010 by the Economic and Social Research Council in the project 'London and the Tidal Thames 1250–1550: Marine Flooding, Embankment and Economic Change' (Grant Ref: RES-000-22-2693), based at the Centre for Metropolitan History, Institute of Historical Research, University of London.

Hoggart, S.P.G., Hanley, M.E., Parker, D.J., Simmonds. D.J., Bilton, D.T., Filipova-Marinova, M., Franklin, E.L., Kotsev, I., Penning-Rowsell, E.C., Rundle, S.D., Trifonova, E., Vergiev, S., White, A.C. and R.C. Thompson (2014) The consequences of doing nothing: The effects of seawater flooding on coastal zones, Coastal Engineering, 87, 169–182

Sea level rise and an increased frequency and severity of storm surge events due to climate change are likely to increase the susceptibility of low lying coastal areas to seawater flooding. An integral part of any coastal management strategy throughout European countries is the "do nothing" scenario; this is the benchmark against which putative intervention strategies are evaluated. While the prime concern of a flood defense scheme appraisal often focuses on the sustained financial "benefits" of an intervention, intrinsic to a complete multi-criteria analysis is a comprehensive evaluation of the ecological and social consequences of coastal flooding, reflecting the needs of end users and satisfying relevant national and international policies. An ecological perspective may be usefully employed to examine the impact of the do nothing option on coastal environments (e.g. estuaries, sand dunes and grasslands) and businesses. Although at first sight coastal environmental and business systems appear quite different, they have similarities in that both are vulnerable and susceptible to flood damage or loss and both may be analyzed by employing ecological, adaptive, resilience frameworks. From an ecological perspective many coastal environments are of international conservation importance and provide important ecosystem services including coastal protection, nutrient cycling, carbon sequestration, food production and recreation. Nonetheless, despite their potential vulnerability to coastal flooding, our understanding of the effects of salinity on the biological response of many coastal plants and animals is extremely limited. We show here how plant physiology and patterns of plant and invertebrate distribution are impacted by

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sea water flooding. We also present responses of model plants to sea water inundation based on the Intergovernmental Panel on Climate Change (IPCC) (2007) predictions of sea level rise and storm surge events. Results showed that coastal habitats surveyed are relatively resilient to flooding due to their species rich nature and their ability to adapt to flooding. However specific groups of plants such as grasses are more affected by flooding and less able to recover. The socio-economic dimensions of doing nothing are addressed in relation to the impacts of coastal flooding specifically on business activity, which has received little attention to date. Here the focus is on the presence or absence of business disruption and recovery plans as a means of increasing a business's adaptation and resilience to flooding. Results show that some businesses, particularly small ones, are more likely to fail to recover from flooding due to lack of forward planning. Therefore from an ecological perspective business recovery post flooding is likely to be dependent upon ability to adapt, which itself depends upon the construction of resilient business environments.

Johnson, J. and E. Penning-Rowsell (2009) What really determines policy? An evaluation of outcome measures for prioritising flood and coastal risk management investment in England, Journal of Flood Risk Management, 3, 1, 25 – 32

In April 2008, outcome measures (OM) replaced the old priority scoring system for the prioritisation of flood and coastal erosion risk management (FCERM) capital expenditure in England. In the context of the governance arrangements for this investment, the purpose of this paper is to provide a critical evaluation of this change: (1) to assess the 'fitness for purpose' of OMs for achieving government policies and goals in the delivery of sustainable FCERM and (2) to examine the capacity of the Environment Agency's proposed methodology to deliver projects against the targets set. The analysis concludes that it is far from clear whether the new OM system will deliver all the targets; offers any greater transparency, clarity or accountability; offers 'better' value for money across the spectrum of projects; and matches the ambitious policy aims of the government or the appraisal system within which it is a part. More positively, OMs do offer important progress and are suggestive of the 'right' direction of travel.

Pontee, N.I. and Parsons, A (2010) A review of coastal risk management in the UK, Proceedings of the ICE - Maritime Engineering, Volume 163, Issue 1, 01 March 2010 , 31 –42.

This paper reviews the approaches that have been developed in the UK in order to deliver sustainable policies for managing risks from coastal erosion and flooding. One of the most important facilitators has been the adoption of a strategic framework at a national scale. This framework involves several scales of plans (shoreline management plans and strategy plans) as well as schemes. The recognition that funding sources are finite, and therefore need to be spent wisely, has also encouraged the development of more sustainable schemes. This has necessitated the development of a national appraisal methodology under which only the highest priority schemes achieve central government funding. The government also funds a national research programme to support flood and coastal erosion risk management. This paper gives examples of some of the outputs of this programme, which have included studies that have led to an improved understanding of coastal processes, coastal evolution, and risk levels, as well as the development of national data sets and management tools. The paper suggests some further improvements that could be made to the research programme. The discussion focuses on the likelihood of increasing choice of 'managed realignment' and 'no active intervention' policies in the future, their potential unpopularity with local stakeholders, and the current work under way to deal with these issues. The paper concludes with some thoughts on the priorities for coastal management over the next decade.

Sekovski, I., Armaroli, C., Calabrese, L., Mancini, F., Stecchi, F., and L. Perini (2015) Coupling scenarios of urban growth and flood hazards along the Emilia-Romagna coast (Italy), Nat. Hazards Earth Syst. Sci., 15, 2331-2346

The extent of coastline urbanization reduces their resilience to flooding, especially in low-lying areas. The study site is the coastline of the Emilia-Romagna region (Italy), historically affected by marine storms and floods. The main aim of this study is to investigate the vulnerability of this coastal area to marine flooding by considering the dynamics of the forcing component (total water level) and the dynamics of the receptor (urban areas). This was done by comparing the output of the three flooding scenarios (10, 100 and > 100 year return periods) to the

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output of different scenarios of future urban growth up to 2050. Scenario-based marine flooding extents were derived by applying the Cost–Distance tool of ArcGIS® to a high-resolution digital terrain model. Three scenarios of urban growth (similar-to-historic, compact and sprawled) up to 2050 were estimated by applying the cellular automata-based SLEUTH model. The results show that if the urban growth progresses compactly, flood-prone areas will largely increase with respect to similar-to-historic and sprawled growth scenarios. Combining the two methodologies can be useful for identification of flood-prone areas that have a high potential for future urbanization, and is therefore crucial for coastal managers and planners.

Contingency/emergency planning

Australian Government, Attorney General's Department (2009) Flood Preparedness, Australian Emergency Management Series, Manual 20. Available for download at http://www.bom.gov.au/australia/flood/EMA_Flood_preparedness_manual.pdf. Accessed on 23 Jan 2015

The Guide is designed for use by all those who have roles to play in preparing communities for floods, whether in lead or supporting agencies. These people will include emergency management practitioners and members of agencies and organisations that will be involved in flood response operations, including staff and volunteers in the State/Territory Emergency Service (S/TES) organisations which in most jurisdictions in Australia have a lead role in the management of floods. The document is intended to provide broad guidance on all the important aspects of flood preparedness. It reflects considerable expertise developed over many years of flood planning and other facets of flood preparedness in the Australian states and territories. Like the other documents in the Australian Emergency Manual Series (Managing the Floodplain, Flood Warning, Flood Response and Emergency Management Planning for Floods Affected by Dams), the Guide focuses on defining 'best practice' as this is presently understood in Australia. It does not seek to define or describe current practices, which may vary considerably between jurisdictions. Users will find it valuable to refer to the companion documents and to other documents in the Australian Emergency Manuals series.

The other Guides in this series are:

Australian Emergency Manual Series structure and content
Principles and reference manuals
Manual 2 Australian Emergency Management Arrangements
Manual 3 Australian Emergency Management Glossary
Manual 4 Australian Emergency Management Terms Thesaurus
Manual 18 Community and Personal Support Services
Manual 29 Community Development in Recovery from Disaster
Manual 15 Community Emergency Planning
Manual 27 Disaster Loss Assessment Guidelines
Manual 9 Disaster Medicine
Manual 28 Economic and Financial Aspects of Disaster Recovery
Manual 8 Emergency Catering
Manual 1 Emergency Management Concepts and Principles
Manual 23 Emergency Management Planning for Floods Affected by Dams
Manual 5 Emergency Risk Management—Applications Guide
Manual 43 Emergency Planning
Manual 11 Evacuation Planning
Manual 22 Flood Response
Manual 21 Flood Warning
Manual 25 Guidelines for Psychological Services: Emergency Managers Guide
Manual 26 Guidelines for Psychological Services: Mental Health Practitioners Guide
Manual 44 Guidelines for Emergency Management in Culturally and Linguistically Diverse Communities
Manual 13 Health Aspects of Chemical, Biological and Radiological Hazards
Manual 6 Implementing Emergency Risk Management—A facilitators guide to working with committees and communities

Manual 42 Managing Exercises
Manual 19 Managing the Floodplain
Manual 17 Multi-Agency Incident Management
Manual 31 Operations Centre Management
Manual 7 Planning Safer Communities—Land Use Planning for Natural Hazards
Manual 14 Post Disaster Survey and Assessment
Manual 10 Recovery
Manual 24 Reducing the Community Impact of Landslides
Manual 12 Safe and Healthy Mass Gatherings
Manual 41 Small Group Training Management
Manual 16 Urban Search and Rescue—Capability Guidelines for Structural Collapse
Skills for emergency services personnel manuals
Manual 38 Communications
Manual 39 Flood Rescue Boat Operation
Manual 37 Four Wheel Drive Vehicle Operation
Manual 35 General and Disaster Rescue
Manual 33 Land Search Operations (refer to website http://natsar.amsa.gov.au/Manuals/index.asp.)
Manual 32 Leadership
Manual 36 Map Reading and Navigation
Manual 34 Road Accident Rescue
Manual 30 Storm and Water Damage Operations
Manual 40 Vertical Rescue

Colbourne, L. (2009) Collaboration with civil contingency partners and communities for improved FCERM outcomes, Improving Institutional and Social Responses to Flooding, Science Report: SC060019 Work Package 3. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290965/scho0509bqbp-e-e.pdf on 22 Jan 2015

Recent efforts to cope with and recover from major floods in the UK have mainly been successful where professional partners and communities have worked together. Collaboration will become more important with the need to prepare for future flooding in the UK. This report summarises work carried out under Work Package 3 of the project Improving Institutional and Social Responses to Flooding. The overall aim of this work package was 'to understand what is needed to achieve a successful partnership with the Environment Agency's professional partners (as defined under the Civil Contingencies Act) in effectively responding to a flood incident. And in the light of this information, to provide whatever practical tools and guidance might be useful for developing the institutional capacity required, so that staff can work more effectively in partnership in flood incidents across England and Wales.' The focus on 'partnership with professional partners' was later broadened to encompass 'collaboration with professional partners and communities'.

Kolen, B. and Helsloot, I. (2014) Decision-making and evacuation planning for flood risk management in the Netherlands, Disasters, Vol 38, 3, 610

A traditional view of decision-making for evacuation planning is that, given an uncertain threat, there is a deterministic way of defining the best decision. In other words, there is a linear relation between threat, decision, and execution consequences. Alternatives and the impact of uncertainties are not taken into account. This study considers the 'top strategic decision-making' for mass evacuation owing to flooding in the Netherlands. It reveals that the top strategic decision-making process itself is probabilistic because of the decision-makers involved and their crisis managers (as advisers). The paper concludes that deterministic planning is not sufficient, and it recommends probabilistic planning that considers uncertainties in the decision-making process itself as well as other uncertainties, such as forecasts, citizens responses, and the capacity of infrastructure. This results in less optimistic, but more realistic, strategies and a need to pay attention to alternative strategies.

Lumbroso, D.M., Di Mauro, M., Tagg, A.F., Vinet, F. and K. Stone (2012) FIM FRAME: a method for assessing and improving emergency plans for floods, Nat. Hazards Earth Syst. Sci., 12, 1731-1746

Over the past decade Europe has been hit by a number of severe flood events. Reviews of recent large flood events in England and France have indicated that there is room for improvement in the emergency planning for floods. Methods that can be used for the systematic assessment and improvement of emergency plans are extensively documented in readily available literature. However, those that do exist are often limited to appraising the content of the plans rather than the process that the plan should guide. This paper describes research to develop a systematic method for assessing and improving emergency plans, which is called the FIM FRAME method. The development of the method was informed by research carried out with stakeholders in France, the Netherlands and England, as well as an appraisal of available tools that can be used to develop and improve plans, and an analysis of a selection of flood emergency plans from the three countries. One of the fundamental requirements of the FIM FRAME method was that it should be able to be applied by the relevant stakeholders to a range of emergency plans that mainly focus on flooding. The method comprises a series of steps (known as Appraise, Tackle and Implement) that can assist stakeholders with assessing and improving emergency plans. The method was piloted in the three countries and then refined following feedback from end users. This paper describes the development of the FIM FRAME method and its application in three case studies affected by different types of floods.

Molinari, D., Ballio, F. and S. Menoni (2013) Modelling the benefits of flood emergency management measures in reducing damages: a case study on Sondrio, Italy, Natural Hazards and Earth System Sciences, Vol 13, 8, 191

The European "Floods Directive" 2007/60/EU has produced an important shift from a traditional approach to flood risk management centred only on hazard analysis and forecast to a newer one which encompasses other aspects relevant to decision-making and which reflect recent research advances in both hydraulic engineering and social studies on disaster risk. This paper accordingly proposes a way of modelling the benefits of flood emergency management interventions calculating the possible damages by taking into account exposure, vulnerability, and expected damage reduction. The results of this model can be used to inform decisions and choices for the implementation of flood emergency management measures. A central role is played by expected damages, which are the direct and indirect consequence of the occurrence of floods in exposed and vulnerable urban systems. How damages should be defined and measured is a key question that this paper tries to address. The Floods Directive suggests that mitigation measures taken to reduce flood impact need to be evaluated also by means of a cost–benefit analysis. The paper presents a methodology for assessing the effectiveness of early warning for flash floods, considering its potential impact in reducing direct physical damage, and it assesses the general benefit in regard to other types of damages and losses compared with the emergency management costs. The methodology is applied to the case study area of the city of Sondrio in the northern Alpine region of Italy. A critical discussion follows the application. Its purpose is to highlight the strengths and weaknesses of available models for quantifying direct physical damage and of the general model proposed, given the current state of the art in damage and loss assessment.

Flood cases and scenarios

Barry, J.M. (1998) Rising Tide. The Great Mississippi Flood of 1927 and How it Changed America, A Touchstone Book, Simon & Schuster, New York

The epic story of the 1927 Mississippi flood and of science, politics, race, honour and high society. The book tells the story of the greatest natural disaster that the United States has experienced. The river flooded the homes of nearly 1 million people, helped Huey Long get elected as Governor and made Herbert Hoover President. It also drove hundreds of thousands of black people north and transformed American society and politics forever. The story captures the panic, the desperation and the suffering of those affected. This is also a story of the flood control doctrine – the attempt by man to dictate to the river and the engineers of the US Army Corps of Engineers

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that attempted to do so. The book reads like a novel but is factual and is, in effect, a classic about a great flood and flood control.

Baxter, P.J. The east coast Big Flood, 31 January–1 February 1953: a summary of the human disaster, Phil. Trans. R. Soc. A (2005) 363, 1293–1312 Available at: sta.royalsocietypublishing.org/content/roypta/363/1831/1293.full.pdf. Accessed on 22 Jan 2015

The Big Flood was the worst natural disaster to befall Britain during the twentieth century, and the scale of its human impact was due to the lack of adequate disaster preparedness. The 307 deaths on land were caused by drowning or from the effects of exposure. Two-thirds occurred in four clusters along the shoreline and mainly comprised inhabitants of post-war prefabricated buildings, bungalows and chalets, with the highest mortality among the elderly. The emergency response was spontaneous and community led, with the main search and rescue completed before central government became involved. No individuals or agencies were blamed for the neglected state of the flood defences or the absence of warnings, along with the post-war shortage of adequate housing, which were the main causes of vulnerability. The media played a limited role, and television was in its infancy. Mental health impacts were either self-limiting or failed to be articulated in a society recovering from the Second World War. The major mitigating factors included the empathetic response of people, locally and nationally, as well as the availability of armed forces personnel based in East Anglia, whose actions played a decisive part in the battle against the sea. The major legacies of the Big Flood were a coastal flood forecasting system, a more scientific approach to sea defences and the building of the Thames barrier.

Delderfield, E.R. (1958) The Lynmouth Flood Disaster, The Raleigh Press

An excellent illustrated account of the disaster in N. Devon and W. Somerset which took place on August 15th, 1952 causing the destruction of buildings in Lynmouth and nearly 30 deaths. The book traces the cause of the floods and depicts the enormous damage done to the Lynmouth area in the space of a few hours, the dreadful experience of many people, and the heroism so often displayed.

Environment Agency (Undated) Living with the risk: The floods in Boscastle and North Cornwall of 16th August 2004, Environment Agency, Bristol

A report on some of the worst floods ever seen in Britain devastated Boscastle and surrounding areas of North Cornwall on 16 August 2004. This booklet has been produced by the Environment Agency to explain what happened, the work we have done since and the possible options that may reduce the risk of future flooding. It is based on an expert study of the floods that we commissioned from consultants HR Wallingford with support work by Halcrow, the Centre for Ecology and Hydrology, Wallingford, the Met Office and Royal Haskoning. They analysed information about the storms, rainfall and rivers in the area.

Fice, J. and S.A. Lewin (1990) The Flood-Prevention Scheme of Venice: Experimental Module Water and Environment Journal, Vol 4, 1, 70-7

Records exist of the flooding of Venice from the days of the Republic. During the last century flooding incidents have become more severe due to subsidence of the city and rising water levels in the Adriatic. Calamitous flooding occurred in 1966, and two devastating floods were experienced during the last decade. The 'Special Law for Venice', enacted by the Italian Parliament in 1973, paved the way for a competition to devise a flood-prevention scheme. A consortium of Italian contractors, who were commissioned to submit proposals for the implementation of the scheme, designated Technital Spa of Verona to carry out the design of the flood-prevention works and improvements within the lagoon. This resulted in the design of three movable barrages to seal off the Venice lagoon in the event of a flood. The construction of a full-size gate and caisson (the prototype of the eighty gates forming the barrages) was subsequently authorized. This paper describes the experimental module containing the buoyant gate and its caisson, its novel features as well as some of the events leading up to its design and construction.

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Galloway, G. (2008) Flood risk management in the United States and the impact of Hurricane Katrina. International Journal of River Basin Management, Vol. 4, 6, 303–6

In 1993, the United States experienced a flood that produced the highest economic damages of the century Large areas of the Midwest were underwater for weeks as the Missouri and Upper Mississippi Rivers left their banks. Over 130 people lost their lives and flood losses grew to over $20 billion (US). For a few years after, national attention was focused on floodplain management, but, as other issues faced the government, efforts to develop a new approach to dealing with flood losses faded. Hurricane Katrina, with the deaths of over 1300 persons and billions of dollars in damages, brought flooding back to the front page of the newspapers and has stirred a new interest in developing a more rational approach to occupance of the floodplain and to use of new approaches to flood damage reduction. As a result of several recent studies and government actions, attention is now being focused on the use of risk analysis methodologies to support decisions on floodplain use, slowly edging the United States closer to flood risk management and away from floodplain management. This paper discusses the lessons learned from the 1993 flood, the actions taken in the United States since 1993, and the impact Hurricane Katrina is having on bringing risk into the decisions that shape floodplain use in the United States.

Government Office of the North West (2005) Carlisle storms and associated flooding, Multi-agency debrief report, Issue on 14 July 2005

This report contains the outcomes of the multi-agency debrief into the emergency response to the storms and resulting flooding that affected Carlisle in January 2005. It is recognised that the January Storms affected most parts of Cumbria, resulting in storm and flood damage in many other areas. However, this report primarily addresses the situation in Carlisle as this was the most severely affected area and the focus of the multi-agency response. This report does not describe in detail what the responding organisations and agencies did or the individual challenges they faced. However, it does provide a summary of the events that took place and how they were handled. The report examines the most and least successful aspects of the emergency response, and highlights potential areas of improvement to the response to future incidents. No assessment has been made as to whether these would have resulted in an enhanced response, and no judgement is being made on the response to the storms and resulting flooding.

This report does not cover the outcomes of the recovery phase that followed the handover of responsibility from Cumbria Police to Carlisle City Council. The recovery phase is still ongoing, and it would therefore be premature to carry out a recovery debrief at this time. The recovery phase will, however, be the subject of a separate debrief to be conducted in summer 2005 led by Carlisle City Council. Members of the public have not been consulted during the production of this report and this is an area that responders may wish to consider as part of the recovery phase debrief process. The recommendations in this report will be taken forward by the Cumbria Resilience Forum in liaison with regional and national organisations as necessary. Cumbria Resilience Forum, along with others across the country, will also be considering the implications of the Civil Contingencies Act that received Royal Assent in November 2004. This act will, in itself, require responder organisations to review and possibly amend their processes and procedures in responding to future incidents, and many of the recommendations made here will overlap with the requirements of the Act. Whilst the production of the report has been co-ordinated by the Government Office North West Regional Resilience Team and some sections written by it, the recommendations contained within this report are those of the responders to the emergency and not necessarily endorsed by Government at this stage.

Home Office, Scottish Office, Ministry of Housing and Local Government and Ministry of Agriculture and Fisheries (1954) Report of the Departmental Committee on coastal flooding. London: HMSO

This is the Waverley Commission report which followed the 1953 floods.

Jeffers, J. (2011) The Cork City flood of November 2009: Lessons for flood risk management and climate change adaptation at the urban scale, Irish Geography, Vol 44, 1, 61-80

Flood hazards are a pressing challenge in several Irish and European cities and their impacts seem likely to

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intensify as climate change brings sea level rise, changes in storm patterns and increases in rainfall. Drawing on the example of Cork City and the November 2009 flood in particular, this paper evaluates contemporary policy and decision-making responses to flood hazards to determine whether they are sufficient to address current and future flood risks and vulnerabilities. It is clear that current policy and practice remains heavily influenced by a risk management paradigm that emphasises physical exposure and largely ignores socio-economic vulnerability. Floods and the losses they induce are seen as identical while engineering and technological fixes are viewed as the optimal means of reducing future flood losses. This framing of flood hazards is shaped by several influences including the historic evolution of flood policy and current institutional structures. The November 2009 flood highlights the limits of current policy and practice. Recent changes in national and European policy may also prove to be ineffective in facilitating effective adaptation and further changes in policy and practice are likely to be required.

Kolen, B., Slomp, R. and Jonkman, S.N. (2012) The impacts of storm Xynthia February 27–28, 2010 in France: lessons for flood risk management, Journal Of Flood Risk Management, Vol 6, 3, 261

This paper documents and discuss the facts, findings and lessons after the storm (in French Tempête) Xynthia, February 27–28, 2010. A storm surge combined with the high tide and waves caused failure and damages to flood defences along a coastline of 200 km. More then 50 000 ha of land was consequently flooded, and 47 people died as a result of the flood and storm. Findings and lessons are defined along the principals of a flood risk management strategy of three layers (multilayer safety approach): prevention, land use planning and emergency management. The findings can be used to improve flood prevention, land use planning and preparedness. These findings can also be used for further development of the relation between the authorities and citizens for low frequent, and not preventable, coastal flood events.

Medd, W., Deeming, H., Walker, G., Whittle, R., Mort, M., Twigger-Ross, C., Walker, M., Watson, N. and Kashefi, E. ( ) The flood recovery gap: A real-time study of local recovery following the floods of June 2007 in Hull, North East England, Journal of Flood Risk Management

Learning to live with flood requires learning to manage flood recovery. While in the UK much attention has been given to improving preparedness to flood events – from more sophisticated warning systems to the development of flood event planning – we bring attention to in-depth research on the processes of recovery and the challenges of addressing what we call the flood 'recovery gap'. A growing body of research has documented the social, economic and health impacts of flooding, and the relationship between social and physical parameters of community resilience and preparedness. However there remains a dearth of understanding about the processes people go through in recovering from flood disasters in the UK and the ways in which improving the experience of recovery can enhance resilience. Indeed, since resilience is defined in part by the time it takes to recover, it is imperative that more effective recovery is established. This paper reports on the findings of a real-time longitudinal study using an action research model to document and understand the everyday experiences of individuals following the floods of June 2007 in Hull. We argue recovery involves a more varied process than is assumed within current accounts, one which falls between institutional boundaries. We conclude with suggestions for addressing the 'recovery gap'.

North Cornwall District Council (2005) Boscastle Framework Plan, Final Report, April, accessed at http://www.boscastlecornwall.org.uk/Regenminutes/BoscastleFinalReport.pdf. Accessed on Jan 22 2015

Following the flooding of Boscastle on 16th August 2004, major works are needed to restore public facilities and services to the village and to instigate new investment in public infrastructure to help protect the area from future flooding. The works are substantial and are, and will, cause major disruption to the life of the village. In order to minimise disruption, North Cornwall District Council (NCDC) has brought together all key organisations that are involved in providing public facilities and services together with representatives of the local community in the Boscastle Regeneration Steering Group. The purpose of this group is to ensure that proposed works are what is wanted by the community, that they are undertaken in as efficient a way as possible, and that any opportunities for improving public services or the public realm are included in the proposals wherever possible.

The Steering Group provides a forum for discussion of proposals for Reinstatement and improvement of facilities in the village.

The Framework Plan is intended to act as a master document setting out the works proposed by the statutory agencies and others such as the National Trust, the views of the public on the proposals and their ideas for improvements to facilities in the village, identification of proposals and projects for inclusion in the Plan as the basis for a further round of consultations, together with a critical path for planning and implementation of proposals. The report identifies proposals for organisation and funding and will act as a master document for grant applications to fund the proposed works as appropriate. Map One shows the main area covered by the Framework Plan. The Framework Plan is a position statement for the developments proposed as at March 2005. All the proposals within the Framework Plan are at different stages of development. The Plan provides a baseline for measuring the progress of proposals.

Penning-Rowsell, E.C. (2014) What do the 2013/14 floods tell us about overall flood risk in England and Wales? Circulation 12, 3-5

A recent paper of mine analyses the available data on flood damage since 1947 and up to 2010. The results show that annual average economic fluvial and coastal flood damage over the last two decades or so –- a period seeing several large flood events — had not amounted to more than circa £0.25 billion (see Penning-Rowsell, 2015).

Floodplain management

Associated Program on Floodplain Management (2009) Integrated Flood Management Concept Paper, APFM Technical Document No. 1, 3rd Edition, WMO No. 1047

Integrated flood management (IFM) calls for a paradigm shift from the traditional, fragmented and localized approach, and encourages the use of the resources of a river basin as a whole, employing strategies to maintain or augment the productivity of floodplains, while at the same time providing protective measures against losses due to flooding. Since IFM is essentially a dynamic notion, the perception presented in this third revised edition also includes a number of emerging issues, such as risk management, urban floods, climate variability and change, and adaptive management.

Associated Program on Floodplain Management (2006) Legal and Institutional Aspects of Integrated Flood Management, APFM Technical Document No. 2, WMO No. 997

- Legal and Institutional Requirements of Integrated Flood Management at the National Level
- Special Requirements for International Watercourses
- Analysis of Existing National Legal Regime for Flood Management

Associated Program on Floodplain Management (2006) Legal and Institutional Aspects of Integrated Flood Management Case Studies, Flood Management Policy Series, WMO No. 1004

- Legal and Regulatory Framework for Flood Management in India
- Legislative Arrangements of Flood Management in Japan
- Protection against the Detrimental Effects of Waters: the Legal System of Serbia
- From Flood Defence to Flood Management: Legal and Institutional Aspects of Swiss Flood Management

Associated Program on Floodplain Management (2006) Environmental Aspects of Integrated Flood Management, APFM Technical Document No. 3, WMO No. 1009

- Setting the Scene: Environment and Sustainable Development
- Understanding the Basic Concepts of the Morphology and Ecology or Rivers and their Flood Plans
- Flood Processes and Ecosystem Services: Interrelationships
- Flood Management Interventions and Ecosystems

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- Factoring Environmental Considerations in Decision-making Processes

Associated Program on Floodplain Management (2006) Social Aspects and Stakeholder Involvement in Integrated Flood Management, APFM Technical Document No. 4, WMO No. 1008

- People and Floods
- Social Aspects of Flood Risk Reduction
- Stakeholder Involvement in Integrated Flood Management
- Enhancing Stakeholder Involvement

Associated Program on Floodplain Management (2007) Economic Aspects of Integrated Flood Management, APFM Technical Document No. 5, WMO No. 1010

- Making Choices: Decision-making & economic analysis
- Cost-benefit analysis
- Economic Evaluation Techniques
- Sources of Financing

Ballesteros-Cánovas, J., Sanchez-Silva, M., Bodoque, J. and Díez-Herrero, A. (2013) An Integrated Approach to Flood Risk Management: A Case Study of Navaluenga (Central Spain), Water Resources Management, Vol 27, 8, 3051-3069

Flood risk management decisions require the rational assessment of mitigation strategies. This is a complex decision-making process involving many uncertainties. This paper presents a case study where a cost-benefit based methodology is used to define the best intervention measures for flood-risk mitigation in central Spain. Based on different flood hazard scenarios, several structural measures considered by the local Basin Water Authority and others defined by engineering criteria were checked for operability. Non-systematic data derived from dendrogeomorphological analysis of riparian trees were included in the flood frequency analysis. Flood damage was assessed by means of depth-damage functions, and flooded urban areas were obtained by applying a hydraulic model. The best defense strategies were obtained by a cost-benefit procedure, where uncertainties derived from each analytical process were incorporated based on a stochastic approach to estimate expected economic losses. The results showed that large structural solutions are not economically viable when compared with other smaller structural measures, presumably because of the pre-established location of dams in the upper part of the basin which do not laminate the flow generated by the surrounding catchment to Navaluenga.

Cutter, S., Emrich, C.T., Morath, D.P. and Dunning, C.M. (2103) Integrating social vulnerability into federal flood risk management planning, Journal Of Flood Risk Management, Vol 6, 4, 332

While flood risk management planning in the United States has focused on flood control structures designed to protect the economic value of property, it has consistently undervalued other social impacts associated with flooding. The US Army Corps of Engineers (USACE) recently initiated research aimed at understanding how to incorporate social characteristics into the measures currently utilised in flood control project evaluation and consideration. This paper proposes a methodology for incorporating a known measure of social vulnerability, the Social Vulnerability Index (SoVI), into USACE civil works planning. Using the USACE South Atlantic Division as the study area, this paper evaluates eight different variations of the social vulnerability metric and their potential deployment in USACE projects. Each formulation is compared with the original-computed SoVI as a means to test its spatial and statistical sensitivity, including an assessment of each variant's robustness, reducibility, scalability, and transferability. Results indicate that while it is possible to create simplified, yet robust, versions of SoVI for individual places, such 'lite' metrics tend to fall short in areas of scalability and transferability in relation to the original SoVI formulation.

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Department of the Environment, Food and Rural Affairs (Defra) 2005. Making Space for Water: Taking Forward a New Government Strategy for Flood and Coastal Erosion. First Government Response to the Autumn 2004 Making Space for Water Consultation Exercise. London, DEFRA

The document sets out a new English policy on flood and coastal erosion risk management. The Government confirms its strategic direction of travel which, over the 20-year lifetime of the new strategy, will implement a more holistic approach to managing flood and coastal erosion risks in England. The approach will involve taking account of all sources of flooding, embedding flood and coastal risk management across a range of Government policies, and reflecting other relevant Government policies in the policies and operations of flood and coastal erosion risk management. The aim will be to manage risks by employing an integrated portfolio of approaches which reflect both national and local priorities, so as to:

• reduce the threat to people and their property; and
• deliver the greatest environmental, social and economic benefit, consistent with the
To deliver that aim the Government is setting in hand a wide-ranging programme of action firstly involving a more holistic approach involving taking action to ensure adaptability to climate change becomes an integral part of all flood and coastal erosion management decisions. The Government will continue to promote a programme of research on the impacts of climate change and will review current allowances and recommendations for climate change in the light of the outcome of that research. The Government will adopt a whole catchment and whole shoreline approach that is consistent with, and contributes to the implementation of, the Water Framework Directive. All stakeholders will be involved at all levels of risk management in order to achieve a better balance between the three pillars of sustainable development (economic, social and environmental) in our risk management activities. So as to facilitate an holistic approach that is risk-driven, the Government will work towards giving the Environment Agency an overarching strategic overview across all flooding and coastal erosion risks.

Emergency Management Australia (Undated) Managing the floodplain - a guide to best practice in flood risk management in Australia - Handbook 7, Publication code: HB7-2ND. Free PDF download at https://ema.infoservices.com.au/items/HB7-2ND. Accessed on 23 Jan 2015

Flooding is a natural phenomenon that occurs when water covers land that is usually dry. Floods can have a devastating impact upon communities. Effective flood risk management can enable a community to become as resilient as practicable to floods. This is achieved through planning and preparing for, responding to and recovering from flooding. This requires a coordinated, multidisciplinary approach across all levels of government and between agencies with different responsibilities. It also requires the support of a range of non-government organisations and industry professionals in a wide range of activities and fields (such as land-use planning) and the active engagement of the community. The goal of increased resilience to floods requires the management of the flood impacts on both existing developed areas of the community and areas that may be developed in the future. Generally, this involves a combination of flood mitigation, emergency management, flood forecasting and warning measures, land-use planning, and infrastructure design considering the local flood situation and the associated hazards. Decision makers in these areas, insurers and the general public require access to information on flood risk to make informed management and investment decisions. The National strategy for disaster resilience, adopted by the Council of Australian Governments on 13 February 2011 (COAG 2011), outlines the increasing regularity and severity of natural disasters. Australian governments recognised that a national coordinated and cooperative effort is required to enhance Australia's capacity to withstand and recover from emergencies and disasters. A disaster resilient community is one that works together to understand and manage the risks that it confronts. Disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals. If all these sectors work together with a united focus and a shared sense of responsibility to improve disaster resilience, they will be far more effective than the individual efforts of any one sector.

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European Commission (EC) (2004) Flood risk management - Flood prevention, protection and mitigation. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Accessed at http://ec.europa.eu/environment/water/flood_risk/com.htm on 19 Jan 2015.

In this communication the Commission proposed to develop and implement a concerted EU Action Programme on flood risk management. It proposed that the Member States and the Commission shall work together to develop and implement a co-ordinated flood prevention, protection and mitigation action programme. The issue of flood protection including the Communication were discussed at both the Informal Environment Council on 18 July 2004 and at the Environment Council on 14 October 2004. In October the Council has adopted Conclusions on flood risk management and agreed that based on the Communication, the Member States and the European Commission, in the context of the regular meetings of the EU Water Directors in co-operation with other stakeholders and relevant parties, should prepare the contents of such concerted European action. The Council invited the Commission to submit an "appropriate proposal taking into account the Council conclusions and the work of the Informal meeting of the Water Directors, preferably before mid 2005".

European Commission (EC) (2007) Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks.

This Directive came into force on 26 November 2007. It requires EU Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. The Directive also reinforces the rights of the public to access this information and to have a say in the planning process. The Directive was proposed by the European Commission on 18/01/2006, and was finally published in the Official Journal on 6 November 2007. Its aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. The Directive requires Member States to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU. The Directive shall be carried out in coordination with the Water Framework Directive, notably by flood risk management plans and river basin management plans being coordinated, and through coordination of the public participation procedures in the preparation of these plans. All assessments, maps and plans prepared shall be made available to the public. Member States shall furthermore coordinate their flood risk management practices in shared river basins, including with third counties, and shall in solidarity not undertake measures that would increase the flood risk in neighbouring countries. Member States shall in take into consideration long term developments, including climate change, as well as sustainable land use practices in the flood risk management cycle addressed in this Directive.

General Directorate for Risk Prevention (DGPR), Ministry of Ecology, Sustainable Development and Energy with the active participation of the Joint Flood Commission (2014) French national flood risk management strategy, July edition. http://www.developpement-durable.gouv.fr/IMG/pdf/French_Flood_Strategy.pdf accessed on 24 Jan 2015

This strategy document explains the reasons for a national flood risk management strategy referring to the current situation, the policy implemented and the advantage of a national framework. It explains the national strategy's three major priority objectives which include improving the safety of exposed populations, stabilising in the short term and reducing in the medium term the cost of flood damage and significantly shortening the time required by affected areas to return to normal. There is also an explanation of the Action framework including the guiding principles serving objectives which are the solidarity principle, the subsidiarity principle and public policy synergy principle and prioritisation and continuous improvement principle. In the strategic orientations there are four challenges to meet which are developing governance and project management, sustainable territorial development, knowing more to react better and learning to live with floods.

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Hall, J., Meadowcroft, I., Sayers, P. and Bramley, M. (2003) Integrated flood risk management in England and Wales. Natural Hazards Review, Vol. 4, No. 3, 126–35.

To follow

Levy, J.K., Gopalakrishnan, C. and Lin, Z. (2005) Advances in Decision Support Systems for Flood Disaster Management: Challenges and Opportunities, International Journal of Water Resources Development, Vol 21, 4, 593-612

Natural variations in the global climate are governed by complex interactions among the atmosphere, oceans, and land cover. Modern climate models suggest that these variations will continue, but with larger magnitudes and greater variability due to human influences. This is expected to increase the risk of flood disaster events. To improve flood risk management, a flood decision support system architecture is proposed that capitalizes on the latest advances in remote sensing, geographic information systems, hydrologic models, numerical weather prediction, information technology, and decision theory. Specifically, the dynamic climate prediction system developed by the Institute of Atmospheric Physics, Chinese Academy of Sciences, is discussed in the context of flood management and planning in the Yangtze River valley, China.

Merz, B., Hall, J., Disse, M. and A. Schumann (2010) Fluvial flood risk management in a changing world Nat. Hazards Earth Syst. Sci., 10, 509-527. www.nat-hazards-earth-syst-sci.net/10/509/2010/

Flood risk emerges from the interaction of hazard and vulnerability. Over recent decades the notion of risk being the basis for flood management decisions has become widely accepted and operationalised through the use of models and quantified risk analysis providing the evidence for risk-informed decision making. However, it is now abundantly apparent that changes in time, at a range of scales, of pertinent variables that determine risk are not a second order consideration but, instead, fundamentally challenge the conventional approach to flood risk management. The nature of some of these changes, particularly those that operate on extended timescales, are highly uncertain, yet decisions that may have implications for several decades still have to be taken. In this paper we explore how flood risk management may be adapted to address processes of uncertain future change. We identify a range of levels at which change may be incorporated in decision making: in the representation of uncertain non-stationary quantities; in the rules that are used to identify preferred options; in the variety of options that may be contemplated for flood risk management; in the scope of problem definition, which increasingly extends to address multiple hazards and multiple functions of river basins; and in the social and organizational characteristics that promote adaptive capacity. Integrated responses to changing flood risk need to attend to each of these levels of decision making, from the technicalities of non-stationarity, to the promotion of resilient societies.

Mostert, E. and S. J. Junier (2009) The European flood risk directive: challenges for research Hydrol. Earth Syst. Sci. Discuss., 6, 4961–4988, 2009 (www.hydrol-earth-syst-sci-discuss.net/6/4961/2009/)

In recent years, flood management has shifted from protection against floods to managing the risks of floods. In Europe, this shift is reflected in the 2007 Flood Risk Directive (FRD) of the European Commission. The FRD requires EU Member States to undertake a preliminary assessment of flood risks and, for areas with a significant flood risk, to prepare flood hazard and flood risk maps and flood risk management plans. This paper introduces the FRD and its purpose and discusses the challenges that it poses to research. These challenges include the issue of how to define and measure flood risk, the selection of alternatives to be assessed, coping with uncertainty, risk communication, and nurturing trust and promoting collaboration. These challenges involve a variety of disciplines and must involve flood risk managers and other stakeholders. The paper concludes that the FRD presents a large need for interdisciplinary and participatory research.

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Mysiak, J., Testella, F., Bonaiuto, M., Carrus, G., De Dominicis, S., Ganucci Cancellieri, U., Firus, K. and P. Grifon (2013) Flood risk management in Italy: challenges and opportunities for the implementation of the EU Floods Directive (2007/60/EC), Nat. Hazards Earth Syst. Sci, 13, 2883-2890

Italy's recent history is punctuated with devastating flood disasters claiming high death tolls and causing vast but underestimated economic, social and environmental damage. The responses to major flood and landslide disasters have contributed to shaping the country's flood risk governance. Insufficient resources and capacity, slow implementation of the (at the time) novel risk prevention and protection framework, embodied in the law 183/89 of 18 May 1989, increased the reliance on the response and recovery operations of civil protection. As a result, the importance of the Civil Protection Mechanism and the relative body of norms and regulation developed rapidly in the 1990s. In the aftermath of the Sarno (1998) and Soverato (2000) disasters, the Department for Civil Protection installed a network of advanced early warning and alerting centres, the cornerstones of of Itlay's preparedness for natural hazards and a best practice worth following. However, deep convective ,clouds, not uncommon in Italy, producing intense rainfall and rapidly developing localised floods still lead to considerable damage and loss of life that only be reduced by stepping up the risk prevention efforts. The implantation of the EU Floods Directive (2007/60EC) provides an opportunity to revise the model of flood risk governance and to confront the shortcomings encountered during more than 20 years of organised flood risk management. The paper offers joint recommendations towards this end from three projects funded by the 2nd CRUE ERA-NET Funding Initiative (FREEMAN, IMRA and URFlood.

Pardoe, J., Penning-Rowsell, E.C and S. Tunstall (2011) Floodplain conflicts: regulation and negotiation, Natural hazards and earth system sciences, 11, 2889-290

In the continuing shift from engineered solutions towards more holistic methods of managing flood risk, spatial planning has become the primary focus of a conflict between land and water, water and people. In attempting to strike a balance between making space for water and making space for people, compromises are required. Through five case studies in the UK, this paper analyses the effectiveness of Planning Policy Statement 25 (PPS 25) and the processes of negotiation that it promotes. This assessment allows us to draw conclusions on the nature of the compromises this kind of negotiation can achieve and the implications of this for flood risk management. What emerges is that the beneficial impacts of decisions to develop floodplain areas are given a proper hearing and sensible conditions imposed, rather than arguments to prevent such development remaining unchallenged.

Parker, D.J (ed) (2000) Floods, Vols 1 and 2. Routledge, London. ISBN 0-415-17238-1 (2 volume set), ISBN 0-415-22743-7 (Volume 1) and ISBN 0-415-22744-5 (Volume 2)

This is a large collection of chapters, 48 in total, designed to bring together both new and landmark research from leading experts worldwide including academics and practitioners. The contents represent contributions from a wide variety of disciplines which can make valuable contributions to flood risk management. The contents also embrace a variety of perspectives and viewpoints on the causes of flood hazards and the most effective ways of managing them. This volume dispenses with the traditional approach to flood hazard analysis which begins with physical flood-producing processes and proceeds to human impacts and flood risk management strategies. Instead floods are viewed as hazards to humans and flood risk management is seen as an essentially human management problem. Therefore the volumes emphasise the significance of social, economic and political processes which structure flood hazard and disaster problems. The chapters are structured into nine parts each of which is introduced by an integrative discussion.

Penning-Rowsell, E.C and J. Pardoe (2012) Who benefits and who loses from flood risk reduction?, Environment and Planning C, Government and Policy, 30, 3

The distributional effects of investment for the reduction of flood risk are explored, with the UK as an example. Using three case studies, we initially investigate the 'gainers' and the 'losers' from three contrasting engineering-oriented flood alleviation and land drainage schemes, the results of which appear to show that property owners at risk of flooding were the gainers and the general flood-free taxpayer was the loser. An analysis of flood damages, however, shows that those losing work from repairing or replacing flood damaged goods are a primary

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loser group as risk is reduced. Investigating insurance cover for flooding (near-universal in the UK) also shows that the principal real gainers appear to be insurance companies and their shareholders, since premiums generally do not appear to fall as risk is reduced. The implication of these novel results are evaluated both for the UK and, briefly, for elsewhere in the world.

Slomp, R. (2012) Flood Risk and Water Management in the Netherlands A 2012 update, Rijkwaterstaat, Ministry of Infrastructure and Environment.
http://www.preventionweb.net/files/29781_hr3845545binnenwerkfloodriskandwate.pdf accessed on 23 Jan 2015

This report describes Dutch context of flood risk management, institutions involved, disasters that influence flood risk policy and disaster management, flood protection standards for flood defenses, financial issues, urban planning and the choice not to insure against flood risk. It also discusses the influence of European legislation and presents specific issues on disaster management and response. Some current and unresolved problems are also covered, including financing the next round of major revision of flood defenses 2015-2023, preparing Dutch flood risk management for 2050 and 2100, and the issues that arise when applying different European directives.

Sultana, F. (2011) Living in hazardous waterscapes: Gendered vulnerabilities and experiences of floods and disasters, Environmental Hazards, 9, 1, 43-53

Considerable literature exists on floods and weather-related disasters, but limited attention has been given to the varied social implications of hazards in the lives of people, especially from a gender perspective. This is particularly poignant in floodplains and coastal areas, where water is a key element in giving, sustaining and taking away life and livelihood. Critical social and geographical analyses enable better understanding of the ways hazardous waterscapes are perceived, experienced and negotiated by people across social categories in their everyday life. This article attempts to highlight the gendered and classed coping strategies and adaptation measures that men and women engage with (that both challenge and reproduce social relations and vulnerabilities) in their attempts to survive in hazardous environments. Drawing from an analysis of the gendered dynamics of floods and disasters as well as the interventions that were undertaken via the Flood Action Plan in Bangladesh, I demonstrate the differential and gendered implications of both water-related hazards and the structural interventions that were envisioned to address the hazards. With climate change likely to exacerbate floods and disasters, it is important to heed such differentiations and marginalizations, so as to draw insights to better inform current and future adaptation approaches, flood management and disaster management strategies.

Sultana, P., Johnson, C. and P. Thompson (2008) The impact of major floods on flood risk policy evolution: Insights from Bangladesh, International Journal of River Basin Management, Vol 6, 4, 339-34

Building on conceptual work conducted within the UK, the authors examine the incremental and crisis-driven nature of changes in flood risk mitigation policies in Bangladesh since the 1950s. They highlight the key factors which have influenced the incremental and catalytic changes in policy, noting in particular the role and attitudes of international agencies and donors. By exploring incremental changes as a function of coalitions, the authors illustrate the importance of these external forces in their changing alignment with key national-level actors; firstly through an 'engineering coalition' and more recently through an 'environmental coalition'. The extent to which floods act as 'catalysts' for changing policy is then evaluated using the four most significant inland floods, or series of floods, in Bangladesh during the time period under investigation. The findings from which endorse many of the conceptual findings in the UK, the main exception being that in Bangladesh factors unconnected with floods continue to be the dominant forces of change - not least significant of which is institutional and political change, resource constraints and the international donor community. In addition, major floods have the capacity to delay policy changes, whilst simultaneously accelerating policy debate, and to destabilise established coalitions.

Sultana, P. (2012) Implications of floodplain aquaculture enclosure, Journal of Environmental Planning and Management, Vol 55, 9, 1159-117

In Bangladesh, extensive common pool fisheries exist in the wet season on private lands in the floodplains. This study investigated the trend in year-round enclosure of these seasonal commons for private aquaculture and the

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impacts of this practice. The floodplain area enclosed for aquaculture was found to be growing at 30–100% a year. Enclosures are organised by individual landowners, informal groups or companies that lease in land. Aquaculture in enclosures produces more fish than capture fisheries, but input costs are high. Traditional fishers report that catches of wild fish decline in the floodplains as a whole and there is a loss of livelihood. Those with large farms benefit while marginal farmers lose access to common aquatic resources and also to land for sharecropping. The landless have less fish to eat and sell, but some gain employment. The government has encouraged private floodplain aquaculture in recent years. However, it is recommended that this trend should be regulated to limit loss of key natural fisheries and widening inequality. This should be informed by more detailed quantification of the costs and benefits of floodplain aquaculture, including fishery and distributional impacts.

Floodplain planning

Communities and Local Government (CLG) (UK) (2009) Planning Policy Statement 25: Development and Flood Risk, Practice Guide, London, CLG.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7772/pps25guideupdate.pdf. Accessed on 19 January 2015

This is the Practice Guide for Planning Policy Statement 25 (PPS25) Development and Flood Risk (Communities and Local Government 2006, Revised in 2010) which is about positive planning at all levels to deliver appropriate sustainable development in the right places, taking full account of flood risk. PPS25 sets out the policy approach. This practice guide explains further how to implement this approach. PPS25 is part of the holistic approach to managing risk set out in the Government's strategy for flood and coastal erosion management, Making Space for Water. Planning has a key role to play in avoiding and reducing the risk from floods. Flooding from rivers and coastal waters is a natural process that plays an important role in shaping the natural environment. But flooding can cause substantial damage to property and threaten human life, as the floods of summer 2007 showed. Such damage is a consequence of previous decisions about the location and nature of settlement and land use. It cannot be prevented entirely, but its effects can be reduced. We can manage new development in a way that ensures risks do not increase and can even be reduced. The aim of our policies for managing flood risk through the planning system is to avoid such inappropriate development in flood risk areas. The key message of PPS25 is to avoid such inappropriate development and to locate development away from flood risk whenever possible. The approach it adopts to do this is to assess risk so it can be avoided and managed. This can be summarised in the following: assess – avoid – substitute – control – mitigate. The hierarchy used in this practice guide further develops the appraise, manage and reduce flood risk approach in PPS25. This guide shows how this can be done in practice.

Parker, D.J. (1995) Floodplain development policy in England and Wales, Applied Geography, 15, 4, 341-363

There is evidence of substantial floodplain development in England and Wales. An 'escalator effect' is observed whereby progressively higher levels of flood defence are provided to protect against progressively increasing flood damage potential, caused mainly by post-defence development. The efficacy of current flood defence and floodplain planning policy is questioned. Planning influences floodplain development rather than prevents it. Wider planning constraints divert development towards floodplains to avoid other environmental problems. Floodplain development decisions should be taken in the context of the wider benefits of such development, as well as the natural and cultural functions of floodplains.

Flood risk assessment and risk strategies

Asian Development Bank (2013) Flood Risk Management: A Strategic Approach, ADB, Metro Manila, Philippines, ISBN 978-92-3-001159-8 (Print)

What are the best practice approaches to flood risk management? This book reviews modern approaches to water management in challenging environments, providing new insights into good strategic planning and risk management of water resources. Over recent decades the concept of flood risk management has been cultivated

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across the globe. Implementation however remains stubbornly difficult to achieve. In part this reflects the perception that a risk management paradigm is more complex than a more traditional standard-based approach as it involves "whole systems" and "whole life" thinking; yet this is its main strength and a prerequisite for more integrated and informed decision making.

This book is the result of a collaborative effort between the World Wide Fund for Nature (WWF), the General Institute of Water Resources and Hydropower Planning and Design (GIWP), Ministry of Water Resources, People's Republic of China, UNESCO, the Asian Development Bank (ADB), and a number of leading international experts from the United Kingdom, South Africa, Australia, and the United States. It was originally conceived to review and disseminate modern approaches to water management in challenging environments, providing new insights into good strategic planning and risk management of water resources. This book provides a focus on strategic flood risk management and is one in series of six books, which together consider three fundamental water resources management issues: river basin planning, basin water allocation and strategic flood risk management.

The book focuses on strategic flood risk management policy and practice, and provides an overview of:

- the historical developments and emerging trends in flood management;
- the purpose and characteristics of modern flood risk management;
- the goals, objectives and outcomes sought;
- the ongoing challenges in developing and implementing flood risk management in practice together with some of the common pitfalls and misconceptions; and
- a summary of some specific tools and techniques and how they support good decision making.

Doorn, N. (2013) Rationality in flood risk management: the limitations of probabilistic risk assessment in the design and selection of flood protection strategies, Journal of Flood Risk Management, Vol 7, 3, 230

The introduction of new flood protection strategies prompts the need for a general framework for evaluating these strategies. The focus of this paper is on the rationality in selecting between flood protection strategies, more particularly on the question to what extent risk-based design and probabilistic risk assessment (PRA) can provide a general framework for rational evaluation of different strategies. On the basis of Arrow's impossibility theorem and the standard literature on cost–benefit analysis, the limitations of risk-based design and PRA are discussed. Applied to the context of flood risk management, it is shown that the problem of selecting between different flood protection strategies is susceptible to Arrow's impossibility theorem, which makes risk-based design seem less suitable as a generally applicable procedure. The incommensurability of criteria in the selection of flood protection strategies is related to the uncertainties pertaining to the different flood protection strategies. When selecting between strategies, risk-based design should therefore be complemented with other decision tools.

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P. et al. (2004a) Foresight Future Flooding, Scientific Summary: Vol. 1: Future Risks and Their Drivers. London, Office of Science and Technology.

(see below)

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P. et al. (2004b) Foresight Future Flooding, Scientific Summary: Vol. 2: Managing Future Risks. London, Office of Science and Technology.

This report is aimed at policy-makers in central and regional Government and the privatesector. It will also be of interest to a wide range of professionals, whose work is affected by flooding and coastal erosion, including planners, environmentalists, those in business, social scientists, researchers and flood managers. The report answers two questions:

- How might the risks of flooding and coastal erosion change in the UK over the next 100 years?
- What are the best options for Government and the private sector for responding to the future

challenges?

The Report is built around four global growth scenarios: World Markets, National Enterprise, Local Stewardship and Global Sustainability. World Markets is the global capitalism scenario with minimal mitigation of greenhouse gas emissions; National Enterprise is World Markets with protectionism; Local Stewardship is green utopia; and Global Sustainability is statist in nature.

Based on the four scenarios, Foresight produced estimated annual damage (EAD) figures out to 2080 for both fluvial (river in this case) and coastal flooding as well as what they called intra-urban flooding (pluvial, i.e. rainwater run-off, and groundwater). For the World Markets scenario—the dash for growth and ignore carbon emissions one—flood damage is estimated to rise 20-fold by 2080. On a GDP basis the position at first glance looks a lot better with damage only rising by 50%. Against current annual average cost of £1.4 billion from floods, the report estimated that £800 million per annum was spent on flood and coastal defences. Moreover, it also calculated than an annual increase in above-inflation spending of £10 to £30 million would be required just to maintain flood risk at its current level.

The report then looked at a suite of policy measures. Some would be at the macro level in terms of carbon emission mitigation, others at the local level such as increased flood defence and flood proofing. Rather optimistically, the report believed that if all their micro measures where enacted, there would be a dramatic reduction in flood-related damage. Note 'high' risk means a greater than one in 75 chance of flooding in any given year. Finally, Foresight also realised that the private sector would likely take a much more hard-nosed approach to flood insurance going forward, with the result that the government may have to step in to fill a potential insurance void.

The availability of insurance to cover the costs of flood damage will vary depending on changes in risk and society's ability to pay. Cover could range from a continuation of the current situation to progressive withdrawal of cover for areas at greatest risk of flooding. Government might have to consider how to respond to pressure to act as insurer of last resort if the insurance market withdrew cover from large parts of the UK, or if there was a major flood which the insurance market could not cover.

Gain, A.K. and Hoque, M.M. (2012) Flood risk assessment and its application in the eastern part of Dhaka City, Bangladesh, Journal of Flood Risk Management, Vol 6, 3, 219

Traditional flood design methods are increasingly supplemented by risk-oriented methods based on comprehensive risk analysis. This analysis requires: (1) the estimation of flood hazard that represents intensity of a flood, (2) estimation of vulnerability, e.g. percentage of damage to total property as a function of flood depth and duration, and (3) the consequences of flooding, e.g. loss of life and damage to property. In this study, flood hazard maps of the Balu-Tongikhal River system within the eastern part of Dhaka City are prepared using geo-processing tools and a hydrodynamic model. The raster-based vulnerability maps and expected damage maps of several return period floods are then produced. In comparison with the classical inundation maps, these damage maps generate more information about the flooding events. Consequently, the produced maps are useful in evaluating policy alternatives and minimising property loss because of floods in the study area.

Hall, J., Evans, E., Penning-Rowsell, E., Sayers, P., Thorne, C., and Saul, A. (2003) Quantified scenarios analysis of drivers and impacts of changing flood risk in England and Wales: 2030–2100, Environmental Hazards, Vol 5, 2, 51-6

Flood risk to the economy, society and the environment reflects the cumulative effects of environmental and socio-economic change over decades. Long-term scenarios are therefore required in order to develop robust and sustainable flood risk management policies. Quantified national-scale flood risk analysis and expert appraisal of the mechanisms causing change in flood risk have been used to assess flood risk in England and Wales over the period 2030–2100. The assessment involved the use of socio-economic and climate change scenarios. The analysis predicts increasing flood risk unless current flood management policies, practices and investment levels are changed—up to 20-fold increase in economic risk by the 2080s in the scenario with highest economic growth.

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The increase is attributable to a combination of climate change (in particular increasing precipitation and relative sea level rise in parts of the UK) and increasing socio-economic vulnerability, particularly in terms of household/industrial contents and infrastructure vulnerability. The policy implications of these findings are discussed.

Hartmann, T. and Albrecht, J. (2014) From Flood Protection to Flood Risk Management: Condition-Based and Performance-Based Regulations in German Water Law, Journal Of Environmental Law, Vol 26, 2, 243

In many European countries, a paradigm shift from technically oriented flood protection to a holistic approach of flood risk management is taking place. In Germany, this approach is currently being implemented after several amendments of the Federal Water Act. The paradigm shift is also reflected in the theoretical structure of the legal stipulations. While the former regulations of flood protection were predominantly conditions-based, linked with clear preconditions and legal consequences, the legal implementation of the flood risk management approach is accompanied by an increase of goal-oriented, performance-based regulations. This contribution discusses the interrelationship between the two legislative approaches and the specific challenges for the administration. Flood risk management, as a policy field, requires the law to provide robustness but also flexibility. It is concluded that the German way could accidentally provide a viable answer to this dilemma. The conclusions drawn for the flood risk management in Germany might be applicable also to other policy fields and even outside Germany.

Hooijer, A., Klijn, F., Pedroli, G., Bas M., Van Os, A. G., and P.H. Nienhuis (2004) Towards sustainable flood risk management in the Rhine and Meuse river basins: synopsis of the findings of IRMA-SPONGE, River Research and Applications, Vol 20, 3, 343-357

Recent flood events in western Europe have shown the need for improved flood risk management along the Rhine and Meuse rivers. In response, the IRMA-SPONGE research programme was established, consisting of 13 research projects, in which over 30 organizations from six countries co-operated. The aim of IRMA-SPONGE was 'the development of methods and tools to assess the impact of flood risk reduction measures and of land-use and climate change scenarios, in order to support the spatial planning process for the Rhine and Meuse River Basins'. Several important conclusions were agreed upon by participants in the programme; they emphasize the role of spatial planning, especially in areas at risk of flooding, as an important component of flood risk management.

Interagency Floodplain Management Review Committee (IFMRC) (1994) Sharing the Challenge: Floodplain Management into the 21st Century. Report of the Interagency Floodplain Management Review Committee to the Administration Floodplain Management Task Force. Washington DC, FEMA

During the decade ending in 1993, average annual flood damages in the United States exceeded $3 billion. In this report the Interagency Floodplain Management Review Committee poses a better way to manage the nation's floodplains. It begins by establishing that all levels of government, all businesses and all citizens have a stake in properly managing floodplains. All of those who support risky behaviour, either directly or indirectly, must share in floodplain management and in the costs of reducing that risk. The Committee supports a floodplain management strategy of sequentially avoiding inappropriate use of the floodplain, minimizing vulnerability to damage through both structural and non-structural means, and mitigating flood damages where they do occur. To ensure a long-term, nationwide approach to floodplain management the Committee proposes legislation to develop and fund a national Floodplain Management Program with principal responsibility at the State level.

Jeffers, J.M. (2014) Environmental knowledge and human experience: using a historical analysis of flooding in Ireland to challenge contemporary risk narratives and develop creative policy alternatives, Environmental Hazards, Vol 13, 3, 229-247

Focusing on three of the largest coastal cities in the Republic of Ireland, this paper highlights the importance of a historical analysis of flood hazards in contextualising current events and potential future risks. Over the last decade, the cities of Dublin, Cork and Galway have experienced several major coastal, river and pluvial floods. In the aftermath of these floods, two distinct but related narratives have dominated public discourse and official responses. The first narrative presents recent floods as unprecedented and as possible evidence of climate

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change. The second constructs floods primarily as natural events and assumes that the optimal means of reducing flood losses is to prevent flood events. In this paper, I suggest that these narratives are not supported by a historical analysis of exposure and vulnerability to flood hazards in Irish cities. This paper draws primarily on newspaper archives to construct a record of past flooding that challenges these narratives in several ways and in doing so offers lessons for similar cities in other countries. I contend that these narratives are perpetuated by a narrow form of knowledge production (quantitative risk assessment) and a narrow range of data (numeric instrumental records). Incorporating a broader range of sources and data types into risk and vulnerability assessments may illuminate more creative strategies for reducing both contemporary and future flood losses.

Kellens, W., Vanneuville, W., Verfaillie, E., Meire, E., Deckers, P. and P. Maeyer (2013) Flood Risk Management in Flanders: Past Developments and Future Challenges, Water Resources Management, Vol 27, 10, 3585-360

This paper presents the state of the art of flood risk management in Flanders, a low-lying region in the northern part of Belgium which is vulnerable to flooding. Possible flood hazard sources are not only the many rivers which pass through the Flemish inland, but also the North Sea, which is sensitive to the predicted sea level rise and which can affect large parts of the Flemish coastal area. Due to the expected increase in flood risks in the 21st century, the Flemish government has changed its flood management strategy from a flood control approach to a risk-based approach. Instead of focusing on protection against a certain water level, the objective now is to assure protection against the consequences of a flood, while considering its probability. In the first part, attention is given to the reasoning and functioning of the risk-based approach. Recent improvements to the approach are discussed, as well as the GIS-implementation of the entire model. The functioning of the approach is subsequently demonstrated in two case studies. The second part of the paper discusses future challenges for the flood risk management in Flanders. The driving force behind these challenges is the European Directive on the assessment and management of flood risks, which entered into force in 2007. The Flemish implementation of the directive is discussed and situated in the European landscape. Finally, attention is given to the communication of flood risks to the general public, since the “availability” of flood risk management plans is among the requirements of the EU Floods Directive.

Klijn, F., Samuels, P. and Van Os, A. (2008) Towards flood risk management in the EU: State of affairs with examples from various European countries, International Journal of River Basin Management, Vol 6, 4, 307-321

On 27 June 2006 the Council of the European Union reached political agreement on a draft directive on the assessment and management of flood risks. This directive prescribes approaches and procedures which should be met by the member states. The website of the EU on this directive links to another EU-initiative, the Integrated Project FLOODsite, which aims at providing methodologies for flood risk analysis and management. Obviously, the directive and the IP emerged in a common but much larger context of public and scientific debate on a more integrated and coordinated approach to dealing with flood risks. In this paper we briefly discuss this context and examine a few national cases in order to find out whether flood risk management is already common practice or is still in its infancy, or whether it involves merely good intentions. We base this examination primarily on our experiences within FLOODsite and on presentations held within the special session on River Flood Risk Management which was organised by The Netherlands Centre for River Studies (NCR) during the ISDF3 conference in May 2005. This paper goes into the similarities and differences between some national approaches and tries to place them in a cultural context. It appears that the seemingly most sophisticated management policies do not automatically imply the most comprehensive flood risk management approach. But the intention to evolve from flood management into flood risk management is evident and promising.

Lane, S., November, V., Landstrom, C . and Whatmore, S. (2013) Explaining Rapid Transitions in the Practice of Flood Risk Management, Annals Of The Association Of American Geographers, Mar 1, Vol 103, 2, 330-34

This article draws on empirical material to reflect on what drives rapid change in flood risk management practice, reflecting wider interest in the way that scientific practices make risk landscapes and a specific focus on extreme events as drivers of rapid change. Such events are commonly referred to as a form of creative destruction, ones that reveal both the composition of socio-environmental assemblages and provide a creative opportunity to

remake those assemblages in alternate ways, therefore rapidly changing policy and practice. Drawing on wider thinking in complexity theory, we argue that what happens between events might be as, if not more, important than the events themselves. We use two empirical examples concerned with flood risk management practice: a rapid shift in the dominant technologies used to map flood risk in the United Kingdom and an experimental approach to public participation tested in two different locations, with dramatically different consequences. Both show that the state of the socio-environmental assemblage in which the events take place matters as much as the magnitude of the events themselves. The periods between rapid changes are not simply periods of discursive consolidation but involve the ongoing mutation of such assemblages, which could either sensitize or desensitize them to rapid change. Understanding these intervening periods matters as much as the events themselves. If events matter, it is because of the ways in which they might bring into sharp focus the coding or framing of a socio-environmental assemblage in policy or scientific practice irrespective of whether or not those events evolve the assemblage in subtle or more radical ways.

Loucks, D. P., Stedinger, J.R., Davis, D.W.,Stakhiv, E.Z. (2008) Private and Public Responses to Flood Risks, International Journal of Water Resources Development, Vol 24, 4,.541-553

People continue to build and live on land subject to flooding. People do this knowing that their property may be flooded, if not totally destroyed, by raging waters and accompanying debris, however, many do not fully understand and appreciate that risk. As a result, each year on average observes increasing property damage, more lives being threatened and increased degradation of floodplain ecological functions. It can be argued that with regard to floodplain development governmental policies are not preventing it, indeed, they may be facilitating it.

Marchi, L., Preciso, M., Borga, E., and Gaume, E. (2010) Characterisation of selected extreme flash floods in Europe and implications for flood risk management, Journal of Hydrology, 17 November, Vol 394, 1-2, 118-133

High-resolution data enabling identification and analysis of the hydrometeorological causative processes of flash floods have been collected and analysed for 25 extreme flash floods (60 drainage basins, ranging in area from 9.5 to 1856km 2) across Europe. Most of the selected floods are located in a geographical belt crossing Europe from western Mediterranean (Catalunia and southwestern France) to Black Sea, covering northern Italy, Slovenia, Austria, Slovakia and Romania. Criteria for flood selection were high intensity of triggering rainfall and flood response and availability of high-resolution reliable data. Hydrometeorological data collected and collated for each event were checked by using a hydrological model. The derivation and analysis of summarising variables based on the data archive has made it possible to outline some characteristics of flash floods in various morpho-climatic regions of Europe. Peak discharge data for more than 50% of the studied watersheds derive from post-flood surveys in ungauged streams. This stresses both the significance of post-flood surveys in building and extending flash flood data bases, and the need to develop new methods for flash flood hazard assessment able to take into account data from post-event analysis. Examination of data shows a peculiar seasonality effect on flash flood occurrence, with events in the Mediterranean and Alpine-Mediterranean regions mostly occurring in autumn, whereas events in the inland Continental region commonly occur in summer, revealing different climatic forcing. Consistently with this seasonality effect, spatial extent and duration of the events is generally smaller for the Continental events with respect to those occurring in the Mediterranean region. Furthermore, the flash flood regime is generally more intense in the Mediterranean Region than in the Continental areas. The runoff coefficients of the studied flash floods are usually rather low (mean value: 0.35). Moderate differences in runoff coefficient are observed between the studied climatic regions, with higher values in the Mediterranean region. Antecedent saturation conditions have a significant impact on event runoff coefficients, showing the influence of initial soil moisture status even on extreme flash flood events and stressing the importance of accounting soil moisture for operational flash flood forecasting. The runoff response displays short lag times (mostly <6h). The identified relations between watershed area, stream length and response time enable determination of a characteristic mean velocity of the flash flood process (at basin scales less than 350km 2), defined as the ratio of characteristic length (mean river length) and time (response time or lag time), equal to 3ms -1 . This is related to the celerity with which the flood wave moves through the catchment. The analysis of the response time provides

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information on the time resolution and the spatial density of the networks required for monitoring the storms that generate flash floods.

McMinn, W.R., Yang, Q. and Scholz, M. (2010) Classification and assessment of water bodies as adaptive structural measures for flood risk management planning, Journal of Environmental Management, Vol 91, 9, 1855-1863

Severe rainfall events have become increasingly common in Europe. Flood defence engineering works are highly capital intensive and can be limited by land availability, leaving land and communities exposed to repeated flooding. Any adaptive drainage structure must have engineered inlets and outlets that control the water level and the rate of release. In Scotland, there are a relatively high number of drinking water reservoirs (operated by Scottish Water), which fall within this defined category and could contribute to flood management control. Reducing the rate of runoff from the upper reaches of a catchment will reduce the volume and peak flows of flood events downstream, thus allowing flood defences to be reduced in size, decreasing the corresponding capital costs. A database of retention basins with flood control potential has been developed for Scotland. The research shows that the majority of small and former drinking water reservoirs are kept full and their spillways are continuously in operation. Utilising some of the available capacity to contribute to flood control could reduce the costs of complying with the EU Flood Directive. Furthermore, the application of a previously developed classification model for Baden in Germany for the Scottish data set showed a lower diversity for basins in Scotland due to less developed infrastructure. The principle value of this approach is a clear and unambiguous categorisation, based on standard variables, which can help to promote communication and understanding between stakeholders.

Menoni, S., Molinari, D., Parker, D.J., Ballio, F. and Tapsell, S. (2012) Assessing multifaceted vulnerability and resilience in order to design risk-mitigation strategies, Natural Hazards, Vol 64, 3, 2057-2082

Vulnerability studies have evolved significantly in recent decades. Although not overly theoretical compared with some other fields of science, some important conceptual progress has been made. At the practical level, vulnerability indicators have been used either at a generic level or for particular hazard contexts. However, these indicators are often predictably too narrow in their coverage of aspects of vulnerability. An important need remains to produce more conceptually informed vulnerability indicators or parameters and more satisfactory operational tools to assess weaknesses and resilience in coping with natural risks. In this paper, we present the methodology developed in the context of a recently concluded EU funded project, ENSURE (Enhancing resilience of communities and territories facing natural and na-tech hazards). The resulting vulnerability and resilience assessment framework tool adopts a systemic approach embedding and integrating as much as possible the multifaceted and articulated nature of concepts such as vulnerability and resilience. The tool guides evaluators towards a comprehensive and context-related understanding of strengths and fragilities of a given territory and community with respect to natural extremes.
In this paper, both the framework tool and its application to Sondrio in Italy, which is exposed to flash floods, are presented and discussed. The merits and demerits of the new tool are discussed, and the results of the application to Sondrio indicate where data are currently missing, suggesting the kind of data, which will need to be gathered in future to achieve more complete assessments. The results also suggest vulnerability reduction policies and actions and further ways of revising the existing framework tool in the future.

National Flood Risk Advisory Group Flood risk management in Australia (2008) National Flood Risk Management Guideline, The Australian Journal of Emergency Management, Vol, 4, November. https://www.em.gov.au/Documents/AJEM_Nov08_Flood%20risk%20management_Eliot_Middelmann.PDF. Accessed on 23 Jan 2015

This paper introduces the work of the National Flood Risk Advisory Group in providing advice and guidance on the management of flood risk in Australia, in particular its work on the development of a set of national guidelines. The guidelines are included as an appendix and they highlight that communities utilise the support and cooperation of departments and agencies across all levels of government to effectively access the broad range of

skills and the funding essential to implement flood risk management solutions. The paper discusses the more important flood risk considerations embodied in the guidelines**.**

Olbert, A. (2009) Methodology for ex-post evaluation of measures and instruments in flood risk management, T12_07_04_Ex-Post_Evaluation_D12_1_ExecSum_V1_3_P04.pdf. Accessed at http://www.floodsite.net/html/partner_area/search_results3b.asp?docID=39 on 19 Jan 2015.

Task 12 pf the FLOODsite project provides a framework for the ex-post evaluation of measures and instruments for flood risk management. The framework is tested in case studies within the scope of the FLOODsite research project. It combines various elements which facilitate ex-post evaluation in flood risk management, viz.: a classification of measures and instruments; a comprehensive set of effect indicators; a web-based tool for case-specific selection of effect indicators; methods for effect analysis and evaluation with respect to the criteria effectiveness, efficiency, robustness, and flexibility; and examples of how these methods can be applied. With this framework, a comprehensive methodology for ex-post evaluation is available. The testing has shown that the framework can facilitate ex-post evaluation in real cases. It has also shown that the methodology is applicable for different types of interventions as confirmed by first reactions of involved stakeholders.

Parker, D.J. and S. Tapsell (1995) Hazard Transformation and Hazard Management Issues in the London Megacity, GeoJournal, 37, 3 313-328

Megacities are likely to present the greatest future challenges for hazard management. In them increasingly complex societies are continually modifying responses to dynamic sets of external risks. Although most have proven resilient to past disasters including flood disasters, new types of threat are emerging. London - which is both the world's oldest megacity and one of its most resilient - has long experience of the transformation of hazards in time and space. Although not as hazard-prone as some megacities, this one is increasingly exposed to a wide range of interactive hazards. Here trends of flooding, air pollution and terrorism are discussed together with policy responses. London demonstrates that robust action can be successful in reducing high-intensity hazards but it also shows that contemporary management is characterised by top-down technological fixes whose long-term effectiveness is questionable. In general, anticipatory responses have been limited and present-day London has not capitalised on its rich legacy of successful experience in coping with hazard.

Penning-Rowsell, E.C. (2015) A realistic assessment fluvial and coastal flood risk in England and Wales, Transactions of The Institute of British Geographers, Vol 40, 1, 44-61

Accurate national-scale economic assessment of flood risk should, first, allow policy and resource allocation to be determined sensibly by relating both the scale of that risk, and second, provide a benchmark against which any possible future changes in risk can be assessed. This paper critiques the UK's National Flood Risk Assessment (NAFRA), its development for England and Wales over a decade, and its evaluation of economic fluvial and coastal flood risk. We find, when comparing the results with other data on flooding and damage caused over 20+ years (including insurance claims) that NAFRA appears to overestimate the economic risk by between four and five-fold (i.e. at c.£1.1bn p.a., as opposed to a central estimate here of £0.25bn p.a.). The flood protection faced is still serious, and may be increasing, but we suggest that an exaggeration has become embedded. The assessment models and their data need further enhancement it this situation is to be corrected and a realistic assessment made of the scale of the current fluvial and coastal flood risk. Only then will the results be adequately credible and hence useful.

Ramsbottom, D., Sayers, P. and Panzeri, M. (2012) Climate Change Risk Assessment for the Floods and Coastal Erosion Sector, (Defra Project Code GA0204), Defra, DoE, Welsh Government, Scottish Government. Accessed at http://www.defra.gov.uk/environment/climate/government/ **on 11.10.15**

This is a lengthy assessment of some 244 pages. The Climate Change Risk Assessment (CCRA) provides an assessment of the risks to the UK that could be caused by climate change in the future. This report covers the risk assessment for the Floods and Coastal Erosion sector. This risk assessment is designed to examine the potential changes in flood and coastal erosion risk as a result of climate change. The assessment has been made assuming

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that there are no changes in the existing flood and coastal erosion risk management measures. Thus the analysis includes the current flood defences and protection against coastal erosion, but does not include any future changes as a result of adaptation policies and measures. This means that the projections given in this report do not take account of the risk reduction benefits of future or planned adaptation measures, or the increase in risk that would occur as existing flood defences and other assets deteriorate, or the change in risk that would occur as existing flood defences and other assets are repaired or replaced. The impact that adaptation policies would have on the projections presented in this report will depend on the resources that are made available to maintain the existing flood risk management system and implement further adaptation measures. As such, this report presents the potential risks that may be reduced further by targeted investment in flood risk management. The subsequent Economics of Climate Resilience study and more detailed investment plans of the Environment Agency, other risk management authorities and relevant Devolved Government agencies will determine the cost effectiveness of different adaptation measures. The assessment is based on the UKCP09 climate projections, which indicate that the main climate drivers of flood risk (sea level rise, winter precipitation and storm rainfall intensity) will increase, leading to an increase in the risk of flooding. In order to assess the magnitude of climate change impacts, changes in the most important impacts have been estimated for the following epochs:

- Future climate scenarios, in the 2020s, 2050s and 2080s
- Future climate scenarios and projections of socio economic change, in the 2020s, 2050s and 2080s.

The three epochs used in the analysis (2020s, 2050s and 2080s) are those used for the climate projections in UKCP09. The analysis has been carried out for tidal and river flooding, but not surface water flooding. Whilst the number of properties at risk from surface water flooding is similar to the number at risk from tidal and river flooding, suitable information for analysis were not available at the time of writing this report.

It is estimated that about six million people in the UK (about 10% of the population) are at risk of flooding from rivers or the sea. A similar number are at risk from surface water flooding. In addition, about 3,000 km of the coastline (17% of the total length) is eroding. Global sea level has risen at a mean rate of 1.8 mm per year since 1955. From 1992 onwards a higher mean rate of 3 mm per year has been observed. The climate change projections indicate that the sea level is highly likely to continue to rise and that the rate of rise is projected to increase. This would lead to an increase in tidal flood risk on the coast and in estuaries. There has been significantly increased precipitation over northern Europe (an area which includes the UK) between 1900 and 2005. Based on projections, the analysis indicates that the risk from tidal and river flooding could increase. For example, the annual flood damages to properties is projected to increase by between 70% and 400% by the 2080s compared with the baseline as a result of climate change assuming no change in population or property numbers, and assuming no change in existing flood risk management measures. The current level of vulnerability to flood risk is deemed to be high. Many of the properties exposed to a degree of flood risk are in areas with flood defences. However the current system of flood defences will deteriorate over time and may require significant future investment. A sizeable part of important infrastructure and public services is in flood risk areas. For example, over 50% of water and sewage pumping stations and treatment works are in the floodplain. The analysis goes on to examine different types of assets and people exposed to flooding and direct and indirect consequences of potential flooding and erosion. It also discusses drivers of change, uncertainties and challenges for the future including awareness and adaptive capacities.

Samiolo, R. (2012) Commensuration and styles of reasoning: Venice, cost–benefit, and the defence of place, Accounting, Organizations and Society, Vol 37, 6, 382-402

This paper discusses some preconditions for “making things the same” by means of quantification and economic calculation. It examines a controversial cost–benefit analysis, conducted as part of the environmental appraisal of a large public sector project in Italy: the long-debated scheme for flood protection in Venice. By tracing the different “styles of calculation” that characterised the economic and environmental appraisal of the project, the paper analyses the inter-relationship between economic representations of the urban and natural environment, its political symbolism, and various attempts to intervene upon it. It follows how the objectivity of numbers is debated, stabilised or disrupted, as differing appeals to realism and accuracy are advanced in the context of different modes of intervention and practical aims. The paper shows that the “commensuration” and

"standardisation" that numbers can bring about rest on how the object of calculation as well as, crucially, its subject are represented and conceived.

Sayers, P., L.i, Y., Galloway, G., Penning-Rowsell, E., Shen, F., Wen, K., Chen, Y. and T. Le Quesne. (2013) Flood Risk Management: A Strategic Approach. Paris, UNESCO. ISBN 978-92-3-001159-8. Free copies of Parts A, B and C available for PDF download at http://www.wwf.org.uk/what_we_do/rivers_and_lakes/publications/?6599/strategic-water-management

Over recent decades the concept of flood risk management has been cultivated across the globe. Implementation however remains stubbornly difficult to achieve. In part this reflects the perception that a risk management paradigm is more complex than a more traditional standard-based approach as it involves 'whole systems' and 'whole life' thinking; yet this is its main strength and a prerequisite for more integrated and informed decision making. This book results from an international collaborative effort to explore and distil best practice approaches to flood risk management in challenging large scale and inter-related environments. Part A provides a historical perspective on the flood events that have shaped modern approaches. Part B describes emerging good practice, including (i) the purpose and characteristics of strategic "Flood risk management, (ii) the goals, objectives and outcomes sought, (iii) the necessary governance frameworks, (iv) the development of adaptive strategies, (v) the relationship with ecosystem services, (vi) the barriers to, and enablers of, implementation, and, finally, (vi) the 'nine golden rules' that underpin good "flood risk management decision making today. Part C presents particular techniques in more detail, including (i) risk and uncertainty analysis, (ii) spatial planning, (iii) infrastructure management, (iv) emergency planning, (v) flood hazard and risk mapping, (vi) the management of "ash "floods and (vii) insurance.

Sayers, P., L.i, Y., Galloway, G., Penning-Rowsell, E., Shen, F., Wen, K., Chen, Y. and T. Le Quesne (2014) Strategic flood management: ten 'golden rules' to guide a sound approach, International Journal of River Basin Management, 1-15

Over recent decades, remarkable progress in cultivating the concepts of flood risk management has taken place across countries as diverse as India, China, Australia, the UK and the USA. This change highlights a risk management paradigm as potentially more complex than a more traditional standard-based approach as it involves 'whole systems' and 'whole-life' thinking, yet this is also its main strength – paving the way for more integrated and informed decision-making. Strategic flood management uses a portfolio of responses to manage flood risk and to promote opportunities of ecosystem services. It recognises the interrelationships between the actions taken and the contribution flood management provides to integrated river basin and coastal zone planning. The paper results from an international collaborative effort for research and distils approaches to flood risk and water management in challenging large-scale and complex environments. The paper provides an overview of the emerging good practice in Strategic Flood Management. Our conclusions are encapsulated in a set of 'golden rules' that underpin sound Strategic Flood Management.

Schanze, J., Zeman, E. and Marsalek, J. (Eds.) (2006) Flood Risk Management: Hazards, Vulnerability and Mitigation Measures, Proceedings of the NATO Advanced Research Workshop on Flood Risk Management - Hazards, Vulnerability and Mitigation Measures, Ostrov, Czech Republic, from 6 to 10 October 2004, Series: NATO Science Series IV, Vol. 67, Springer Available at an eBook ISBN 978-1-4020-4598-1 and as a Hardback and Softcover

Floods are of increasing public concern world-wide due to increasing damages and unacceptably high numbers of injuries. Previous approaches of flood protection led to limited success especially during recent extreme events. Therefore, an integrated flood risk management is required which takes into consideration both the hydrometeorogical and the societal processes. Moreover, real effects of risk mitigation measures have to be critically assessed. The book draws a comprehensive picture of all these aspects and their interrelations. It furthermore provides a lot of detail on earth observation, flood hazard modelling, climate change, flood forecasting, modelling vulnerability, mitigation measures and the various dimensions of management strategies. In addition to local and regional results of science, engineering and social science investigations on modelling and

management, transboundary co-operation of large river catchments are of interest. Based on this, the book is a valuable source of the state of the art in flood risk management but also covers future demands for research and practice in terms of flood issues.

US Army Corps of Engineers (USACE). 2011c. National Flood Risk Management Program. http://www.iwr.usace.army.mil/Missions/FloodRiskManagement/FloodRiskManagementProgram/AbouttheProgram.aspx. Accessed 19 Jan 2015.

The U.S. Army Corps of Engineers established the Flood Risk Management Program in May of 2006 for two primary purposes. Firstly, to work across the agency to focus the policies, programs and expertise of the Corps toward reducing overall flood risk, including reducing the risk of loss of life, reducing long-term economic damages to the public and private sector, and improving the natural environment. Secondly, to convene and facilitate dialogue at all levels of government and with other key interests (e.g., national organizations and the private sector) to develop a national vision for flood risk management.

As a part of the Army, USACE is assigned mission responsibilities in major construction and other engineering support to the Army and Air Force, in nationwide water resource management, in engineering research and development, and in real estate services for the Army and the Department of Defense. In addition to these long-standing programs, USACE has been called upon with increasing frequency to take a leadership role in the nation's flood risk management arena. As a result, USACE established the National Flood Risk Management Program (NFRMP) in May 2006 for the purpose of integrating and synchronizing USACE flood risk management programs and activities, both internally and externally with counterpart activities of the Department of Homeland Security, Federal Emergency Management Agency (FEMA), other Federal agencies, state organizations and regional and local agencies as well as non-governmental organizations (NGO). The official guidance (pdf, 526 KB) establishing the USACE National Flood Risk Management Program was issued in October 2009. The Program Management Plan (pdf, 1.75 MB) provides further guidance and information on the implementation of the program to supplement the initial guidance first issued to Major Subordinate Commands (MSCs) and Districts in October of 2009. Silver Jackets teams are continuously operating, state-led, collaborative interagency teams working together to reduce flood risk at the state level. USACE, FEMA, and other Federal, state and tribal and local agencies provide a unified approach to addressing a state's priorities. No single agency has the complete solution — each has one or more pieces, similar to squares in a patchwork quilt. The Silver Jackets program can be viewed as the quilting bee, the forum where all agencies come together to put their programs together and implement a solution.

Van Alphen, J. Bourger, L., Elliott, C., Fujita, K.I., Riedstra, D., Rooke, D., Tachi, K. (2011) Flood risk management approaches: As being practiced in Japan, Netherlands, United Kingdom and United States, Report 2011-09-01 Repository Hydraulic Engineering Reports, TU Delft

Many countries are reassessing their approaches in the face of improved understanding of flood risks. The Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Dutch Rijkswaterstaat, the United Kingdom Environment Agency, and the United States Army Corps of Engineers agreed in 2009 to develop a document to explore risk-informed approaches as being practiced and developed primarily in those four countries. Although very different in frequency and scale of flooding as well as cultural and governmental characteristics, each country had significant efforts underway to better orient its practices to flood risk realities, including those induced by altered land use and by climate change and variability. The quadric-lateral collaboration was envisioned as a continuing step in international collaboration and as one means for each country to learn from the other countries' experiences. This document, the result of that collaboration, reflects contributions from agencies within the four participating nations but is not an official position of any government or international organization. The document is organized around a conceptual framework developed to encompass flood risk drivers, risk assessment, and the source-path-receptor concept; the flood risk management cycle with its overarching policies and supporting players and mechanisms; and the adaptive management cycle of maintenance, monitoring, evaluation, and adjustment over time. Differences in scale are addressed through consideration of national and regional/local levels. The document highlights the approaches in each country, the

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drivers for those approaches, and practices that are working or hold particular promise. Specific examples illustrate various approaches without trying to fully reflect the entirety of any one country's effort or to include an example from each country for any particular aspect.

Wadey, M.P., Brown, J.M., Haigh, I.D., Dolphin, T., and P. Wisse (2015) Assessment and comparison of extreme sea levels and waves during the 2013/14 storm season in two UK coastal regions, Nat. Hazards Earth Syst. Sci., 15, 2209-2225

The extreme sea levels and waves experienced around the UK's coast during the 2013/14 winter caused extensive coastal flooding and damage. Coastal managers seek to place such extremes in relation to the anticipated standards of flood protection, and the long-term recovery of the natural system. In this context, return periods are often used as a form of guidance. This paper provides these levels for the winter storms, and discusses their application to the given data sets for two UK case study sites: Sefton, northwest England, and Suffolk, east England. Tide gauge records and wave buoy data were used to compare the 2013/14 storms with return periods from a national data set, and also joint probabilities of sea level and wave heights were generated, incorporating the recent events. The 2013/14 high waters and waves were extreme due to the number of events, as well as the extremity of the 5 December 2013 "Xaver" storm, which had a high return period at both case study sites. The national-scale impact of this event was due to its coincidence with spring high tide at multiple locations. Given that this event is such an outlier in the joint probability analyses of these observed data sets, and that the season saw several events in close succession, coastal defences appear to have provided a good level of protection. This type of assessment could in the future be recorded alongside defence performance and upgrade. Ideally other variables (e.g. river levels at estuarine locations) would also be included, and with appropriate offsetting for local trends (e.g. mean sea-level rise) so that the storm-driven component of coastal flood events can be determined. This could allow long-term comparison of storm severity, and an assessment of how sea-level rise influences return levels over time, which is important for consideration of coastal resilience in strategic management plans.

Webler, H. (Undated) German Framework for Flood Risk Management Plans: The Example of the River System Nahe, Paper for IWA, World Congress on Water, Climate and Energy. http://www.vmm.be/pub/presentaties-studiedag-overstromingsaanpak-floodresiliencity/achtergronddocument-german-framework-for-flood-risk-management-plans accessed on 23 Jan 2015

The German federal state of Rheinland-Pfalz is well advanced in its programme of actions required to comply with the provisions of the EU Flood Directive. So far, the preliminary flood risk assessments; the flood hazard maps; and, the flood risk maps have been completed for the entire state. In early 2011, the flood risk management plans for the River Nahe (4.000 km²) catchment were commenced. These follow the framework set out in the German LAWA-directive "Recommendations for the Establishment of Flood Risk Management Plans" which includes a comprehensive guide to all the diverse action areas that occur in the flood risk management cycle. Appropriate policy objectives have been set and strategies formulated. The latter include both structural and non structural measures. A distinguishing feature of the Nahe pilot project is to create stakeholder involvement in the assessment process and the final plan. This is being achieved through a series of workshops with the public stakeholders. To date, three of these workshops have been held to address the action areas: "emergency planning", "providing information" and "natural water storage" and these have been very successful. The workshops have identified a wealth of good ideas among the communities and have promoted stakeholder "buy in" to the process. This is being achieved much earlier and in a much more constructive manner than would have been anticipated following a more traditional approach involving the circulation of draft proposals to the public for information and comment.

Werrity, A. (2006) Sustainable Flood Management: Oxymoron or New Paradigm? Area, 1 March, Vol 38, 1, 16-23

The existing paradigm of UK flood risk management that privileges structural solutions over non-structural ones is evolving in response to threats posed by climate change and higher environmental standards required by the EC Water Framework Directive. This paper examines the contrasting reactions of DEFRA and the Scottish Executive. The Scottish 'experiment', which embraces a strong definition of sustainability, is contrasted with a weaker version emerging in England and Wales. Divergent levels of risk and histories of managing that risk explain many

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of these contrasts. Scotland's more radical approach has the potential to become a new paradigm.

World Wide Fund for Nature (WWF). 2007. Flood Planner, A Manual for the Natural Management of River Floods. Dunkeld, Scotland, WWF.

The requirement for a sustainable approach to flood management involves taking an informed catchment approach, using natural river processes to manage floods where they arise, not just where they have their effect, and putting the emphasis on soft engineering solutions. Achieving sustainable flood management involves social, economic, planning and natural components. Flood Planner describes the natural component of sustainable flood management: natural flood management (NFM). This unique and practical resource for flood risk managers outlines the background to natural flood management and helps them perform their role in meeting current and future legislation. It provides evidence of the effect of NFM on run-off rates and storage and describes the techniques required to successfully lower flood risk to communities within that catchment.

Flood risk mapping

Buchele, B., Kreibich, H., Kron, A., Thieken, A., Ihringer, J., Oberle, P., Merz, B. and Nestmann, F. (2006) Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks, Nat. Hazards Earth Syst. Sci., Vol 6, 485–503

Currently, a shift from classical flood protection as engineering task towards integrated flood risk management concepts can be observed. In this context, a more consequent consideration of extreme events which exceed the design event of flood protection structures and failure scenarios such as dike breaches have to be investigated. Therefore, this study aims to enhance existing methods for hazard and risk assessment for extreme events and is divided into three parts. In the first part, a regionalization approach for flood peak discharges was further developed and substantiated, especially regarding recurrence intervals of 200 to 10 000 years and a large number of small ungauged catchments. Model comparisons show that more confidence in such flood estimates for ungauged areas and very long recurrence intervals may be given as implied by statistical analysis alone. The hydraulic simulation in the second part is oriented towards hazard mapping and risk analyses covering the whole spectrum of relevant flood events. As the hydrodynamic simulation is directly coupled with a GIS, the results can be easily processed as local inundation depths for spatial risk analyses. For this, a new GIS-based software tool was developed, being presented in the third part, which enables estimations of the direct flood damage to single buildings or areas based on different established stage-damage functions. Furthermore, a new multifactorial approach for damage estimation is presented, aiming at the improvement of damage estimation on local scale by considering factors like building quality, contamination and precautionary measures. The methods and results from this study form the base for comprehensive risk analyses and flood management strategies.

Falconer, R.H., Cobby, D., Smyth, P., Astle, G., Dent J. and Golding, B. (2009) Pluvial flooding: new approaches in flood warning, mapping and risk management, Flood Risk Management, Vol 2, 198-208

In response to Defra's First Government Response to the Making Space for Water consultation, the Feasibility study into expanding flood warning to cover other flood risks (reference RF5) has investigated the technical feasibility of providing warning services for sources of flooding other than from rivers and the sea. Following a review of all nonfluvial and noncoastal sources of flooding perceived as significant, it was concluded that it is currently technically feasible to consider providing some form of warning service for pluvial and three forms of groundwater flooding. Although a warning service for pluvial flooding is considered less advanced than that for groundwater, a trigger rainfall forecast and a method for identifying locations most susceptible to pluvial flooding has been proposed. This form of service could provide responding organisations with more warning of possible flooding than is currently available.

Fohringer, J., Dransch, D., Kreibich, H. and K. Schröte (2015) Social media as an information source for rapid flood inundation mapping Nat. Hazards Earth Syst. Sci., Vol 15, 2725-2738

During and shortly after a disaster, data about the hazard and its consequences are scarce and not readily available. Information provided by eyewitnesses via social media is a valuable information source, which should

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be explored in a~more effective way. This research proposes a methodology that leverages social media content to support rapid inundation mapping, including inundation extent and water depth in the case of floods. The novelty of this approach is the utilization of quantitative data that are derived from photos from eyewitnesses extracted from social media posts and their integration with established data. Due to the rapid availability of these posts compared to traditional data sources such as remote sensing data, areas affected by a flood, for example, can be determined quickly. The challenge is to filter the large number of posts to a manageable amount of potentially useful inundation-related information, as well as to interpret and integrate the posts into mapping procedures in a timely manner. To support rapid inundation mapping we propose a methodology and develop "PostDistiller", a tool to filter geolocated posts from social media services which include links to photos. This spatial distributed contextualized in situ information is further explored manually. In an application case study during the June 2013 flood in central Europe we evaluate the utilization of this approach to infer spatial flood patterns and inundation depths in the city of Dresden.

Hankin, B., Waller, S., Astle, G. and Kellagher, R. (2008) Mapping space for water: screening for urban flash flooding, Flood Risk Management, Vol 1, 13-22

This paper builds on the 'Flooding from Other Sources' project (HA4a), funded as part of Defra's Making Space for Water strategy. The HA4a study concluded that flood risk mapping is feasible for many of the sources of flooding that were investigated, which are not currently covered by the Environment Agency Flood Map, using existing flow modelling and GIS tools. However, there are some major constraints in terms of the need to undertake extensive data collection to allow the generation of useful flood maps that are not dominated by modelling uncertainties. The project anticipated that different levels of data collection and modelling might be needed for different purposes, given the hierarchical nature of UK flood risk assessment and management in the United Kingdom under PPS25 and the EC Floods Directive. This paper compares and contrasts three different approaches to urban flood modelling using topographic analysis, blanket extreme rainfall and semi-coupled sewer/overland routing. The UK summer floods 2007 have highlighted the pressing need for mapping the risk from urban flash flooding, and the Pitt Review has recommended that areas at high risk from surface waters should be urgently identified. This can be done now at some level of detail, and we can be guided as to what level, from our increasing knowledge of vulnerable populations, from records of historical flooding and by using some of the screening methods described herein.

Jelínek, R., Wood, M. and Hervás, J. (2007) Risk mapping of flood hazards in new Member States, European Commission, Joint Research Centre

In 2003 the Joint Research Centre conducted a survey of mapping practices in eleven (11) new Member States (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia) for eight (8) major natural and technological hazards such as floods, forest fires, storms, landslides, earthquakes, industrial installations, transport of dangerous goods and contaminated lands. This activity was funded as part of the project entitled "Management of Natural and Technological Risks". One fundamental project objective was to examine the existing situation in each of the surveyed countries, and compare different mapping methodologies in order to define guidelines for establishing compatible risk mapping systems, in particular multi-hazard risk mapping. This report describes the results of the flood section of the risk mapping activity. Responses to the survey provide important information about the current status of flood hazards and risk mapping in different countries and advantages and obstacles to developing a common methodology for multi-hazard risk mapping including this hazard in each country

Koivumaki, L., Alho, P., Lotsari, E., Kayhko, J., Saari, A. and Hyyppa, H. (2010) Uncertainties in flood risk mapping: a case study on estimating building damages for a river flood in Finland, Flood Risk Management, 166-183

In our review of recent flood risk mapping approaches in Europe, we noted that the sources of uncertainty were rarely questioned. We demonstrated potential sources of uncertainty in flood risk mapping of buildings using a case study of a spring flood in 2005, in Kittila¨, Finland. One-and two-dimensional hydraulic models of the flood corresponded well with the actual inundation. The initial modelling result of the inundated buildings differed

considerably from reality, but this could be improved through modelling performed with more diverse building elevation data. The accuracy of the digital terrain model is a key determinant in the accuracy of flood hazard modelling. An exposure analysis of buildings is often utilized by an overlay analysis of map layers representing both the flood and the buildings. However, we indicated that the analysis may be partly hindered by the characteristics and inaccuracies of the building datasets used and the modelled flood. In flood damage modelling, the average damages calculated from the database were used, as empirical damage data were too general for a detailed flood damage assessment. Damage modelling with empirical and synthetic damage data could be made more reliable through better archiving of actual flood damages and by performing more diverse damage estimates of standard buildings.

Lewis, M., Horsburgh, K., Bates, P. and Smith, R. (2011) Quantifying the Uncertainty in Future Coastal Flood Risk Estimates for the U.K, Journal of Coastal Research, Vol 27, 5, 870-881

Future sea-level rise will increase coastal flood risk in the U.K., yet the hazard uncertainties associated with such future risk estimates have not been fully explored. The sensitivity of coastal flood-risk mapping to future uncertainties was investigated by propagating ranges of plausible parameters through a LISFLOOD inundation model of a significant historic flood event to the North Somerset (U.K.) coast. Mean sea-level rise (including land movement) was found to have the greatest effect on the extent of flood inundation. Analysis of the latest research into the future storm-surge climate of the U.K. indicates no change above natural variability, thus, future, extreme water-level estimates (for the U.K.) should be based on observations and not Regional Circulation Models until research indicates otherwise. Evidence suggests that the current approach of forcing the inundation model with an extreme water level of a constant return period is incorrect. This uncertainty of the peak storm tide height along the coastline had a significant effect on our results. We present a new boundary-forcing technique to force the inundation model with (method C), based on the spatial characteristics of real events, which can account for the natural storm-surge variability. Indeed, if sea-level rise is included with method C, a great deal of the uncertainty surrounding such a future flood-hazard estimate can be quantified and communicated clearly and effectively.

Maantay, J. and Maroko, A. (2009) Mapping urban risk: Flood hazards, race, & environmental justice in New York, Applied Geography, Vol 29, 111–124

This paper demonstrates the importance of disaggregating population data aggregated by census tracts or other units, for more realistic population distribution/location. A newly developed mapping method, the Cadastral-based Expert Dasymetric System (CEDS), calculates population in hyper-heterogeneous urban areas better than traditional mapping techniques. A case study estimating population potentially impacted by flood hazard in New York City compares the impacted population determined by CEDS with that derived by centroid-containment method and filtered areal-weighting interpolation. Compared to CEDS, 37% and 72% fewer people are estimated to be at risk from floods city- wide, using conventional areal weighting of census data, and centroid-containment selection, respectively. Undercounting of impacted population could have serious implications for emergency management and disaster planning. Ethnic/racial populations are also spatially disaggregated to determine any environmental justice impacts with flood risk. Minorities are disproportionately undercounted using traditional methods. Underestimating more vulnerable sub-populations impairs preparedness and relief efforts.

Morris, S.E., Cobby, D. and Parkes, A. (2007) Towards groundwater flood risk mapping, Quarterly Journal of Engineering Geology and Hydrogeology, Vol 40, 203–211

Whereas fluvial flood risks have, in recent years, become better appreciated and understood, little is generally known about the risks posed by groundwater emergence. To better understand the risks of groundwater flooding, the Department for the Environment, Food and Rural Affairs (Defra) commissioned a scoping study to assess these risks. As part of the scoping study, provisional maps of areas vulnerable to groundwater emergence from consolidated aquifers were produced that reflect the groundwater conditions experienced in the exceptionally wet winter of 2000–2001. These maps, covering all consolidated aquifers of England, are presented as a

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provisional set of risk maps that, with further refinement, could be utilized in regional planning decisions and for flood risk management.

Naughton, 0., Johnston, P.M., McCormack, T. and Gill, L.W. (2015) Groundwater flood risk mapping and management: examples from a lowland karst catchment in Ireland, Flood Risk Management

The complexity of groundwater flooding poses unique challenges to policy makers and flood risk management agencies. An understanding of the interactions among recharge, storage and transport mechanisms during flood conditions is a precursor to effective groundwater flood risk assessment, but is often absent due to a lack of adequate data. The example of the Gort Lowlands, a major lowland karst catchment in the Republic of Ireland, is used to elucidate key flood mechanisms which must be considered when characterising ground- water flood risk in a lowland karst setting. The combination of large quantities of allogenic recharge, a high-capacity conduit system and deep surface depressions renders the catchment susceptible to groundwater flooding. Observed flood mechanisms include backwater flooding of sinks, overland flow caused by the overtopping of sink depressions, high water levels in turlough basins and surface ponding in local epikarst watersheds. Flood hazard maps are developed for the region using data collected during a major flood event in the winter of 2009, representing a significant contribution in the assessment and management of groundwater flood risk in Ireland. Major challenges to groundwater flood management and forecasting remain, however, and are discussed in the context of the prevailing hydrogeological and ecohydrological setting.

Neal, J., Keef, C., Bates, P., Beven, K. and Leedal, D. (2013) Probabilistic flood risk mapping including spatial dependence, Hydrological Processes, Vol 27, 1349–1363

Effective flood risk management depends on methods for estimating flood hazard and an appraisal of the dominant uncertainties in the analysis. Typically, hydraulic models are used to simulate the extent of flooding for an estimate of the flow in a particular reach for a chosen probability of exceedance. However, this definition causes problems at river confluences where flows derive from multiple sources. Here, a model-based approach was adopted to describe the multisite joint distribution of river flows for three rivers that converge on the city of Carlisle (UK). Monte-Carlo methods were used to generate flood events with realistic spatial dependence between tributaries which would occur over a 1000 year period. To account for the uncertainty in the data used to create the event set, block bootstrapping was used to produce a further 100 runs of the event generator over notional 1000 year periods. Each of the 20 000 events created by this process was then simulated using a 10 m resolution two-dimensional hydraulic model of the whole city to demonstrate the feasibility of the approach. Spatial dependence was found to be important because no single event caused the maximum flood extent at all locations and assuming perfect correlation between tributaries overestimated flood hazard. Uncertainty in estimates of inundation probability was significant to the extent that confidence intervals in risk estimates were larger than expected; however, the interaction of flows with the flood defences and valley topography gave a distinct structure to the inundation probabilities and risk. Copyright © 2012 John Wiley & Sons, Ltd.

Queensland Flood Mapping Project (QFMP), Department of Natural Resources and Mines (2014) Flood ready Queensland, Flood mapping implementation kit. Available to copy at https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0009/230778/flood-mapping-kit.pdf. Accessed on 23 Jan 2015

Flood Ready Queensland – Flood Mapping Implementation Kit has been developed to assist a broad range of stakeholders more effectively implement the outcomes of flood studies. In particular, it aims to increase the use of flood mapping outputs, improving the community's understanding of their exposure to flood risk and therefore strengthening economic and community resilience. The kit is intended to be a living document that will be enhanced over time through feedback and comments. It aims to encourage effective use of available flood information to:

• improve community safety;

• increase business resilience through preparedness and business continuity planning;

• improve community resilience through increased awareness and preparedness to the hazard;

• position local disaster management groups to be better prepared to respond to flood events;

• reduce recovery costs borne by community, insurance industry and all levels of government.

Ray-Bennett, N.S. (2009) The influence of caste, class and gender in surviving multiple disasters: A case study from Orissa, India, Environmental Hazards, Vol 8, 1, 5-22

Sociological and anthropological studies in India reveal that caste, class and gender in everyday life are both rigid and dynamic, but little is known about how they influence the survival mechanisms of women during 'multiple disasters', nor about how women negotiate with these structural mores to meet their cultural and biological needs. This is explored through the experiences of 12 women-headed households from different social castes in Orissa, India. Multiple disasters or disasters that occur in 'one specific place' (such as floods, cyclone and drought) are regular events in coastal parts of the state of Orissa. The super-cyclone of 1999, two floods of 2001 and 2003 and drought of 2000 and 2002 form the case study. Participant observation, in-depth interviews and documentary evidence complement the fieldwork. The findings suggest a complex interplay of caste, class and gender in surviving the multiple disasters including structural mutability under the purview of social organization. In doing so, women demonstrated their individual and collective agencies in order to meet their cultural and biological needs under severe crisis. This research stresses that gender and disaster studies must include a consideration of caste and class for effective disaster management and social vulnerability reduction.

Tam, T.H. (2014) Development of flood risk mapping in Kota Tinggi, Malaysia, Earth and Environmental Science, Vol 18, DOI: 10.1088/1755-1315/18/1/012192

Flood risk maps provide valuable information for development of flood risk management. Geospatial technology and modeling enable us to monitor natural disasters around the world. Flooding is the most severe natural disaster that causing huge economic losses every year. Flood risk maps are an essential tool for assessing the consequences of flooding. The main aim of this study is to initiate a framework to develop a local-based flood risk map. Flood risk maps can be produced by using integration of geospatial technology and hydrodynamic modeling. Results show that a flood risk map for Kota Tinggi is produced with unsatisfactory information in term of flood damage.

van Alphen, J., Martini, F., Loat, R., Slomp, R. and Passchier, R. (2009) Flood risk mapping in Europe, experiences and best practices, Flood Risk Management, Vol 2, 285–292

Within the context of the European Flood Risk Management Directive, adopted in 2007, the European countries are required to prepare flood hazard and flood risk maps before 2014. The Exchange Circle on Flood Mapping (EXCIMAP) has made an inventory of flood mapping practices in Europe. This inventory has resulted in a 'Handbook on Good Practices for flood mapping in Europe' and an 'Atlas of Flood maps containing examples from 19 European countries, Japan and USA'. This paper highlights the main conclusions of the EXCIMAP Handbook and Atlas, regarding the most appropriate ways to present flood-related information. Distinction is made between different types of use and users, such as land-use planning, emergency planning, flood risk management, reinsurance and the general public. Many countries disseminate flood maps (mainly flood extent maps) and flood hazard maps (depth or depth–velocity combinations) already via Internet. Many European rivers are part of transboundary water systems. There- fore, uniform approaches in flood (risk) assessments, map legend and presentation are urgently needed.

Visser, F. (2015) Rapid mapping of urban development from historic Ordnance Survey maps: An application for pluvial flood risk in Worcester, Journal of Maps, Vol 10, 2, 276-288

Between 2004 and 2008 the city of Worcester, UK experienced a number of pluvial flood events. The causes of this kind of flooding are the topic of ongoing research. This paper describes a study that aimed to investigate the urban development of Worcester over time in relation to the location of recorded pluvial flood incidents. A

novel rapid mapping method has been developed to derive urban development over five time periods between 1886 and 1995 from scanned Ordnance Survey historical maps. The technique compared well with manual digitisation results with k-hat values ranging from 0.67 to 0.87 for the land use maps created for different time periods. The technique performed least well for the oldest map series, due to misclassification of the abundant symbols and annotation. The method will be particularly beneficial for investigation of town/city development in time over large areas. The resulting map of urban development in Worcester (scale 1:20,000) shows that almost half of the recorded pluvial flood incidents occurred in areas developed between 1956 and 1975, which contradicts local belief that an outdated (Victorian) drainage system causes most of the problems. The quality of the post World War II developments is more likely to be a source for concern.

Webster, T., McGuigan, K., Collins, K. and MacDonald, C. (2014) Integrated River and Coastal Hydrodynamic Flood Risk Mapping of the LaHave River Estuary and Town of Bridgewater, Nova Scotia, Canada, Water, Vol 6, 517-546

Bridgewater, Nova Scotia, is located 20 km inland from the mouth of the LaHave River estuary on the Atlantic Coast of Canada. Bridgewater is at risk of flooding due to the combined effects of river runoff and a storm surge on top of high tide. Projected increases in sea-level and possible increased river runoff with climate change increase the risk of future flooding. A set of river and ocean water level simulations were carried out to determine the risk of flooding to Bridgewater today and in the future under climate change. The hydrodynamic simulation developed incorporates return periods of a time series of river discharge measurements for the LaHave watershed, ocean water dynamics at the mouth of the river under normal tidal conditions and with two levels of storm surge, near shore and river bathymetry, as well as high precision topographic lidar derived ground elevations and survey grade GPS. The study was supported by data from two tide gauge sensors, and qualitative evidence provided by the community such as historical flood levels and photographs. Results show that areas upstream of the town are vulnerable to large discharge events of the LaHave River. The downtown waterfront and infrastructure are not susceptible to fluvial flooding, but is vulnerable to sea-level rise and storm surge flooding.

Webster, T. L. (2010) Flood Risk Mapping Using LiDAR for Annapolis Royal, Nova Scotia, Canada, Remote Sensing, Vol 2, 2060-2082

A significant portion of the Canadian Maritime coastline has been surveyed with airborne Light Detection and Ranging (LiDAR). The purpose of these surveys has been to map the risk of flooding from storm surges and projected long-term sea-level rise from climate change and to include projects in all three Maritime Provinces: Prince Edward Island, New Brunswick, and Nova Scotia. LiDAR provides the required details in order to map the flood inundation from 1 to 2 m storm surge events, which cause coastal flooding in many locations in this region when they occur at high tide levels. The community of Annapolis Royal, Nova Scotia, adjacent to the Bay of Fundy, has been surveyed with LiDAR and a 1 m DEM (Digital Elevation Model) was constructed for the flood inundation mapping. Validation of the LiDAR using survey grade GPS indicates a vertical accuracy better than 30 cm. A benchmark storm, known as the Groundhog Day storm (February 1–3, 1976), was used to assess the flood maps and to illustrate the effects of different sea-level rise projections based on climate change scenarios if it were to re-occur in 100 years time. Near shore bathymetry has been merged with the LiDAR and local wind observations used to model the impact of significant waves during this benchmark storm. Long-term (*ca*. greater than 30 years) time series of water level observations from across the Bay of Fundy in Saint John, New Brunswick, have been used to estimate return periods of water levels under present and future sea-level rise conditions. Results indicate that under current sea-level rise conditions this storm has a 66 year return period. With a modest relative sea-level (RSL) rise of 80 cm/century this decreases to 44 years and, with a possible upper limit rise of 220 cm/century, this decreases further to 22 years. Due to the uncertainty of climate change scenarios and sea-level rise, flood inundation maps have been constructed at 10 cm increments up to the 9 m contour which represents an upper flood limit estimate in 100 years, based on the highest predicted tide, plus a 2 m storm surge and a RSL of 220 cm/century.

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Flood warnings

Drobot, S. and D. J. Parker (2007) Advances and challenges in flash flood warnings, Environmental Hazards 7 (2007) 173–178

Advances in meteorological, hydrological and engineering sciences are fast generating a range of new methodologies for forecasting weather and flood events, including ensemble prediction systems (EPS) and new hydrodynamic models. These advances are in addition to those already made in weather radar and quantitative precipitation forecasting which have enhanced flood warning lead time potential; in integrated real-time monitoring and modeling; and in long-term models. Each of these advances presents new challenges within the complex information and data flows which now exist between actors generating forecasts and actors using them. At the same time, the natural, physical and engineering sciences, which are generating the technical advances noted above, are being challenged by social science. The social science paradigm focuses on human perceptions of risk information and the under-estimated complexities of communicating risk between actors, and stresses that uncertainty must be managed rather than eradicated. It has already contributed much to a broader and deeper understanding of human behaviour in the face of hazard warnings. It promises to contribute further in addressing the risk communication and response issues now raised by the new wave of technical advances.

Fernández-Bilbao, A. and C. Twigger-Ross (2009) More targeted flood warnings: A Review Improving Institutional and Social Responses to Flooding, Science Report: SC060019 - Work Package 1b, Environment Agency, Bristol

The aim of this work package is 'to produce flood warnings that work, so that they are more targeted, matched to the perceptions and behaviours of different social groupings, including vulnerable communities'. Currently the flood warning system is not reaching enough people at risk, and more specifically that it is not reaching people who are most vulnerable over the flood incident cycle. In addition, there is a recognition that one size of flood warning will not "fit all", both in terms of the characteristics of the flood (such as rapid response versus slow onset) and in terms of differences within populations. This report is structured in five main sections, with separate contributions from the project's team of researchers as follows:

- Introduction and background to flood warnings.
- A review of the contextual factors of a flood event that are relevant to targeting flood warnings: the characteristics of a flood, the area where the event takes place and the social groups affected.
- A review of the risk perception and communication literature as related to flood warning.
- A overview of the "values mode" approach to segmenting the population.
- A review of how the "value mode" approach to segmenting the population might be used for flood warning.

A brief summary of the work presented here together with some suggestions as to implications for flood warnings is presented in the sister document to this document Improving Institutional and Social Responses to Flooding – Interim Report WP1, 2 and 5. (see also Colbourne and Straw and Colbourne in this bibliography).

Gwimbi, P. (2007) The effectiveness of early warning systems for the reduction of flood disasters: some experiences from cyclone induced floods in Zimbabwe, Journal of Sustainable Development in Africa, Vol, 9, No 4. Accessed at http://www.jsd-africa.com/Jsda/V9n4_Winter2007/PDF/EfectivenessEalierWarningSystem.pdf on 11.0815

The aim of any early warning systems is to provide warning to people of an impending natural hazard so that those vulnerable are aware of the potential impact of the natural processes in order to respond appropriately and minimise damage. This paper looks at variables affecting the implementation of flood hazard early warning

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systems in a flood prone area of Zimbabwe. Documenting the experiences of the local communities, the Civil Protection Unit responsible for managing disasters, the meteorological services department responsible for weather forecasts, non-governmental organisations operating in the area and local authorities, the study provides an important insight for future non structural flood mitigation strategies. The current early warning communication is a one-way process, with those issuing warnings not fully aware of the needs and priorities of vulnerable communities, and therefore not responsive to their needs. Warning information is poorly disseminated to poor communities with limited capacity to respond. The absence of preparedness plans for evacuation, and overdependence on rain fed agriculture by locals hamper the implementation of early warning systems. As a recommendation, there is need for those issuing warning information to acquire more information themselves about how communities perceive risk, and the reasons that underlie their behaviour when floods threaten them. There is also a need to strengthen local communities' capacity to play a key role in information dissemination before the onset of flood disasters.

Hurford, A.P., Parker,D.J., Priest, S.J. and D.M. Lumbroso (2012) Validating the return period of rainfall thresholds used for Extreme Rainfall Alerts by linking rainfall intensities with observed surface water flood events, Journal of Flood Risk Management, 5, 2,

In 2008, the Environment Agency and the Meteorological Office launched a pilot Extreme Rainfall Alert (ERA) service as a first step towards providing a warning for surface water flooding. An ERA is based on rainfall intensity thresholds of an average of 1-in-30 year storms, to represent rainfall thought likely to cause severe surface water flooding in urban areas. This research investigates whether this return period is appropriate for warning of surface water flooding by examining the intensity and return period of rainfall associated with observed surface water flood (SWF) events. Data from rainfall gauges and flood events were analysed which showed that most of the SWF events were associated with rainfall intensities of less than 1-in-10 year return period. Improvements in data recording could provide flood magnitudes and durations, which would facilitate better understanding of the relationship between flood magnitude and rainfall intensity and allow more informed debate about SWF warning thresholds.

Parker, D.J. (1999) Criteria for Evaluating the Condition of a Tropical Cyclone Warning System Disasters, 23, 3, 193-216

This paper evaluates the condition (i.e. health) of a tropical cyclone and related warning system (TCWS) during a `quiet period' between infrequent intense cyclones. Capacity to make pre-disaster evaluations is important — disaster warning systems need to be in sound condition before, not after, disaster. The research — part of the UK's International Decade of Natural Disaster Reduction Flagship Programme — focuses upon an evaluatory method first used on flood warning systems. The Criteria-development Matrix comprises social, organisational and institutional criteria by which a TCWS may be assessed using a five-stage development scale. This method is used to evaluate Mauritius's TCWS using in-depth interview data. Ways to enhance the method and apply it to other disaster warning systems are discussed. The TCWS in Mauritius is a relatively sound one from which others can learn. Weaknesses requiring attention for Mauritius's TCWS to progress to an advanced level of development are identified.

Parker DJ, Fordham M (1996) An evaluation of flood forecasting, warning and response systems in the European Union. Water Resource Management, 1, 10, 279–302

This paper develops an evaluatory framework which is a criteria-development matrix which is subsequently employed to evaluate the condition of flood forecasting, warning and response systems in five European countries. The evaluatory framework embraces a wider range of technical, social and economic variables than is usually employed to gauge the effectiveness of flood forecasting, warning and response systems and the evaluation is also unusual in that it spans the forecasting-warning-warning response chain which is rarely evaluated in an integrated manner. The results clearly indicate where the strengths and weaknesses lie and the challenges posed to each country in terms of enhancing their flood forecasting, warning and response systems.

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Parker, D.J., Priest, S, J. and S.S. McCarthy (2011) Surface water flood warnings requirements and potential in England and Wales, Applied Geography, 31, 891- 900

This paper examines the potential for developing surface water flood warnings in England and Wales by focusing upon the requirements of professional and public flood warning responders. The recent development of Extreme Rainfall Alerts (ERAs) presents an opportunity to develop such warnings. However, uncertainties concerning event probability, the location and likely impact of floods would significantly complicate the risk communication and warning response process limiting warning effectiveness. Feedback, interviews and workshops involving professional emergency responders and public focus groups allow the reception to existing ERAs and to proposed linked flood warnings to be gauged. For professional responders ERAs are useful and the majority take preparatory actions on receipt of them. There is support for surface water flood warnings among professional responders, particularly if uncertainties can be reduced and warnings tailored to their requirements. Higher quality linkages are required between rainfall intensity and duration and flooding and between forecasters, warners and the warned. Most flood experienced members of the public want surface water flood warnings but scepticism exists about ability to effectively provide them. Reasons include inherent forecasting uncertainties and lack of confidence in the responsible authorities. Existing constraints on developing warnings include reliability issues surrounding flood warnings, the current level of understanding of probabilities and low levels of public flood risk awareness.

Parker, D.J., Priest, S.J. and S. M. Tapsell (2009) Understanding and enhancing the public's behavioural response to flood warning information, Meteorological Applications 16, 103–114

Drawing on evidence from the United Kingdom and elsewhere in Europe, this paper explores how people have responded to flood warning information and how these responses impact upon the effectiveness of a flood warning through saving lives and injuries, and reducing economic damages. Methods of flood warning that the public rely upon are discussed alongside empirical evidence of how flood victims prepare for, and respond to, flood warnings in rapid to medium-onset floods. The paper investigates why some members of the public fail to act appropriately, or most effectively, to flood warning information, touching on ideas of a lack of understanding, mistrust in authority and a lack of ownership of flood reducing actions. The paper examines the styles of public learning about flood warning response which might be most appropriate and effective, and how recent positive steps to increase the public's understanding of effective response might be further enhanced in the United Kingdom.

Pescaroli, G. and Magni, M. (2015) Flood warnings in coastal areas: how do social and behavioural patterns influence alert services?, Nat. Hazards Earth Syst. Sci. Discuss., 3, 641-674

Many studies discuss the economic and technical aspects of flood warnings. Less attention has been given to the social and psychological patterns that affect alert services. In particular, the literature focuses on warnings activated in river basins or marine environments without providing clear evidence of relevance to Mediterranean coastal areas, even though these are subjected to growing flood risk related to climate change. This paper is a first attempt to bridge this gap. Our research develops an in- depth analysis of the village of Cesenatico on the Adriatic Sea coast. Here the municipality adopted two complementary warning systems: a siren and an alert via Short Message Service (SMS). The analysis focuses on a survey conducted in 2011 and 2012 with 228 participants. The relationships between social and behavioural variables and warning services are investigated, and so are flood preparedness and information dissemination. Qualitative evidence from informal interviews is used to support the understanding of key responses. The conclusions show how different social and behavioural patterns can influence the effectiveness and use of warning systems, regardless of the technology adopted and the structural mitigation measures implemented. Education, training and accountability are seen to be critical elements for improvement. Finally, the statistical output is used to suggest new questions and new directions for research.

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Priest, S.J., Parker, D.J., Hurford, A.P., Walker, J., and K. Evans (2011) Assessing options for the development of surface water flood warning in England and Wales, Journal of Environmental Management, Vol 92, 12, 3038-304

This paper explores the technical options for warning of surface water flooding in England and Wales and presents the results of an Environment Agency funded project. Following the extensive surface water flooding experienced in summer 2007 a rainfall threshold-based Extreme Rainfall Alert (ERA) was piloted by the Met Office and Environment Agency providing initial steps towards the establishment of a warning for some types of surface water flooding. The findings of this paper are based primarily on feedback on technical options from a range of professionals involved in flood forecasting and warning and flood risk management, about the current alerts and about the potential options for developing a more targeted surface water flood warning service. Providing surface water flooding warnings presents a set of technical, forecasting and warning challenges related to the rapid onset of flooding, the localised nature of the flooding, and the linking of rainfall and flood forecasts to flood likelihood and impact on the ground. Some examples of rainfall alerting and surface water flood warning services from other countries are evaluated, as well as a small number of recently implemented local services in England and Wales. Various potential options for implementation of a service are then explored and assessed. The paper concludes that development of a surface water flood warning service for England and Wales is feasible and is likely to be useful to emergency responders and operational agencies, although developing such a service for the pluvial components of this type of flooding is likely to be feasible sooner than for other components of surface water flooding such as that caused by sewers. A targeted surface water flood warning service could be developed for professional emergency responders in the first instance rather than for the p**ublic for whom such a service without further operational testing and piloting would be premature.**

Rahman, M., Goel, N.K. and Arya, D.S. (2012) Study of early flood warning dissemination system in Bangladesh, Journal of Flood Risk Management, Vol 6, 4, 290

A study has been conducted with the objective to assess the existing early flood warning dissemination system (EFWDS) in Bangladesh and to suggest the suitable improvements in the same system based on review of literature, interaction with stakeholders of various organisations involved in flood forecasting and dissemination, and analysis of feedback from the flood-affected people of Dhobaura and Shibalaya sub-districts in Bangladesh. The existing set-up has been studied to assess the present activities and future expectations. The recommendation for active participation by all related organisations has been made in this study. Two studies have been conducted by surveying the opinion of flood vulnerable communities so that all elements of the EFWDS would provide useful flood warnings to all potential users.

Forecasting and warning

Cloke, H.L. and F. Pappenberger (2009) Ensemble flood forecasting: A review. Journal of Hydrology, 2009, Vol 375, 3, 613-626

Operational medium range flood forecasting systems are increasingly moving towards the adoption of ensembles of numerical weather predictions (NWP), known as ensemble prediction systems (EPS), to drive their predictions. We review the scientific drivers of this shift towards such 'ensemble flood forecasting' and discuss several of the questions surrounding best practice in using EPS in flood forecasting systems. We also review the literature evidence of the 'added value' of flood forecasts based on EPS and point to remaining key challenges in using EPS successfully.

Demeritt, D., Cloke, H., Pappenberger, F., Thielen, J., Bartholmes, J., Ramos, M-H. (2007) Ensemble predictions and perceptions of risk, uncertainty, and error in flood forecasting, Environmental Hazards, Vol 7, 2 115-127

Under the auspices of the World Meteorological Organization, there are a number of international initiatives to promote the development and use of so-called ensemble prediction systems (EPS) for flood forecasting. The campaign to apply these meteorological techniques to flood forecasting raises important questions about how the probabilistic information these systems provide can be used for what in operational terms is typically a binary

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decision of whether or not to issue a flood warning. To explore these issues, we report on the results of a series of focus group discussions conducted with operational flood forecasters from across Europe on behalf of the European Flood Alert System. Working in small groups to simulate operational conditions, forecasters engaged in a series of carefully designed forecasting exercises using various different combinations of actual data from real events. Focus group data was supplemented by a follow-up questionnaire survey exploring how flood forecasters understand risk, uncertainty, and error. Results suggest that flood forecasters may not instinctively use ensemble predictions in the way that promoters of EPS perhaps think they should. The paper concludes by exploring the implications of these divergent 'epistemic cultures' for efforts to apply ensemble prediction techniques developed in the context of weather forecasting to the rather different one of flood forecasting.

De Roo, A., Thielen, J., Salamon, P., Bogner, K., Nobert, S., Cloke, H., Demeritt, D., Younis, J., Kalas, M., Bodis, K., Muraro, D. & Pappenberger, F. (2011) Quality control, validation and user feedback of the European Flood Alert System (EFAS), International Journal of Digital Earth. 4, Suppl 1, 77 – 90

To follow

De Roo, A.P.J., Gouweleeuw, B., Thielen, J., Bartholmes, J., Bongioannini-Cerlini, P., Todini, E., Bates, P., Horritt, M., Hunter, N., Beven, K., Pappenberger, F., Heise, E., Rivin, G., Hils, M., Hollingsworth, A., Holst, B., Kwadijk, J., Reggiani, P., Van Dijk, M., Sattler, K., and E. Sprokkereef (2003) Development of a European flood forecasting system, International Journal of River Basin Management, Vol 1, 1, 49-59

Recent advances in meteorological forecast skill now enable significantly improved estimates of precipitation quantity, timing and spatial distribution to be made up to 10 days ahead for model scales of 40 km in forecast mode. Here we outline a prototype methodology to downscale these precipitation estimates using regional Numerical Weather Prediction models to spatial scales appropriate to hydrological forecasting and then use these to drive high-resolution scale (1 or 5 km grid scale) water balance and rainfall-runoff models. The aim is to develop a European Flood Forecasting System (EFFS) and determine what flood forecast skill can be achieved for given basins, meteorological events and prediction products. The output from the system is a probabilistic assessment of n-day ahead discharge exceedence risk (where n < 10) for the whole of Europe at 5 km resolution which may then be updated as the forecast lead time reduces. At each stage the discharge estimates can be used to drive detailed (25–100 m resolution) hydraulic models to estimate the flood inundation which may potentially occur. Initial results are presented from a prototype version of the system used to perform a hindcast of the January 1995 flooding events in NW-Europe (Rhine, Meuse).

Haiden, T., Magnusson, L., Tsonevsky, I., Wetterhall, F., Alfieri, L., Pappenberger, F., De Rosnay, P., Muñoz-Sabater, J., Balsamo, G., Albergel, C., Forbes, R., Hewson, T., Malardel, and S. D. Richardson (2014) ECMWF forecast performance during the June 2013 flood in Central Europe, Technical Memorandum, European Centre for Medium-Range Weather Forecasting, Reading

A case of orographically enhanced, extreme precipitation which led to extensive flooding in Central Europe is investigated. The ECMWF Integrated Forecasting System (IFS) provided good forecasts of the location of the heaviest precipitation on the northern side of the Alps but underestimated the magnitude. As a result, streamflow predictions for the Danube by the European Flood Alert System (EFAS) run with ECMWF input underestimated peak discharge values. We investigate possible causes for the underestimation such as model resolution, the microphysical parameterization, and soil moisture in the model. Increasing the model resolution has a substantial positive effect on the magnitude of the predicted rainfall in the worst affected region on the northern side of the Alps. It also improves forecasts over the Czech Republic where an observed, non-orographic band of enhanced precipitation is predicted which was not simulated in the operational forecast. A new parameterization of precipitation formation which will become operational in 2014 is shown to have a positive effect as well, leading to about 10% increase in total precipitation on the northern side of the Alps. Experiments with different options for soil moisture assimilation show little effect since the near-saturated conditions due to positive rainfall anomalies in the weeks prior to the event were already well captured by the soil model in the IFS, even without soil moisture assimilation.

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Lavers, D.A., Pappenberger, F. and E. Zsoter (2014) Extending medium-range predictability of extreme hydrological events in Europe, Nature Communications, 5, 5382

Widespread flooding occurred across northwest Europe during the winter of 2013/14, resulting in large socioeconomic damages. In the historical record, extreme hydrological events have been connected with intense water vapour transport. Here we show that water vapour transport has higher medium-range predictability compared with precipitation in the winter 2013/14 forecasts from the European Centre for Medium-Range Weather Forecasts. Applying the concept of potential predictability, the transport is found to extend the forecast horizon by 3 days in some European regions. Our results suggest that the breakdown in precipitation predictability is due to uncertainty in the horizontal mass convergence location, an essential mechanism for precipitation generation. Furthermore, the predictability increases with larger spatial averages. Given the strong association between precipitation and water vapour transport, especially for extreme events, we conclude that the higher transport predictability could be used as a model diagnostic to increase preparedness for extreme hydrological events.

Lorenzo, A.,Thielen, J. and F. Pappenberger (2012) Ensemble hydro-meteorological simulation for flash flood early detection in southern Switzerland, Journal of Hydrology, Vol 424-425, 143-153

Ongoing changing climate has raised the attention towards weather driven natural hazards. Local flooding and debris flows following exceptional downpours often come without any adequate warning and cause heavy tolls to the human society. This work proposes a novel flood alert system for small catchments prone to flash flooding, capable of monitoring a large portion of the European domain. Operational streamflow simulations are produced through distributed hydrological modeling of ensemble weather forecasts. A long-term reforecast dataset is run through the same hydrological model to derive coherent warning thresholds. These are compared with operational discharge ensembles in a threshold exceedance analysis to produce early warnings. A case study in the southern Switzerland is tested over a 17-month period and system skills are evaluated by means of different quantitative and qualitative analyses. Results from three different predictors derived from the streamflow ensemble are shown and compared, also by accounting for the persistence of lagged forecasts. Significant improvements in predicting discharge thresholds exceedance are achieved by fitting gamma probability distributions to the raw ensemble. Further discussion underlines the limits of predictability of extreme events in small catchments due to the comparatively coarse space–time resolution of current weather forecasts.

Nobert, S., Demeritt, D. and Cloke, H. (2010) Informing operational flood management with ensemble predictions: lessons from Sweden, Journal of Flood Risk Management, 3, 72–79

This paper highlights some communicative and institutional challenges to using ensemble prediction systems (EPS) in operational flood forecasting, warning, and civil protection. Focusing in particular on the Swedish experience, as part of the PREVIEW FP6 project, of applying EPS to operational flood forecasting, the paper draws on a wider set of site visits, interviews, and participant observation with flood forecasting centres and civil protection authorities (CPAs) in Sweden and 15 other European states to reflect on the comparative success of Sweden in enabling CPAs to make operational use of EPS for flood risk management. From that experience, the paper identifies four broader lessons for other countries interested in developing the operational capacity to make, communicate, and use EPS for flood forecasting and civil protection. We conclude that effective training and clear communication of EPS, while clearly necessary, are by no means sufficient to ensure effective use of EPS. Attention must also be given to overcoming the institutional obstacles to their use and to identifying operational choices for which EPS is seen to add value rather than uncertainty to operational decision making by CPAs.

Vieira, J., Føns, J., and G. Cecconi (1993) Statistical and hydrodynamic models for the operational forecasting of floods in the Venice Lagoon, Coastal Engineering, Vol 21, 4, 301-33

The risk of flooding in Venice has increased strongly since the beginning of the century. To reduce the damage to the city and the negative impact on the activities in the lagoon, an accurate flood warning system is necessary. This system will also be fundamental during the construction and for the efficient operation of storm surge

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barriers covering the three existing inlets of the lagoon. In this context new operational statistical and hydrodynamic models have been developed. Forecast winds and pressure fields which constitute basic information for the warning system have been obtained through an ad hoc Limited Area Meteorological model. It has been demonstrated that, provided that this information is available on an operational basis, the implementation of a flood warning system for Venice using the models developed is feasible. The statistical model, which is based on a multiple regression technique, extends the forecasting range of the model presently in operation at the Centro Previsioni e Segnalazioni Maree del Comune di Venezia, from 3 hrs up to 24 hrs, and presents good accuracy (estimated mean absolute errors smaller than 10 cm) for short-term forecasts up to 9 hrs. The hydrodynamic model includes all the physical processes important for the simulation of water levels and currents in coastal and marine environments. The model set-up adopted covers the entire Adriatic Sea, with a grid spacing of 6 km. Special attention has been given to the positioning of the open boundary and to the correct reproduction of the main free oscillation of the Adriatic, which is responsible for the possible recurrence of flooding after the main storm has passed. The inclusion of this model in a flood warning system is mainly intended for long-term forecasts (> 24 hrs), and can typically be used to forecast up to 3–4 days ahead, with an estimated mean absolute error smaller than 20 cm.

Governance

Hegger, D., Driessen, P., Dieperink, C., Wiering, M., Raadgever, G. and H. Rijswick (2014) Stability and Dynamics in Flood Risk Governance, Water Resources Management, Vol 28, 12, 4127-4142

European urban agglomerations face increasing flood risks due to urbanization and the effects of climate change. These risks are addressed at European, national and regional policy levels. A diversification and alignment of Flood Risk Management Strategies (FRMSs) can make vulnerable urban agglomerations more resilient to flooding, but this may require new Flood Risk Governance Arrangements (FRGAs) or changes in existing ones. While much technical knowledge on Flood Risk Management is available, scientific insights into the actual and/or necessary FRGAs so far are rather limited and fragmented. This article addresses this knowledge gap by presenting a research approach for assessing FRGAs. This approach allows for the integration of insights from policy scientists and legal scholars into one coherent framework that can be used to identify Flood Risk Management Strategies and analyse Flood Risk Governance Arrangements. In addition, approaches for explaining and evaluating (shifts in) FRGAs are introduced. The research approach is illustrated by referring to the rise of the Dutch risk-based approach called 'multi-layered safety' and more specifically its application in the city of Dordrecht. The article is concluded with an overview of potential next steps, including comparative analyses of FRGAs in different regions. Insights in these FRGAS are crucial to enable the identification of action perspectives for flood risk governance for actors at the level of the EU, its member states, regional authorities, and public-private partnerships.

Hegger, D., Dieperink, C., Green, C., Driessen, P., Bakker, M. H., Rijswick, H. F. M. W., Van, C. and K. Ek, (2013) Flood Risk Management In Europe: an exploration of governance challenges, STAR-FLOOD consortium

In order to make European regions more resilient to flood risks a broadening of Flood Risk Management strategies (FRMSs) might be necessary. The development and implementation of FRMSs like risk prevention, flood defence, mitigation, preparation and recovery is a matter of governance, a process of more or less institutionalized interaction between public and/or private entities ultimately aiming at the realization of collective goals. Such processes are institutionally embedded in Flood Risk Governance Arrangements (FRGAs), which can be defined as "the constellation resulting from a dynamic interplay between actors and actor coalitions involved in all policy domains relevant for Flood Risk Management – including water management, spatial planning and disaster management; their dominant discourses; formal and informal rules of the game; and the power and resource base of the actors involved". This definition stresses that FRGAs have an actor dimension, a rule dimension, a power and resource dimension and a discursive dimension. By focussing on FRGAs we hope to get a better insight into the societal aspects of FRMSs and the way they are institutionally embedded in a broad sense. The concept allows us to combine insights from policy scientists as well as legal scholars and urges researchers to focus on FRMSs using combined perspectives. The aim of this report is twofold. First we want to

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explore the governance challenges a shift in FRMSs may pose to society and second we will identify questions for further research. The report is based on a first exploration of relevant scientific articles and reports. Governance challenges are found within each of the four dimensions of the FRGAs. We therefore discuss these dimensions in separate chapters. Major challenges in the actor dimension are the necessity to organise joint working between relevant actors in an effective way, to adequately involve stakeholders and to optimise the science-policy interface. In the rule dimension we have found that the major challenge concerns the translation of general Flood Risk Management principles into a set of more specific organisational, substantive and procedural provisions. Efficient and joint use of resources is the major challenge addressed under the power and resources dimension. The overarching discourse-related governance challenge is the realisation of a discursive shift. Overall, our exploration indicates that FRGAs tend to be highly fragmented. The overall challenge flood risk governance has to face is the development and implementation of inspiring bridging concepts which change agents may use to create synergies between key actors involved in flood risk governance. Concepts like Integrated Water Resources Management (IWRM) or climate proofing are examples of this. Empirical research is needed to further elaborate on this.

Hegger, D. L. T., Bakker, M. H., Green, C., Driessen, P., Delvaux, B., Rijswick, H. F. M. W., Van Suykens, C., Beyers, J - C., Deketelaere, K., Doorn - Hoekveld, W. V. and C. Dieperink, C. (2013) Flood Risk Management In Europe: European flood regulation, STAR-FLOOD consortium

In Europe, water management is moving from flood defense to a risk management approach, which takes both the probability and the potential consequences of flooding into account. In this report, we will look at Directives and (non-)EU- initiatives in place to deal with flood risk in Europe indirectly and directly. Emphasis will lie on the two Directives most specifically aimed at floods: the Water Framework Directive (WFD) and the Floods Directive (FD) – how are they related and how they have been or are implemented in the Member States (MSs)? In February 1995, the Netherlands and France took the initiative for a discussion on streamlining the water legislation of the European Union (EU) which resulted in the creation of the WFD in 2000. The WFD provided a new system for the protection and improvement of Europe's water environment – its rivers, lakes, estuaries, coastal waters and groundwaters. Its main innovation is the requirement that water be managed in an integrated way, with river basin management as leading managing unit. Since flood protection is not explicitly addressed in the WFD, the need to clarify the role of the WFD in flood protection was put on the European agenda as early as 2003, and in 2007, the FD became a fact. The FD is to be implemented in coordination with the WFD, notably by coordinating Flood Risk Management Plans (FRMPs) and River Basin Management Plans (RBMPs). Both the WFD and the FD reflect a shift in EU-governance. Instead of the more traditional top-down legalistic approach they emphasise the importance of more bottom up initiatives from the actors who have to implement the Directives. Combined with the expanded freedom and flexibility for national and local governments, with this new approach, the FD is the first Water Directive in EU law that does not offer an equal minimum level of protection for EU citizens. While both Directives are meant to harmonise European legislation, much flexibility on objectives and measures in the FD is left to the MSs, justified by the nature of flooding and the subsidiarity principle. This creates multi-actor, multi-level and multi-sector challenges addressed in report D1.1.2 (Hegger et al. 2013). For instance, the FD sets out general obligations for transboundary cooperation, but at the national level, the scope and distributions of duties, rights and powers of the various organizations involved should be set out in law. Other challenges identified in the literature are concrete issues related to mandatory flood risks assessments, flood risk maps, and Flood Risk Management plans, but also the involvement of the public and stakeholders, the science-policy interface, uncertainties related to climate change predictions and effects, the coordination with the WFD, the lack of safety standards, the lack of possibilities for EU citizens to rely on substantive provisions before the administrative courts and finally, transboundary aspects such as issues of scale, mismatches between national policies, the assessment of transboundary effects and division of costs related to this. In sum, this report has clarified the development, content and implementation of the current European flood risk governance policies, possible synergies between the two most important Directives linked to floods, and identified topics and questions for more in-depth questions relevant for the next work packages, pertaining to, in no particular order, a) the level of implementation and level of ambition as well as the competent authorities in the case study

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countries; b) the transboundary nature of floods; c) synergies and conflicts between FD and WFD and other issues not mentioned in these Directives; d) the degree of harmonization, for instance when it comes to flood safety standards and e) the subsidiarity principle – is this conform the requirements set out in the FD? Because while current European flood regulation specified in the WFD and FD provides several potential opportunities for improving flood risk governance, it is not self-evident that all of these opportunities will materialise in all MSs.

Ruigh-Van Der Ploeg, T. and Broekhans, B.H. (2012) Experts and Expertise in the Governance of Infrastructures: Flood-Risk Management as an Example, Administrative Culture, Issue 13, 1, 20-38

The current focus on risk-based approaches to the governance of technology poses new challenges to the combined effort of policymakers and experts since the current worlds of technology and governance are very different. We make use of two hegemonic perspectives in these worlds, i.e. the systems and the network perspective, to analyse the expected contributions from expertise and experts to policy-making about infrastructures. The first question we address is how these two perspectives shape the expectations of the contribution of experts and expertise to problem solving and policy-making. Second, we explore how practitioners may deal with inevitable conflicting expectations. Based on documents and previous research and illustrated with examples of flood-defence projects from the Netherlands, this paper concludes that perspectives may be coupled or uncoupled in practices of collaboration, and that practitioners should reconsider the contingent room to manoeuvre in policy-making, and the role they may take.

Thaler, T. and Priest, S. (2014) Partnership funding in flood risk management: new localism debate and policy in England, Area, Vol 46, 4, 418

The new flood risk policy discussion in England has started to redefine national policy regarding flood and coastal risk management. The key issue in the new policy agenda is to encourage the responsibilities of local authorities in flood risk management, which involve defining local strategies to manage local risks. This downscaling process in flood risk management has a series of consequences in the development of new governance structures and institutions as well as new working relations and intervention strategies. Nevertheless, the main problem is the gap between the downscaling of responsibility and the transfer of resources; in particular the question concerning funding and social capacity. In this way, the focus of policy discussion refers to two main aspects: (a) the equitable sharing of risk-burdens between public authorities, private companies and individuals and (b) how to encourage government agencies and nongovernment agents to take over responsibility for certain tasks from central government. The aim of this paper is to discuss the new funding regime for English flood risk management policy under the new policy paradigm.

Thompson, P. (2010) Local institutions for floodplain management in Bangladesh and the influence of the Flood Action Plan, Environmental Hazards, 9, 1, 26-42

Institutional arrangements are a key issue for sustainable natural resource management. Recent water and fisheries management projects in Bangladesh have established new local institutions for floodplain management based on community organizations. Although the Flood Action Plan (FAP) was the culmination of an earlier emphasis on technical and structural `solutions' to managing floods and water in Bangladesh, the expected large engineering works were never built. One legacy of FAP lies in a contested process that accelerated emphasis on public participation, smaller scale hazard adjustments and maintaining a wider range of floodplain resource values including conserving and restoring fisheries. This paper compares institutional arrangements and outcomes in two fisheries and two water management projects taken up after FAP. Local organizations appeared generally successful in sustaining themselves and continuing floodplain resource management. Facilitation, the extent of consensus among different stakeholders, and fit between institutional arrangements and scale of resource were all important influences on effectiveness. Local organizations have sustained in smaller floodplains, but in larger areas co-management bodies were a key to effective coordination and troubleshooting among a series of linked community organizations. Local leaders tend to dominate after projects end, especially where planning was less participatory and organizational structures were determined from above. Participants stressed that for continued success formally recognized well-run organizations are needed with accountable and adaptable decision-making

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processes and good leaders. This process built on participatory guidelines from FAP but the local institutions have not addressed hazard risks. Community resource management institutions could develop a more integrated approach that internalizes the interactions between water, land and fishery management. So far, local planning for floods has been a notable gap in the activities of community institutions, but the enhanced social capital could be a basis for adaptation to climate change. For this, an enabling policy environment is needed, which could be facilitated by the open high-profile debate on floodplain issues that characterized FAP.

Ziervogel, G., Waddell, J., Smit, W. and A. Taylor (2014) Flooding in Cape Town's informal settlements: barriers to collaborative urban risk governance, South African Geographical Journal, 1-20

When managing urban flood risk, traditional flood risk management which prioritizes infrastructural and technical solutions is important but is not sufficient to reduce the risk to acceptable levels, particularly in informal settlements. Understanding how flood risk is governed needs to complement flood risk interventions in order to be able to move towards a more collaborative response to managing flood risk. Drawing on the case of Cape Town, South Africa, where annual flood events impact on many informal settlements, we identify barriers to collaborative governance that could be addressed to help to build a more holistic flood management approach that proactively reduces flood risk. Our focus is on local government as a key arena of flood risk management. Using a nodal governance framework, we assess the mentalities, technologies, resources and institutional structures of four different local government departments in the City of Cape Town and the extent to which they collaborate on flood risk management. Four key constraints to collaborative urban flood risk management are identified: the domination of a technocratic approach, lack of particular capacities, the challenge of how to share risk, and political contestation and short-termism. Unpacking the nature of nodal governance is a key step in identifying possibilities for collaboration and thus strengthening processes of urban flood management. This is particularly important for urban environmental risk management in the global South, which needs to engage with a development agenda that includes the politics of informality and the complexities of social, as well as environmental, change.

Insurance

Association of British Insurers (ABI) (2014) The future of flood insurance: what happens next, at https://www.abi.org.uk/Insurance-and-savings/Topics-and-issues/Flooding/Government-and-insurance-industry-flood-agreement/The-future-of-flood-insurance

The ABI and the Government agreed a Memorandum of Understanding (MoU) in June 2013 on how to develop a not-for-profit scheme - Flood Re – to allow flood insurance to remain widely affordable and available, while allowing a sustainable transition to risk reflective pricing over 25 years. The MoU was a first step towards establishing Flood Re, confirming it as the UK Government's preferred option to ensure the continued availability of flood insurance to flood risk households.

Flood Re is an agreement between UK insurers and the UK Government to develop a not-for-profit company – Flood Re – to allow insurers to pass the flood risk element of a home insurance policy into a fund that will pay any subsequent flood claim. It is designed to enable high flood risk households to obtain affordably priced flood insurance.

Ball, T., Werritty, A. and Geddes, A. (2013) Insurance and sustainability in flood-risk management: the UK in a transitional state, Area Vol 45, 3, 266

The emerging new paradigm of 'sustainable flood-risk management', emphasising non-structural management approaches over engineered defences, is subject to differing, and sometimes contested, interpretations by key actors. This is well illustrated by the present lack of agreement between the UK government and the private insurance sector on the future of flood insurance. This paper examines the diversity of views on how best to manage flood risk, given projected changes in the UK insurance market. The issues examined comprise: the linkage of flood defences to the insurability of properties at risk, possible implications of partial or full removal of cross-subsidisation of policies, and the sustainability of communities in high flood-risk areas. Finally, the paper

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looks critically at alternative models that might be applied in the future, based on international experience, which may offer a means of securing insurance for high flood-risk areas, while also being compatible with sustainable flood-risk management policies.

Cobbing, P., and Miller, S. (2012) Property Level Protection and Insurance, Available at: nationalfloodforum.org.uk/wp.content/uploads/PLP-and-insurance-Report-FINAL.pdf

This Defra supported report presents the findings of a study to explore the relationship between property level protection (PLP) to reduce the impact of flooding and the availability of flood risk insurance for households. PLP has developed rapidly in the last few years as one way of reducing the impact of flooding and is still developing. Households that are likely to suffer less damage from flooding and the loss of fewer possessions might be expected to incur fewer and lower value insurance claims and that this might result in lower household insurance premiums and excesses.

Lamond, J., Proverbs, D. G. and Hammond, F.N. (2009) Accessibility of flood risk insurance in the UK: confusion, competition and complacency, Journal of Risk Research, Vol 12, 6, 825-841

Flood risk insurance can be an effective tool in assisting the restoration of damaged property after a flood event and sustaining communities through difficult times. It can also form part of a wider flood risk management strategy. In the light of recent flood events in the UK and in the context of changing property insurance markets, the universal cover previously enjoyed by floodplain residents has been called into question. Conflicting media and industry views leave the floodplain resident and the wider community in confusion. A survey of floodplain residents in England regarding their experience with flooding and flood insurance in England has been undertaken. The results reveal that some floodplain residents do indeed encounter difficulties when seeking insurance for their homes. However, despite the risk-averse policies of some insurers, availability of insurance is still strong in both at-risk and previously flooded locations. Success in gaining insurance may lead to complacency among residents who see no advantage in pursuing other, more costly, damage mitigation actions. As a tool in risk management, therefore, the market is prevented from realising its potential by competition, which results in a lack of a consistent approach, rewards homeowners' search strategies and reduces information flow.

Penning-Rowsell, E.C., Johnson, C. and S.M. Priest (2014) The evolution of UK flood insurance: incremental change over six decades, International Journal of Water Resources Development 11.

In this paper, the authors' theorizing shifts away from the catalytic role of the flood itself – or other crises – towards a deeper understanding of the relationship between change and stability, taking the example of UK flood insurance and the agreements – and the implicit policy approaches – between the actors involved: private insurers and the government. The study relies upon in-depth analysis of policy agreements governing flood insurance since the 1960s, and semi-structured interviews with six current or former flood insurance professionals. The important agents of change have been, firstly, threats to existing household insurers from new entrants unencumbered by agreements to insure all comers. Secondly, technological changes have made exposure more explicit and pricing risk both easier and less expensive. The slow pace of change and the relatively stable role of the different actors and coalitions is now clearer. Many windows of opportunity created by major flooding or financial crises have not significantly affected the pace or direction of policy change. The overriding importance of the London location for – and the profitability of – the insurance industry, both to government and to the insurers, explains the extraordinary policy stability described here. This history suggests that the UK may not be a good model for imitation elsewhere.

Treby, E., Clark, M. and S.J. Priest (2007) Confronting flood risk: implications for insurance and risk transfer, Journal of Environmental Management, 81, 4, 351-9

The UK floods in late 2000 reinforced an emerging awareness which questioned the long-term sustainability of an exclusive reliance on hard-engineered flood defences to protect the UK population against increased flood risk. The debate has subsequently focused on a broader interpretation of the risks associated with flooding. This paper explores the notion that, although social and technical issues are already being integrated to understand and

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manage flood, practitioners are now realising the importance of accommodating public hazard understanding and perception of risk into their management models, and there remains a need to fit such ideas to the insurance-based system of flood management in the UK.

Post-flood reviews, lessons learned

Cabinet Office (UK). 2007. The Pitt Review: Learning Lessons from the 2007 Floods. London, Cabinet Office

This is a report of the Review of the severe floods of the Summer of 2007 in the UK. In all the Review made 92 recommendations on improving flood risk management in the UK. At the time the floods caused the country's largest peacetime emergency since World War II. The impact of climate change means that the probability of events on a similar scale happening in future is increasing. The Review calls for urgent and fundamental changes in the way the country is adapting to the likelihood of more frequent and intense periods of heavy rainfall. Pitt and his collaborators in this Review searched for practical solutions to highly complex problems and thought carefully about the public interest. Their recommendations are challenging and they suggested that strong national leadership will be needed to make them a reality.

The Review called for a step change in the quality of flood warnings and suggested that this could be achieved through closer cooperation between the Environment Agency and Met Office and improved modelling of all forms of flooding. The public and emergency responders must be able to rely on this information with greater certainty in future. The Review also recommended a wider brief for the Environment Agency and suggested that councils strengthen their technical capability in order to take the lead on local flood risk management. More could also be done to protect communities through robust building and planning controls.

The Review noted that during the flood emergency, there were excellent examples of emergency services and other organisations working well together, saving lives and protecting property. However, this was not always the case; some decision making was hampered by insufficient preparation and a lack of information. Better planning and higher levels of protection for critical infrastructure are needed to avoid the loss of essential services such as water and power. There must be greater involvement of private sector companies in planning to keep people safe in the event of a dam or reservoir failure. Generally, we must be more open about risk. People would also benefit from better advice on how to protect their families and homes. Levels of flood risk awareness should be raised through education and publicity programmes.

Coulthard, T., and Frostick, L. E. 2010. The Hull Floods of 2007: implications for the governance and management of urban drainage systems. Journal of Flood Risk Management, Vol. 1, No. 3, pp. 223–31

On 25 June, the City of Hull, England, suffered from extensive pluvial flooding, causing damage to over 8600 homes and 1300 businesses. Over 100 mm of rain fell over a 24-h period, rapidly overwhelming the city's drainage system. Hull is especially vulnerable to flooding as it is largely below sea level and relies on a pumped drainage system with no natural ways of drainage. The causes of the flooding can be locally attributed to blocked roadside gulleys but in the main were due to issues with the conveyance of drained water in sewers and the performance of the three pumping stations. In particular, an extensive redesign of the system in 2001 increased flood storage and reduced the pumping capacity. In 2004, remodelling of the 2001 system indicated that it may be under-predicting flood volumes by 100% and decommissioned pumping stations were re-activated to rectify matters. Subsequent modelling showed that the performance of the drainage system in 2007 was slightly worse than its 2001 configuration. The floods also revealed a series of key weaknesses in how urban drainage systems are managed. There is no system of warning from surface water flooding in the United Kingdom, despite there being an extensive warning system for coastal and fluvial flooding. Urban drainage is largely designed to accommodate 1 in 30-year events, but this level is not appropriate in all areas, especially low-lying regions with little or no natural drainage such as Hull. Finally, the structure of the UK water industry post-privatisation, with Local Authority, the Environment Agency and the Water Utility all having control over separate parts of the system, left no single agency with lead control or responsibility for urban surface water flooding.

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Lorraine, N. S. R. 1954 Canvey Island flood disaster, February, 1953. Br. Med. J. 1, 59–62

To follow

Queensland Flood Commission of Inquiry (2012) Final Report. Available for download at http://www.floodcommission.qld.gov.au/__data/assets/pdf_file/0007/11698/QFCI-Final-Report-March-2012.pdf. Accessed on 3 Jan 2015

The Commission was set up fourteen months after the floods of 2010/2011 to enquire into the preparation and planning for the floods by governments, agencies and the community; the adequacy of the response to the floods; management of essential services; the adequacy of forecasts and early warning systems; insurers' performance of their responsibilities; the operation of dams; and land use planning to minimise flood impacts. It was a broad and daunting range of subject matter. Those questions had to be examined over a very large geographical area, because most of the state was affected; inquiries had to be made and hearings held in a variety of locations. As to how the floods were managed, there is no doubt that they took a state more accustomed to drought by surprise. Generally, though, Queenslanders can be relieved that governments at all levels were able to provide a prompt, if not perfect, response, which compares favourably with the apparent paralysis of government agencies and breakdown in order apparent on the Gulf coast after Hurricane Katrina struck New Orleans. In Queensland there was an already existing, coherent emergency management structure, although it had not yet been tested by disaster of these proportions. Although some councils struggled, there was no breakdown in order, and people came to the assistance of others. There is certainly a good deal of room for improvement in planning for emergency response, as the many recommendations in this report and the interim report demonstrate. This report deals at considerable length with the land planning systems of the State and their application by councils. In land use planning, attention to flood risk has been ad hoc. The recommendations made are designed to insert into the land planning system uniform controls which will ensure that the risk of flood is consistently recognised and planning assessments made with regard to it. Queensland also lacks a coherent approach to floodplain management; a number of recommendations have been made relating to the need for current and comprehensive flood studies and flood mapping, particularly in urban areas. There are also recommendations on dam management and safety and flood insurance.

Traver, R (2014) Flood Risk Management: Call for a National Strategy, American Society of Civil Engineers, Task Committee on Flood Safety Policies and Practices, ASCE, ISBN (PDF): 978-0-7844-7858-5, Available on-line as a PDF download (Complete Book PDF (598 KB) PDF with links (432 KB)) at http://ascelibrary.org/doi/book/10.1061/9780784478585

In 2005, the devastation caused by Hurricane Katrina graphically revealed the vulnerability of U.S. communities to the loss of life and property resulting from flooding. In the aftermath, the American Society of Civil Engineers issued a call for action to address growing flood losses and threats to public safety. Then, in 2012, Hurricane Sandy found the nation still unprepared and unaware of the magnitude of flood risk.

ASCE charged a task committee with investigating the extent to which the lessons learned from the failure of the hurricane protection system during Hurricane Katrina have been incorporated into the planning, design, construction, and management of engineered water resources projects. The investigation would provide a basis for influencing changes in national policy and engineering practice related to flood safety. The committee met with government agencies, the private sector, nongovernmental organizations, and those affected by Katrina and subsequent disasters. The committee concluded that the federal government, in close collaboration with state, tribal, and local governments, concerned public and private organizations, and the public at large, must develop and use forward-thinking flood risk management processes. Doing so would reduce the nation's vulnerability to dangers and damages resulting from floods while concurrently protecting natural resources, enhancing the functions of floodplains, and supporting wise and sustainable economic development of appropriate coast and river areas.

A must-read for key decision-makers and any member of the public living on or near water, this report highlights the difference between doing what we've been doing—reactively recover from catastrophic events—and doing

what we must do—proactively minimize the life-changing impacts of floods and hurricanes.

Waverley, J.A., (1954) Report of the departmental committee on coastal flooding, HMSO, London

The landmark report into the causes of the infamous East coast flooding of 1953 which severely affected large parts of Eastern England and the Thames estuary leading to major inundation of farmland, towns and villages. Over 300 people died in England in these catastrophic floods and thousands more died on the coasts of The Netherlands and Belgium. The existing sea defences were insufficient and breached in many locations demonstrating that new standards of sea defence needed to be established. This report set the standard for East coast flood defences thereafter.

Risk communication and engagement

Blöschl, G. (2008) Flood warning - on the value of local information, International Journal of River Basin Management, Vol 6, 1, 41-5

Based on the experience with the flood forecasting system of the Kamp catchment in Austria the role of local information in warning is discussed. Local hydrological process information from field surveys can be used to build more reliable models than is possible with regional data bases. River basin management processes are difficult to quantify in a general way, so familiarity with the local situation and interaction with local stakeholders will help to more accurately quantify the effects of river basin management on the flood situation. Local real time data, such as runoff data and water levels of reservoirs, can be used to improve forecasts by updating the routing and rainfall runoff models. Communication and the credibility of warnings may be strongly enhanced by local human forecasters that are familiar both with the model and the flood situation in the area of interest. Global information can assist at the local scale to extend lead times by precipitation forecasts and to assess forecast uncertainty by ensemble forecasts but much additional information at the local scale is needed to maximise the credibility of the forecasts.

Colbourne, L. (2009) Mainstreaming collaboration with communities and stakeholders for FCERM, Improving Institutional and Social Responses to Flooding Science Report: SC060019 Work Package 4, Environment Agency, Bristol

This report proposes a new analysis tool to help Environment Agency staff decide how much collaboration is appropriate in different situations, to improve flood and coastal erosion risk management (FCERM). The need for such a tool is based on a review of literature and practice which shows that FCERM solutions can no longer be imposed or delivered by the Environment Agencyusing traditional decide-announce-defend (DAD) approaches alone. Instead, a broader range of approaches is required, especially those which enable others to engage deliberate-decide (EDD). Many examples of the EDD-type of collaboration exist, and programmes such as Building Trust with Communities are helping to develop these examples. The research found that two myths pervade, preventing the consistent use of collaboration to improve FCERM outcomes.To counter these myths, the report suggests that new processes are needed to help theEnvironment Agency decide when to collaborate and how much collaboration is required,in a similar way to current Environment Agency processes which assist engineering-based decision-making.

Demeritt, D., Nobert, S., Cloke, H., Pappenberger, F., van Schalk, J., Schaake, J., Thielen, J. and M-F. Ramos (2012) The European Flood Alert System and the communication, perception, and use of ensemble predictions for operational flood risk management, Hydrological Processes, Vol 27, 1, 147

Although ensemble prediction systems (EPS) are increasingly promoted as the scientific state-of-the-art for operational flood forecasting, the communication, perception, and use of the resulting alerts have received much less attention. Using a variety of qualitative research methods, including direct user feedback at training workshops, participant observation during site visits to 25 forecasting centres across Europe, and in-depth interviews with 69 forecasters, civil protection officials, and policy makers involved in operational flood risk management in 17 European countries, this article discusses the perception, communication, and use of

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European Flood Alert System (EFAS) alerts in operational flood management. In particular, this article describes how the design of EFAS alerts has evolved in response to user feedback and desires for a hydrographic-like way of visualizing EFAS outputs. It also documents a variety of forecaster perceptions about the value and skill of EFAS forecasts and the best way of using them to inform operational decision making. EFAS flood alerts were generally welcomed by flood forecasters as a sort of 'pre-alert' to spur greater internal vigilance. In most cases, however, they did not lead, by themselves, to further preparatory action or to earlier warnings to the public or emergency services. Their hesitancy to act in response to medium-term, probabilistic alerts highlights some wider institutional obstacles to the hopes in the research community that EPS will be readily embraced by operational forecasters and lead to immediate improvements in flood incident management. The EFAS experience offers lessons for other hydrological services seeking to implement EPS operationally for flood forecasting and warning.

Demeritt, D. and S. Nobert (2014) Models of best practice in flood risk communication and management, Environmental hazards, 13, 4, 313-328

Risk communication plays an increasingly central role in flood risk management, but there is a variety of conflicting advice about what does - and should - get transmitted, why, how, and to whom. The aim of this paper is to elucidate the underlying normative and conceptual models on which those competing assessments of 'good' risk communication depend. To that end, the paper identifies four broad models, or approaches, to risk communication: a risk message model of information transfer; a risk instrument model of behavioural change; a risk dialogue model of participatory deliberation; and a risk government model of self-regulation and normalization. These models differ in their theoretical and disciplinary origins and associated philosophical and political commitments, and consequently they define the basic purpose, practice, and future prospects of flood risk communication in quite different ways. Unless these different models of 'good' risk communication are acknowledged and understood, efforts to identify best practice for flood risk management are likely to produce inconsistent, if not contradictory, recommendations.

Evers, M., Jonoski, A., Maksimovič, C., Lange, L., Ochoa Rodriguez, S., Teklesadik, A., Cortes Arevalo, J., Almoradie, A., Eduardo Simões, N., Wang. L. and C. Makropoulos (2012) Collaborative modelling for active involvement of stakeholders in urban flood risk management, Natural Hazards and Earth System Sciences, Vol 12, 9, 2821

This paper presents an approach to enhance the role of local stakeholders in dealing with urban floods. The concept is based on the DIANE-CM project (Decentralised Integrated Analysis and Enhancement of Awareness through Collaborative Modelling and Management of Flood Risk) of the 2nd ERANET CRUE funding initiative. The main objective of the project was to develop and test an advanced methodology for enhancing the resilience of local communities to flooding. Through collaborative modelling, a social learning process was initiated that enhances the social capacity of the stakeholders due to the interaction process. The other aim of the project was to better understand how data from hazard and vulnerability analyses and improved maps, as well as from the near real-time flood prediction, can be used to initiate a public dialogue (i.e. collaborative mapping and planning activities) in order to carry out more informed and shared decision-making processes and to enhance flood risk awareness. The concept of collaborative modelling was applied in two case studies: (1) the Cranbrook catchment in the UK, with focus on pluvial flooding; and (2) the Alster catchment in Germany, with focus on fluvial flooding. As a result of the interactive and social learning process, supported by sociotechnical instruments, an understanding of flood risk was developed amongst the stakeholders and alternatives for flood risk management for the respective Market-based instruments for flood risk management: A review of theory, practice and perspectives for climate adaptation policy.

Green, C. and E. C. Penning-Rowsell (2010) Stakeholder Engagement in Flood Risk Management, Flood Risk Science and Management, 11, 372 – 385

To follow

Greenberg, M. (2013) We Need Risk Communication and Perception Research Focused on Flood Risks for Senior

Citizens, Risk Analysis, Vol 33, 1, 52-53

For example, in the case of Hurricane Katrina, which struck the U.S Gulf Coast, Jonkman estimated that 80–90% of those at risk evacuated, and 1.2% of the people who did not evacuate died, primarily due to drowning. The authors report that 65% of the 829 New Orleans region victims whose age could be determined were 65+ and almost half were 75+. In comparison, 12% of the residents of the area were 65+ and 6% were 75+ years old. More than half of the victims were found in their home, another 20% were found in medical facilities, and, notably, 10% were in nursing homes. Most of the elderly who died had drowned, and the majority of the others were found on upper floors and had died from dehydration, stroke, heart attack, and lack of medical supplies. The authors' explanations for the high mortality rate were that responsible parties failed to provide assistance for evacuation prior to the storm, some victims resisted evacuation, there were delays in rescue operations, some seniors were unable to survive the stresses of the flood, and life-sustaining services were not provided to seniors stranded in the flooded areas.

These appalling findings are not unique to this flood event. Studies of the impact of the Indian Ocean tsunami in 2004 and the Fukushima disaster in 2011 show enormous toll on seniors, most of them women. The lack of warning in some flooding events means that many could not have evacuated. But many flood events are predictable, and while the overwhelming majority do leave, there is no reason why almost everyone cannot be persuaded to evacuate or otherwise be protected.

Older seniors are typically less mobile and more restricted in other ways than their younger counterparts. Notwithstanding their limitations, communication programs that focus on seniors created in response to heat-related disasters have been effective at reducing risk. I stipulate that there are publications in the gray literature that provide some of the needed communication information. Nevertheless, there is a major need not only in the United States but also in France, Germany, Italy, the United Kingdom, Russia, Japan, China, and every other nation with a rapidly growing senior population. A risk communications and perception research program focused on flood events and directed at seniors and those who help them is important and will be more effective if grounded in theory rather than based on trial and error.

Guinea, B., Estuardo, H. and Swain, A. (2014) Stakeholders' views towards flood risk management in the Paz River catchment area of Guatemala and El Salvador, Local Environment, 2014, 1-1

The river Paz is a trans-boundary river that flows through Guatemala and El Salvador. Its frequent floods endanger the lives and livelihoods of downstream communities. Attempts have previously been made to develop flood management programmes for this watershed. However, these approaches were generally made by high-level governmental institutions with few if any contributions from floodplain communities and other stakeholders. Recognising that public consultation is a key aspect in flood management programmes, we intend in this work to extract different stakeholders' views regarding current and future flooding and flood management programmes in the Paz River basin. This is achieved using Future Scenarios Workshops with a projected time horizon of 30 years. The exercise was expected to identify consensual short- and medium–long-term flood management strategies for the Paz River basin that draws on input from inhabitants of flood-prone areas and other stakeholders.

Martens, T., Garrelts, H., Grunenberg, H. and H. Lange (2009) Taking the heterogeneity of citizens into account: flood risk communication in coastal cities – a case study of Bremen, Nat. Hazards Earth Syst. Sci., 9, 1931-1940

The likely manifestations of climate change like flood hazards are prominent topics in public communication. This can be shown by media analysis and questionnaire data. However, in the case of flood risks an information gap remains resulting in misinformed citizens who probably will not perform the necessary protective actions when an emergency occurs. This paper examines more closely a newly developed approach to flood risk communication that takes the heterogeneity of citizens into account and aims to close this gap. The heterogeneity is analysed on the meso level regarding differences in residential situation as well as on the micro level with respect to risk perception and protective actions. Using the city of Bremen as a case study, empirical data from n=831 respondents were used to identify Action Types representing different states of readiness for protective actions in view of flood risks. These subpopulations can be provided with specific information to meet their heterogeneous

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needs for risk communication. A prototype of a computer-based information system is described that can produce and pass on such tailored information. However, such an approach to risk communication has to be complemented by meso level analysis which takes the social diversity of subpopulations into account. Social vulnerability is the crucial concept for understanding the distribution of resources and capacities among different social groups. We therefore recommend putting forums and organisations into place that can mediate between the state and its citizens.

McCarthy, S.S. (2007) Contextual influences on national level flood risk communication, Environmental Hazards, 7, 128–140

With high profile flooding events and increasing risk and probable damages of flooding in the future flood risk management (FRM) in England and Wales has undergone substantial changes over the last decade. The contextual influences on flood risk communication in the areas of flood forecasting, warning and response, spatial planning and development control and flood insurance at a national level are investigated in this paper. Research is based on qualitative interviews with 21 representatives of key organisations and activities at a national level of FRM. Drawing on communication theory the research highlights the key contextual features at play: the characteristics of communication flow through organisations, the importance of policy as a communication tool informed and constrained by flood events, organisational agendas, communication approaches and the development of knowledge and technology. The paper describes the influence of clear policy guidance on activities in certain government FRM communication initiatives and the commercial imperative driving the insurance industry activities.

McKay, J.M. (1984) Community response to hazard information, Disasters, Special Issue: Australian disasters, Vol 8, 2, 118–123

The impact of flood hazard information on public acceptance of a selected flood mitigation strategy was assessed by an analysis of the content of newspaper reports of community reaction and letters to the editor. The impact of personal delivery of a flood hazard map on individual perception of risk and attitude to such information was assessed using personal interviews. The results indicated that media coverage of the flood hazard information reduced public criticism of the works. This result must be partially attributable to the dramatic style of media coverage and the fact that the media only emphasized the positive value of the works. The interview demonstrated that personal delivery of the information raised perception of risk, improved comprehension of flood risk, had no impact on acceptability of risk but discouraged some respondents from seeking such information in the future. Factors to explain the last negative change were identified to be the format of the map sheet and low salience of flood hazard. On the basis of all results, methods to improve community response to hazard information are provided.

Norbert, S. and Demerrit, D. (2015) Models of best practice in flood risk communication and management. Accessed at http://www.kcl.ac.uk/sspp/departments/geography/people/academic/demeritt/Demeritt--Nobert-Env-Hazards-for-submission.pdf on 25.08.15

Risk communication plays an increasingly central role in flood risk management, but there is a variety of conflicting advice about what does—and should-- get transmitted, why, how, and to whom. The aim of this paper is to elucidate the underlying normative and conceptual models on which those competing assessments of 'good' risk communication depend. To that end, the paper identifies four broad models, or approaches, to risk communication: a risk message model of information transfer; a risk instrument model of behavioural change; a risk dialogue model of participatory deliberation; and a risk government model of self-regulation and normalization. These models differ in their theoretical and disciplinary origins and associated philosophical and political commitments, and consequently they define the basic purpose, practice, and future prospects of flood risk communication in quite different ways. Unless these different models of 'good' risk communication are acknowledged and understood, efforts to identify best practice for flood risk management are likely to produce inconsistent, if not contradictory, recommendations.

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Nye, M., Tapsell, S., and C. Twigger-Ross (2011) New social directions in UK flood risk management: moving towards flood risk citizenship? Journal of Flood Risk Management, Vol 4, 4, 288-297

This paper explores the evolution of a more sociotechnical variety of flood and coastal risk management () in the that emphasises community engagement and personal or community level responsibility for flood risk planning, awareness and resilience alongside more traditional, centrally managed structural and technical measures. Specifically, it explores three interlocking drivers of the social turn in : (i) the need to adapt to climate change and address the lessons from associated high profile flood events; (ii) pressures to integrate with the sustainable development agenda; and (iii) a broader trend towards a 'civic model' in environmental policy-making and delivery. The paper also explores the practical impact and manifestation of these drivers in current planning and delivery frameworks, and suggests several critical pathways for a deeper embedding of the approach.

O'Sullivan, J.J., Bradford, R.A., Bonaiuto, M., De Dominicis, S., Rotko, P. Aaltonen, J., Waylen, K. and S. J. Langan (2012) Enhancing flood resilience through improved risk communications Nat. Hazards Earth Syst. Sci., 12, 2271-2282.

A framework of guiding recommendations for effective pre-flood and flood warning communications derived from the URFlood project (2nd ERA-Net CRUE Research Funding Initiative) from extensive quantitative and qualitative research in Finland, Ireland, Italy and Scotland is presented. Eleven case studies in fluvial, pluvial, coastal, residual and "new" flood risk locations were undertaken. The recommendations were developed from questionnaire surveys by exploring statistical correlations of resilience groupings. Groupings were based on a conceptual relationship of self-assessed levels of awareness, preparedness and worry. Focus groups and structured interviews were used to discuss barriers in flood communications, explore implementation of the recommendations and to rank the recommendations in order of perceived importance. Results indicate that the information deficit model for flood communications that relies on the provision of more and better information to mitigate risk in flood-prone areas is insufficient, and that the communications process is very much multi-dimensional. The recommendations are aimed at addressing this complexity and their careful implementation is likely to improve the penetration of flood communications. The recommendations are applicable to other risks and are transferrable to jurisdictions beyond the project countries.

Orr, P and C. Twigger-Ross (2009) Communicating risk and uncertainty in flood warnings: a review of Defra/Environment Agency FCERM literature, Science project SC070060/SR2, Environment Agency, Bristol

This report addresses Objective 2 of the Environment Agency Science project: 'Communication and Dissemination of Probabilistic Flood Warnings'. Objective 2 is to: Review output from parallel projects on flood warning communications to establish what personal or cultural factors require consideration for the communication of risk and uncertainty. There are two associated tasks as part of Objective 2:

• Task 1 – collate relevant information from parallel Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D projects;

• Task 2 – establish from the previous research the significance of circumstance, personal experience and culture that require consideration for the communication of risk and uncertainty.

The review starts by characterising the current flood forecasting and warning system, in order to able to understand where and how probabilistic information might be used within the flood forecasting and warning system. The review then discusses the research to date on the social aspects of probabilistic flood forecasting in general. The remit for the review covered only Joint Defra/Environment Agency Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme (FCERM) projects focused on flooding. The projects examined included both predominantly technical and predominantly social research projects and consider information from both types of projects alongside each other. In addition, it was felt appropriate to draw on information about the summer 2007 flooding: the Environment Agency's report into the lessons learnt from summer 2007 floods (nd the Pitt Review (Pitt 2008) which collected information on flood warnings from a number of perspectives. In examining the factors that influence response to flood warnings, the literature indicates that a

range of variables together determine flood warning response either by inhibiting or enabling response by individuals and organisations. As well as the characteristics of the warning message, individual factors and social factors influence whether a response is made to a warning. All these variables are relevant to the design of any future warnings. The provision of information is only one of the variables. The way that information is understood and acted on is often influenced by other variables such as trust in the source of the information or warning. More information will not necessarily improve responses to flooding. The review found little information about differences between different groups (members of the public, professional partners, businesses) in terms of their perception of risk and uncertainty in flood warnings:

• There is a lack of information about the way that professional partners use warning information to inform their response to flooding. However, the needs of professional partners are likely to vary according to their scientific background and how they use the information. This underlines the conclusion that a 'one size fits all' approach is unlikely to be effective.

• Almost no relevant information was found on businesses, for example on how they use flood warning information, their perceptions of risk and uncertainty in relation to flooding or whether there are any significant differences in response between businesses of different sizes and characteristics.

One of the potential benefits of probabilistic flood warnings perceived by Environment Agency staff and professional partners is the possibility of giving earlier warnings. These could be of particular benefit to certain groups of people and emergency responders who may need more time to make preparations for flooding. The review has brought out a useful distinction between decision uncertainty and scientific uncertainty. The provision of probabilistic information in flood warning can be considered as making transparent one aspect of scientific uncertainty. To what extent it reduces either scientific uncertainty or decision uncertainty remains an empirical question.

Straw, E. and L. Colbourne (2009) For the Shaldon Flood Risk Project, Lindsay Colbourne Associates

This report explores the actual and potential benefit-cost of engagement7, based on an evaluation of the pilot Building Trust with Communities - Working with Others (BTwC) approach used on the Shaldon Flood Risk project between 2005 and 2009. The BTwC approach encourages a shift from working practices based on a „Decide-Announce-Defend" (DAD) relationship with the community towards practices which encourage more proactive engagement, based on the „Engage-Deliberate-Decide" (EDD) model8. The report is based on Environment Agency documentation and interviews with staff, engineering consultants and members of the Shaldon and Ringmore Liaison Group. It uses insights from the Shaldon pilot to highlights areas of process efficiency for flood and coastal risk management (FCRM) in similar situations in the future. It also indicates what needs to be done if these efficiencies are to be robust in the future, including tailoring the amount and type of engagement to the risk and needs of the work.

Sultana , P., Thompson, P. and C. Green (2008) Can England Learn Lessons from Bangladesh in Introducing Participatory Floodplain Management, Water resources management, Vol 22, 3, 357-376

Public or stakeholder participation in planning and management of natural resources is now widely practiced, but means different things in different contexts. Examples of recent participation in floodplain management in Bangladesh and England are reviewed in the national policy context. Participation in floodplain planning in England is influenced by a centralised state and European Union directives. The Ribble process tried to involve a wide range of stakeholders, but is limited to the development of plans through consultations structured and managed by the Environment Agency. By comparison in Bangladesh local participatory planning with different stakeholders has articulated their separate needs and suggestions, and brought them together to search for consensus. Decision making and responsibilities over flood management infrastructure and floodplain resources have been devolved to community organisations and co-management committees formed through the participation process. The Bangladesh examples show how participation can be made more accessible to people through events that have real local meaning since representatives gain power to raise funds and implement decisions for the benefit of their stakeholder constituencies. In Bangladesh rural populations dependent on

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floodplain resources have an incentive to participate in implementation and oversight of management decisions and actions that is lacking for most urban people in England. However, the merits of building up from local participation to catchment planning and of linking floodplain specific participatory institutions with existing local government are lessons that could be adapted from Bangladesh to England.

Tseng, C. and W.C. Penning-Rowsell (2012) Micro-political and related barriers to stakeholder engagement in flood risk management, The Geographical Journal, Vol 178, 3, 253-269

Modern conceptualisations of flood risk management (FRM) embody the active engagement of citizens in the appraisal of risk and the development of risk reducing options. But such engagement is known not to be easy. The relevant literature suggests that the potential barriers to stakeholder engagement in FRM are conventionally theorised in three categories: stakeholder-based barriers; time-related barriers; and barriers caused by power inequalities. This paper describes research exploring these issues, by critiquing existing ideas about the barriers to stakeholder engagement in FRM and elsewhere, and by using a case study from Taiwan. Using in-depth interviews of stakeholders we found that failure to acknowledge and take account of the micro-politics in the engagement process brought about new impediments to participation: power sharing unexpectedly created new barriers. We conclude that these results may have relevance elsewhere but that conflicts will remain as long as there are choices to be made. Stakeholder engagement is about resolving these conflicts, but the promoters of flood risk reducing interventions need to be much more analytical in their efforts to understand the 'micro-political positions' of all the stakeholders they encounter, rather than see such differences as themselves inherently problematic.

Van Herk, S., Zevenbergen, C., Ashley, R. and Rijke, J. (2011) Learning and Action Alliances for the integration of flood risk management into urban planning: a new framework from empirical evidence from The Netherlands,, Environmental Science and Policy, Vol 14, 5, 543-554

Urban development and regeneration present windows of opportunity to reduce flood vulnerability that are often not taken advantage of. Collaborative planning is needed to integrate planning and flood risk management and can be achieved by a social learning framework: Learning and Action Alliance (LAA). This paper presents a new framework on how to organise a LAA to support collaborative planning. The framework is verified based on empirical evidence from 2 case studies in The Netherlands where LAAs supported the adoption of an integrated approach to flood risk management and urban development. More than 60 interviews reported that the LAA helped develop and applied relevant knowledge in 3 types of joint activities: system analysis; collaborative design; and governance. These supported demonstration projects through 3 threads by: establishing facts; creating images; and setting ambitions. This was done via 3 streams by: addressing problems; developing solutions; and influencing politics. The new framework has been demonstrated to provide an effective guide to the organisation of a LAA and provides a new analytical tool to assess the impact of LAAs. Other success factors for LAAs and the better integration of flood risk management into the planning process are considered.

Vari, A., Linnerooth-bayer, J. and F. Zoltan (2003) Stakeholder Views on Flood Risk Management in Hungary's Upper Tisza Basin, Risk Analysis, Vol 23, 3, 585-600

With escalating costs of flood mitigation and relief, a challenge for the Hungarian government is to develop a flood mitigation and insurance/relief system that is viewed as efficient and fair by the many stakeholders involved. To aid policymakers in this task, this article reports on a recent study to elicit stakeholder views on flood risk management in the Upper Tisza Basin, including views on appropriate means of reducing losses and for transferring the residual losses from the direct victims to taxpayers or an insurance pool. This study is part of a project to develop an integrated approach to flood risk management coordinated by the International Institute of Applied Systems Analysis (IIASA) in collaboration with Swedish and Hungarian researchers. The discussion begins by describing the background of flood risk management problems in the Upper Tisza Basin. The results of interviews carried out with selected key stakeholders and the results of a public survey eliciting views on flood risk management are reported. The final section draws conclusions on incorporating stakeholder views into a flood risk management model, which will be used to illustrate policy paths at an upcoming stakeholder workshop.

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The conclusions are also of direct interest to Hungarian policymakers.

Risk perception and attitudes

Armas, J., Ionescu, R. and Posner, C.N. (2015) Flood risk perception along the Lower Danube river, Romania, Natural Hazards, Vol 79, 3, 1913-1931

Risk can be seen as both objective, quantifiable, and subjective, constructed at an individual level. This paper focuses on the latter and aims to explore flood perceptions in relation to socio-demographic variables and various economic measures. The data were drawn from four villages on the banks of the Danube using quantitative questionnaires, villages data sheet and in-depth semi-structured interviews. This mixed method approach allowed for ecologically sound findings. Inequality of income and capital are linked with variations of some risk perception dimensions such as disaster temporal proximity, perceived resilience, and also with a reluctance to think about the future and the dangers it might pose. Past floods are associated with most dimensions tested, including income, inequality, and whether the next flood appears to be imminent. Lower-income households expect some form of assistance not from the community, the church, or local authorities, but from the government. This highlights erosion of social values, or inter-household monetisation, as the other major issue, alongside inequality, faced by rural populations living on the banks of one of Europe's greatest rivers.

Baan, P.J.A. and Klijn, F. (2004) Flood risk perception and implications for flood risk management in the Netherlands, International Journal of River Basin Management, Vol 2, 2

A society well@aware of risks must not only give attention to the prevention of flood risks but must also consider disaster management, i.e. minimising casualties and flood damages, and enhancing recovery. The Netherlands has a solid network of levees along the rivers that protect the many low-lying polders from flooding. But nature is unpredictable, extreme events may happen, and absolute protection against flooding cannot be offered.

It is common practice to perform technical and economic analyses to determine the feasibility of flood protection plans. And usually also institutional and administrative aspects are addressed. But how the people that live in the polders feel about flood risk and protection plans seldom gets due attention. This paper primarily looks into the attitude of the people. How do people live with (flood) risks and how do they feel about that? What can be learned from that for communication on flood risks and flood risk management? Finally, we give some recommendations about what elements to consider when developing a flood risk management strategy.

Becker, G., Aerts, J.C.J.H. and Huitema, D. (2013) Influence of flood risk perception and other factors on risk-reducing behaviour: a survey of municipalities along the Rhine, Journal of Flood Risk Management, Vol 7, 1, 16

A survey of German public officials responsible for municipal flood management along the Rhine has been carried out to assess their perceptions of flood risk and protective behaviour. A socio-psychological framework based on expectancy-valence models was used to develop an overview of potentially important factors in prompting action to avoid flood damage. The applied framework was confirmed as a useful tool to get more insight into the risk-reducing processes in the public-sector sphere. The study delivers valuable guidance on those factors, which should be given more attention in order to improve the level of preparedness and to reduce flood losses.

Birkholz, S., Muro, M., Jeffrey, P. and Smith, H.M. (2014) Rethinking the relationship between flood risk perception and flood management, Science of The Total Environment, Vol 478, 12–20

Although flood risk perceptions and their concomitant motivations for behaviour have long been recognised as significant features of community resilience in the face of flooding events, there has, for some time now, been a poorly appreciated fissure in the accompanying literature. Specifically, rationalist and constructivist paradigms in the broader domain of risk perception provide different (though not always conflicting) contexts for interpreting evidence and developing theory. This contribution reviews the major constructs that have been applied to understanding flood risk perceptions and contextualises these within broader conceptual developments around risk perception theory and contemporary thinking around flood risk management. We argue that there is a need to re-examine and re-invigorate flood risk perception research, in a manner that is comprehensively

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underpinned by more constructivist thinking around flood risk management as well as by developments in broader risk perception research. We draw attention to an historical over-emphasis on the cognitive perceptions of those at risk to the detriment of a richer understanding of a wider range of flood risk perceptions such as those of policy-makers or of tax-payers who live outside flood affected areas as well as the linkages between these perspectives and protective measures such as state-supported flood insurance schemes. Conclusions challenge existing understandings of the relationship between risk perception and flood management, particularly where the latter relates to communication strategies and the extent to which those at risk from flooding feel responsible for taking protective actions.

Bosschaart , A., Kuiper, W., Van der Schee, J. and Schoonenboom, J. (2013) The role of knowledge in students' flood-risk perception, Natural Hazards, Vol 69, 3, 1661-1680

Until now, flood-risk perception in the Netherlands has been solely studied as it relates to adults. This exploratory study focused on 15-year-old students who have taken geography courses for 3 years. Since geography education focuses on the formation of knowledge and understanding with respect to flooding in the Netherlands, we were interested in finding out to what extent knowledge and understanding of flooding leads to a rational judgment of flood risk that influences flood-risk perception among 15-year-old students. A cross-sectional survey was conducted among 483 15-year-old students from different flood-prone areas in the Netherlands. A reference group of 134 students from higher-elevation areas also participated. In addition to risk perception and risk-related factors, the survey also consisted of a knowledge test about flood hazards and water management with respect to the Netherlands in general and with regard to the surroundings of the students' schools. In general, students showed low personal flood-risk perceptions and much stronger general flood-risk perceptions. Students' level of knowledge of floods and flood-related aspects was low. Predictors of personal risk perception included fear, knowledge of flooding in the surroundings of the school and the awareness of environmental cues. Further study is needed of the formation of knowledge in relation to engendering flood-risk awareness among students.

Bradford, R.A., O'Sullivan, J.J., van der Craats, I.M., Krywkow, J., Rotko, P., Aaltonen, J., Bonaiuto, M., De Dominicis, S., Waylen, K. and K. Schelfaut (2012) Risk perception – issues for flood management in Europe, Nat. Hazards Earth Syst. Sci., 12, 2299-2309.

Public perception of flood risk and flood risk information is often overlooked when developing flood risk management plans. As scientists and the public at large perceive risk in very different ways, flood risk management strategies are known to have failed in the past due to this disconnect between authorities and the public. This paper uses a novel approach in exploring the role of public perception in developing flood risk communication strategies in Europe. Results are presented of extensive quantitative research of 1375 questionnaire responses from thirteen communities at risk across six European countries. The research forms part of two research projects funded under the 2nd ERA-Net CRUE Funding Initiative: URFlood and FREEMAN. Risk perception is conceptualised as a pillar of social resilience, representing an innovative approach to the issue. From this process recommendations are identified for improving flood risk management plans through public participation.

Bronfman, N. C. and Cifuentes, L. A. (2008) Risk Perception in a Developing Country: The Case of Chile, Risk Analysis: An International Journal. Dec, Vol. 23 Issue 6, 271-1285

In this work we characterize risk perception in Chile, based on the psychometric paradigm, exploring the difference between perceived social and personal risk. For this purpose, we conducted a survey including 54 hazards, 16 risk attributes, and 3 risk constructs. The survey, divided into four parts, was administered to 508 residents of Santiago, Chile. Using factor analysis, three main factors, which accounted for 80% of the sample's variance, were identified: factor 1, commonly called "Dread Risk" in the literature, explained 37% of variance; factor 2, "Unknown Risk," explained 28%; and factor 3, which we called "Personal Effect," explained 15% of the variance. On average, individuals perceived themselves as less exposed to risk and with more control and knowledge about them than the general population. OLS regression models were used to test the association of perceived risk with the three main factors. For social risk, factor 1 had the greatest explanatory power, while

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factor 2 had a negative sign. For personal risk, only factors 2 and 3 were significant, with factor 3 having the greatest explanatory power. Risk denial (defined as the difference between perceived personal and social risk) was associated with factors 1 and 2 only, with factor 2 having a negative sign. The difference between desired and actual regulation levels proved positive for all hazards, thus indicating that Chileans are dissatisfied with the current regulation level for all the hazards analyzed. The comparison of data at the aggregate and at the individual subject's level suggests that while the aggregate analysis overestimates the magnitude of the correlations it still reflects the tendency of the individual responses.

Burningham, K. and Fielding, J. (2007) 'It'll never happen to me': understanding public awareness of local flood risk, Disasters, Vol 32, Issue 2, 216–238

Following the severe flood events of 1998 and 2000, the United Kingdom's Environment Agency prioritised the need to increase public flood risk awareness. Drawing on data collected during research undertaken for the Environment Agency, this paper contributes to understanding of one aspect of flood awareness: people's recognition that their property is in an area that is potentially at risk of flooding. Quantitative analyses indicate that class is the most influential factor in predicting flood risk awareness, followed by flood experience and length of time in residence. There are also significant area differences. Our qualitative work explores how those defined as 'at risk' account for their lack of awareness or concern about their risk status. We conclude that the problem is often not simply a lack of awareness, but rather, assessments of local risk based on experience that underestimate the impact of rare or extreme events. We underline the importance of engaging with local perspectives on risk and making local people part of 'awareness-raising' processes.

De Dominicis, S., Crano, W.D., Cancellieri, L.G., Mosco, B., Bonnes, M., Hohman, Z. and Bonaiuto, M. (2014) Vested interest and environmental risk communication: improving willingness to cope with impending disasters, Journal of Applied Social Psychology, Vol 44, 5, 364–374

Vested interest theory (VIT), first investigated on environmental risk, suggests that the hedonic relevance of an attitude object moderates relations between attitudes, intentions, and responses to danger. Emphasizing vested interest may maximize impacts of risk communications. Study 1 ($N = 215$) assessed differences between inhabitants of two flood-risk areas in Italy on past experience, risk perceptions, concerns, attitudes, and behavioral intentions.
Objectively, higher risk areas' residents reported more experience, and greater perceived risk and concern, while no preparedness differences were found (both at "between cities" and "within city" levels). Study 2 ($N = 444$) looked at the moderating role of VIT-based risk communication messages on the relationship between vested interest and behavioral intentions. Components of vested interest moderate attitude–intention consistency, suggesting a new method of developing effective risk announcements.

Kellens, W., Zaalberg, R., Neutens, T., Vanneuville, W. and De Maeyer, P. (2011) An analysis of the public perception of flood risk on the Belgian coast, Risk Analysis, Vol 31, 7, 1055-1068

In recent years, perception of flood risks has become an important topic to policy makers concerned with risk management and safety issues. Knowledge of the public risk perception is considered a crucial aspect in modern flood risk management as it steers the development of effective and efficient flood mitigation strategies. This study aimed at gaining insight into the perception of flood risks along the Belgian coast. Given the importance of the tourism industry on the Belgian coast, the survey considered both inhabitants and residential tourists. Based on actual expert's risk assessments, a high and a low risk area were selected for the study. Risk perception was assessed on the basis of scaled items regarding storm surges and coastal flood risks. In addition, various personal and residence characteristics were measured. Using multiple regression analysis, risk perception was found to be primarily influenced by actual flood risk estimates, age, gender, and experience with previous flood hazards.

Ludy, J. and Kondolf, G.M. (2012) Flood risk perception in lands "protected" by 100-year levees, Natural Hazards, Vol 61, 2, 829-842

Under the US National Flood Insurance Program, lands behind levees certified as protecting against the 100-year

flood are considered to be out of the officially recognized “floodplain.” However, such lands are still vulnerable to flooding that exceeds the design capacity of the levees—known as residual risk. In the Sacramento-San Joaquin Delta of California, we encounter the curious situation that lands below sea level are considered not “floodplain” and open to residential and commercial development because they are “protected” by levees. Residents are not informed that they are at risk from floods, because officially they are not in the floodplain. We surveyed residents of a recently constructed subdivision in Stockton, California, to assess their awareness of their risk of flooding. Median household income in the development was $80,000, 70% of respondents had a 4-year university degree or higher, and the development was ethnically mixed. Despite the levels of education and income, they did not understand the risk of being flooded. Given that literature shows informed individuals are more likely to take preventative measures than uninformed individuals, our results have important implications for flood policy. Climate-change-induced sea-level rise exacerbates the problems posed by increasing urbanization and aging infrastructure, increasing the threat of catastrophic flooding in the California Delta and in flood-prone areas worldwide.

Pagneux, E., Gísladóttir, G. and Jónsdóttir, S. (2011) Public perception of flood hazard and flood risk in Iceland: a case study in a watershed prone to ice-jam floods, Natural Hazards, Vol 58, 1, 269-287

Understanding and improving the public perception has become an important element in the management of flood risk worldwide. In Iceland, studying perception of flood hazard and flood risk is, however, in its early stages. This paper presents a case study on the public perception of flood hazard and flood risk in an Icelandic town prone to ice-jam floods. Awareness of the population regarding historical inundations, self estimation of flood risk and worry is considered. The factual knowledge of the residents is deconstructed in flood hazard parameters accessible to the lay population: number of events, dates, genesis and boundaries. The performance of the respondents is rated for each parameter and the influence of several predictors evaluated. The research shows three significant patterns: there is poor awareness and little worry about historical inundations in the area; experience of the past flooding events in town is the most effective source of knowledge; awareness, risk estimation and worry are not correlated.

Rohrmann, B. and Chen, H. (1999) Risk perception in China and Australia: an exploratory cross-cultural study, Journal of Risk Research, Vol 2, 3, 219-241

Perceptions and subjective evaluations of risky activities and environmental conditions were explored in several 'Western' and 'Eastern' countries, based on a socio-psychological approach. The aim of these cross-cultural studies is to analyse the cognitive structure of judgments about the magnitude and acceptability of risks to which individuals are exposed: to compare risk judgments across countries of different cultural background in which risk issues in general as well as particular risk sources (e.g., industrial facilities or natural hazards) have distinct salience, and to examine disparities between societal groups which differ in their professional background. In the current project, fully comparable data were collected in China (N = 270) and Australia (N = 203), utilizing psychometric instruments. The sampling in both countries focused on 3 groups of students (i.e., geography, psychology, engineering) and a group of scientists/researchers. Participants were asked for judgments on 25 hazards (based on a taxonomy) according to 12 risk aspects (derived from a structural risk perception model). Data comparisons for countries, for societal groups and for types of risks yield a complex picture. Cross-cultural disparities are evident in two ways: there is considerable cross-national variation in risk perception, and groups affiliated with particular professional orientations differ in their judgment and evaluation of hazards as well. A major disparity between the two country data is that the Chinese respondents seem to be less prepared than the Australian ones to accept risks in principal (while there is no difference in the mean of risk magnitude ratings). Regarding specific hazards, the largest differences emerge for hazards related to politically morally 'banned' activities, such as gambling, using hallucinogenic drugs or unsafe sex. With respect to the 'cognitive structure' underlying risk evaluations, the main influences are similar for the compared samples. Altogether the results demonstrate the strong influence of socio-psychological variables and the cultural context on risk evaluations. However, the empirical basis for the findings gained so far is still small and generalizability restricted. A wider range of cultures needs to be looked at in order to clarify further the influence of cultural factors on the cognition and evaluation of risks. Such research is under way.

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Scolobig, A., De Marchi, B. and Borga, M. (2012) The missing link between flood risk awareness and preparedness: findings from case studies in an Alpine Region, Natural Hazards, Vol 63, 2, 499-520

The low risk awareness of the residents living in flood-prone areas is usually considered among the main causes of their low preparedness, which in turns generates inadequate response to natural disasters. In this paper, we challenge this assumption by reporting on the results of a sociological research in four communities exposed to flood risk in the Eastern Italian Alps. The research design included semi-structured interviews and focus groups with key local stakeholders and a standardized questionnaire submitted to 400 residents. Results revealed that residents felt both slightly worried about flood risk and slightly prepared to face an event. Considerable differences were found between the evaluations of individual subjects as opposed to overall communities. There was also a clear discrepancy between the actual adoption of household preparatory measures and the willingness to take self-protection actions. Overall, the risk awareness was significantly higher among those residents who had been personally affected by a flood in the past, were living in isolated (vs. urban) communities, in the most risky areas or had a lower level of trust in local authorities. The improvement of residents' knowledge about their environment and the residual risk seemed to be crucial to increase risk awareness, and the same was true for the strengthening of local support networks to foster preparedness. The link between risk awareness and preparedness was not at all straightforward. Results revealed instead the complexity of residents' perspectives, attitudes, behaviours and decisions about risk-related issues.

Viglione, A., Di Baldassarre, G., Brandimarte, L., Kuil, L., Carr, G., Salinas, J.L., Scolobig, A., Blöschl, G. (2014) Insights from socio-hydrology modelling on dealing with flood risk – Roles of collective memory, risk-taking attitude and trust, Journal of Hydrology, Vol 518, 71-82,

The risk coping culture of a community plays a major role in the development of urban floodplains. In this paper we analyse, in a conceptual way, the interplay of community risk coping culture, flooding damage and economic growth. We particularly focus on three aspects: (i) collective memory, i.e., the capacity of the community to keep risk awareness high; (ii) risk-taking attitude, i.e., the amount of risk the community is collectively willing to be exposed to; and (iii) trust of the community in risk reduction measures. To this end, we use a dynamic model that represents the feedback between the hydrological and social system components. Model results indicate that, on the one hand, by under perceiving the risk of flooding (because of short collective memory and too much trust in flood protection structures) in combination with a high risk-taking attitude, community development is severely limited because of high damages caused by flooding. On the other hand, overestimation of risk (long memory and lack of trust in flood protection structures) leads to lost economic opportunities and recession. There are many scenarios of favourable development resulting from a trade-off between collective memory and trust in risk reduction measures combined with a low to moderate risk-taking attitude. Interestingly, the model gives rise to situations in which the development of the community in the floodplain is path dependent, i.e., the history of flooding may lead to community growth or recession.

Warren, R., Tindle, A., and Whalley, R. (2011) Flood resilient repairs and resistance measures - Qualitative and quantitative research to examine the views of consumers, Available at: hb.betterregulation.com/external/Research%20Paper%20No.%2028%20-%20Flood%20Resilient%20Repairs%20and%20Resistance%20Measures.pdf

To follow

Whittle, R., Walker, M., Medd, W. and Mort, M. (2012) Flood of emotions: emotional work and long-term disaster recovery, Emotion, Space and Society, 02/2012

This paper uses concepts of emotion work and emotional labour to explore people's experiences of the long-term disaster recovery process. It draws on data taken from two qualitative research projects which looked at adults' and children's recovery from the floods of June 2007 in Hull, UK. The paper argues that the emotional work of recovery cannot be separated from the physical and practical work of recovering the built environment. It shows that a focus on emotion work can lead to a more nuanced understanding of what recovery actually means and who is involved, leading to the identification of hidden vulnerabilities and a better understanding of the longer

timescales involved in the process.

Wood, M., Bridges, T., Linkov, I., Kovacs, D. and Bostrom, A. (2012) Flood Risk Management: US Army Corps of Engineers and Layperson Perceptions, Risk Analysis, Vol 32, 8, 1349-136

Recent severe storm experiences in the U.S. Gulf Coast illustrate the importance of an integrated approach to flood preparedness planning that harmonizes stakeholder and agency efforts. Risk management decisions that are informed by and address decision maker and stakeholder risk perceptions and behavior are essential for effective risk management policy. A literature review and two expert models/mental models studies were undertaken to identify areas of importance in the flood risk management process for layperson, non-USACE-expert, and two USACE-expert groups. In characterizing and mapping stakeholder beliefs about risks in the literature onto current risk management practice, recommendations for accommodating and changing stakeholder perceptions of flood risks and their management are identified. Needs of the U.S. Army Corps of Engineers (USACE) flood preparedness and response program are discussed in the context of flood risk mental models.

Wood, M., Kovacs, D., Bostrom, A., Bridges, T. and Linkov, I. (2012) Flood Risk Management: US Army Corps of Engineers and Layperson Perceptions, Risk Analysis, Vol 32, 8, 1349–1368

Recent severe storm experiences in the U.S. Gulf Coast illustrate the importance of an integrated approach to flood preparedness planning that harmonizes stakeholder and agency efforts. Risk management decisions that are informed by and address decision maker and stakeholder risk perceptions and behaviour are essential for effective risk management policy. A literature review and two expert models/mental models studies were undertaken to identify areas of importance in the flood risk management process for layperson, non-USACE-expert, and two USACE-expert groups. In characterizing and mapping stakeholder beliefs about risks in the literature onto current risk management practice, recommendations for accommodating and changing stakeholder perceptions of flood risks and their management are identified. Needs of the U.S. Army Corps of Engineers (USACE) flood preparedness and response program are discussed in the context of flood risk mental models.

Structural defences

Allsop, N. W., Kortenhaus, A. and Morris, M. 2007. Failure mechanisms for Flood Defence Structures. FLOODsite project report T04_06_01. www.f!oodsite.org.uk. (Accessed 19 January 2015)

This report provides an analysis of flood defence asset failure modes, structured according to asset and loading type. Failure mode information for each asset is presented in a common format and structured for use within reliability analysis models. The intention is that this document forms a central store of agreed failure mechanisms for flood defence assets and that individual failure mode templates are updated within the report as new or refined methods are developed.

Huang, W.-C., Yu, H.-W., and Weng, M.-C. (2015) Levee reliability analyses for various flood return periods – a case study in Southern Taiwan, Nat. Hazards Earth Syst. Sci. Discuss., 3, 457-495

In recent years, heavy rainfall conditions have caused damages around the world. To prevent damages by floods, levees have often been constructed in prone-to-inundation areas. This study performed reliability analyses for the Chiuliao 1st Levee located in southern Taiwan. The failure-related parameters were the water level, the scouring depth, and the in-situ friction angle. Three major failure mechanisms were considered, including the slope sliding failure of the levee, and the sliding and overturning failures of the retaining wall. When the variabilities of the in-situ friction angle and the scouring depth are considered for various flood return periods, the variations of the factor of safety (FS) for the different failure mechanisms show that the retaining wall sliding and overturning failures are more sensitive to the variability of the friction angle. When the flood return period is greater than 2 years, the levee can undergo slope sliding failure for all values of the water level difference. The results for levee stability analysis considering the variability of different parameters could assist engineers in designing the levee

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cross sections, especially with potential failure mechanisms in mind.

Morris, J. ; Hess, T.M. ; Gowing, D.J.G. ; Leeds-Harrison, P.B. ; Bannister, N. ; Vivash, R.M.N. ; Wade, M. (2005) A framework for integrating flood defence and biodiversity in washlands in England, International Journal of River Basin Management, Vol 3, 2, 105-11

Concerns about increased flood risk and loss of biodiversity in lowland areas, coupled with changing priorities in the countryside have drawn attention to the potential contribution that managed washlands can make to improved flood management, habitats and wildlife. Following a review of research literature, a survey of flood managers and conservation officers, and an evaluation of selected case sites in England, a framework to help integrate potential flood management and biodiversity opportunities was constructed. This framework consists of three components, namely: a Hydraulic classification which categorises washlands according to degree of hydraulic control; a Habitat classification which captures attributes of washland hydrology that define the type of existing or potential habitats; and, a Menu of Interventions to "engineer" or manage particular flooding and soil wetness regimes and thereby better exploit habitat potential. Washlands were also categorised by main type of benefit whether this is flood management, conservation, or in the case of integrated washland, a balance of the two. The advantages of alternative administrative and funding arrangements for washlands, whether land acquisition or annual payment to existing land owners, were also explored. It was concluded that the classification of washland flooding and water level regimes can help to define habitat potential. It can also help to guide hydraulic engineering and management actions that can be taken to realise this potential. Although there is potential synergy between flooding and biodiversity under some flood regimes, biodiversity benefits mainly depend on the management of water regimes following flood events. There is a clear need to "join up" hitherto fragmented policy and funding mechanisms in order to exploit the potential for washlands to simultaneously deliver flood management and biodiversity benefits.

Sayers, P. (ed) (2012) Flood Risk: Planning, Design and Management of Flood Defence Infrastructure, ICE Publishing, London. ISBN: 9780727741561 Hardback

This uniquely comprehensive guide for engineers and scientists demonstrates the feasibility of an integrated approach that combines resilient infrastructure with adaptive flood risk management. The book offers practical guidance on managing existing flood defences and designing and planning new ones. Key legislation is discussed together with insights into emerging flood risk management concepts and future developments in policy and practice. The authors address the core concepts of flood risk management and equip readers with the tools and techniques needed to better assess the reliability and adaptability of defences and – ultimately – make robust risk-based decisions.

"Flood Risk" is

- a single resource covering fluvial, coastal and urban issues
- globally applicable, highlighting the flood risk management lessons learned from international case studies
- authored by an expert group of practising engineers and academic specialists
- extensively referenced with sources of further information on all topics.

Placing flood defence infrastructure within the context of a broader flood risk management approach, this key text is essential reading for engineers, scientists, and government and local authority stakeholders who must meet the increasingly complex challenges of flood risk, both now and in the future.

Contents

- Introduction
- Twenty-first Century flood risk management
- Past failures and design lessons
- Visual inspections and surveys, remote sensing techniques and sensors for detailed analyses of flood defence infrastructure
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- Dams and reservoirs - regulations, performance and past failures
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- adaptive and resilient flood risk management infrastructure
- Managing flood risk in the Thames Estuary – the development of a long-term robust and flexible strategy
- The 2001 flood of Houston and Harris County, Texas, USA
- Design of an environmentally aligned flood alleviation scheme: the Burn of Mosset, Moray, Scotland
- Glossary of terms
- Further Information / Reviews

Thompson , P.M. and P. Sultana, P. (1996) Operation and maintenance performance and conflicts in flood-control projects in Bangladesh, International Journal of Water Resources Development, Vol 12, 3, 311-32

This paper examines the common conflicts that exist in the operation of flood control projects in Bangladesh.

Thompson, P. M. and P. Sultana (1996) Distributional and Social Impacts of Flood Control in Bangladesh, The Geographical Journal, Vol 162, 1, 1-13

The losses and suffering of the rural poor of Bangladesh during floods are frequently in the attention of the world media. This is despite a considerable investment in flood protection over the past three decades. This paper reports on distributional and socio-economic impacts of selected flood control projects which were subject to multidisciplinary evaluations using both rapid appraisal and sample survey methods. Flood protection has disadvantaged some groups, notably fishermen and boatmen, but has generally had a limited impact on work opportunities, partly because some projects had little impact on agriculture. One consequence of differential impacts is new conflicts over the management of water inside projects. Where there were benefits these accrued mostly to larger landowners, but labourers and small farmers did also benefit. There is little evidence that flood protection has stabilized the economic condition of households. In four out of five projects studied in detail flood losses were higher in the 1988 flood inside the project compared with unprotected control areas. Embankment failure (owing to erosion and deliberate embankment cuts associated with conflicts) is a serious hazard, although embankments also act as refuges in peak floods.

Cost-benefit analysis

General overview and theory

Commonwealth of Australia (2006) Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies, Financial Management Reference Material No. 5, January, Department of Finance and Administration Financial Management Group, Canberra ISBN 1 921182 00 8 (print) ISBN 1 921182 02 4 (online)

Managers in Australian Government agencies are often called on to evaluate programmes and projects to ensure that they represent an efficient and effective use of public money. Cost-benefit analysis (CBA) is a method of quantitative economic analysis that is widely used to evaluate existing and proposed projects, programmes and policies, and which can inform decision-making. Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies (hereafter the Introduction to CBA) introduces CBA in a non-technical way and outlines the basic steps for its use.
The Introduction to CBA also discusses two alternative quantitative methods for evaluating
proposals that have broad relevance to Australian Government agencies: financial evaluation
and cost-effectiveness analysis. However, the Introduction to CBA focuses mainly on CBA. Three case studies are also provided. They are a cost-benefit analysis of an infrastructure proposal; a financial evaluation of a property

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project; and a cost-effectiveness analysis of a health programme.
The Introduction to CBA also includes a short technical section. Readers seeking a more technical account of these methods should refer to published texts on this matter, including Handbook of Cost-Benefit Analysis (hereafter the Handbook of CBA) published by the Department of Finance and Administration (2006).

Commonwealth of Australia (2006) Handbook of Cost-Benefit Analysis, Financial Management Reference Material No. 6, Canberra ISBN (Print) 19 21182 01 6 ISBN (On-line) 19 21182 03 2

The Handbook of Cost-Benefit Analysis provides guidance in the use of cost-benefit analysis for evaluation and decision-making. It is aimed at enhancing capacities and fostering good practices in the use of cost-benefit analysis. The Handbook also covers two alternative methodologies – financial evaluation and cost-effectiveness analysis – for the evaluation of projects and programmes. The target audience of this Handbook is Australian Government agencies. It is intended for use by those officers involved in appraising and evaluating projects and programmes that carry major resources implications. However, it should be noted that other evaluation methodologies, which are not covered in the Handbook, are available and may be used by agencies. In any case, agencies should outline and justify the evaluation methodology chosen. Agencies are responsible for conducting and presenting (normally through written reports) their own evaluations. The Handbook is intended to be a resource document and guide for officers undertaking a cost-benefit analysis of a project or programme. It aims to explain concepts clearly and, in this way, does not assume any prior knowledge of economics. However, readers with a background or particular interest in economic principles are likely to relate to the material more readily than others. The Handbook includes a useful section on the criticisms and limitations of Cost-Benefit Analysis.

Dobes, L. (2008) A century of Australian cost-benefit analysis: lessons from the past and the present, Working papers in cost-benefit analysis, Office of Best Practice Regulation, Department of Finance and Deregulation and ANU, WP 2008-01, Canberra https://www.dpmc.gov.au/deregulation/obpr/docs/Working-paper-1-Leo-Dobes.rtf, accessed 18/11/14

A wide-ranging paper beginning with the origins of cost-benefit analysis in the USA with Benjamin Franklin and the much later 1936 Flood Control Act. The paper discusses the US experience with cost-benefit analysis and although Australia never institutionalised CBA in the way the US did, Australia can be proud of its heritage of early economic analysis. The author examines the costs and benefits that were attributed in Australia to rail gauge unification – a key area to which CBA was applied – and draws some lessons from history. The current use of CBA in Australia is discussed next focusing upon the large infrastructure projects promoted by Auslink (i.e. transportation projects) which introduces some interesting distributional issues. The relevance of CBA in the health and defence sectors are discussed next before the author makes the case for a renaissance of CBA and puts forward an argument for greater use of CBA but in ways which reduces the cost of such analyses. Ways of encouraging greater use are discussed.

Green, C. H. (2003) A Handbook of Water Economics, John Wiley, Chichester (ISBN: 978-0-471-98571-6)

The Handbook of Water Economics is presented in three sections: theory, methods and applications, providing the latest information in the growing area of water economics and the environment, covering the theory and issues relating to resource management techniques, policy formulation, implementation and evaluation in the water sector.
* Includes strong theory section which links to real world examples in the applications section
* Methods section includes coverage of methods of economic evaluation, use of economic instruments and cost-benefit analysis
* Applications section includes case studies on flooding and coastal zone management
Essential reading for those studying environmental economics modules in Departments of Environmental Management, Geography and Engineering, researchers in hydrology as well as professionals and policy makers in water companies, water authorities, NGO's and government agencies.

Hallegatte, S. (2008) An Adaptive Regional Input-Output Model and Its Application to the Assessment of the

Economic Cost of Katrina. Risk Analysis 28, 779–799

This article proposes a new modelling framework to investigate the consequences of natural disasters and the following reconstruction phase. Based on input-output tables, its originalities are (1) the taking into account of sector production capacities and of both forward and backward propagations within the economic system; and (2) the introduction of adaptive behaviours.
The model is used to simulate the response of the economy of Louisiana to the landfall of Katrina.
The model is found consistent with available data, and provides two important insights. First, economic processes exacerbate direct losses, and total costs are estimated at $149 billion,
for direct losses equal to $107 billion. When exploring the impacts of other possible disasters, it is found that total losses due to a disaster affecting Louisiana increase nonlinearly with respect to direct losses when the latter exceed $50 billion. When direct losses exceed $200 billion, for instance, total losses are twice as large as direct losses. For risk management, therefore, direct losses are insufficient measures of disaster consequences. Second, positive and negative backward propagation mechanisms are essential for the assessment of disaster consequences, and the taking into account of production capacities is necessary to avoid overestimating the positive effects of reconstruction. A systematic sensitivity analysis shows that, among all parameters, the overproduction capacity in the construction sector and the adaptation characteristic time are the most important.

Hallegatte, S. and Przyluski,V. (2010) The Economics of Natural Disasters, Concepts and Methods, Policy Working Paper 5507, World Bank

Large-scale disasters regularly affect societies over the globe, causing large destruction and damage. After each of these events, media, insurance companies, and international institutions publish numerous assessments of the "cost of the disaster." However these assessments are based on different methodologies and approaches, and they often reach different results. Besides
methodological differences, these discrepancies are due to the multi-dimensionality in disaster impacts and their large redistributive effects, which make it unclear what is included in the estimates. But most importantly, the purpose of these assessments is rarely specified, although
different purposes correspond to different perimeters of analysis and different definitions of what a cost is. To clarify this situation, this paper proposes a definition of This paper is a product of the Chief Economist of the Sustainable Development Network. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at hallegatte@centre-cired.fr.
the cost of a disaster, and emphasizes the most important mechanisms that explain and determine this cost. It does so by first explaining why the direct economic cost, that is, the value of what has been damaged or destroyed by the disaster, is not a sufficient indicator of disaster seriousness and why estimating indirect losses is crucial to assess the consequences on welfare. The paper describes the main indirect consequences of a disaster and the following reconstruction phase, and discusses the economic mechanisms at play. It proposes a review of available methodologies to assess indirect
economic consequences, illustrated with examples from the literature. Finally, it highlights the need for a better understanding of the economics of natural disasters and suggests a few promising areas for research on this topic.

HM Treasury (2012) The Green Book: Appraisal and Evaluation in Central Government, HM Treasury, London

The UK Government's guidance in public investment appraisal including benefit-costs analysis. The 'Green Book' sets the standards by which central government departments, such as Defra, are required to adopt in assessing the benefits and costs of investments. This guidance applies to the full range of public investment appraisal and not just cost-benefit analysis applied to flood risk management, but it contains highly pertinent guidance for practitioners in flood risk management.

Johansson, P. O. (1987) The economic theory and measurement of environmental benefits, Cambridge University Press, Cambridge

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This book is an advanced text in welfare economics and its application to environmental economics. It provides, in the first chapters, a comprehensive survey of developments in the theory of measurement of welfare, and then applies this theory to environmental economics. The first part derives consumer surplus measures to be used in a timeless world, and the second part looks at international issues.

Lequeux, Q. abnd Ciavola, P. (2012) Methods for Estimating the Costs of Coastal Hazards, WP7 Final Report, CONHAZ Consortium, Costs of Natural Hazards, Universita degli Studi di Ferrara, Italy

Cost assessments of damages of, prevention of, and responses to natural hazards provide crucial information for decision support and policy development in the fields of natural hazard management and planning for adaptation to climate change. There is a considerable diversity of methodological approaches and terminology being used in costs assessments of different natural hazards. This complicates the assessment of comprehensive, robust and reliable costs figures, as well as comparison of costs across hazards and impacted sectors. This report is part of the EU project ConHaz. The first objective of ConHaz is to compile state-of-the-art methods and terminology as used in European case studies. This compilation considers coastal hazards, droughts, floods, and alpine hazards, various impacted sectors such as health and nature. ConHaz distinguishes different types of costs among which: direct, indirect and intangible costs. On the other hand, it further examines the costs and benefits of risk-prevention and emergency response policies. The second objective of ConHaz is to evaluate the compiled methods by considering theoretical assumptions underlying cost assessment methods and issues appearing in application of the methods, such as availability and quality of data. ConHaz will also assess the reliability of the end results by considering the accuracy of cost predictions and best-practice methods of validation, and will identify relevant gaps in assessment methods. The third objective of ConHaz is to compare available assessment methods with end-user needs and practices, so as to better identify best practice and knowledge gaps in relation to policy-making. A final objective of ConHaz is to give recommendations about best practices and to identify research needs.

Navas, F., Malvarez, A., Correro, R. and Pereira de Silva, C. (2014) FLOOD-CBA Project: Stocktaking on Flood Risk Management and Cost-Benefit Analysis, Seminaro FLOOD CBA Lisboa, 21 January 2014 accessed at http://www.floodcba.eu/main/wp-content/uploads/TASK_B-Actions-and-Results.pdf on 1.11.14

This is a PowerPoint presentation document from the FLOOD-CBA project. One of the FLOOD-CBA project goals is to ensure the involvement and engagement of stakeholders dealing with Cost-Benefit Analysis (CBA) for flood risk management in different economic environments within the EU, and to collect and facilitate the exchange of information among them. The peer-to-peer stakeholder network within this project is described as are the legal and other underpinnings relating to CBA in a number of EU member states. How CBA is employed and where it is employed in described as an output from a peer consultation process.

Richard, P., Layard, G., Layard, R. and Glaister, S Eds (1994) Cost-Benefit Analysis, 2nd Edition, Press Syndicate of the University of Cambridge, Cambridge, ISBN 0521 46128 6

This second edition covers all the main problems that arise in a typical cost-benefit exercise. It is entirely up to date, reflecting the most recent research in the area. Part One covers the main theoretical issues affecting cost-benefit analysis. Part Two considers the problem of ascribing a monetary value to things. The third part covers six separate case studies drawn from real-life examples. The book begins with an extended elementary introduction written by the editors.

Flood damages

Admiraal, J. (2011) Flood damage to port industry, MSc. Thesis, Faculteit der Aard – en Levenswtenschappen, Vrije Universiteit, Amsterdam

Sea ports will experience many consequences of climate change; most of all rising water levels. However, no accepted method exists to assess flood damage to port industry. This study aims to illustrate a methodology to assess flood damage by climate change to port industry and infrastructure. A useful survey is made of

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known flood damage models from around the world and their characteristics. A comprehensive overview is made of the most recent estimations of the replacement value of port industry and infrastructure, and of the most detailed knowledge available about damage curves, which illustrate the direct economic damage to structures per inundation depth. From these surveys, a synthetic flood damage methodology is set up and applied to the port of Rotterdam, the largest port of Europe. Using pre-made climate change scenarios developed specifically for the port of Rotterdam, the vulnerability of the port to climate change is investigated.

The case study concludes that the unembanked areas of port of Rotterdam are very vulnerable to rising costs of flood events due to climate change. In comparison with the current situation (2010), the possible total costs of a flood event in 2050 range from approximately half as much to more than 6 times as much in cost. For 2100, the costs can be up to 14 times as high in comparison to 2010. The adaptation measure lockable/open˙ does not provide a substantial relief in damage costs.

Boettle, M., Rybski, D. and Kropp, J.P. (2013) How changing sea level extremes and protection measures alter coastal flood damages, Water Resources Research, Vol 49 (3), 1199-1210

Estimations due to the stochastic nature of extreme events are studied. Starting with the probability distribution of extreme flood levels, we calculate the distribution of implied damages in a specific regions employing stage-damage functions. Universal relations of the expected damages and their standard deviation, which demonstrate the importance of the shape of the damage function, are provided. How flood protection reduces the damages leading to a more complex picture is calculated, where the extreme value behaviour plays a fundamental role.

Blanco, A . and Schanze, J. (2013) Conceptual and methodological frameworks for large scale and high resolution analysis of the physical flood vulnerability of buildings, In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 591-598, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

The impacts of floods on buildings in urban areas are increasing due to i.e. the intensification of extreme weather events, unplanned or uncontrolled settlements and rising vulnerability of assets. There are some approaches available for assessing flood damage to buildings and critical infrastructure. However, these methods up to now cannot be adapted to a large scale because of lacking high resolution classification and characterisation approaches for the built structures. To overcome this obstacle, the paper presents, first, a conceptual framework for understanding physical flood vulnerability of buildings and, second, a methodological framework on the combination of methods for according large scale and high resolution analysis. The conceptual framework supports an in-depth understanding of the physical aspects of vulnerability and its influence on social, economic and ecological vulnerabilities. It describes key features that shape the physical flood vulnerability of buildings. Hereby, depth-impact functions are seen as a means for the interrelation between the water level and the physical impacts. They provide the basis for the subsequent derivation of depth-damage functions as basic indicator of economic vulnerability and depth-social impact function as basic indicator of social vulnerability. Geographic position of buildings is considered as a feature of exposure and hence is not part of the applied vulnerability definition. The methodological framework combines a taxonomic approach for the classification of buildings and an analysis of the physical flood vulnerability for representatives of building types. The building taxonomic approach results from classification of remote sensing data considering roof surface, topological and geometrical building characteristics. Then, representatives of the building types are selected through the similarity coefficient method. For representatives of each building type, their physical flood vulnerability is analysed based on depth-impact functions. The depth-impact function is calculated referring to the principal components of the buildings (e.g. height of storeys, building elements and their materials) affected by different water levels. All components are designed for a final integration into a technological framework.

Bubeck, P. (Undated) Memo: Flood damage evaluation methods, accessed at file:///C:/Users/Dennis/Downloads/200711%20Bubeck_MEMO_flood_damages.pdf on 1.11.14

A paper which gives insights into flood damage evaluation in the Netherlands and parts of Germany. This paper sets out a classification of flood damages and then examines flood damage evaluation methods which include the transfer of historic date and use of synthetic data. Quality aspects of flood damage data are then discussed

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before the author considers flood damage evaluation in the Netherlands. This includes a discussion of the objective of damage evaluation in The Netherlands, flood damage categories considered and the 'Standard Method (HIS damage module)'. The author then goes on to examine flood damage assessment in Germany, including the HOWAS data base and damage evaluation in Nordrhein-Westfalen. Again the objective of the damage evaluations, the damage categories considered, and the methods used for damage evaluation are discussed. Finally, methods of ascribing potential flood damages to land uses in relation to the Rhine Atlas and the damage scanner are discussed.

Bubeck, P., de Moel, H., Bouwer, L.M. and Aerts, J.C.J. (2011) How reliable are projections of future flood damage? Natural Hazards And Earth System Sciences, Vol 11 (12), 3293-3306

This paper examines flood damage along the river Rhine between 1990 and 2030 in terms of different flood-damage modelling approaches. The results show that relative estimates of flood damage developments differ by a factor of 1.4. These variations, which result from the application of different modelling approaches, are considerably smaller than differences between the approaches in terms of absolute damage estimates (by a factor of 3.5 to 3.8), or than differences resulting from land-use projections (by a factor of 3). The differences that exist when estimating relative changes principally depend on the differences in damage functions. In order to improve the reliability of relative estimates of changes in the development of potential flood damage, future research should focus on reducing the uncertainties related to damage functions. Assessments are still characterized by considerable uncertainties in stage-damage functions and methodological differences in estimating exposed asset values. In this paper, the authors evaluate the reliability of estimates of absolute flood damage assessments and investigate the reliability of estimates of relative changes in the development of potential flood damage. Studies that estimate (relative) changes in flood damage over time usually address uncertainties resulting from different projections (e. g. land-use characteristics) and other factors. Flood damage modelling is an important component in flood risk management, and several studies have investigated the possible range of flood damage in the coming decades.

Burzel, A., Dassanayake, D.R and Oumeraci, H. (2013) Spatial modelling of tangible and intangible losses in integrated risk analysis—results of the XtremRisK project. In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 557 -567, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

The expected climate change and associated increasing frequency of extreme storm surges may lead to larger storm surge hazards than have been observed in the past. Therefore, the German XtremRisK project aims to improve the understanding of the impact of extreme storm surges under current and future climate conditions by conducting an integrated flood risk analysis for two selected pilot sites in Germany, representing an open coast (Sylt Island) and a megacity in an estuarine area (Hamburg). The research has also been focused on developing and improving the knowledge, methods and models for the assessment of intangible losses (social and ecological), their spatial modelling as well as their integration with direct and indirect economic losses. After a brief introduction into the integrated risk analysis, the paper describes the methodologies and discusses the results with a focus on the spatial modelling of tangible and intangible losses in the pilot site Hamburg-Wilhelmsburg.

Cochrane, H. C. (2004), Economic loss: myth and measurement. Disaster Prevention and Management: An International Journal, Vol 13 (4): 290-296

this paper covers a number of pitfalls that could hinder the development of a common methodology for estimating flood damage. such pitfalls include double counting, ignoring post-disaster liabilities, ignoring non-market losses (e.g. recreation, loss of leisure, damage to historic sites and cultural assets, etc.), ignoring the needs of the end user, and questions as to how indirect/systemic losses might be modelled. with one exception, much of what is discussed in the paper is based on off-the-shelf economics and will not prove to be contentious. regional economists are likely to have different opinions as to how to best model indirect and systemic loss; it is this that will lead to a lively debate as to how to proceed. assessments of economic fallout from the world trade center attack are used to illustrate some of the problems reported in this paper.

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Chrichton, D. (2006) Climate change and its effects on small businesses in the UK, Commissioned by AXA Insurance plc. ISBN 978-0-9554108-0-2

The threat of climate change has taken on a new urgency during the last 12 months following the discovery last December of a 30% reduction in the thermohaline ocean circulation (which drives the Gulf Stream) and increased melting in the Greenland ice cap. New research reports are increasingly discussing "dangerous" climate change and so called "tipping points". A tipping point is a point of no return where feedback effects start to accelerate change resulting in an escalation of global warming, or sea level rise. This summer there were predictions from mainstream scientists in a new OECD report 2 that global sea levels could rise by as much as a metre in the next 100 years. This is the first research to look specifically at the impact of climate change and insurance on small and medium size enterprises (SMEs) in the UK. It concentrates on flood risks, although climate change will produce many other threats for small businesses. It is based on insurance data from AXA Insurance, a major insurer of SMEs, combined with a survey of small businesses in recently flooded areas and comments from focus groups of the managers and owners of small companies which have survived recent major floods. The potential effect on SMEs of increasing flood damage and reducing insurance availability could be serious for the economy as a whole, but our survey shows that while 85% of businesses are aware that climate change is a problem for the world: • 46% of small businesses think that climate change is blown out of proportion and; • only 26% think it is a real threat to them.

The Small Business Council's Annual Report for 2005 barely mentions climate change as an issue3, despite government concern on the subject, but suggests it is something to look at in the future. This has to change: there are many things that SMEs can do to adapt to climate change impacts and to mitigate carbon emissions. The insurance industry must do much more to help and AXA Insurance has already published guidance on business continuity planning for small businesses.

Our survey shows: • Small businesses seem to be missing out. Most assistance is going to domestic households. • Few small businesses receive flood warnings or help from the local council. • The survey indicates that the most help for small businesses came from their insurance companies. Part B of the study quotes from the Government's own research under the UK Climate Impacts Programme and the Foresight programme, and applies it to SMEs. It points out that Government research shows if nothing is done then within the lifetimes of our children or grandchildren flood damage economic costs could average between £5.5 billion and £42 billion every year. It would not take many bad flood years in a row, for England to face significant economic consequences. Part C looks at some of the ways insurers could help and some of the work already done by insurers to help in Scotland. In the last ten years, detailed insurance advice has been requested by almost every local council and has been given freely and regularly in face to face meetings with council staff on land use planning, sustainable drainage and sustainable flood management measures.

In most of Scotland there is now virtually no new building in floodplains and flood problems are being tackled urgently. This is reflected by the attitudes of a number of insurers which treat risks more sympathetically in council areas where insurance advice is followed. Where advice is not followed, insurance availability can potentially become a problem. The Elgin case study examined in this report is a good example.

England is a much bigger problem: insurance advice to individual local authorities has not been requested by more than a handful of English councils. Local authority planners in many areas in England, often under pressure to meet central government targets, are still allowing new development in floodplains. The disastrous floods in Carlisle, where AXA's claims payments were £24.5m, are also the subject of a special study • Insurers are experts at dealing with risk. They know how to control it and reduce it, yet many research reports ignore the major contribution insurers can make and are already making. The insurance industry needs to move up a gear to face this challenge.

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Cumbria Intelligence Observatory (2010) Cumbria Floods November 2009: An Impact Assessment, 18.03.2010, accessed at http://www.cumbriaobservatory.org.uk/elibrary/Content/Internet/536/671/4674/4026717419.pdf on 10.110.14

A 26 page report on the impact of the 2009 floods in Cumbria covering the meteorological circumstances, causes and effects of the floods, the properties flooded by type and district, flood extent mapping for each town or locality, impacts on community welfare including health, temporary accommodation, disease, elderly people etc., impacts on the environment and farming including a detailed map of the holdings affected, impacts on the economy and businesses including tourism, and the impacts on infrastructure including roads and bridges some of which were destroyed.

De Moel, H and Aerts, J. (2011) Effect of uncertainty in land use, damage models and inundation depth on flood damage estimates, Natural Hazards Vol 58 (1), 407-425

Land use and inundation depth present a certain degree of uncertainty which propagates through the calculation of flood damage and accumulates in the final analyses of damage. There are uncertainties in the exposure, value and susceptibility components. For the flood hazard component, inundation depth has been varied systematically to estimate sensitivity. With the recent transition to a more risk-based approach in flood management, flood risk models-being a key component in flood risk management-are becoming increasingly important. In this study, an effort has been made to assess the influence of uncertainty in these four components on the final damage estimate. Different land-use data sets and damage models have been used to arrive at flood damage estimates. The results indicate that, assuming the uncertainty in inundation depth is about 25 cm (about 15% of the mean inundation depth), the total uncertainty surrounding the final damage estimate in the case study area can amount to a factor 5-6. The value of elements at risk and depth-damage curves are the most important sources of uncertainty in flood damage estimates and can both introduce about a factor 2 of uncertainty in the final damage estimates. Very large uncertainties in inundation depth would be necessary to have a similar effect on the uncertainty of the final damage estimate, which seem highly unrealistic. Hence, in order to reduce the uncertainties surrounding potential flood damage estimates, these components deserve prioritisation in future flood damage research. While absolute estimates of flood damage exhibit considerable uncertainty (the above-mentioned factor 5-6), estimates for proportional changes in flood damages (defined as the change in flood damages as a percentage of a base situation) are much more robust.

Department for Environment, Food and Rural Affairs (Defra) (2001) Flood and Coast Defence Project Appraisal Guidance, Flood and Coastal Defence Project Appraisal Guidance: FCDPAG1 Overview, May, May, Defra, London, UK (includes general guidance)

The Flood and Coastal Defence Project Appraisal Guidance (FCDPAG) series aims to provide best practice advice to flood risk management practitioners in the UK involved in the preparation of strategies and projects. The guidance contains theory, principles, methods and techniques for use in cost-benefit appraisals. Use of the guidance is intended to encourage a consistently high quality of decision-making supported by a rigorous appraisal of options so that the most appropriate scheme or strategy is proposed.

FCDPAG1 - Overview (including general guidance)

FCDPAG2 - Strategic planning and appraisal

FCDPAG3 - Economic appraisal

FCDPAG4 - Approaches to risk

FCDPAG5 - Environmental appraisal

FCDPAG6 - Post project evaluation

Department for Environment, Food and Rural Affairs (Defra) (2008) Flood and Coast Defence Appraisal Guidance, Economic Appraisal, Supplementary Note to Operating Authorities: Valuation of Agricultural Land and Output for Appraisal Purposes, Defra, London, UK

See above

Department for Environment, Food and Rural Affairs (Defra) (2008) Flood and Coast Defence Appraisal Guidance, FCDPAG3 Economic Appraisal, Supplementary Note to Operating Authorities: Assessing and Valuing the Risk to Life from Flooding for the Use in Appraisal of Risk Management Measures, May, Defra, London, UK

See above

Department for Environment, Food and Rural Affairs (Defra) (2006) Flood and Coast Defence Appraisal Guidance, Social Appraisal, Supplementary Note to Operating Authorities: Climate Change Impacts, October, Defra, London, UK

See above

Department for Environment, Food and Rural Affairs (Defra) (2004) Flood and Coast Defence Project Appraisal Guidance, FCDPAG3 Revisions to Economic Appraisal on Reflecting Socio-economic Equity in Appraisal and Human Related Intangible Impacts of Flooding Economic Appraisal, Supplementary Note to Operating Authorities, July, Defra, London, UK

See above

Department for Environment, Food and Rural Affairs (Defra) (2003) Flood and Coast Defence Project Appraisal Guidance, FCDPAG3 Revisions to Economic Appraisal Procedures Arising from the New HM Treasury 'Green Book', Supplementary Note to Operating Authorities, March, Defra, London, UK

See above

Drdacky, M. (2010) Flood Damage to Historic Buildings and Structures, Journal of Performance of Constructed Facilities, Vol 24, (5), 439-445

This paper presents typical examples of damage to immovable cultural heritage due to flooding. Flooding can damage architectural heritage, historic infrastructure consisting of individual structures These forces can be categorized according to the types of damage that they can cause: horizontal static pressure of raised water; upward hydrostatic pressure; dynamic low velocity streams are examples. Examples of damage caused by individual actions are presented in the paper, which goes on to present some general lessons applicable for the most vulnerable categories of immovable heritage objects and buildings including objects of art standing alone or firmly attached as an integral part of buildings. All these objects are subjected to various forces and actions during floods.

Dutta, D., Herath, S., and Musiake, K. (2003) A mathematical model for flood loss estimation, Journal of Hydrology, Vol 277, 24–49

This paper introduces an integrated model for flood loss estimation in a river basin. The model is the combination of a physically based distributed hydrologic model and a distributed flood loss estimation model. The hydrologic model considers major processes of the water cycle through physically based governing equations, which are solved to simulate the propagation of water in each of these processes. It is designed to consider the man-made flood control structures, such as river embankments, retarding basins, etc. which affect flooding characteristics. The loss estimation model is formulated based on stage-damage relationships between different flood inundation parameters and land use features. It calculates the economic loss to different land use features based on the simulated flood parameters obtained from the hydrologic model for any flood event. A case study illustrates the real world application of the integrated model to a medium size river basin in Japan, which is frequently affected by floods. The simulated river discharge and surface inundation by the flood model show good agreement with

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the observations. Urban flood loss simulated by the loss estimation model with the simulated flood parameters agrees with the estimated damage using post flood surveyed parameters.

Elmer, F., Seifert, I., Kreibich, H. and Thieken, A.H. (2010) A delphi method expert survey to derive standards for flood damage data collection, Risk Analysis, Vol 30 (1), 107-24

For the purpose of flood damage analyses reliable, comparable, comprehensive, consistent, and up-to-date data are an indispensable need. Like in many other countries a database with this kind of datasets does not exist in Germany. To establish it, standards have to be set for flood damage data collection. We approached this problem by questioning experts about their information needs for flood damage analysis. This survey is done by applying a Delphi survey approach. The aptitude of the Delphi approach to assess, structure, and standardize expert knowledge is evaluated in this article. In the survey a panel of 55 experts working in the field of flood damage analysis for insurances, engineering companies/consultancy, public water management, and universities and other scientific institutions helped to identify common information needs. The multi-step Delphi method proved to reduce the deviation of answers thereby enabling consensual results and also enhanced the quality by modifying group answers in the direction of experience based answers. There was also a high level of congruence in information needs between experts from different fields of employment that allowed the derivation of common standards.

Ericksen, N. (1985) ANUFLOOD in New Zealand, Part 1 Approaches to urban flood-loss assessment in New Zealand, CRES Working Paper, 1986/2, CRES, Australian National University, Canberra

This is the first of three papers which came out of a joint Australian/New Zealand seminar-workshop held in Waikato in 1985. Flooding is a serious problem in New Zealand with annual average losses exceeding NZ$100 million (1984 NZ$) and increasing. The past approach to flood hazard assessment focused on engineered structures, reinforced by post-disaster relief that reinstated people a nd property in flood prone locations, steadily increasing the people and property at risk. Thus, while the frequency of smaller floods has been reduced the potential for major disasters has escalated. To reverse this trend the paper argues that flooding must be seen as a social rather than an engineering problem. Such a perspective requires a comprehensive approach to flood hazard management, new means for evaluating flood hazards and mitigation strategies and the development of an integrated or unified flood loss reduction policy.

Evans, E. P., Ashley, R., Hall, J., Penning-Rowsell, E., Sayers, P., Thorne, C. R. and Watkinson, A. (2004) Foresight. Future Flooding, 1 and 2 London

A major study of future flood risk commissioned by the UK government in the early 2000s. The study considers are range of growth and change scenarios for the UK and projects the likely flood future flood losses of each. Climate change is expected to lead to a significant growth in flood risk in the UK but socio-economic change, especially land use change and rising living standards, are expected to be the major contributory factor in rising flood damage potential, which is steep in some scenarios. The report contains a range of interesting graphics demonstrating the spatial distribution of flood impacts under different assumptions.

Gerl, T., Bochow, M., Kreibich, H. (2014) Flood Damage Modeling on the Basis of Urban Structure Mapping Using High-Resolution Remote Sensing Data, Water, Vol 6, 2367-2393

The modeling of flood damage is an important component for risk analyses, which are the basis for risk-oriented flood management, risk mapping, and financial appraisals. An automatic urban structure type mapping approach was applied on a land use/land cover classification generated from multispectral Ikonos data and LiDAR (Light Detection And Ranging) data in order to provide spatially detailed information about the building stock of the case study area of Dresden, Germany. The multi-parameter damage models FLEMOps (Flood Loss Estimation Model for the private sector) and regression-tree models have been adapted to the information derived from remote sensing data and were applied on the basis of the urban structure map. To evaluate this approach, which is suitable for risk analyses, as well as for post-disaster event analyses, an estimation of the flood losses caused by the Elbe flood in 2002 was undertaken. The urban structure mapping approach delivered a map with a good accuracy of 74% and on this basis modeled flood losses for the Elbe flood in 2002 in Dresden were in the same

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order of magnitude as official damage data. It has been shown that single-family houses suffered significantly higher damages than other urban structure types. Consequently, information on their specific location might significantly improve damage modeling, which indicates a high potential of remote sensing methods to further improve risk assessments.

Gloucestershire County Council (2007) Case Study: Gloucestershire, GB flood 2007, FloodProbe, Fact Sheet, Document Ref: WP05-11-11-05, Seventh Framework Programme, accessed at http://www.floodprobe.eu/partner/assets/documents/GloucestershireFactsheet.pdf on 13.10.14

A description and fact sheet for the 2007 floods in Gloucestershire setting out the impacts of flooding on residences, businesses, electricity supplies, transport and motorists and other commuters. The fact sheet also describes the event and the command structure utilised in the area for flood emergency response including how the fire and police services were involved as well as the military.

Gissing, A. and Blong, R (2004) Accounting for variability in commercial flood damage estimation, Australian Geographer, 35:2, 209-222

Flooding in the business district of Kempsey, New South Wales, Australia, in 2001 allowed the collection and analysis of commercial flood damage data. Analysis indicated that direct losses were significant, totalling A$2.5 million. Data were variable owing to differences in the vulnerability of businesses to flood damage, differences in the impacts of the hazard upon businesses and survey uncertainty. Little direct relationship was found between direct commercial damage and over-floor water depth. Simple averaging and stage-damage curve loss estimation methods ignore the large variability present and result in inaccurate estimation of direct commercial damage. Probability loss estimation methods account for the variability present by assessing the chance of loss values occurring at specified depths of over-floor flooding.

Handmer. J. (1986) ANUFLOOD in New Zealand Part 2, Background to flood loss assessment, CRES Working Paper 1986/3, Australian National University, Canberra

This working paper is one of three containing papers presented at a seminar-workshop entitled ANUFLOOD An Integrated Computer Package for Flood-Loss Adjustment and Abatement held at the University of Waikato, Hamilton, New Zealand from December 11-13, 1985. The meeting was sponsored jointly by the Geography department of the University of Waikato, the Water and Soil Directorate of the Ministry of Works and Development (NZ) and CRES. ANUFLOOD is an interactive computer package developed in CRES and commercially available from ANUTECH at the Australian National University. It is designed to assess tangible urban damage and to evaluate the likely effects of a wide range of mitigation options. Part 1 (CRES Working Paper 1986/2 contains a paper by Neil Ericksen (see above under Ericksen). Part III is a paper by David Ingle Smith (1985) ANFLOOD Development and Application (CRES Working Paper 1986/4).

HEC-FDA (Flood Damage Reduction Analysis) (2008) User Guide V1.2.4 http://www.hec.usace.army.mil/software/hec-fda/documentation/CPD-72_V1.2.4.pdf

The Hydrologic Engineering Center (HEC) is an organization within the Institute for Water Resources of the U.S. Army Corps of Engineers and is based in Davis, California. This is a user guide for practitioners intending to use the HEC's Flood Damage Reduction Analysis (HEC-FDA) computer program as part of undertaking a cost-benefit analysis of flood damage reduction measures. The user guide covers the data preparation and input needs of the computer program including, for example, exceedance probability functions, stage-discharge functions and depth-damage functions for a range of buildings and inventories.

Huttenlau, M., Stö̈tter, J., Stiefelmeyer, H. (2010) Risk-based damage potential and loss estimation of extreme flooding scenarios in the Austrian Federal Province of Tyrol, Natural Hazards and Earth System Sciences, Vol 10, 2451–2473

Within the last decades serious flooding events occurred in many parts of Europe and especially in 2005 the Austrian Federal Province of Tyrol was serious affected. These events in general and particularly the 2005 event have sensitised decision makers and the public. Beside discussions pertaining to protection goals and lessons

learnt, the issue concerning potential consequences of extreme and severe flooding events has been raised. Additionally to the general interest of the public, decision makers of the insurance industry, public authorities, and responsible politicians are especially confronted with the question of possible consequences of extreme events. Answers thereof are necessary for the implementation of preventive appropriate risk management strategies. Thereby, property and liability losses reflect a large proportion of the direct tangible losses. These are of great interest for the insurance sector and can be under- stood as main indicators to interpret the severity of potential events. The natural scientific-technical risk analysis concept provides a predefined and structured framework to analyse the quantities of affected elements at risk, their corresponding damage potentials, and the potential losses. Generally, this risk concept framework follows the process steps hazard analysis, exposition analysis, and consequence analysis. Additionally to the conventional hazard analysis, the potential amount of endangered elements and their corresponding damage potentials were analysed and, thereupon, concrete losses were estimated. These took the specific vulnerability of the various individual elements at risk into consideration. The present flood risk analysis estimates firstly the general exposures of the risk indicators in the study area and secondly analyses the specific exposures and consequences of five extreme event scenarios. In order to precisely identify, localize, and characterize the relevant risk indicators of
buildings, dwellings and inventory, vehicles, and individuals, a detailed geodatabase of the existing stock of elements and values was established on a single object level. There- fore, the localized and functional differentiated stock of elements was assessed monetarily on the basis of derived rep- resentative mean insurance values. Thus, well known difference factors between the analysis of the stock of elements and values on local and on regional scale could be reduced considerably. The spatial join of the results of the hazard analysis with the stock of elements and values enables the identification and quantification of the elements at risk and their corresponding damage potential. Thereupon, Extreme Scenario Losses (ESL) were analysed under consideration of different vulnerability approaches which describe the individual element's specific susceptibility. This results in scenario-specific ranges of ESL rather than in single values. The exposure analysis of the general endangerment in Tyrol identifies (i) 105 330 individuals, (ii) 20 272 buildings and 50 157 dwellings with a corresponding damage potential of approx. EUR 20 bn. and (iii) 62 494 vehicles with a corresponding damage potential of EUR 1 bn. Depending on the individual extreme event scenarios, the ESL solely to buildings and inventory vary between EUR 0.9–1.3 bn. for the scenario with the least ESL and EUR 2.2–2.5 bn. for the most serious scenarios. The correlation of the private property losses to buildings and inventory with further direct tangible loss categories on the basis of investigation after the event in 2005, results in potential direct tangible ESL of up to EUR 7.6 bn. Apart from the specific study results a general finding shows that beside the further development of modelling capabilities and scenario concepts, the key to considerably decrease uncertainties of integral flood risk analyses is the development and implementation of more precise methods. These are to determine the stock of elements and values and to evaluate the vulnerability or susceptibility of affected structures to certain flood characteristics more differentiated.

Jongman, B., Kreibich, H., Apel, H., Barredo, J. I., Bates, P. D., Feyen, L., Gericke, A., Neal, J., Aerts, J.C.J.H. and Ward, P. J. (2012) Comparative flood damage model assessment: towards a European approach, Natural Hazards and Earth System Science, Vol 12 (12), 3733-3752

There is a wide variety of flood damage models in use internationally, differing substantially in their approaches and economic estimates. Since these models are being used more and more as a basis for investment and planning decisions on an increasingly large scale, there is a need to reduce the uncertainties involved and develop a harmonised European approach, in particular with respect to the EU Flood Risks Directive. In this paper we present a qualitative and quantitative assessment of seven flood damage models, using two case studies of past flood events in Germany and the United Kingdom. The qualitative analysis shows that modelling approaches vary strongly, and that current methodologies for estimating infrastructural damage are not as well developed as methodologies for the estimation of damage to buildings. The quantitative results show that the model outcomes are very sensitive to uncertainty in both vulnerability (i.e. depth–damage functions) and exposure (i.e. asset values), whereby the first has a larger effect than the latter. We conclude that care needs to be taken when using aggregated land use data for flood risk assessment, and that it is essential to adjust asset values to the regional economic situation and property characteristics. We call for the development of a flexible but consistent European framework that applies best practice from existing models while providing room for including necessary

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regional adjustments.

Jonkman, S.N., Bočkarjova, M., Kok, M. and Bernardini, P. (2008) Integrated hydrodynamic and economic modelling of flood damage in the Netherlands, Ecological Economics, Vol 66, (1), 77-90

This paper presents a model developed in the Netherlands for the estimation of damage caused by floods. The model attempts to fill the gap in the international literature about integrated flood damage modelling and develop an integrated framework for the assessment of both direct hazard-induced damages and indirect economic damages such as the interruption of production flows outside the flood affected area, as well as loss of life due to flooding. The scale of damage assessment varies from a specified flood-prone area in a river basin or a coastal region to the country's entire economy. The integrative character of the presented model is featured by the combination of information on land use and economic data, and data on flood characteristics and stage-damage functions, where the geographical dimension is supported by modern GIS to obtain a damage estimate for various damage categories. The usefulness of the model is demonstrated in a case study estimating expected flood damage in the largest flood-prone area in the Netherlands.

Kellermann, P., Schöbel, A. Kundela′ G. and A. H. Thieken (2015) Estimating flood damage to railway infrastructure – the case study of the March River flood in 2006 at the Austrian Northern Railway, Nat. Hazards Earth Syst. Sci., 15, 2485-2496

Models for estimating flood losses to infrastructure are rare and their reliability is seldom investigated although infrastructure losses might contribute considerably to the overall flood losses. In this paper, an empirical modelling approach for estimating direct structural flood damage to railway infrastructure and associated financial losses is presented. Via a combination of event data, i.e. photo-documented damage on the Northern Railway in Lower Austria caused by the March River flood in 2006, and simulated flood characteristics, i.e. water levels, flow velocities and combinations thereof, the correlations between physical flood impact parameters and damage occurred to the railway track were investigated and subsequently rendered into a damage model. After calibrating the loss estimation using recorded repair costs of the Austrian Federal Railways, the model was applied to three synthetic scenarios with return periods of 30, 100 and 300 years of March River flooding. Finally, the model results are compared to depth-damage-curve-based approaches for the infrastructure sector obtained from the Rhine Atlas damage model and the Damage Scanner model. The results of this case study indicate a good performance of our two-stage model approach. However, due to a lack of independent event and damage data, the model could not yet be validated. Future research in natural risk should focus on the development of event and damage documentation procedures to overcome this significant hurdle in flood damage modelling.

Kreibich,H., Muller, M., Thieken, A.H. and Merz,, B (2007) Flood precaution of companies and their ability to cope with the flood in August 2002 in Saxony, Germany, Water Resources Research Vol. 43, W03408, 1-15

An insightful survey into fluvial flood damages in Germany indicating the type and degree of benefits that could accrue to flood risk management initiatives. The German federal state of Saxony was the most affected region during the severe flood in August 2002, and damage to companies was high. A survey of 415 companies representing a variety of sectors and sizes was undertaken to identify deficits in the flood management of companies. In August 2002, preparedness and precaution of companies was low. Additionally, 45% of the companies had not received any flood warning. Consequently, many companies were unable to perform emergency measures successfully. The mean total damage to companies amounted to 1.1 million Euros. However, because of relatively good flood compensation, recovery advanced quickly. After the flood, preparedness and precaution increased, but there is still significant potential for more precautionary measures. The flood warning system should be further improved. Specific incentive and communication programs should be developed for the service and financial sectors, where preparedness and precaution is weakest, as well as for the manufacturing sector, which has the highest damage potential.

Kreibich, H., Seifert, I., Thieken, A.H., Lindquist, E., Wagner, K. and Merz, B. (2011) Recent changes in flood preparedness of private households and businesses in Germany Regional Environmental Change, 11:59–71

Another insightful piece of research into flood damages in Germany. Using the focusing event framework, a

comprehensive analysis of private households' and businesses' preparedness was undertaken in the aftermath of the 2002 and 2006 flood events on the Elbe River in Germany. In August 2002, preparedness of households (n = 235) and businesses (n = 103) was low: 30% of the households and 54% of the businesses took no precautionary measures before the flood event. Many undertaken emergency measures were ineffective, since only 26% of all households knew how to react when the flood warning came, and only 9% of businesses had an emergency plan in place. Due to this extreme flood, double-loop learning occurred in many households and businesses, so that many did implement precautionary measures. The distribution of adopted precautionary measures for households fits well to Preisendorfer's low-cost hypothesis, but does not apply for businesses. Only 10% of the households (n = 112), but still 29% of the businesses (n = 41) were unprepared before the flood in 2006. Significant improvement in flood preparedness activities is still necessary. Particularly for businesses, regulatory programs and programs encouraging proactive behaviour should be implemented. The focusing event framework proofed to be a useful tool for a differentiated analysis of the responses to and learning due to a disaster also in the commercial and private sector.

Kreibich, H., Seifert, I., Merz, B., Thieken, A.H. (2012) Development of FLEMOcs - a new model for the estimation of flood losses in the commercial sector, Hydrological Sciences Journal, Vol 55, (8), 1302-1314

The estimation of flood damage is an important component for risk-oriented flood design, risk mapping, financial appraisals and comparative risk analyses. However, research on flood-loss modelling, especially in the commercial sector, has not gained much attention so far. Therefore, extensive data about flood losses were collected for affected companies via telephone surveys after the floods of 2002, 2005 and 2006 in Germany. Potential loss determining factors were analysed. The new Flood Loss Estimation MOdel for the commercial sector (FLEMOcs) was developed on the basis of 642 loss cases. Losses are estimated depending on water depth, sector and company size as well as precaution and contamination. The model can be applied to the micro-scale, i.e. to single production sites as well as to the meso-scale, i.e. land-use units, thus enabling its countrywide application.

Leach, K. (2015) Impact of flooding and flood risk on community economic resilience in the Upper Calder Valley, Commissioned by Calderdale Council and DEFRA, Localise West Midlands

The purpose of this study, commissioned by Calderdale Council (England) and DEFRA, is to provide greater understanding of the scale, reach and complexity of the economic impacts of flooding and flood risk in the Upper Calder Valley and how this relates to community economic resilience. It has done this by investigating impacts of the major floods that hit the Calder Valley in June and July 2012, firstly on a 'first tier' of flood-affected businesses and then the impacts on their suppliers, customers and employees in the area, to give the collective 'multiplied' economic impact of flooding and flood risk. It is based on responses from a wide range of 50 local businesses as well as wider literature. 14 impact pathways, based on information from respondent businesses, mapped what losses and gains were experienced, their values and their reach. The results demonstrate the variability of these impacts and how they interconnect, giving a sense of the complexity and scale and showing both losses and gains to the local economy.

The results show that flooding does impact along the supply and demand chains of flooded businesses. The impacts are highly variable, positive and negative, societal as well as economic, and of varying magnitude and timescale. Some might appear minor but may scale up through replication across the local economy. As with the benefits of flood resilience measures, it is difficult to quantify these impacts and to separate them from the impacts of other factors. From what quantifiable information there was, the negative impacts on the local area significantly outweighed the positive. By way of illustrating this, from 26 businesses where impacts could be quantified, net losses totalled £823,900 and net gains £17,300, giving a combined net loss to the local economy of £806,600 through the activities of these businesses. The biggest loss to the local economy came from the drop in trade amongst businesses and their supply chains in the months after the floods (£831,324 from 21 businesses), not from uninsured direct impacts (£199,449 from 12 businesses). The biggest gain came from insurance payout spend on local suppliers (£132,970 from 14 businesses). Even in cases where insurance payouts are fairly comprehensive, there are usually knock-on losses to local supply chains. Where businesses have a more localised supply chain, this knock-on impact will obviously be higher, but also gives a greater earning potential for the area to assist recovery. Other findings nd recommendations are included in the report.

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Leahy, A. and Crop, A. (Undated) Cost Benefit Analysis of Urban Flood Protection consulted at https://www.waternz.org.nz/Folder?Action=View%20File&Folder_id=92&File=Allan%20Leahy.pdf on 28/07/14

This paper is co-authored by engineers working in a local authority environment in New Zealand. In New Zealand engineers are often asked to make decisions on the spending of public money to provide flood protection to existing at risk urban structures. Historically, and currently, in New Zealand there has been limited quantitative information available on which to base these investment decisions. This has led to these decisions often being based on ad hoc assessments or political pressure rather than value for money.

This paper describe a simple flood damage analysis of a residential area. The methodology is based on a modified version of the US Army Corps of Engineers HEC-Flood Damage Analysis methodology – which provides a quantified cost benefit approach to flood protection investment decisions. The paper describes the flood scenario, the approach adopted and the sources of flood damage cost information used. It also describes the limitations of available information on social impacts and the work needed to provide more robustness in this area.

Logtmeijer, C. (2006) Guidelines for socio-economic damage evaluation , Institute for the Protection and Security of the Citizen, EUR 22637 EN European Commission Directorate-General Joint Research Centre Institute for the Protection and Security of the Citizen, Ispra, Italy

The major purpose of these guidelines is to give guidance for practitioners of governmental authorities and executing bodies dealing with ex-ante flood damage evaluation in order to appraise public flood defence projects or strategies on different spatial scales. Since such appraisals involve private and public goods, flood damage evaluation is mainly described from a broader economic perspective. Although the other perspectives will be mentioned and referred to time and again, these guidelines aim at becoming a practical guide for policy makers by demonstrating how to proceed appropriately in flood damage evaluation in order to use it as an important source of information for flood defence and its decision making process. Since there is a large diversity of methods existing for all types of damages within the EU & as research of Meyer and Messner (2005) revealed for four EU countries & another purpose of the guidelines is to give some orientation, which flood damage evaluation method should be used, and which damage types should be included for which kind of policy issues under consideration of case-specific requirements regarding time horizons, spatial precision requirements and budgetary restrictions. While it is not the goal to present one harmonised flood damage evaluation method, we aim at proposing a harmonised set of assessment principles and general procedures of flood damage evaluation studies in order to advance the quality and the comparability of such studies within Europe.

Maiwald, H. and Schwarz, J. (2014) Damage models for extreme flood events - Part 1: Modeling and validation based on the 2002 flood, Bautechnik, Vol 91, (3), 200-21

An engineering based flood damage model was developed in different research projects at the Earthquake Damage Analysis Center (EDAC) at the Bauhaus-Universitat Weimar. In the context of cost-benefit analysis the paper show the demand for development of new resilient damage functions for each usage class. Conventional loss models are limited to the relationship between flood height and damage. The actual 2013 flood events illustrate the importance of the flood protection measures planned and partly already implemented after the 2002 flood.

Merz, B., Kreibich, H., Thieken, A. and Schmidtke, R. (2004), Estimation uncertainty of direct monetary flood damage to buildings, Natural Hazards and Earth System Science 4: 153-163

Traditional flood design methods are increasingly supplemented or replaced by risk-oriented methods which are based on comprehensive risk analyses. Besides meteorological, hydrological and hydraulic investigations such analyses require the estimation of flood impacts. Flood impact assessments mainly focus on direct economic losses using damage functions which relate property damage to damage-causing factors. Although the flood damage of a building is influenced by many factors, usually only inundation depth and building use are considered as damage-causing factors. In this paper a data set of approximately 4000 damage records is analysed. Each

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record represents the direct monetary damage to an inundated building. The data set covers nine flood events in Germany from 1978 to 1994. It is shown that the damage data follow a Lognormal distribution with a large variability, even when stratified according to the building use and to water depth categories. Absolute depth-damage functions which relate the total damage to the water depth are not very helpful in explaining the variability of the damage data, because damage is determined by various parameters besides the water depth. Because of this limitation it has to be expected that flood damage assessments are associated with large uncertainties. It is shown that the uncertainty of damage estimates depends on the number of flooded buildings and on the distribution of building use within the flooded area. The results are exemplified by a damage assessment for a rural area in southwest Germany, for which damage estimates and uncertainty bounds are quantified for a 100-year flood event. The estimates are compared to reported flood damages of a severe flood in 1993. Given the enormous uncertainty of flood damage estimates the refinement of flood damage data collection and modelling are major issues for further empirical and methodological improvements.

Merz, B., Kreibich, H., Shwarze, R. and Thieken, A. (2010) Review article. Assessment of economic flood damage, Nat. Hazards Earth Syst. Sci., 10, 1697–1724

Damage assessments of natural hazards supply crucial information to decision support and policy development in the fields of natural hazard management and adaptation planning to climate change. Specifically, the estimation of economic flood damage is gaining greater importance as flood risk management is becoming the dominant approach of flood control policies throughout Europe. This paper reviews the state-of-the-art and identifies research directions in economic flood damage assessment. Despite the fact that considerable research effort has been spent and progress has been made in flood damage data collection, data analysis and model development in recent years, there still seems to be a mismatch between the relevance of damage assessments and the quality of the available models and datasets. Often simple approaches are used, mainly due to limitations in data and knowledge on damage mechanisms. The results of damage assessments depend on many assumptions e.g. selection of spatial and temporal boundaries, and there ae many pitfalls in economic evaluation e.g. the choice between replacement costs or depreciated values. Much larger efforts are required for empirical and synthetic data collection and for providing consistent, reliable data to scientists and practitioners. A major shortcoming of damage modelling is that model validation is rarely performed. Uncertainty analyses and thorough scrutiny of model inputs and assumptions should be mandatory for each damage model development and applications, respectively. In our view, flood risk assessments are often not well balanced. Much more attention is given to the hazard assessment part, whereas damage assessment is treated as some kind of appendix within the risk analysis. Advances in flood damage assessment could trigger substantial methodological improvements in other natural hazard areas with comparable time-space properties.

Merz, B. and Kreibich, H. (2013) Non-linear and non-parametric modeling of flood damage, In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 599-602, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

The usual approach for flood damage assessment consists of stage-damage functions which relate the relative or absolute damage for a certain class of objects to the inundation depth. Other characteristics of the flooding situation and of the flooded object are rarely taken into account, although it is clear that flood damage is influenced by a variety of factors. In this paper we apply a group of data mining techniques, known as regression trees, to flood damage assessment. A very comprehensive data set of more than 2000 damage records of private households in Germany is used. Each record contains details about a large variety of potential damage-influencing characteristics, such as hydrological and hydraulic aspects of the flooding situation, state of precaution of the household, early warning and emergency measures undertaken, socio-economic status of the household. Regression trees derive water depth, return period, duration of inundation, precaution, building floor space and net income of the household as the dominating damage-influencing variables. We show that regression trees are a flexible and powerful alternative to traditional damage assessment approaches such as stage-damage functions.

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Messner, F., Penning-Rowsell, E., Green, C., Meyer, V., Tunstall, S. and van der Veen, A. (2006) Guidelines for Socio-economic Flood Damage Evaluation, Project Contract No: GOCE-CT-2004-505420, FLOODsite, Report T9-06-01 Co-ordinator: HR Wallingford, UK (Project website: www.floodsite.net)

The major purpose of these guidelines is to provide guidance for practitioners of governmental authorities and executing bodies dealing with ex-ante flood damage evaluation in order to appropriately appraise public flood defence projects or strategies on different spatial scales. Therefore these guidelines address a large community. On the one hand, they give guidance to countries just starting with flood damage evaluation studies. For this group the guidelines demonstrate how to proceed step by step in flood damage evaluations (especially chapters 3-4). Chapter 3 describes the state-of-the-art in evaluating direct, tangible flood damages. This chapter can be used by practitioners of countries with few or even no experience in flood damage evaluation in order to find an appropriate start into the endeavour of applying flood damage evaluation as a decision support tool. Chapter 4 reveals the principal rules and the procedure of building up a proper flood damage data base in order to ensure a consistent set of flood damage data, which is needed if flood damage evaluation is to be used as a long-term decision support tool. On the other hand, there is a need to address flood damage evaluators in countries which already possess some experience in this field and so the guidelines to them as a checklist and to inspire them to improve their evaluation methodology, e.g., by including methods for damage types which have been neglected hitherto in their work (especially chapters 5-9). Chapter 5 outlines the approaches for evaluating flood effects on industrial production. Chapter 6 indicates possible procedures to includes social flood effects. Environmental flood effects and methods of their evaluation are described in chapter 7. Thereafter, chapter 8 focuses on damage reducing effects of flood warning in order to support specific decisions on flood warning systems. Chapter 9 gives an overview of flood damage categories which have not been considered in more detail in these guidelines and indicates relevant literature sources for further reading. Last but not least to provide fundamental standard knowledge, key principals are specified for economic evaluation of damages and reveal the sources of uncertainty that need to be considered.

Meyer, V. and Messner, F. (2005), National Flood Damage Evaluation Methods, A Review of Applied Methods in England, the Netherlands, the Czech Republic and Germany, UFZDiskussionspapiere21/2005

This Report is the first deliverable of FLOODsite task 9, which is on flood damage evaluation methods. It summarises both the outcome of a literature survey on flood damage evaluation methods in selected EU countries and the major results of complementary expert interviews. The overall objective is to identify the methodological diversity regarding the practical application of flood damage evaluation methods in EU countries, which are known to have a leading position in this field. The results of this report are an important prerequisite for the major deliverable of task 9, which aims, among others, at proposing harmonised state-of-the-art methods and principles for flood damage analysis in EU countries. The report shows that the four countries, England, the Netherlands, the Czech Republic and Germany, which feature very different histories of flood protection policy and different institutional settings, use sophisticated methods of flood damage valuation. These in principle follow the same idea, namely trying to put economic values to elements of flood risk in order to estimate the benefits of flood protection measures in terms of prevented flood damage. In detail, though, the methods exhibit many different approaches. The major differences in flood damage evaluation methods relate to the damage categories considered, the degree of detail, the scale of analysis, the application of basic evaluation principles (e.g., replacement cost versus depreciated cost), and the application or non-application of results in benefit-cost and risk analyses. This diversity of flood damage evaluation methods, even in riparian states which share a major river, indicates that there is still a lack in transboundary cooperation in flood policy decision making in the EU.

http://www.floodsite.net/html/partner_area/project_docs/DP_Meyer_Messner_national_flood_damage_evaluation_methods24112005.pd, accessed on 21.10.14

Molinari, D., Ballio, F., Handmer, J. and S. Menoni (2014) On the modeling of significance for flood damage assessment, International Journal of Disaster Risk Reduction, Vol 10, 381-391

Despite decades of research, flood loss estimation is still a challenging task. Drawing on recent research, a

number of major problems can be identified among them the question of what specific damages under what circumstances are seen as significant? It is sensible that people would choose risk management strategies according to their capacity to reduce significant damages, disregarding those ones which mainly influence losses not seen as significant. The question arises as to what damage is significant when? The paper proposes and tests a model for assessing significance through case studies in Australia and Italy. Despite the explorative nature of this paper, results provide evidence for (i) the importance of its systematic analysis, as a first step of damage assessment as well as (ii) the need for a deeper knowledge of significance.

Montz, B. and Tobin, G. (1997) The environmental impacts of flooding in St. Maries, Idaho, US National Science Foundation under Grant No. CMS-9632458, Quick Response Report No. 93 Accessed at http://www.colorado.edu/hazards/research/qr/qr93/qr93.html on 8.9.14

All natural disasters create adverse impacts when they damage buildings, destroy possessions, and compromise the integrity of structures. Planning for such events and implementing mitigation measures is fairly common, at least in the United States where building codes, land-use regulations and other measures are often adopted to minimize potential losses. In contrast, these impacts are not usually taken into account when developing or redeveloping hazardous areas, and even less concern is given to any environmental assessment of development decisions with regard to hazards. This is somewhat surprising, since hazards invariably create secondary environmental impacts that can have severe repercussions for society. For instance, following the 1993 Mississippi River floods, more than $34 million were allocated to the Environmental Protection Agency to deal with a range of environmental concerns.. Additional money was spent by local and state governments to alleviate other environmental impacts associated with polluted water supplies and the safe disposal of solid wastes. Such unanticipated damages can also slow the recovery process by raising costs and complicating remedial action plans. Furthermore, failure to accommodate such potential impacts into the planning process only serves to perpetuate the problems. Inevitably, it seems, disasters lead to damages, and then repairs merely recreate the status quo. It would seem appropriate, therefore, to consider environmental impacts in the development of hazardous areas as an input into the decision-making process.

This paper looks at the range of environmental impacts of flooding as they exist immediately following an event. The flood hazard is then seen as a strategic problem that can be addressed through environmental impact assessment techniques.

Parker, D J and Thompson, P M 1988 An 'extended' economic appraisal of coast protection works: Hengistbury Head, Journal of Ocean and Shoreline Management, Vol 11, 45-72

An assessment of the benefits of both flood protection and coastal erosion prevention at an environmentally sensitive location on England's south coast where storm surges could erode the narrow neck of land joining Hengistbury Head to the mainland. The assessment was innovative at the time because it not only estimated flood damage potential consequent upon a breach of the coastline near Hengistbury Head but it also combined an assessment of the ecological, recreational, nature conservation, geological and archaeological impacts.

Parker, D.J., Green, C.H. and Thompson, P.M. (1987) Urban flood protection benefits. A project appraisal guide, Gower Technical Press Ltd., Aldershot, UK (ISBN 0-291-39707-7)

Obtaining value for money is a key objective of any capital investment and the techniques for assessing this developed rapidly prior to this publication. Flood protection projects present particular benefit-costs appraisal difficulties and the Flood Hazard Research Centre at the then Middlesex Polytechnic (now Middlesex University) has been to the forefront in developing methods for overcoming these problems. One particular difficulty is that some of the benefits of minimising a flood risk are indirect: examples are traffic disruption, industrial production loss, utility outages, emergency service costs and so on. This volume addresses this difficult area and presents methods of making rational assessments and a range of depth-damage and depth-duration-damage data. Together with a volume published in 1977, known as the 'Blue Manual', which primarily presents direct damage data, this volume known as the 'Red Manual' made available are family of techniques for assessing the benefits of

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urban flood protection in a structured manner. Then volume presents data which may be applied throughout the United Kingdom. In some cases these data may be transferable to parts of continental Europe but the principles, methods and techniques are more generally applicable elsewhere.

Penning-Rowsell, E. C. and Chatterton, J. B. (1977) The benefits of flood alleviation. A manual of assessment techniques, Gower Publishing Co. Ltd, Aldershot, UK (ISBN 0-566-00190-X)

This volume, which rapidly became the practical desk-top manual for flood engineers undertaking flood alleviation benefit assessments in the United Kingdom, provides a detailed set of principles, methods, techniques and data principally on the assessment of direct benefits. The manual provides depth-damage data for a range of residential properties common throughout the British Isles and similar data for different types of non-residential property. Methods and data for assessing the agricultural benefits of flood alleviation are also included. The manual is a product of research undertaken at the Flood Hazard Research Centre of Middlesex Polytechnic (now Middlesex University) following receipt of a research grant from the UK Natural Environment Research Council. The manual became known as 'the Blue Manual'.

Penning-Rowsell, E C and Parker, D J 1987 The indirect effects of floods and benefits of flood alleviation: evaluating the Chesil Sea Defence Scheme, Applied Geography, Vol 7, 263-88

An assessment of the potential flood damage and loss impacts of sea flooding at an environmentally sensitive location and settlement on England's south coast. Chesil beach is a natural shingle beach which, under wave attack, could be breached and/or overtopped inundating the settlement of Chiswell on the Isle of Portland with both shingle and seawater. The settlement had become semi-abandoned after recent sea floods. This study assessed the direct and indirect benefits of protecting the settlement. The innovative element of the study was the analysis of the indirect effects of a breach of the important road connection behind the beach which joins the Isle of Portland to the mainland at Weymouth. Important defence work, a prison and other commercial activities on the Isle would be disrupted by erosion and flooding of the road. The assessment eventually led to an innovative sea defence project at this location.

Penning-Rowsell, E.C., Green, C.H., Thompson, P.M., Coker, A., Tunstall, S.M., Richards, C. and Parker, D.J. (1992) The economics of coastal management. A manual of benefit assessment techniques, Belhaven Press, London and Florida (ISBN 1 85293 161 2)

This manual provides principles, methods, techniques and data for evaluating the benefits of investing in coast protection (i.e. protection of the coastline from erosion) and sea defence (i.e. protection of the coastline from sea flooding). It also makes an important contribution to the valuation of recreational gains and losses at the coast. This manual is the third produced by the Flood Hazard Research Centre at Middlesex Polytechnic (now Middlesex University) and is known as the 'Yellow Manual'. The manual provides chapters on theoretical perspectives, coastal erosion losses and benefits, the impacts of coast protection and sea defence projects on recreation at the coast, the benefits of sea defences, the environmental gains and losses from sea defence and coast protection projects, integrated computer-based analysis and five UK coastal case studies.

Penning-Rowsell, E.C., Johnson, C., Tunstall, S. M., Tapsell, S.M., Morris, J., Chatterton, J., and Green C. (2005) The benefits of flood and coastal risk management. A manual of assessment techniques, Middlesex University Press, London (ISBN 1 904750 52 4)

This manual, produced by the Flood Hazard Research Centre at Middlesex University and jointly funded by the Defra and the Environment Agency (England and Wales), is known as the 'Multi-Coloured Manual' and is a direct 'descendant' of the 'Blue', 'Red' and 'Yellow' manuals also produced by this Centre. It is accompanied by the Multi-Coloured Handbook and CD. Like its predecessors this manual sets out principles, methods, techniques and data for assessing the benefits of flood and coast flood risk management and it provides updated data and new experimental methods on data filtering and assessing environmental resources. It reflects important policy shifts away from flood and coast 'protection' towards flood and coast 'flood risk management'. The manual presents updated data on flood damages to residential and non-residential properties in the UK and includes methods and

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data on utilities, roads, railways and emergency service costs. The parallel Handbook and CD are provided for those intending to apply the methods and data in project appraisals.

Penning-Rowsell, E.C., Priest, S.J., Parker, D.J., Morris, J., Tunstall, S.M., Viavatenne, C., Chatterton, J., and Owen D. (2013) Flood and Coastal Erosion Risk Management. A manual for economic appraisal, Routledge, London (ISBN 978-0-415-81514-4 (hbk) 978-0-203-06639-3 (ebk))

This manual draws on collaboration between the Flood Hazard Research Centre at Middlesex University, Defra, the Environment Agency and others stakeholders and is known as the 'Multi-Coloured Manual (MCM)'. It is an update of the 2005 manual of this name but includes a range of brand new methods and data. The manual is accompanied by MCM-Online which provides everything available in the manual plus a vast array of benefit data together with methods, techniques and guidance for its application. MCM-Online is available to professional users under licence agreement although there is also a free to use public division of this website. This updated version of the MCM provides a completely new set of potential; flood damage data for non-residential properties (including retail and office businesses, industry, logistics and public buildings). It provides methods for assessing benefits in sectors not previously covered by the MCM. It also provides a single compendium of research by the Flood Hazard Research Centre.

Penning-Rowsell, E., Chatterton, J., Wilson, T. and Potter, E. (2002), Autumn 2000 floods in England and Wales: assessment of national economic and financial losses, Flood Hazard Research Centre, Middlesex University

A research report which collates evidence on the damage caused by the extensive Autumn 2000 floods in England and Wales. The report draws together all of the data available in order to present an overall assessment.

Penning-Rowsell, E.C. and Green, C.H. (2000) New insights into the appraisal of flood alleviation benefits (1): flood damage and flood loss information. J. Institution of Water and Environmental Management. 14 (October), 347-353

New approaches to the appraisal of flood alleviation investment have been developed over the last twenty-five years. This has led to (a) increased precision in benefit-cost analysis as better data have become available, and (b) a more rational approach to decision-making as the UK Government has clarified and enhanced the decision criteria. This paper presents a detailed account of some of these developments, with an emphasis on the data on flood damages and losses avoided by flood alleviation schemes, and draws out lessons for those involved in this form of investment appraisal.

Penning-Rowsell, E.C. and Green, C.H. (2000) New insights into the appraisal of flood alleviation benefits (2): the broader context. J. Institution of Water and Environmental Management 14 (October), 354-362

During the last twenty-five years new approaches to the appraisal of flood alleviation investment have developed. This paper (a) identifies some of the key data inputs to this process, and (b) explores the issues concerning the relationship between flood losses and flood probability including in the Thames floodplain West of London. The paper draws upon a range of project appraisals undertaken by the Flood Hazard Research Centre in London.

Penning-Rowsell, E.C., Priest, S.J. and Johnson, C. (2013) The evolution of UK flood insurance: incremental change over six decades, International Journal of Water Resources Development, at http://www.tandfonline.com/doi/abs/10.1080/07900627.2014.903166#.VG9lYfmsXtU

In this paper, the authors' theorizing shifts away from the catalytic role of the flood itself – or other crises – towards a deeper understanding of the relationship between change and stability, taking the example of UK flood insurance and the agreements – and the implicit policy approaches – between the actors involved: private insurers and the government. The study relies upon in-depth analysis of policy agreements governing flood insurance since the 1960s, and semi-structured interviews with six current or former flood insurance professionals. The important agents of change have been, firstly, threats to existing household insurers from new entrants unencumbered by agreements to insure all comers. Secondly, technological changes have made exposure more explicit and pricing risk both easier and less expensive. The slow pace of change and the relatively

stable role of the different actors and coalitions is now clearer. Many windows of opportunity created by major flooding or financial crises have not significantly affected the pace or direction of policy change. The overriding importance of the London location for – and the profitability of – the insurance industry, both to government and to the insurers, explains the extraordinary policy stability described here. This history suggests that the UK may not be a good model for imitation elsewhere.

Penning-Rowsell, E.C. and Pardoe, J. (2014) The distributional consequences of future flood risk management in England and Wales, Environment and Planning C: Government and Policy 2014, Vol 32

Much flood risk management (FRM) research has examined the predicted increased burden of risk from future climate change. In contrast, this paper examines the changing funding regime for FRM and arrangements for flood insurance in the UK today. These changes, after the 1998–2013 period of severe and repeated flooding, may considerably increase the burden for at-risk households, but affect different groups differently, raising the question as to how to manage the risk and who should pay for this risk management. We explore this through scenarios incorporating modelled changes both to government investment to reduce risk and to flood insurance. The key findings are that moving towards a more risk-based approach could move the burden hugely, particularly onto financially deprived at-risk households, such that both investment and insurance could be unaffordable or unavailable. As insurance becomes more risk based, deprived households are less likely to purchase cover, but higher costs might incentivise those at risk to adapt to the risk they face. In the end, society has to decide whether to promote more substantial incentives discouraging occupation of the floodplain, with the likely adverse consequences for those there who are financially deprived, or retain the current discouragement of self-help.

Pielke, R.A. (2000) Flood Impacts on Society, Damaging floods as a framework for assessment, In Parker, D.J. (ed) Floods, Vol 1, Chapter 8, 133-155, Routledge, London

This chapter usefully goes back to fundamentals and asks what is flood damage and what are the problems of measurement? Pielke addresses some key issues including the problems of multiple-order impacts, causation, spatial scale and comparison. A case study of the 1993 Midwest floods in the United States is employed to exemplify some of the issues.

Scawthorn, C., Flores, P., Blais, N., Seligson, H., Tate, E., Mifflin, E., Thomas, W., Murphy, J. and Jones, C. (2006) 'HAZUS-MH flood loss estimation methodology, 1: overview and flood hazard characterization', Natural Hazards Review, Vol. 7, No. 2, 60-71

See below

Scawthorn, C., Flores, P., Blais, N., Seligson, H., Tate, E., Mifflin, E., Thomas, W., Murphy, J. and Jones, C. (2006) 'HAZUS-MH flood loss estimation methodology, II: damage and loss assessment', Natural Hazards Review, Vol. 7, No. 2, 72-81

These related papers describe the HAZUS-MH Flood Model and related software first developed in the United States in the 1990s. The first paper covers flood hazard characterization and the second paper reports on damage and loss estimation capability of the Flood Model. The Flood Model employs depth-damage functions to estimate benefits: these functions being provided by the Federal Insurance Administration. Additionally, depth-damage functions developed by the US Army Corps of Engineers are also considered suitable in selected instances. The Flood Model incorporates data on direct, indirect and intangible impacts of flooding. It covers lifeline systems, damages to vehicles, damage to crops and the damage-reducing effects of flood warnings which should be taken into account in estimating flood damage reduction potential. Social damages and induced damages are also considered.

Schröter, K., Kreibich, H., Vogel, K., Riggelsen, C., Scherbaum, F. and Merz, B. (2014) How useful are complex flood damage models? Water Resources Research, Vol 50, Issue 4, 337

We investigate the usefulness of complex flood damage models for predicting relative damage to residential

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buildings in a spatial and temporal transfer context. We apply eight different flood damage models to predict relative building damage for five historic flood events in two different regions of Germany. Model complexity is measured in terms of the number of explanatory variables which varies from 1 variable up to 10 variables which are singled out from 28 candidate variables. Model validation is based on empirical damage data, whereas observation uncertainty is taken into consideration. The comparison of model predictive performance shows that additional explanatory variables besides the water depth improve the predictive capability in a spatial and temporal transfer context, i.e., when the models are transferred to different regions and different flood events. Concerning the trade-off between predictive capability and reliability the model structure seem more important than the number of explanatory variables. Among the models considered, the reliability of Bayesian network-based predictions in space-time transfer is larger than for the remaining models, and the uncertainties associated with damage predictions are reflected more completely.

Smith, D.I. (1994) Flood damage estimation – A review of urban stage-damage curves and loss functions, Water SA, Vol 20, (3), 231-238 Accessed at http://www.wrc.org.za/Knowledge%20Hub%20Documents/Water%20SA%20Journals/Manuscripts/1994/03/WaterSA_1994_03_0818.PDF on 9.9.14

The estimation of flood damages is integral to the formulation of flood policy. Dor the assessment of flood losses this requires the use of stage-damage curves for different classes of buildings. A review is presented of the methods used to construct them. The use of synthetic techniques is stressed and attention is given to actual and potential losses and to the susceptibility of buildings to failure in response to flood water depth and velocity. Re\commendations are presented for the construction and use of stage-damage curves for residential and commercial buildings in South Africa.

Su, H-t. and Tung, Y. K. (2013) Incorporating uncertainty of distribution parameters due to sampling errors in flood-damage-reduction project evaluation, Water Resources Research, Vol 49, (3), 1680-169

A decision making framework considering the epistemic uncertainty is proposed. The effects of sample size on potential risk of alternatives and ranking result. The ranking of project alternatives can be changed by adjusting the sample size. Epistemic uncertainty is a result of knowledge deficiency about the system. Sampling error exists when limited amounts of hydrologic data are used to estimate a year event quantile. Both the natural randomness of hydrologic data and the sampling error in design quantile estimation contribute to the uncertainty in flood damage estimation. This paper presents a framework for evaluating a flood-damage-mitigation project in which both the hydrologic randomness and epistemic uncertainty due to sampling error are considered in flood damage estimation. Different risk-based decision-making criteria are used to evaluate project merits based on the mean, standard deviation, and probability distribution of the project net benefits. The results show that the uncertainty of the project net benefits is quite significant. Ignoring the data sampling error will underestimate the potential risk of each project. It can be clearly shown that adding data to existing sample observations leads to improved quality of information, enhanced reliability of the estimators, and reduced sampling error and uncertainty in the project net benefits. Through the proposed framework, the proper length of the extended record for risk reduction can be determined to achieve the required level of acceptable risk.

Sugden, R. (2007) Developing the Cost-Benefit Framework for the Appraisal of Flood and Coastal Erosion Risk Management Projects R&D Project Record FD2018/PR1 Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme, Environment Agency and Defra, London

Cost-benefit analysis can be described in two different ways – as a calculus of willingness-to-pay (WTP) or as a calculus of social costs and benefits (SCB). The current UK Defra FCDPAG3 framework adopts the calculus of social costs and benefits, as it seeks to measure the costs to be incurred, and the benefits created by a project in national economic terms. The willingness to pay approach differs in that it measures the net welfare change brought about by the project under consideration for each individual interest group. The summation of individual welfare changes leads to the same valuation of net social costs and benefits as the SCB approach. The principle advantage of the WTP approach is that it leads naturally to a presentation of results which makes clear how a project impacts on the members of different economic interest groups (e.g. in a flood defence context house

owners, farmers, taxpayers), how it impacts on different financial budgets (e.g. the budgets of different branches of government, and those of project partners), and how far the benefits created by the project are of the kind for which the relevant public funds have primarily been allocated (through for example the Spending Review process). With the SCB approach, in contrast, whilst it would be possible to disaggregate results in many cases some significant transfers between groups are not generally evaluated and these distinctions are liable to be hidden in the aggregation of resource costs and benefits.

Thieken, A.H., Muller, M., Kreibich, H. and Merz, B. (2005) Flood damage and influencing factors: New insights from the August 2002 flood in Germany, Water Resources Research, Vol. 41, W12430, doi:10.1029/2005WR004177

In the aftermath of a severe flood event in August 2002 in Germany, 1697 computer aided telephone interviews were undertaken in flood-affected private households. Besides the damage to buildings and contents a variety of factors that might influence flood damage were queried. It is analyzed here how variables describing flood impact, precaution, and preparedness as well as characteristics of the affected buildings and households vary between the lower and upper damage quartiles of all affected households. The analysis is supplemented by principal component analyses. The investigation reveals that flood impact variables, particularly water level, flood duration, and contamination are the most influential factors for building and for content damage. This group of variables is followed by items quantifying the size and the value of the affected building/flat. In comparison to these factors, temporal and permanent resistance influences damage only to a small fraction, although in individual cases, precaution can significantly reduce flood damage.

Thomas, M., King, D., Keogh, D.U., Apan, A. and S. Mushtaq (2008) Resilience to climate change impacts: a review of flood mitigation policy in Queensland, Australia. Based on case studies of flood events in 2008. The Australian Journal of Emergency Management, Vol 26, 1, January, 8-17. https://www.em.gov.au/Documents/AJEM%20Vol%2025%20PDF.PDF accessed on 23 Jan 2015

The vulnerability of cities to inundation from the impacts of climate change associated with the increased inter-annual variability associated with extreme weather events has been highlighted in the 2007 Intergovernmental Panel on Climate Change report. Predictions of an increased intensity of rainfall are likely to result in subsequent flood disaster events. Flood mitigation has been addressed by planning policy in Queensland through the State Planning Policy 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide (SPP 1/03) which will expire at the end of 2013 under the new Sustainable Planning Act 2009. The effectiveness of the SPP 1/03 was researched using two cases studies from the 2008 floods in Queensland: the rural town of Charleville was compared with the coastal city of Mackay.

Thompson, P M, Wigg, A and Parker, D J 1991 Urban flood protection post-project appraisal in England and Wales, Project Appraisal, Vol 6, (2), 84-92

A post-project analysis of the impacts of several flood alleviation schemes in England and Wales. Post-project appraisals are designed to find out whether the originally estimated benefits and costs of flood alleviation schemes were actually realised sometime after the projects or schemes had been implemented: such studies are few and far between yet can be informative. In this appraisal a number of flood alleviation schemes were revisited.

Veldhuis, T. (2011) How the choice of flood damage metrics influences urban flood risk assessment Journal of Flood Risk Management, 2011, Vol 4, (4), 281-287

Damage includes material damage to buildings and infrastructure; intangible damage includes damages that are difficult to quantify exactly, such as stress and inconvenience. The data used in examples of lowland flooding incidents with return periods up to 10 years. The results show that monetarisation of damage prioritises damage to buildings in comparison with roads, cycle paths and footpaths. What is needed is the kinds of damage metrics to quantify flood risk which provide the opportunity to weigh tangible and intangible damages from an economic and societal perspective. This study presents a first attempt to quantify tangible and intangible flood damage according to two different damage metrics: monetary values and number of people affected by flooding.

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When damage is expressed in terms of numbers of people affected by a flood, road flooding is the main contributor to total flood damage.

Wagenaar, D. J., de Bruijn, K. M., Bouwer, L. M., and De Moel, H. (2016) Uncertainty in flood damage estimates and its potential effect on investment decisions, Nat. Hazards Earth Syst. Sci. 16, 1-14

This paper addresses the large differences that are found between damage estimates of different flood damage models. It explains how implicit assumptions in flood damage models can lead to large uncertainties in flood damage estimates. This explanation is used to quantify this uncertainty with a Monte Carlo Analysis. As input the Monte Carlo analysis uses a damage function library with 272 functions from 7 different flood damage models. This results in uncertainties in the order of magnitude of a factor 2 to 5. The resulting uncertainty is typically larger for small water depths and for smaller flood events.

The implications of the uncertainty in damage estimates for flood risk management are illustrated by a case study in which the economic optimal investment strategy for a dike segment in the Netherlands is determined. The case study shows that the uncertainty in flood damage estimates can lead to significant over- or under-investments.

Walliman, N.S.R, Ogden, R., Baiche, B., Tagg, A. and Escarameia, M. (2013) A tool to predict the costs of reinstatement of individual buildings after flooding, In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 529-536, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

A review of the literature from Europe, USA and Australia, revealed that existing flood damage estimation methods are not sufficiently detailed to be reliably used at the individual building scale,so a more detailed tool was developed. A balance had to be drawn between excessive complexity and accuracy. The major inputs to the model are the depth, duration and dynamic qualities of the flooding, and the types of construction system, the building materials used and their positions within the construction, their drying characteristics and ease of repair or replacement. The output of the model expresses the damage in cost form as a percentage of the cost of new construction. This enables calculations to be made in order to assess the cost/benefit analysis of installing flood mitigation measures to the building and/or its surroundings. This paper provides examples of its application in several case studies.

Wedawatta, G., Ingirige, B. and Proverbs, D. (2014) Small businesses and flood impacts: the case of the 2009 flood event in Cockermouth, Journal of Flood Risk Management, Vol. 7, Issue 1, 42–53

Flooding can have a devastating impact on businesses, especially on small- and medium-sized enterprises (SMEs) who may be unprepared and vulnerable to the range of both direct and indirect impacts. SMEs may tend to focus on the direct tangible impacts of flooding, limiting their ability to realise the true costs of flooding. Greater understanding of the impacts of flooding is likely to contribute towards increased uptake of flood protection measures by SMEs, particularly during post-flood property reinstatement. This study sought to investigate the full range of impacts experienced by SMEs located in Cockermouth following the floods of 2009. The findings of a questionnaire survey of SMEs revealed that businesses not directly affected by the flooding experienced a range of impacts and that short-term impacts were given a higher significance. A strong correlation was observed between direct, physical flood impacts and post-flood costs of insurance. Significant increases in the costs of property insurance and excesses were noted, meaning that SMEs will be exposed to increased losses in the event of a future flood event. The findings from the research will enable policy makers and professional bodies to make informed decisions to improve the status of advice given to SMEs. The study also adds weight to the case for SMEs to consider investing in property-level flood risk adaptation measures, especially during the post flood reinstatement process.

Loss of life impacts

Brown, C. A. and Graham, W. J. (1988), Assessing the threat to life from dam failure, Water Resources Bulletin, 24 (6), 1303-1309

To facilitate decisions regarding the need for modification of potentially unsafe dams, the U.S. Bureau of Reclamation developed procedures for assessing the threat to human lives posed by the failure of individual

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dams. The procedures provide a conceptual model of the variables influencing the loss of life from dam failure and a method for predicting loss of life based on the size of the population at risk from failure and the amount of warning time available for that population. The prediction equations are based on an analysis of 24 dam failures and major flash floods occurring since 1950. Adjustments to the predictions to reflect special local conditions are also discussed.

Diakakis, M. and G. Deligiannakis (2013) Vehicle-related flood fatalities in Greece, Environmental Hazards, Vol 12, 3-4, 278-29

This work focuses on the analysis of vehicle-related flood fatalities in Greece, in an effort to provide a better understanding on the circumstances under which they occur. Therefore, an inventory of 60 fatalities associated with the use of vehicles, induced during 37 flood events between 1970 and 2010, was studied. To this end, we developed a database consisting of variables that provided a systematic description of the circumstances under which each incident occurred, including details of the surrounding environment, the road infrastructure, specifics on the incident and demographic details of the involved individuals. Analysis showed an increase in vehicle-related cases over the period of study, with the majority of the incidents occurring after 1990. Males, and individuals between 40 and 69 years old, showed an increased representation among both the drivers and the victims, although the latter showed an overrepresentation of young individuals as well. Most events occurred during night-time and in rural areas of the country. With respect to the surroundings, most cases occurred on paved road network and bridges that proved vulnerable to flooding phenomena. In a significant number of cases, fatal incidents occurred on paved river crossings, constructed on the riverbed of usually dry torrents or waterways. Drowning was found to be the primary cause of death. Analysis of the drivers' actions, exactly before the incident, showed that in the majority of occasions, they chose to enter into flooded areas, either to travel across or to save someone, or recover something. In some cases, vehicle occupants found themselves in a hazardous position when floodwaters rose unexpectedly, giving them no chance to avoid danger. It was therefore found that drivers, pursued an active, rather than a passive, stance in the majority of incidents, attributed, in certain occasions, to an underestimation of risk.

Jonkman, S.N., van Gelder, P.H. and Vrijling, J.K. (2003) An overview of quantitative risk measures for loss of life and economic damage, Journal of Hazardous Materials A99 (2003) 1–30

A comprehensive overview of methods to quantify and limit risks arising from different sources is still missing in literature. Therefore, a study of risk literature was carried out by the authors. This article summarises about 25 quantitative risk measures. A risk measure is defined as a mathematical function of the probability of an event and the consequences of that event. The article focuses mainly on risk measures for loss of life (individual and societal risk) and economic risk, concentrating on risk measurement experiences in The Netherlands. Other types of consequences and some international practices are also considered. For every risk measure the most important characteristics are given: the mathematical formulation, the field of application and the standard set in this field. Some of the measures have been used in a case study to calculate the flood risks for an area in The Netherlands.

Jonkman, S.N., Maaskant, B. and Levitan, M. (2008) Loss of life caused by the flooding of New Orleans after Hurricane Katrina: a preliminary analysis of the relationship between flood characteristics and mortality, International Symposium on Flood Defence: Managing Flood Risk, Reliability and Vulnerability Toronto, Ontario, Canada, May 6-8

In late August 2005, the New Orleans metropolitan area suffered the destructive power of hurricane Katrina. Large parts of the city flooded. This article utilizes the available data regarding Katrina related fatalities for Louisiana to analyse the relationship between flood characteristics and mortality. Available data regarding the recovery locations of Katrina related fatalities is presented and discussed. From this data, it is inferred that many, but not all, of the fatalities occurred inside the flooded areas. Insight in various characteristics of the flood has been gained based on available flood depth maps and hydrodynamic simulations that provide information in flood characteristics such as flow velocity, rise rate of the water and arrival time of the water. Combining the

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fatality data with the flood simulation results, the relationship between the flood characteristics and mortality is assessed. Similar to historical flood events, mortality rates were highest in areas near severe breaches and in areas with large water depths. Based on similar previous work a relationship between mortality and flood characteristics is derived for the New Orleans data. It is important to note that the presented results and analyses for New Orleans are preliminary, but they give important insights in the relationship between mortality and flood characteristics.

http://www.hkv.nl/site/hkv/upload/publication/Loss_of_life_caused_by_the_flooding_of_New_Orleans_after_hurricane_Katrina_BM%281%29.pdf, accessed on 21.10.14

Jonkman, S.N. and Kelman, I. (2009) Deaths during the 1953 North Sea storm surge

From 31 January to 1 February 1953, a North Sea storm surge devastated coastal areas of the United Kingdom, Belgium, and the Netherlands. Apart from enormous economic damage and severe societal disruption, over 2,000 people died across the three countries. This paper discusses the available data on loss of life in these three countries and examines the application of these data for loss of life estimations and general flood management practices

http://www.rigsystems.co.uk/members/content/documents/1cd05-6547a.pdf, accessed on 21.10.14

Jonkman, S.N., Maaskant, B., Boyd, E., and Levitan, M.L. (2009) Loss of Life Caused by the Flooding of New Orleans After Hurricane Katrina: Analysis of the Relationship Between Flood Characteristics and Mortality, Risk Analysis, 29, 5, May, 676–698

In this article a preliminary analysis of the loss of life caused by Hurricane Katrina in the New Orleans metropolitan area is presented. The hurricane caused more than 1,100 fatalities in the state of Louisiana. A preliminary data set that gives information on the recovery locations and individual characteristics for 771 fatalities has been analyzed. One-third of the analyzed fatalities occurred outside the flooded areas or in hospitals and shelters in the flooded area. These fatalities were due to the adverse public health situation that developed after the floods. Two-thirds of the analyzed fatalities were most likely associated with the direct physical impacts of the flood and mostly caused by drowning. The majority of victims were elderly: nearly 60% of fatalities were over 65 years old. Similar to historical flood events, mortality rates were highest in areas near severe breaches and in areas with large water depths. An empirical relationship has been derived between the water depth and mortality and this has been compared with similar mortality functions proposed based on data for other flood events. The overall mortality among the exposed population for this event was approximately 1%, which is similar to findings for historical flood events. Despite the fact that the presented results are preliminary they give important insights into the determinants of loss of life and the relationship between mortality and flood characteristics

Jonkman, S. N. (2003) Loss of life caused by floods: an overview of mortality statistics for worldwide floods

Large parts of the Netherlands lie below sea-level, and the hazard of large-scale floods leading to extensive damage and loss of life is always present. In this paper a framework for estimation of loss of life caused by floods in the Netherlands is proposed. The method takes into account the effect of evacuation during the flood and various mechanisms which lead to fatalities during a flood. The relationships between flood characteristics and number of fatalities are based on data from the 1953 North Sea flood disaster, during which the south western part of the country was flooded causing 1,836 deaths. The method is applied in two case studies to give a first estimate of the number of fatalities caused by a river dyke breach near Rotterdam and failure of coastal defences near Katwijk, both leading to a flood in Central Holland. http://www.library.tudelft.nl/delftcluster/theme_risk.htmlAccessed: 16/11/05

Jonkman, S. N. and Kelman, I. (2005), An analyses of the causes and circumstances of flood disaster deaths, Disasters, Vol 29 (1), 75-97

The objective of this paper is to investigate and to improve understanding of the causes and circumstances of

flood disaster deaths. A standardised method of classifying flood deaths is proposed and the difficulties associated with comparing and assessing existing information on flood deaths are discussed. Thirteen flood cases from Europe and the United States, resulting in 247 flood disaster fatalities, were analysed and taken as indicative of flood disaster deaths. Approximately two-thirds of the deaths occurred through drowning. Thus, a substantial number of flood disaster fatalities are not related to drowning. Furthermore, males are highly vulnerable to dying in floods and unnecessary risk-taking behaviour contributes significantly to flood disaster deaths. Based on these results, recommendations are made to prevent loss of life in floods. To provide a more solid basis for the formulation of prevention strategies, better systematic recording of flood fatalities is suggested, especially those caused by different types of floods in all countries.

Jonkman, S. N., van Gelder, P. H. and Vrijling, J. K. (2002), Loss of life models for sea and river floods. In Wu et al. (Eds) Flood Defence 2002, Science Press, New York Ltd.

In this article an overview is given of methods in the literature to estimate the loss of life caused by floods. The methods are described and applied to a case study in the Netherlands. The paper presents s a framework for future research on loss of life modelling.

http://www.waterbouw.tudelft.nl/public/gelder/paper120b-v10210.pdf

Jonkman, S.N., Vrijling, J.K. and Vrouwenvelde, A.C. (2008) Methods for the estimation of loss of life due to floods: a literature review and a proposal for a new method, Natural Hazards, Volume 46, Issue 3, 353-389

This article deals with methods for the estimation of loss of life due to flooding. These methods can be used to assess the flood risks and to identify mitigation strategies. The first part of this article contains a comprehensive review of existing literature. Methods have been developed for different types of floods in different regions. In general these methods relate the loss of life in the flooded area to the flood characteristics and the possibilities for evacuation and shelter. An evaluation showed that many of the existing methods do not take into account all of the most relevant determinants of loss of life and that they are often to a limited extent based on empirical data of historical flood events. In the second part of the article, a new method is proposed for the estimation of loss of life caused by the flooding of low-lying areas protected by flood defences. An estimate of the loss of life due to a flood event can be given based on: (1) information regarding the flood characteristics, (2) an analysis of the exposed population and evacuation, and (3) an estimate of the mortality amongst the exposed population. By analysing empirical information from historical floods, new mortality functions have been developed. These relate the mortality amongst the exposed population to the flood characteristics. Comparison of the outcomes of the proposed method with information from historical flood events shows that it gives an accurate approximation of the number of observed fatalities during these events. The method is applied to assess the consequences for a large-scale flooding of the area of South Holland, in the Netherlands. It is estimated that the analysed coastal flood scenario can lead to approximately 3,200 fatalities in this area.

Jonkman, S.N., and Vrijling, J.K. (2008) Loss of life due to floods, Journal of Flood Risk Management, Vol 1, Issue 1, 43–56

This article gives an overview of the research on loss of life due to floods. The limited information regarding this topic is presented and evaluated. Analysis of global data for different flood types shows that the magnitude of mortality is related to the severity of the flood effects and the possibilities for warning and evacuation. Information from historical flood events gives a more detailed insight into the factors that determine mortality for an event, such as flood characteristics and the effectiveness of warning and evacuation. At the individual level, the occurrence of fatalities will be influenced by behaviour and individual vulnerability factors. Existing methods for the estimation of loss of life that have been developed for different types of floods in different regions are briefly discussed. A new method is presented for the estimation of loss of life due to floods of low-lying areas protected by flood defences. It can be used to analyse the consequences and risks of flooding and thereby provide a basis for risk evaluation and decision-making. The results of this research can contribute to the development of strategies to prevent and mitigate the loss of life due to floods.

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Kellar, D.M.M. and Schmidlin, T.W. (2012) Vehicle-related flood deaths in the United States, 1995–2005 Journal of Flood Risk Management, Vol 5, Issue 2, 153–163

Vehicle-related deaths comprise more than half of all flash flood fatalities in the United States. Using the publication Storm Data from the United States National Climatic Data Center, we found 555 vehicle-related flood deaths that occurred in 355 flooding events during 1995–2005. Males accounted for 60% of the deaths. The difference in death rates between the sexes was small at ages 19 and younger but males died at twice the rate of females for ages 40 and older. Elevated deaths rates were found for both males and females under age 5 and over 60. Flooding events classified as flash floods accounted for most of the fatalities. Vehicle-related flood deaths were concentrated in the Texas Hill Country, the desert Southwest, the Ohio River Valley, and eastern North Carolina.

Health and social impacts

Convery, I. and Bailey, C. (2008) After the flood: the health and social consequences of the 2005 Carlisle flood event, Journal of Flood Risk Management, Vol 1, Issue 2, 100–109

In this paper we consider the health and social impacts of the flooding caused to a number of Carlisle households following the January 2005 floods and storms. In so doing we consider such impacts from a 'lived, local experience' perspective. We reflect on the need for both informal support and locally accessible and ongoing, post-flood information and support centres. Such centres can provide one point of contact for potentially multiple, emotional and practical problems. Crucially we suggest that these centres require both strong multi-partnership and multi-agency working and highly skilled support centre personnel who have local knowledge and understanding of the affected community. In this way, post-disaster local needs may be contextualized and responded to in a way that both draws on existing local knowledge and expertise and further strengthens long-term community-based support.

Du, W., Fitzgerald, G., Clark, M. and Hou, X. (2010) Health impacts of floods. Orehospital and Disaster Medicine, 25(3), pp.265-272

Direct health impacts of floods on households occur during the flood itself and are caused by coming in contact with flood water (these are the impacts which are normally felt immediately the flood event occurs), it could also result from direct exposure to the flooded environment, these includes; mortality from drowning, heart attacks, injuries from debris, chemical contamination and hypothermia. Most of the deaths associated with drowning are recorded during a flash flooding event as against the slower riverine flooding even. Drowning often occurs as a result of individuals under-estimating the velocity of the flood water or the depth of the flood water during late evacuation or attempted salvage. Death by drowning can also occur when people are swept away from their home while attempting to cross a bridge, rafting or sailing in storm water drains. Flood related injuries may occur as individuals attempt to escape from floating objects or building collapse. Disruption of health infrastructure including public health structures, such as clean water and proper waste disposal system, all these have the potential to significantly contribute to social disruption.

Green, C. H. and Penning-Rowsell, E.C. (1986), "Evaluating the intangible benefits and costs of a flood alleviation proposal", Journal of the Institution of Water Engineers and Scientists 40 (3), 229-248

Experimental approaches to evaluating intangible impacts of floods (e.g. on health) are presented and discussed with some case study evidence.

Green, C. H. and Penning-Rowsell, E. C. (1989), "Flooding and the Quantification of 'intangibles'", Journal of the Institution of Water and Environmental Management 3 (1), 27-30

Sources of both systemic and parameter uncertainties in flood alleviation cost-benefit analysis are discussed. Cost-benefit analyses are assessments of the future effects of different scheme options; consequently, there are inherent uncertainties. The omission of consideration of some impacts as 'intangibles', because it has not been

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possible to measure them, is a form of systemic uncertainty.

A significant omission in the past from flood alleviation cost-benefit analyses has been the non-monetary impacts of flooding upon households. It is shown that these impacts are both large and more important to the households affected than are the direct monetary losses.

Hajat, S., Ebi, K. and Kovats, S. (2003) A Review: The human health consequences of flooding in Europe: Applied Environmental Science Public Health 1, 13-21

Floods are the most common natural disaster in Europe. The adverse human health consequences of flooding are complex and far-reaching: these include drowning, injuries, and an increased incidence of common mental disorders. Anxiety and depression may last for months and possibly even years after the flood event and so the true health burden is rarely appreciated. Effects of floods on communicable diseases appear relatively infrequent in Europe. The vulnerability of a person or group is defined in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. Determining vulnerability is a major challenge. Vulnerable groups within communities to the health impacts of flooding are the elderly, disabled, children, women, ethnic minorities, and those on low incomes. There is a need for more good-quality epidemiological data before vulnerability indices can be developed. A comprehensive, risk-based emergency management program of preparedness, response, and recovery has the potential to reduce the adverse health effects of floods, but there is currently inadequate evidence of the effectiveness of public health interventions.

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (undated) A critical synthesis of the intangible impacts of flooding on households, University of the West of England, Bristol, UK http://iiirr.ucalgary.ca/files/iiirr/222.pdf, accessed on 22.10.14

The frequency and magnitude of flood events has increased significantly in the last few decades. This can be linked to a number of causes, including changes in climate patterns and urban development. The occurrence of a flood event brings about a range of impacts including tangible or measurable effects and intangible, less quantifiable aspects. The tangible impacts of flooding has generally received greater attention in policy, the media and society, while the intangible impacts have received less attention possibly because they are more difficult to encapsulate and they are generally health related issues. However, there is a growing awareness by flood risk managers that intangible impacts of floods have been underestimated in post-flood appraisals. In an attempt to conceptualise the intangible impacts of flooding on households, a critical synthesis of literature is presented towards developing a deeper understanding of the extent of the effect of flooding on the health of households. The review highlights that the health of households is affected by the stress and disruption caused by having to vacate homes following flood event. This is especially true for the more vulnerable members of the communities and the finding also reveal that the effect could last for months and even years. The implications of these findings are that the health impacts of flooding on households could be greatly reduced by flood mitigation measures such as the take up of property level flood adaptation measures as this will reduce the amount of time households will need to vacate their home for repair works following flood events. There is therefore a need for further research towards improving the quantification of these long term health impacts for the purpose of cost benefit appraisals.

Lane, K., Charles-Guzman, K., Wheeler, K., Abid, Z., Graber, N. and Matte, T. (2013) Health effects of coastal storms and flooding in urban areas: a review and vulnerability assessment, Environ Public Health, 913064. doi: 10.1155/2013/913064

Coastal storms can take a devastating toll on the public's health. Urban areas like New York City (NYC) may be particularly at risk, given their dense population, reliance on transportation, energy infrastructure that is vulnerable to flood damage, and high-rise residential housing, which may be hard-hit by power and utility outages. Climate change will exacerbate these risks in the coming decades. Sea levels are rising due to global warming, which will intensify storm surge. These projections make preparing for the health impacts of storms even more important. We conducted a broad review of the health impacts of US coastal storms to inform climate adaptation planning efforts, with a focus on outcomes relevant to NYC and urban coastal areas, and incorporated some lessons learned from recent experience with Superstorm Sandy. Based on the literature, indicators of health

vulnerability were selected and mapped within NYC neighbourhoods. Preparing for the broad range of anticipated effects of coastal storms and floods may help reduce the public health burden from these events.

Ohl, C.A. and Tapsell, S.M. (2000) Flooding and human health: the dangers posed are not always obvious, British Medical Journal, 321, 1167-8

The long term effects of flooding on psychological health may perhaps be even more important than illness or injury and therefore the benefits of trying to avoid such impacts are likely to be high. For most people the emotional trauma continues long after the water has receded. Making repairs, cleaning up, and dealing with insurance claims is stressful. If there is a lack of support during the recovery process, stress levels may increase further. This paper is a short editorial which makes the case for those providing medical care – of both a physical and mental kind – to become more aware of the particular health issues relating to flood occurrences.

Orellana, C. (2002) Germany counts cost of flood damage to health-care services, The Lancet, Vol 360, Issue 9334, 698, 31 August

Torrential rain led to widespread floods across several countries in central Europe including Germany, Austria, and the Czech Republic. Across the region, 100 people died, hundreds were injured, and thousands were evacuated. In Germany the bill for repairing the flood damage is estimated to be €15 billion. Germany's national healthcare service has started to assess the impact of the floods. In Saxony, in eastern Germany, 31 doctor's surgeries were destroyed and 22 were severely damaged, leaving a €50 million repair bill, according to a spokesman from the Dresden Medical Association. “Doctors who haven't lost their surgeries are taking patients over or lending rooms to their colleagues”, he said, “but health care will suffer if the damaged surgeries are not restored soon”. Following German reunification doctors in eastern Germany took on substantial loans to build new surgeries in line with western standards. “The payments are still running and some doctors have lost the means to pay these loans”. Local doctors are discussing possible financial solutions with local authorities. The damage to local healthcare services has compromised the ability of doctors to deal with the increased risk of flood-related disease. According to Angela Wirtz and Wilfried Oettler, health experts at the Social Ministry in Saxony, the immediate danger comes from gastrointestinal infections, especially where houses were flooded with sewage from treatment plants and blocked drains. “It is always possible that conditions will favour the spread of more serious faecal-to-oral transmitted diseases”, they warned. So far the levels of infectious disease are below the seasonal average, according to Wirtz and Oettler. Nearly all water-treatment plants are working again and there is little or no risk of faecal matter contaminating drinking water supplies, they said. However, there are some serious outstanding issues. Flooded factories and chemical plants in eastern Germany and the Czech Republic spilt toxic chemicals into the flood waters. Mercury concentrations in the Elbe have doubled but remain below the WHO limit. The long-term effects of this pollution remain to be seen. “We can infer that high levels of heavy metals, such as lead, mercury, arsenic, or cadmium, are likely to persist on cultivable land which will no longer be suitable for growing food”, said Siegmund Fröhlich, East Frisia Technical University, Emden.

Penning-Rowsell, E.C., Tapsell, S.M. and Wilson, T.Key (2005) Policy Implications of the Health Effects of Floods, accessed at http://eknygos.lsmuni.lt/springer/154/207-223.pdf on 22.10.14

The frequency and extent of flooding world-wide, and the accompanying losses and related human health impacts, are expected to increase over the next 50 to 100 years owing to the effects of global warming and other factors. There is cause for concern here, as the impacts of floods are serious and far-reaching. These impacts include impacts on health, as elaborated in this chapter. In turn these have implications for policies for flood defence, the environment and the provision of local services to, help people recover from flood emergencies and their aftermath. This chapter outlines some of the research undertaken at Middlesex University Flood Hazard Research Centre on the health effects of floods in the UK, and describes how these effects might be mitigated by policies and strategies to identify those who might be worst affected, to warn people of the impacts that they might suffer, and to help them during and after flood emergencies.

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Tapsell, S.M., Penning-Rowsell, E.C., Tunstall, S.M. and Wilson, T. (2002) Vulnerability to flooding: health and social dimensions, Phil. Trans. R. Soc. Lond. 360, 1511-1525

This paper presents research results on the impacts that floods can have on the people affected, thus complementing the existing data on the monetary losses liable to occur in flood events. Both datasets should be used when deciding on investment in flood defence measures. We report on research on the vulnerability of flood-affected communities to adverse health effects, and the development of an index of community vulnerability based on extensive focus-group research and secondary-source census data.

Tunstall, S., Tapsell, S., Green, C., Floyd, P. and George, C. (2006) The health effects of flooding: Social research results from England and Wales, Journal of Water and Health, Vol. 4, (3), 365-380

This paper presents interview survey data by social scientists using established health measures on the health effects of flooding for residents in 30 locations in England and Wales. First, it examines the extent to which flooded residents reported suffering physical and psychological health effects during and after the event. Second, it explores the issue of whether these effects were long-lasting by comparisons with the general population and with those at risk but not flooded. In the study, about two thirds of the flood victims were found to have scores on the General Health Questionnaire-12 scale indicative of mental health problems (scores of 4+) at their worst time after flooding. The evidence of the study also suggests that some flood victims suffered long term mental health effects as a result of their experience of flooding. The study examines the influence of a wide range of factors: characteristics of the flood event, types of property, and socio-demographic and the intervening factors such as the extent of family or community support that may explain the health effects of flooding. It finds that a complex set of social and other factors are involved and that some factors susceptible to human intervention such as having adequate flood insurance cover are important factors in the stress experienced by flood victims.

Benefits of non-structural measures

Carsell, K. M., Pingel, N. D. and Ford, P. E. (2004), Quantifying the benefit of a flood warning system, Natural Hazards Review, August 2004, 131-140

A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Day, H.J. (1970) Flood Warning Benefit Evaluation: Susquehanna River Basin (Urban Residences), US Department of Commerce, Environmental Science Services Administration, ESSA Technical Memorandum, WBTM Hydro 10, Weather Bureau, Office of Hydrology, Silver Spring, Maryland

The seminal work on flood warning benefits which introduced the famous 'Day Curve' which predicts damage reduction in terms of percentage of maximum potential inundation damage as a function of the mitigation time The effectiveness of a warning service coupled with either temporary flood proofing or evacuation of residential structures in reducing flood damage is the subject of this report. Communities in the floodplain of the Susquehanna River Basin in New York, Pennsylvania, and Maryland were used for a computer simulation of flood-related action; however, four cities, Harrisburg, Pa., Milton, Pa., Carbondale, Pa., and Owego, N. Y. received detailed investigation. Field data collected by the Baltimore District of the US Army Corps of Engineers and a computer program prepared by that office were used for this study. The interagency comprehensive river basin planning effort for water and land resources motivated this Type II study in the Susquehanna and information

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contained herein may serve as part of it. After a review of related literature, a detailed description of this investigation is presented. The results show that benefits from a warning service are not similar in all communities. The benefit-to-cost relationship is generally favourable since net benefits exist in 80 percent of the cases considered. For the 116 reaches of the river system investigated, flood damage to residences--without any warning--was estimated to be $3 million (expected annual cost). Reducible damages represented one-third of this value, $1 million. Reliable warnings, allowing 6 to 12 hours of action time, could be expected to provide at least two-thirds of the reducible damage as net benefits. Evacuation was generally economically advantageous compared to temporary flood proofing. Efficient local disaster organizations and total public response and compliance with action decisions are assumed. Damage reduction, considering limited reaction by residents, is considered for only four cities. Loss of life has not been included due to the difficulties in evaluating either the effect of a warning on reduced casualties or the dollar value of a life. It should be emphasized that commercial, rural, and industrial flood damages have not been considered in the study; therefore, the overall effectiveness of the warning service has not been estimated.

Day, H.J., Bugliarello, G., Ho, P and. T. Houghton (1969) Evaluation of benefits of a flood warning system, Water Resources Research, Vol. 5, (5), 937-946

Benefits due to a flood warning system are estimated by using individual structure stage damage curves for several warning periods. Typical stage damage warning time data for residences, a grocery Supermarket, and a railroad switchyard serve as examples for benefit evaluation. The application of these concepts to 650 residences involved in the 1959 flood at Meadville, Pennsylvania, indicated that reducible damages represent approximately one third of the total residential damage. Both evacuation and temporary flood proofing, two non-structural alternatives used frequently, may be evaluated more explicitly by this method.

Defra (2008) Developing the Evidence Base for Flood Resistance and Resilience. Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme, R&D Summary Report FD2607/TR1, Entec

It is estimated that around 470,000 properties in England are currently located in areas subject to a significant (greater than 1.33% annual probability) risk of main river and/or coastal flooding. This estimate excludes properties which could be at a similar risk of flooding from minor rivers, surface water run-off and/or groundwater. The economic cost of flooding in these areas is considerable, currently reaching around £1.15 billion per annum (£747 million residential and £401 million commercial). Although some of these properties could be provided with community-level flood protection by the Environment Agency over the coming years, in other areas the numbers of properties are so small or the cost of defences so large that the cost of additional protection is unlikely to be justified. Climate change is likely to increase the pressures on these properties and increases the need to consider a wider portfolio of flood management approaches. The greater use, by individual households and businesses, of flood resistance (i.e. measures to prevent entry of water into a building fabric) and flood resilience measures (i.e. measures to limit the impact of flood water within a building). A key element of the project was the examination of the effectiveness of property based resilience and resistance measures in reducing flood risk. This involved developing a new economic model to quantify the costs and benefits of resilience and resistance at a property level. The model was developed for both residential and selected commercial properties and facilitated the quantification of property-scale benefits and costs for different packages of flood resistance and resilience measures.

Environment Agency (2012) Evaluation of the Defra Property-level Flood Protection Grant Scheme: JBA Consulting, Assessing the Economic Case for Property Level Measures in England, Committee on Climate Change Economics of flood risk adaptation measures, Final Report 9X1055, EA, Bristol

This report sets out the methodology and results of the investigation into the potential forProperty Level Measures (PLM) to enable adaptation to flood risk at present and into the future, addressing the first aim of the study. Section 2 discusses the two key pieces of previous research into the costs and benefits of PLMs, setting the context for this study. Section 3 sets out the methodology for the study. Firstly this details the development of the PLM model for six packages of measures, six property types, three installation scenarios and both an economic and a financial perspective. Secondly the approach taken to obtain a national estimate of the number

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of properties that would find it cost beneficial to install PLMs now and in the future is described. Section 4 gives the results of the PLM model for the various combinations of PLM measures, property type, installation scenario, and economic or financial perspectives. Section 5 discusses sensitivity analysis of the PLM model, testing the key assumptions regarding assessment of the costs and benefits of the measures. These include variability in the cost of measures, the limiting height of resistance measures, assumptions regarding seepage of resistance measures and discount rates used for the financial model. Section 6 outlines the results of the national assessment for England indicating for how many properties it would be cost beneficial to install these measures at present. This assessment considers those properties that are currently at risk from flooding from rivers or the sea. At present there is insufficient data to make similar assessment for properties at risk from surface water flooding. Section 7 presents the assessment of how the number of properties in England that could benefit from these types of measures may change in the future due to climate change, funding of flood defences and property development. Section 8 summarises the key findings of the study and gives recommendations for future work that could improve the understanding of the cost and benefits of PLMs, and how this could be assessed at the national scale.

Joseph, R., Proverbs, D., Lamond, J. and Wassell, P. (2014) Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures, Structural Survey Volume 32, Issue 2, 102

There has been a significant increase in flooding in the UK over the past ten years. During this time, Government policy has moved from investment in flood defences towards encouraging property owners to take responsibility for reducing the impact of flooding. One of the ways in which this can be achieved is for homeowners to adapt their properties to flood risk by implementing property level flood risk adaptation (PLFRA) measures. While there has been some attempt to develop an understanding of the benefits of such measures, these previous studies have their limitations in that the intangible benefits have not been fully considered. As such, there remains a need for further development of these studies towards developing a more comprehensive understanding of PLFRA measures. It is against this background the purpose of this paper is to present a conceptual cost benefit analysis (CBA) framework for PLFRA measure. This framework brings together the key parameters of the costs and benefits of adapting properties to flood risk including the intangible benefits, which have so far been overlooked in previous studies. Design/methodology/approach – A critical review of the standard methods and existing CBA models of PLFRA measures was undertaken. A synthesis of this literature and the literature on the nature of flooding and measures to reduce and eliminate their impacts provides the basis for the development of a conceptual framework of the costs and benefits of PLFRA measures. Within the developed framework, particular emphasis is placed on the intangible impacts, as these have largely been excluded from previous studies in the domain of PLFRA measures. Findings – The framework provides a systematic way of assessing the costs and benefits of PLFRA measures. A unique feature of the framework is the inclusion of intangible impacts, such as anxiety and ill health, which are known to be difficult to measure. The study proposes to implement one of the stated preference methods (SPM) of valuation to measure these impacts, known as the willingness to pay method, as part of a survey of homeowners. The inclusion of these intangible impacts provides the potential to develop a more comprehensive understanding of the benefit cost ratio (BCR) for different stakeholders. The newly developed CBA conceptual framework includes four principal components: the tangible benefits to insurers; the tangible benefits to the government; the tangible benefits to homeowners; and the intangible benefits to homeowners. Originality/value – This tool offers the potential to support government policy concerned with increasing the uptake of PLFRA measures through increasing the information available to homeowners and thereby supporting the decision-making process.

May, P.G. and Chatterton, J.B. (2012) Establishing the Cost effectiveness of Property Flood Protection: FD2657, JBA Consulting, Defra, London.

Although the focus of this report is on cost-effectiveness the data on benefits may be employed in cost-benefit appraisal. A new and extended model has been developed that builds on the strengths of a previous study undertaken by Entec UK in 2007-08. It incorporates the latest data on the economic damage from flooding and the costs and benefits of a range of flood protection measures, updated to a 2011 price base perspective. Innovative, automatic (or passive) protection measures are compared to manually deployed measures. Factors

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such as the service life and reliability of such systems have also been addressed. Assumptions on damage savings have been re-visited and improved, using the 2010 Multi-Coloured Manual data. Additional damage-saving categories have been incorporated, including emergency costs and the cost of electricity during the post-flood drying- out process. The wider social impacts of flooding and the intangible health and well-being benefits and reduced levels of stress that can be gained from property-level flood protection are also considered. The introduction of such measures can help to reduce the severity of these losses compared to an unprotected property. It is also important to recognise that, unlike a traditional flood defence scheme, these measures do not alter the likelihood of floodwater reaching the property. They do however aim to manage the consequences once this happens. Financial and economic models have been developed to analyse the costs relative to the benefits of six packages of flood resistance and resilience measures. These have been applied to a wide range of property types, for various levels of social deprivation and for different thresholds of flooding. Improvements and extensive revisions have been made to the previous economic model developed in 2008, to provide for an interactive model that can be used to explore the impacts of altering a range of key variables. Further analytical tools have also been suggested that could provide a simple to use spreadsheet tool that could also contain spatial links using GIS to help local authority scheme appraisal decisions. The analysis has been extended to explore the implications of applying the new Partnership Funding approach, to determine and make comparisons between over 22,000 possible scenario outcomes, made in terms of benefit cost ratios and typical Partnership Funding Outcome Scores. This has provided an assessment of cost effectiveness and the approaches that could qualify for government funding, together with the levels of contributions that might be necessary from developers or home owners for a scheme to proceed. The study found (a) compelling evidence for the cost effectiveness of manually deployed flood resistance measures, with high benefit cost ratios and high Partnership Funding Outcome Scores for typical flood thresholds of up to 2.5% annual exceedance probability (1 in 40 year); (b) the higher cost of Automatic Resistance measures results in lower benefit cost ratios but there are still significant cost effective opportunities for schemes with appropriate levels of contribution, but at typically lower flood thresholds of 5% annual exceedance probability (1 in 20 year); (c) the high cost of resilience measures indicates that these are a less cost effective option for Government intervention, unless flooding of a property occurs at greater than a 20% annual exceedance probability (1 in 5 year); (d) manual resistance measures are more than twice as cost beneficial as automatic measures, achieving some very high benefit cost ratios: (e) the effects of reliability have been examined but found not to have significant impacts on the overall outcomes.

Meyer, V., Priest, S.J. and Kuhlicke, C. (2012) Economic evaluation of the structural and non-structural flood risk management measures – examples from the Mulde River, Natural Hazards, Vol 62, (2) 301-324

The concept of flood risk management, promoted by the EU Floods Directive, tries to mitigate flood risks not only by structural, hydraulic engineering measures, but also by non-structural measures, like, e.g., land-use planning, warning and evacuation systems. However, few methods currently exist for the economic evaluation of such non-structural measures and, hence, their comparison with structural measures. The objective of this paper is to demonstrate the potential benefits of employing a wider range of economic appraisal methods for flood projects, in particular, it provides examples and applications of methodologies which may be employed to evaluate non-structural measures and their transaction costs. In two case studies at the Mulde River, Germany, two non-structural measures, a resettlement option and a warning system, are evaluated and compared with structural alternatives with regard to their effectiveness, cost-effectiveness and efficiency. Furthermore, a simple approach is tested in order to show the transaction costs of these measures. Case study results show that the choice of evaluation criteria can have a major impact on the assessment results. In this regard, efficiency as an evaluation criterion can be considered as superior to cost-effectiveness and effectiveness as it is also able to consider sufficiently the impacts of non-structural measures. Furthermore, case study results indicate that transaction costs could play an important role, especially with non-structural measures associated with land-use changes. This could explain why currently these kinds of measures are rarely selected by decision makers.

Pappenberger, F., Cloke, H., Parker, D.J., Wetherall, F, Richardson, D. and Theilin, J. (2015) The monetary benefits of early flood warnings in Europe, Environmental Science and Policy, Vol 51, 278-291

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Effective disaster risk management relies on science-based solutions to close the gap between prevention and preparedness measures. The consultation on the United Nations post-2015 framework for disaster risk reduction highlights the need for cross-border early warning systems to strengthen the preparedness phases of disaster risk management, in order to save lives and property and reduce the overall impact of severe events. Continental and global scale flood forecasting systems provide vital early flood warning information to national and international civil protection authorities, who can use this information to make decisions on how to prepare for upcoming floods. Here the potential monetary benefits of early flood warnings are estimated based on the forecasts of the continental-scale European Flood Awareness System (EFAS) using existing flood damage cost information and calculations of potential avoided flood damages. The benefits are of the order of 400 Euro for every 1 Euro invested. A sensitivity analysis is performed in order to test the uncertainty in the method and develop an envelope of potential monetary benefits of EFAS warnings. The results provide clear evidence that there is likely a substantial monetary benefit in this cross-border continental-scale flood early warning system. This supports the wider drive to implement early warning systems at the continental or global scale to improve our resilience to natural hazards.

Parker, D J 1991 The Damage-Reducing Effects of Flood Warnings, Report prepared for Halcrow and National Rivers Authority in connection with the Anglian Region's Regional Telemetry Scheme Appraisal, Middlesex Polytechnic, Enfield

A relatively early piece of research on the damage-reducing effects of flood warnings in both the residential and non-residential property sectors. This research report combines previous research on residential property inventories in the UK with empirical evidence of the damage saving effects of flood warning responses in the UK to generate relationships between the proportion of damage likely to be saved with 2, 4, 6 and 8 hour flood warning lead times. The result is a set of empirically informed synthetic curves, mainly for the residential property sector. Subsequent research by the author and others at the Flood Hazard Research Centre in London now suggest that these curves are too optimistic in terms of the amount of damage which is likely to be saved by flood warning responses in the UK.

Parker, D.J., Tunstall, S.M. and McCarthy, S. (2007) New insights into the benefits of flood warnings: Results from a household survey in England and Wales Environmental Hazards, Vol 7, 193–210

The flood defence agency in England and Wales has been pursuing a programme of flood warning system enhancement, engaging householders at risk in improving their warning responses. The immediate aim of this paper is to test and revise a model of economic benefits of warnings, but the survey data also generate insights into the constraints acting upon flood warning responses. Damage saving is less than previously anticipated: warning reliability and householder availability problems limit savings. Warnings are less likely to be received by those in lower social grades, and flood warning lead time is a factor in avoiding damage. The survey data indicate the complexities involved in improving flood warning response, and provide policy pointers.

Parker, D.J. and Priest, S. J. (2012) The Fallibility of Flood Warning Chains: Can Europe's Flood Warnings Be Effective? Water Resources Management August , Volume 26, Issue 10, 2927-2950

Taking a broad overview, this paper explores recent evidence on flood forecasting, warning communication and public warning response in Europe between 1995 and 2010 which underpins the benefits of flood warnings. Key flood warning chain deficiencies are identified together with the effect these deficiencies have on flood warning effectiveness and loss reduction. Europe-wide data on flood forecasting and warning communication are examined alongside recent in-depth research evidence from various parts of Europe on flood warning receipt, warning response and warning effectiveness. Using the latest flood warning benefit assessment methodologies, the results of case studies of flood loss avoidance through warnings reveal the damage saving potential of flood warning. Although these savings are significant, currently they are inhibited by a series of shortcomings which transfer through the warning chain limiting warning impact. Flood forecasting, warning and warning response systems are inherently fallible and so it is doubtful that they will ever be consistently effective. Sole reliance upon them to protect life and property carries inevitable risks and governments should not be surprised when flood warnings are only partially effective. Although Europe's flood forecasting and warnings have been improving, the

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scope for further improvement is large. Extending flood forecasting and warning coverage, extending warning lead times by combining meteorological and hydrological forecasts, building greater redundancy into warning communication, and crucially also building it into cooperative strategies designed to engage at risk communities in flood warning response, are all likely to be important.

Parker D J, Priest, S J, Schildt A, Handmer J, 2008. Modelling the damage reducing effects of flood warnings, FLOODsite Report No. T10-07-12, FLOODsite: HR Wallingford

A research report from the EC commissioned Floodsite research project, in this case focusing upon devising a new methodology for understanding and assessing the various benefits that potentially flow from installing and operating flood warning systems. The research examines the development of flood warning systems in France and the Czech Republic. The central concept developed in this research is the Flood Warning Response Benefits Pathway Model (FWRPBM) which conceptualises each of about eight pathways through which flood warnings may generate benefit. The model is applied to some hypothetical cases and to the town of Grimma in South Eastern Germany to demonstrate how warning benefits may be estimated. There is also a national level of assessment of flood warning benefits in England and Wales.

Priest, S.J., Parker, D.J. and Tapsell, S M. (2011) Modelling the damage reducing effects of flood warnings using European cases, Environmental Hazards, 10, 2, 101-120

Flood warning systems are now centre-stage in flood risk management strategies in Europe. This is due to advances in flood forecasting and the rapid communication of flood risk information, coupled with a growing understanding that communities need to find better ways of co-existing with rivers and the realization that structural flood defences are insufficient on their own to prevent flooding. However, not enough is known about the potential and actual benefits of flood warnings for avoiding property damages. This paper presents an extended approach to the estimation of potential flood damage reduction benefits of flood warnings for fluvial and tidal floods, drawing upon research completed for the European Commission's Floodsite project. Its aim is to demonstrate the potential economic benefits of coupling flood warnings to a combination of structural and non-structural flood risk management measures. Previous research in this area is critiqued, including that which suggests that flood warnings are futile, and the features, strengths and weaknesses of the extended approach are presented and discussed. Two case studies, a national-level (England and Wales) and a local-level (Grimma, South-Eastern Germany) assessment of flood damage-saving potential, are presented to illustrate the new approach. Although a number of data quality issues need addressing, the model outputs and estimations of potential damage savings may be used to make wise decisions about investment in flood warning systems, and to identify those areas, such as public flood risk awareness, that need attention to achieve the full scope of potential benefits in practice.

Rogers, D. and Tsirkunov, V. (2010) Costs and benefits of early warning systems, Global Assessment Report and Disaster Risk Reduction, GAR 2011, ISDR, The World Bank

This report covers a range of natural hazards (e.g. heatwaves, El Nino, landslides etc.) rather than just floods. It considers the costs of early warnings including the costs of false alarms, as well as the benefits. It tabulates five exemplar cases where the benefits exceeded the costs by more than ten times. It analyses the problem of estimating the costs and benefits of early warnings for flash floods. The report concludes that the case for installing early warning systems is strong and evident.

Schröter, K., Ostrowski, M., Quintero, F., Corral, C., Velasco-Forero, C., Sempere-Torres,D., Nachtnebel, H.P., Kahl, B., Beyene, M., Rubin, C. and M. Gocht (2008) CRUE Research Report No I-5: Effectiveness and Efficiency of Early Warning Systems for Flash-Floods (EWASE), CRUE Coordinator, London

The report of the results of this ERA-NET CRUE research project. EWASE evaluates the efficiency and the effectiveness of early warning systems (EWS) in small river basins that have short hydrological response times. EWASE provides information for optimal alerts through the analysis of the trade-off between the benefit of an increased lead time and the simultaneous decrease of warning reliability. The increase in lead time may provide

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valuable time for the completion of preventive measures, whereas the decrease of warning reliability will cause economic loss in case of a false alert. Two study basins in Austria and Spain are presented to illustrate the application of the methodology
proposed and to identify the key information required to integrate this approach into comprehensive flood risk management strategies. In this way EWASE synthesises data and experiences to help flood managers in finding better solutions for the operation of early warning systems.

The newly developed approaches for the evaluation of flood forecast reliability and comparative risk assessment are introduced in chapter 3. Chapter 4 presents the exemplary application to the study basins and provides detailed information from hydrological and socioeconomic perspectives. In chapter 5 the findings from the study basins are summarised. This includes a comparison of similarities and disparities of both case studies, a discussion of the results obtained in order to provide a general overview of the project success. The findings from the analysis of warning
reliability are integrated in terms of reliability curves, which reflect the hydro-meteorological characteristics of the study basins as well as the specific design of the operational EWS. The economic assessment estimates the potential benefit in form of avoided damages in an event dependent evaluation. The combination of reliability and avoided damages leads to the warning expectation as an indicator for the optimal alert. An event independent evaluation translates the avoided damages into a reduction of risk and compares the costs of the EWS with the benefits. The benefit cost ratio (BCR) for the EWS is compared to the BCR of structural flood protection strategies to appraise the economic dimension of EWS.

Early warning as discussed in EWASE offers a significant potential to transfer responsibilities from
the state to the individuals. The extent to which individuals are enabled to care for their safety and to optimise their benefit from the warning depends to a large part on the distribution of the warning. Particularly in the economic sectors high potential benefits can be realised, because of the ongoing presence of people at least during the day. As 60 to 70% of the risk arises in the economic sectors, there is a high potential for damage reduction due to early warning. It is therefore a promising means to implement the EWASE approach on the company level supporting managers to decide about releasing an alert for optimising their benefit from early warning. Early warning systems as a non-structural protection measure induce very low detrimental effects on the natural environment. Therefore the implementation of early warning is a good opportunity to reconcile the
Water Framework Directive and the Floods Directive. Early warning is well in line with the protection of the weak. In fact timely warning may be the only possibility to evacuate the sick, the elderly, the children and the pupils from hospitals, resorts, kindergartens and schools.

Tiesberg, T.J. and Wieher, R.F. (2008) Background Paper on the Benefits and Costs of Early Warning Systems for Major Natural Hazards, Submitted to The World Bank Group, Global Facility for Disaster Reduction and Recovery (GFDRR). Accessed at https://www.gfdrr.org/sites/gfdrr/files/Teisberg_EWS.pdf on 11.08.15

This paper surveys the benefits and costs of early warning systems (EWS) for natural hazards, and discusses issues associated with the design and implementation of early warning systems to achieve these EWS benefits. The hazards considered include five meteorological hazards --cyclones, floods, heat, tornadoes, drought; and three geological hazards – tsunamis, volcanoes, and earthquakes. The primary interest of this paper is on the design and implementation of EWS in the generally less developed countries surrounding the Indian Ocean, though data from other parts of the world and discussion of institutions in the United States and Europe are used as appropriate to facilitate the analysis. The present paper is in two sections. The first, Section II, contains a discussion of the factors that drive the net economic benefits of EWS, and a discussion of how the eight hazards compare to one another with respect to these drivers of benefits. Section II concludes with some example estimates of net economic benefits for several of the more important types of hazards, and a brief discussion of approaches that have been used to make very aggregate estimate of benefits at a country-wide or even a global scale. Section III then considers issues associated with the design of an early warning system. These include the most appropriate geographic scope for such a system, the most appropriate hazards to be included in the system, the importance of local systems that respond to hazard warnings, and issues concerning how information produced by a warning system should be made publicly available.

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The implications of this analysis may be briefly summarized as follows:

- Careful studies of early warning systems for specific hazards in specific locations lead one to conclude that there are important natural hazards for which early warning systems have benefits that exceed their costs, in some cases by huge margins.
- It makes most sense to focus EWS development efforts in the Indian Ocean region on the meteorological hazards (especially cyclones and floods); generally these hazards are more common and more severe, and it is within our capability to provide forecasts for these hazards with enough lead-time to allow effective responses to such forecasts.
- Forecasting systems should be structured, and institutions designed, to take advantage of efficiencies that come from including multiple hazards and covering appropriate geographic areas in the EWS.
- It will be important not only to have a good forecasting systems but also to follow through with on-the-ground local response systems, so that warnings will be heeded appropriately; this may require careful tailoring of institution-building and educational efforts to the particular needs of individual countries. Accurate forecasts and appropriate local responses are both necessary in order to realize any benefits from an early warning system.

Wurster, S. and Meissen, U. (2014) Towards an Economic Assessment Approach for Early Warning Systems: Improving Cost-Avoidance Calculations with Regard to Private Households Proceedings of the 11th International ISCRAM Conference – University Park, Pennsylvania, USA, May 2014 S.R. Hiltz, M.S. Pfaff, L. Plotnick, and P.C. Shih, eds.

In recent years, Early Warning Systems (EWS) have proven their value by saving many lives. However, most investments in EWS were motivated directly by experience of disaster events and rarely proactively by possible upcoming threats. In order to change this for ethical and humanitarian reasons, the positive effects of early warnings should be analysed. EWS help to protect property but their contribution is no as obvious as it might be because of the lack of quantitative models. This paper presents a disaster-independent formula that shows the benefits of EWS. Additional value to existing approaches stems from a focus on behavioural aspects and the benefits of EWS in comparison to warnings issued via social media.

Agricultural impacts

Morris, J. and Brewin, P. (2014) The impact of seasonal flooding on agriculture: the spring 2012 floods in Somerset, England Journal of Flood Risk Management, Vol 7, Issue 2, 128–140

Exceptional rainfall in spring 2012 caused widespread flooding and damage to agricultural grasslands in Somerset in south western England, much of them farmed under agri-environment agreements. The seasonal timing of the flood and its relatively long duration (in excess of 4 weeks in some areas) led to a serious loss of grazing and winter feed in 2012. A survey of farmers, combined with the development of a framework to estimate the impact of seasonal flooding, identified the effects on farm businesses and the ways that farmers coped. Impacts on agri-environment outcomes were valued at the cost of funding stewardship schemes. The methods and estimates can help inform strategies to deal with changes in flood risk in areas of agricultural and environmental interest, whether induced by changes in catchment land use or climate.

Posthumus, H., Morris, J., Hess, T.M., Neville, D., Phillips, E. and Baylis, A. (2009) Impacts of the summer 2007 floods on agriculture in England, Journal of Flood Risk Management, Vol 2, Issue 3, 182–189

Exceptional rainfall during the summer of 2007 caused widespread flooding in parts of England. While the focus of attention has been correctly placed on the impact on densely populated urban areas, large tracts of rural land were seriously affected by flooding. Summer flooding is particularly damaging to farming. This paper presents the results from an evaluation of the impacts of the summer 2007 flood events on agriculture. High financial losses were incurred in the horticultural sector. Arable farmers incurred direct losses in the form of crop loss or yield reduction due to flooding and associated waterlogging of fields. Livestock farmers incurred indirect losses in

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the form of additional housing and feeding costs for livestock. Although total costs to agriculture were small compared with urban flood costs, they were typically large at the individual farm scale. Such impacts should be properly acknowledged in future strategies for flood risk management.

Environmental benefits

Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R. and Swanson, J. (2002) Economic Valuation with Stated Preference Techniques: A Manual, Edgar Elgar, Cheltenham, UK

This manual offers a detailed, up-to-date explanation of how to carry out stated preference techniques. The techniques use surveys to ask individuals how much they would be willing to pay or willing to accept in compensation for gains or losses of non-market goods and services. Applicants of the technique include changes in air and water quality; noise nuisance; health care; risk; recorded heritage; cultural assets; habitats; landscape and so on. The resulting valuations can be used for a number of purposes including, but not limited to, demonstrating the economic value of environmental and cultural assets; cost-benefit analysis; setting priorities for environmental policy; design of economic instruments; green national/corporate accounting; and natural resource damage assessment. Compiled by the leading experts in the field, this manual starts by explaining the concepts. It shows how to choose the most appropriate technique and how to design the questionnaires. Detailed advice on econometric analysis is provided, as well as explanation of the pitfalls that need to be avoided. The manual is essential reading for those who apply, commission, teach and study stated preference techniques.

Department for Environment, Food and Rural Affairs (2010) An introductory guide to valuing ecosystem services, Defra, London

This Guide provides an introduction to the valuation of ecosystem services. It builds on previous approaches to valuing the environment but takes a more systematic approach to the assessment of impacts on the natural environment. The central theme of this work is to ensure that the true value of ecosystems and the services provided are taken into account in policy decision-making. Ecosystem services are defined as services provided by the natural environment that benefit people. While there is no single, agreed method of categorising all ecosystem services, the Millennium Ecosystem Assessment framework is widely accepted and is seen as a useful starting point. Ecosystem services provide outputs or outcomes that directly and indirectly affect human well-being, and these considerations can link well to taking an economic approach. The underlying case for the valuation of ecosystem services is that it will contribute towards better decision-making, by ensuring that policy appraisals fully take into account the costs and benefits to the natural environment and by highlighting much more clearly the implications for human wellbeing, while providing policy development with new insights. Some of these ecosystem services are well known including food, fibre and fuel provision and the cultural services that provide benefits to people through recreation and appreciation of nature. Other services provided by ecosystems are not so well known. These include the regulation of the climate, the purification of air and water, flood protection, soil formation and nutrient cycling. These services are not generally considered within policy appraisal at present and represent an area where a greater and more systematic focus would be very useful. The appraisal of new policies, programmes and projects all require environmental impacts to be taken into account. The approach to the valuation of ecosystem services presented in this Guide is not intended to be an additional step within the appraisal process but, instead, a common methodology that can be used in order to consider the impact of our actions on the environment. The environmental impacts currently taken into account in policy appraisal can generally fit well within this broad framework. This broader framework allows a shift in emphasis from a focus mainly on valuing environmental damage to highlighting the value of changes in the services provided by the natural environment. Ecosystem services contribute to economic welfare in two ways – through contributions to the generation of income and wellbeing and through the prevention of damages that inflict costs on society. Both types of benefits should be accounted for in policy appraisal. With a broader focus on valuing the benefits provided by ecosystems, policy options that enhance the natural environment are also more likely to be considered that demonstrate that investing in natural capital can make economic sense.

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Eftec (2010) Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal, Non-Technical Summary Report Submitted to Department for Environment, Food and Rural Affairs, London

This document provides practical guidelines for valuing environmental impacts via an approach known as 'value transfer'. It augments guidance provided by Defra in An introductory guide to valuing ecosystem services, which seeks to ensure that the true value of ecosystems and the services they provide are taken into account in policy decision-making. Assessment of the impacts of policies should be consistent and transparent. Cross-Whitehall guidance in the UK HM Treasury Green Book requires that all new policies, programmes and projects be subject to a comprehensive but proportionate appraisal. This is to ensure that interventions enacted by public sector bodies are in the best interest of society overall and provide a full analysis of potential outcomes. A key component of appraisal is the comparison of the total benefits of a proposal to the full costs incurred by Government and society. Here the Green Book requires that all relevant costs and benefits be valued in monetary terms and the net benefit or cost of the proposal be calculated. Costs and benefits of proposals, typically, are estimated using market prices. Wider social and environmental costs and benefits for which market prices are not available, requires the use of economic valuation methods (which are also known as 'non-market valuation' methods). There is a substantial body of evidence on the value of environmental costs and benefits. Value transfer (which is also known as 'benefits transfer') allows existing economic valuation evidence to be applied in a new context, such as estimating the monetary value of environmental benefits associated with a proposed policy. However, 'quick' and 'lower cost' do not mean that value transfer is easy. Judgements are required as to when value transfer can be used and the level of effort that is appropriate. Overall, the more accurate the results need to be, the more effort is required. These guidelines emphasise transparency and the appropriate use of sensitivity analysis to address concerns of accuracy. The role for value transfer promoted by the guidelines is to make the best use of available economic value and other evidence, given the time and resource constraints that limit the scope of the analysis. The core component of these guidelines is a set of 'best practice' steps for value transfer. These guidelines identify the basic steps in valuing environmental impacts.

Eftec (2010) Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects, Handbook for the Environment Agency for England and Wales, Eftec, London

This guidance is intended for practitioners in the EA, Internal Drainage Boards, Local Authorities and contracted consultants responsible for the appraisal of FCERM schemes. It focuses specifically on the economic (monetary) value of environmental effects associated with FCERM schemes and is intended to augment the EA FCERM-AG and the Flood Hazard Research Centre (FHRC) „Multi-coloured Manual" and „Handbook" (Penning-Rowsell et al., 2013). Documentation produced under the title "Economic Valuation of Environmental Effects" includes this summary, a Handbook (Parts 1-3) for practitioners with associated annexes featuring case studies and a review of economic value evidence (Part 4) , and a more detailed Technical Report (Part 5) for the interested reader. Originally completed in August 2007, this material has been revised and updated in March 2010 to reflect recent developments in the valuation of the natural environment and ecosystem services. Accessed at http://webarchive.nationalarchives.gov.uk/20140328084622/http://cdn.environment-agency.gov.uk/geho0310bsfh-e-e.pdf on 29.10.124

International and case study focus

Brinkhuis-Jak, M., Holterman, M., Kok, S. Jonkman, S.N. (2004) Cost benefit analysis and flood damage mitigation in the Netherlands, Heron 49(1): 95-11

The aim of this paper is to investigate the application of cost benefit analysis methods in decision-making on a desired flood protection strategy in the Netherlands. After a discussion of history and developments in flood protection in the Netherlands the method of cost benefit analysis is presented as a useful instrument in decision-making. In the second part of the paper the economic analysis of flood protection strategies is firstly approached from a theoretical point of view. Subsequently the economic analyses carried out in practice are described for two more practical cases, the study on "emergency retention areas" and the dike reinforcement program in the

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river system. The paper shows that an economic analysis, when correctly applied, can provide important rational information in the decision-making process.

Brody, S.D., Zahran, S., Highfield, W.E., Grover, H. and Vedlitz, A. (2008) Identifying the impact of the built environment on flood damage in Texas, Disaster, Vol 32, (1), 1-18.

Floods continue to pose the greatest threat to the property and safety of human communities among all natural hazards in the United States. This study examines the relationship between the built environment and flood impacts in Texas, which consistently sustains the most damage from flooding of any other state in the country. Specifically, we calculate property damage resulting from 423 flood events between 1997 and 2001 at the county level. We identify the effect of several built environment measures, including wetland alteration, impervious surface, and dams on reported property damage while controlling for biophysical and socio-economic characteristics. Statistical results suggest that naturally occurring wetlands play a particularly important role in mitigating flood damage. These findings provide guidance to planners and flood managers on how to alleviate most effectively the costly impacts of foods at the community level.

Chadburn, O., Ocharan, J., Kenst, K, and Venton, C. (2010) Cost benefit analysis for community based climate and disaster risk management: synthesis report, August, consulted at
http://www.preventionweb.net/files/14851_FinalCBASynthesisReportAugust2010.pdfon 28/07/14
This is a comprehensive evaluation of the strengths and limitations of cost benefit analysis contributed to by a range of experts from organisations which include Oxfam America, Tearfund, British Red Cross, International Federation of Red Cross and Red Crescent Societies and the Mercy Fund. The synthesis is focused on the application of CBA to community-based initiatives for disaster and climate risk management. Initiatives may be structural or non-structural, hard or soft, but are part of a community driven process for disaster reduction management and are very much bottom-up.

A variety of case studies looking at the impacts, costs and benefits of Community Based Disaster Risk Management (CBDRM) and Climate Change Adaptation (CCA) have been undertaken over recent years. Further, Non-Governmental Organisations (NGOs) and others are beginning to look more closely at the applicability of CBA as a tool to sit alongside existing processes, such as Vulnerability and Capacity Assessment (VCA) and Monitoring and Evaluation Frameworks (M&E), to help project partners examine in greater detail the quantifiable, as well as the more qualitative impacts of their programming.

The aim of this report is to present a synthesis that takes stock of the significant efforts on Cost Benefit Analysis of community based disaster reduction management, reflecting not only on findings, methodological approaches and lessons learned, but also addressing the implications for where and when CBA may be usefully applied at a community level, and pointing to gaps and methodological constraints that could usefully be addressed going forward. A variety of case studies from countries including India, Pakistan, Nepal and Samoa are drawn upon.

The synthesis concludes that there is broad consensus that the CBA process can be useful at a community level but that there is also no doubt that it has its limitations. Among the key issues identified are: (a) the valuation of non-monetary benefits is a significant constraint in applying CBA; (b) a clear understanding of risk is inherent to conducting CBA, and yet the probability of hazard occurrence, and associated impacts, can be very difficult to estimate, particularly when the analysis is taking place at a community level; (c) climate change adds another level of complexity to probabilistic risk modelling; (d) the distribution of benefits from risk reduction is very important from a development perspective, with many projects focusing on the most vulnerable, including women, children, the elderly and disabled: CBA does not traditionally account for distributional impacts; and (e) for backward looking CBAs, the timing of the study with respect to implementation of project interventions can significantly impact on methodology and results.

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Hinkel. J., Lincke, D., Vafeidis, A.T., Perrette, M., Nicholls, R.J., Tol, R.S., Marzeion, B., Fettweis, X., Ionescu, C. and Levermann, A. (2014) Coastal flood damage and adaptation costs under 21st century sea-level rise, Proceedings Natlonal Academy of Science, USA, 111(9), 3292-7. doi: 10.1073/pnas.1222469111. Epub.

Coastal flood damage and adaptation costs under 21st century sea-level rise are assessed on a global scale taking into account a wide range of uncertainties in continental topography data, population data, protection strategies, socioeconomic development and sea-level rise. Uncertainty in global mean and regional sea level was derived from four different climate models from the Coupled Model Intercomparison Project Phase 5, each combined with three land-ice scenarios based on the published range of contributions from ice sheets and glaciers. Without adaptation, 0.2-4.6% of global population is expected to be flooded annually in 2100 under 25-123 cm of global mean sea-level rise, with expected annual losses of 0.3-9.3% of global gross domestic product. Damages of this magnitude are very unlikely to be tolerated by society and adaptation will be widespread. The global costs of protecting the coast with dikes are significant with annual investment and maintenance costs of US$ 12-71 billion in 2100, but much smaller than the global cost of avoided damages even without accounting for indirect costs of damage to regional production supply. Flood damages by the end of this century are much more sensitive to the applied protection strategy than to variations in climate and socioeconomic scenarios as well as in physical data sources (topography and climate model). Our results emphasize the central role of long-term coastal adaptation strategies. These should also take into account that protecting large parts of the developed coast increases the risk of catastrophic consequences in the case of defense failure.

Islam, K.M.N. (2000) Micro and macro level impacts of floods in Bangladesh, In Parker, D.J. (ed) Floods, Vol 1, Chapter 9, 156-171, Routledge, London

The author reviews unit-loss and linkage effect models for assessing flood losses, and develops an economic assessment approach which utilises both. The principal focus is upon inter-sector linkages and flood impacts in the Bangladesh economy. At the micro-level the author presents household flood damage estimates for five different Bangladeshi house types in three types of floods – fluvial (river), flash (pluvial/fluvial) and tidal floods. These damage data are complemented by similar data for industrial properties breaking down damage potential into structure, machinery, stock and primary indirect damages. At the macro-level the author assesses production deviations in agricultural and manufacturing industry from the trend in order to try to identify flood impacts.

Islam, K.M.N. (2004) Assessment Methods and Standard Loss Database for Bangladesh, Flood Loss Potentials in Non-agricultural sectors, Palok Publishers, Dhaka, Bangladesh

This book is the outcome of the author's research undertaken at the Flood Hazard Research Centre, UK. The research has two main components. The first set out to investigate a number of questions. One of the key questions was whether flood loss, assessment methods developed in the advanced countries can be applied in a developing country such as Bangladesh. Another broad question concerned whether the non-agricultural impacts of flooding are important in Bangladesh, given that it continues as an agricultural economy. In particular the study investigates the linkage effects of flooding in the national economy and seeks to identify how important they are. The second component aimed to reveal, conceptualise and categorise various non-agricultural impacts of floods. Different impacts caused by different types of floods (i.e. flash floods, river floods and tidal floods) are examined and thereby a sound knowledge base of the main impacts at the micro and macro scales is constructed. Different mitigation measures are also examined. The author concludes that, with some modifications, the advanced countries impact assessment methods can be applied in a developing country such as Bangladesh. One of the main contributions of the study is the construction of appropriate potential loss data sets from field level surveys and estimates of actual damages. The research assessed the linkages effects of flooding through construction of output multipliers estimated from a national Input-Output table. Unlike in many countries (e.g. the USA) the linkage effects of flooding in industries in Bangladesh appear to be quite high especially in the cotton and textile industries.

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Islam, K.M.N. (2006) Impacts of Flood in Urban Bangladesh. Micro and Macro Level Analysis, A H Development Publishing House, Dhaka, Bangladesh

This book is mainly intended for use by water and regional authorities in order to facilitate the assessment of flood losses at both the micro and macro level in Bangladesh. Knowledge of potential flood damages is expected to contribute towards a rational allocation of resources in a flood-ravaged country. The research on which this book is based investigated households and business and industrial enterprises in three urban areas in Bangladesh. The three urban areas represented different types of flood: major river flood (Tangail), flash flood (Bahubal, Habiganj) and tidal flood (Khatunganj, Chittagoing). Different household impacts are also examined according to different so socio-economic groupings. The study focused upon the 1988 flood in Tangail, the 1993 flash flood in Bahubal and the 1991 tidal surge in Khatunganj). Per household residential flood damages per five different house types are presented for each case study area. Linkage impacts in the economy are also assessed.

Jones, E., Sumner, K. and Gochfeld, M. (2013) Residential Flood Damage After Hurricane Floyd, Mold, Household Remediation, and Respiratory Health, Remediation Journal, Vol 24, Issue 1, 10 10

We conducted a retrospective, cross-sectional study of flooding, mold exposure, remediation, and respiratory symptom prevalence on a random sample of respondents from Bound Brook, New Jersey, a community that received extensive flood damage from Hurricane Floyd in September 1999. Over 3,000 homes were impacted, some with water damage to the second floor. Many required condemnation. In 2001 to 2002 we conducted a randomized telephone survey of 29 families still living in flood-damaged and repaired homes and 18 families who had not experienced flood damage from Floyd. Flood status was the last question on the interview, leaving the interviewer effectively blinded as to status. Flood damage was a strong predictor of mold growth ($p < 0.001$), and there was a strong association between flooding and physician-confirmed respiratory symptoms in the aftermath of the flood (28 of 29 cases vs. 10 of 18 referents; $p < 0.001$). There was also an association between flood status and continued symptom prevalence in the month prior to the interviews (22 of 29 cases vs. 6 of 18 referents; $p < 0.01$). Most flooded homes required removal and replacement of various building materials, which was usually delayed for days or weeks pending re-occupancy. Many occupants participated in the renovation without adequate personal protection. Persons assisting with clean up work were more likely to report five or more symptoms ($p < 0.002$). Smokers with mold damage reported five or more symptoms in the 30 days before the interviews, more frequently than nonsmokers with mold damage. These results are consistent with previous reports of flooding, mold, and illness, but demonstrate that self-remediation of mold (particularly with lack of training and personal protective equipment) and smoking are significant risk factors for mold-related symptoms. Exposure during clean up of moldy materials was a significant contributor to symptoms, and recommendations should include more reliance on professionals and enhanced personal protective equipment.

Khan, D.M., Rahman, S.M.M., Haque, A.K.E., Chen, A.S., Hammond, M.J., Djordjevic, S. and Butler, D. (2013) Flood damage assessment for Dhaka City, Bangladesh, In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 537-545, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

Flood damage assessment is a key component in the development of city flood risk management strategies. A flood damage assessment model is being developed by combining flood hazard information (depth, extent, velocity, duration, etc.) with geographic information (land use/cover, buildings, infrastructure, etc.), social-economic data and population demographics to estimate urban flood impacts. In this paper, Dhaka city is adopted to demonstrate the approach for damage modeling. Analysis shows that coarse resolution modeling in such a densely developed urban area can lead to either over- or underestimation of the flood damage, depending on the thresholds to distinguish building and non-building cells in modeling. Increased accuracy can be achieved by fine resolution modeling but this would lead to large data sets that require long computational times. The paper demonstrates some key issues for damage assessment using advanced technology for a City like Dhaka.

Kazama, S., Sato, A., and Kawagoe, S. (2009) Evaluating the cost of flood damage based on changes in extreme rainfall in Japan, Sustainability Science, Vol 4, (1), 61-69

We estimated the cost of flood damage using numerical simulations based on digital map data and the flood

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control economy investigation manual submitted by the Ministry of Land, Infrastructure... , Transportation, and Tourism in Japan. The simulation was carried out using a flood model incorporating representative precipitation data for all of Japan. The economic predictions, which estimate flood... damage caused by extreme rainfall for the return periods of 5, 10, 30 50, and 100 years, are as follows: (1) the cost of flood damage increases nearly linearly with increases in extreme precipitation; (2... and assuming that flood control infrastructures will be completed within the 50-year return period and will be able to protect from flooding with a 50-year return period; (4) urban and rural areas are predicted to suffer high and low costs of damage, respectively. These findings will help to derive measures to enhance flood protection resulting from climate change. Assuming that flood protection is completed for a 50-year return period of extreme rainfall, the benefit of flood protection for a 100-year return period of rainfall is estimated to be 210 billion.

Kowalewski, I. and Ujeyl, G. (2013) Estimating direct and indirect damages from storm surges: The case of Wilhelmsburg/Hamburg. In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 568-584, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

This paper estimates the economic costs from a storm surge scenario in the city of Hamburg. It combines hydrodynamic simulations and damage models, which are used for the assessment of direct damages to residential and commercial buildings and equipment, and an economic model accounting for the indirect impacts due to the interruption of production processes. Thus, a large part of total economic costs from flooding are captured in the presented result. The approach is constitutes a helpful tool to assess the potential damages from storm flood scenarios on the city scale and, thus, the effectiveness of possible protection measures.

Middelmann-Fernandes, M.H. (2010) Flood damage estimation beyond stage–damage functions: an Australian example, Journal of Flood Risk Management, Vol 3, Issue 1, 88–96

A number of factors influence the direct consequence of flooding. The most important are depth of inundation, velocity, duration of inundation and water quality and the interaction of these factors with human society. Although computer modelling techniques exist that can provide an estimate of these variables, this information is seldom used to estimate the impact of flooding on a community. This work describes the first step to improve this situation using data collected for the Swan River system in Perth, Western Australia. Here, it is shown that residential losses are underestimated when stage–damage functions or the velocity–stage–damage functions are used in isolation. This is because the functions are either limited to assessing partial damage or structural failure resulting from the movement of a house from its foundations. This demonstrates the need to use a combination of techniques to assess the direct cost of flooding.

Miller, A., Jonkman, S.N. and van Ledden, M. (2013) Risk to life due to flooding in post-Katrina New Orleans, In Klijn, F. and Schweckendiek, T. (eds), Comprehensive Flood Risk Management, 547-556, Taylor and Francis Group, London, ISBN 978-0-415-62144-1

After the catastrophic flooding of New Orleans due to hurricane Katrina in the year 2005, the city's hurricane protection system has been improved to provide protection against storms with at least a 100 year return period. The aim of this article is to investigate the risk to life in the post-Katrina situation for the New Orleans metro bowl. In a risk-based approach the probabilities and consequences of various flood scenarios have been analysed to estimate the risk to life. A two-dimensional hydrodynamic model has been used to simulate flood characteristics. Results indicate that - depending on the flood scenario - the estimated loss of life in case of flooding ranges from about 100 to nearly 500. The highest life loss value is found for breaching of the river levees. Probability and consequence estimates are combined to evaluate the individual risk and societal risk for New Orleans. When compared to risks of other large scale engineering systems (e.g. other flood prone areas, dams and the nuclear sector) and acceptable risk criteria found in literature, the evaluated risk exceeds acceptable risk levels. Thus despite major improvements to the flood protection system, the flood risk of post-Katrina New Orleans is expected to be significant. Effects of risk reduction strategies on the risk level are investigated to assist in providing bases for decision making. Results indicate the necessity of further discussion regarding the management and reduction of the city's risk to flooding.

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Li, Z., Wu, L., Yu, J., Wang, Z. and Liu, C. (2010) GIS-based Rapid Loss Assessment on Flood Disaster: June 21 Flood of Fuhe Basin, Information Science and Engineering (ICISE), 2010 2nd International Conference, 6642 – 6645, 4-6 Dec., IEEE, Hangzhou, China. DOI: 10.1109/ICISE.2010.5691248

In consideration of the serious loss of floods in our country, this paper established the method for assessing the water depth and duration of flood referring to the venerability curve of hazard bearing body, based on the concept of rapid flood loss assessment and from the perspective of regional disaster system theory. A model of rapid assessment on the loss of hazard bearing body was set up. The method for assessment of induced factor was established after analyzing the data acquirability. The venerability curves of hazard bearing bodies were summarized, and then models for rapid assessing the hazard bearing bodies were built up using the overlay method of GIS. Taking the "6•21" flood of Fuhe basin as an example, this paper assessed the loss of crops, the damage of buildings and the affected population. The assessment results are basically in accordance with the reported data from investigation.

Liu, R.1. and Liu, N. (2002) Flood area and damage estimation in Zhejiang, China, Journal of Environmental Management, Vol 66, (1), 1-8

A GIS-based method to estimate flood area and damage is presented in this paper, which is oriented to developing countries like China, where labour is readily available for GIS data collecting, and tools such as, HEC-GeoRAS might not be readily available. At present local authorities in developing countries are often not predisposed to pay for commercial GIS platforms. To calculate flood area, two cases, non-source flood and source flood, are distinguished and a seed-spread algorithm suitable for source-flooding is described. The flood damage estimation is calculated in raster format by overlaying the flood area range with thematic maps and relating this to other socioeconomic data. Several measures used to improve the geometric accuracy and computing efficiency are presented. The management issues related to the application of this method, including the cost-effectiveness of approximate method in practice and supplementing two technical lines (self-programming and adopting commercial GIS software) to each other, are also discussed. The applications show that this approach has practical significance to flood fighting and control in developing countries like China.

Nascimento, N., Machado, M., Baptista, M. and De Paula E Silva, A. (2007) The assessment of damage caused by floods in the Brazilian context, Urban Water Journal, Vol 4, 3, 195-210

The present paper describes theoretical aspects and the main results on the development of a methodology for the global evaluation of direct damage caused by floods. This methodology is based on the use of standard flood damage curves versus depth of inundation on dwelling, commerce and service sectors. The research was developed based on field surveys in the city of Itajubá, located in the valley of the Sapucaí River, in Minas Gerais state in the southeast region of Brazil. In January 2000, this city suffered severe floods where more of 70% of the urban area was affected; with depths of inundation higher than 3 m in certain areas. The empirical data were obtained through questionnaires applied in the ravaged area in 2002. The questionnaires allowed the characterization of the dwellings and their content, as well as the different categories on commercial and service activities. The generic curves obtained from the data in the survey were used at the same site to evaluate the amount of potential flood damage in relation to different hydrologic risks.

Parker, D. J., Islam, N. K. M. and Chan, N. W. (1997) Reducing vulnerability following flood disasters: issues and practices, in Awotona, A (Ed) Reconstruction after disaster: issues and practices, Chapter 3, Ashgate, Vermont, USA, 23-44, ISBN 1 85972 551 1

This chapter examines flood impacts within the context of reconstruction in the developing world. Primary, secondary and multiplier impacts examined together with the factors that breed different types of vulnerability to flood hazards. Urban flood damage values for five different house types commonly found in Bangladesh are provided for river floods, flash floods and tidal floods. Building materials have a key effect on flood damage potential. The chapter goes on to look at the potential in benefits of residential flood proofing in the New Territories of Hong Kong.

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Parker, D. and Thompson, P. (2000) Floods in Africa: Vulnerability, Impacts and Mitigation. In Parker, D. (ed.) Floods, 188-203, London, Routledge

This chapter provides a general overview of the kinds of flood impacts, and thus potential benefits of flood alleviation, in the African continent. Anyone wishing to draw up a list of potential benefits for further investigation is likely to find this chapter generally useful. The chapter examines the causes and types of floods and associated hazards in the African continent as well as the important role of floodplains, identifying the major floodplains. The vulnerable state of African societies is a major contributory factor to the hazard as is environmental degradation. The recorded impacts of a range of floods between 1976 and 1990 are tabulated. Floods frequently cause homelessness and infrastructure disruption as well as food shortages. They also have major impacts upon human health. The acute effects of floods, including mortality are discussed as well as the long term effects and secondary exposures and effects. Mitigation and preparedness measures are explored focusing upon reducing infrastructure vulnerability, compensation for flood-induced food shortages and ways of reducing health impacts.

Penning-Rowsell, E.C, Haigh, N., Lavery, S. and McFadden, L. (2013) A threatened world city: the benefits of protecting London from the sea, Natural Hazards, 66, 1383–1404, DOI 10.1007/s11069-011-0075-3

This paper describes the options appraisal undertaken in the UK within the major TE2100 project to investigate the future of protecting London from flooding from the sea. An economic analysis, within a Benefit-Cost framework complemented by Multi-Criteria Analysis, shows that improving the existing flood defences and, in 2070, constructing a new Thames Barrier downstream of the existing one are the "front runner" options for addressing the increase in flood risk that is anticipated in the future. Both sensitivity and scenario analysis have little effect on option choice. Inevitably uncertainties remain, however, when looking so far ahead but it is clear that continuing to protect this area from the sea is highly cost-beneficial. Also the very high standard of protection now, and the robustness of the existing flood defences, mean that major new interventions will not be required form some time (i.e. until c. 2070). There is therefore time to monitor the situation, carefully plan measures to maintain and enhance the existing defences, and to seek to restrain the growth of risk in the estuary and in London through carefully-designed and implemented resilience-building flood plain management measures. Rather than having to rush to new engineering works, because what is needed has not been anticipated but being forced to respond hastily to a "crisis" situation, the adaptive approach that is now possible is a key legacy of the TE2100 project.

Shabman, L., Stephenson, K., Thunberg, E. and Dietz, B. (1998) Comparing benefit estimation techniques: residential flood hazard reduction benefits in Roanoke, Virginia March, IWR Report 98-R-2, for U.S. Army Corps of Engineers, Institute for Water Resources, Alexandria, VA

The purpose of this research project was to evaluate the differences and potential strengths and weaknesses of different methods for evaluating consumers' willingness to pay for a public good, i.e., a flood hazard reduction project. Three methods are compared and contrasted both collectively and against the theory of revealed consumer preference. These are the Property Damages Avoided (PDA) approach, Hedonic Price Method (Land Price Analysis), and the **Contingent Value Method** (CVM). The report consists of nine sections, a bibliography, and two appendices. The sections provide historical and other situational background information on the location of the proposed project, an overview of the revealed preference approach and P&G guidance for evaluating willingness to pay, a detailed description of each method and its application in the study, and the resulting findings. The first appendix displays the contingent valuation survey forms and procedures used, while the second appendix presents the questions asked to subject consumers of the study concerning a bond referendum to pay for the proposed project.

Suriya, S., Mudgal, B.V. and Nelliyat, P. (2012) Flood damage assessment of an urban area in Chennai, India, part I: methodology, Natural Hazards, Vol.62 (2), 149-158

This paper is Part I of a two-part series in which the objectives and methodology are discussed in Part 1 and results are discussed in Part 2. Based on the objectives and methodology developed for the study, a

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comprehensive flood management strategy is evaluated. This paper focuses on flood damage assessment of an urban area in Chennai, India and explores the economic loss through social investigation in Velachery, a part of urban Chennai.

Tang, J.C.S., Vongvisessomjai, S. and K. Sahasakmontri (1992) Estimation of Flood Damage Cost for Bangkok, Water Resources Management 6: 47-56

Bangkok, located on a low lying alluvial deposit, is flooded almost every year by tide, river
flow, and direct precipitation. Due to land subsidence caused by pumping of groundwater, the flooding is now more severe and more frequent than ever before. Various proposals have been presented to alleviate the flooding; however, selection of these alternatives would require cost-benefit analysis. The objective of this research is to estimate the cost of flood damage by first estimating the flood damage cost function in terms of depth and duration using the multiple regression analysis technique. In the case of Bangkok, results indicate that flood depth and flood duration are significant factors explaining flood damage in the residential and industrial areas. On the other hand, only flood depth was found to be an important factor affecting damage to the commercial and agricultural areas. The estimated cost functions served as a useful aid in the systematic computation of flood damage for 1983 which amounted to over 7.8 billion baht (US$1.00 ~-- baht 25.5).

United Nations Serbia and World Bank Group (2014) Serbia floods 2014, Belgrade

This is a most comprehensive assessment of the effects of the 2014 floods in Serbia. The Government of the Republic of Serbia conducted a post-disaster needs assessment after the floods and landslides that occurred at the end of May 2014. The European Union, the United Nations and the World Bank – on the basis of an inter-agency agreement subscribed in 2008 – provided financial and expert support to conduct the assessment. The assessment enabled to estimate disaster effects – damages and losses – and impacts as well as the financial requirements to undertake recovery and reconstruction. More than 14 sectors of social and economic activity and cross-cutting issues were analysed during the assessment. The process of assessment was initiated on 9 June and was completed by July 10, 2014, thus lasting a total of 5 weeks. The methodology for assessment that was utilised involves collecting available secondary information from different Government and private sources, verified and supplemented by field visits by the assessment teams, to estimate the value and extent of physical assets destroyed and the changes in production flows of all affected activities. A total of 24 municipalities were included in the assessment, which represent the most affected geopolitical subdivisions, as defined by the Government and extrapolations were later on conducted to expand the estimations to other, less affected localities. In addition to the field visits, special sample surveys of formal and informal industrial and commercial establishments were conducted to obtain first-hand information on damage, losses and needs, as well as to estimate the possible impact of the disaster on livelihoods, employment and income losses of the labour force.

The assessment revealed that the total effects of the disaster in the 24 affected municipalities amounts to EUR 1,525 million, of which EUR 885 million (57% of the total effects) represent the value of destroyed physical assets, and EUR 640 million (43% of the total) refer to losses in production. When considering the additional affected municipalities, the total value of disaster effects would rise to EUR 1.7 billion .It was found that total disaster effects were concentrated mostly in productive activities (EUR 1,070 million and 70% of the total), social services (EUR 242 million and 16%), and infrastructure (EUR 192 million and 12%); thus, disaster impact was highest in terms of production and access to social services, than in regard to destruction of infrastructures. The concentration of disaster effects on productive activities of agriculture, trade and industry and of damages to housing will generate a negative bearing on economic growth with a corresponding subsequent impact on livelihoods, income and employment, plus a significant decline in living conditions of the population. In addition, the high destruction that occurred in the mining sector will demand the search for alternative sources of energy and electricity. An analysis of the macro-economic impact reveals that the disaster will lead Serbia into an economic recession; real economic growth will decline by 0.5% in 2014, instead of the expected 0.5% positive growth forecasted before the disaster. At the personal level, it has been estimated that about 51,800 jobs would be temporarily lost because of interruption of productive activities in the affected municipalities, and the income of households would decline proportionally. This negative impact on livelihoods and employment would be more acute in the case of poor families, including Roma and persons with disabilities, who are more vulnerable to disasters. Women are doubly affected: in addition to sustaining livelihood losses, they have had to increase

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the non-paid time they devote to take care of their family. The human development index (HDI) in Serbia would sustain a decline in 2014 because of the combination of income decline and of access to education and health services, losing about two years´ worth of growth. Financial requirements have been estimated for all sectors of social and economic activities, under both public and private domains, to ensure the recovery of personal income, access to basic services, production levels in agriculture, industry, trade and mining, as well as of the environment, together with the needs to rebuild destroyed assets following disaster-resilient standards. Post-disaster needs were valued at EUR 1,346 million, of which EUR 403 million (30% of the total) refers to recovery activities, and EUR 943 million (70%) are reconstruction needs.

Wagemaker, J., Leenders, J. and Huizinga, J. (undated) Economic valuation of flood damage for decision makers in the Netherlands and the Lower Mekong river basin

Economic activities in flood-prone areas are increasing around the world. At the same time we face changing weather conditions and a rising sea level as a result of climatic change. If no measures are carried out both probability and impact of floods will increase severely. In the Netherlands flood hazard and flood damage are combined in a risk-approach using a cost-benefit analysis for proposed measures. In this approach, risk is defined as the probability of flooding and impact of flooding. Could this approach also be applied in the Lower Mekong river basin? As far as flood damage is concerned one can imagine the flood damage for instance in Chiang Rai in Thailand has other characteristics than a given polder in the Netherlands. One can also imagine that decision-makers in the Lower Mekong would make different choices about how to evaluate flood damage compared with their counterparts in the Netherlands. This paper presents some considerations on how the Dutch damage assessment tool 'Hoogwater Informatie System – Schade en Slachtoffermodule (HIS-SSM) and its underlying economic evaluation model may be adjusted to serve the preferences of decision makers in the Lower Mekong river system. It first discusses various economic valuation techniques that are available to determine flood damage and the role of the decision maker Next the backgrounds on risk analysis and cost-benefit analysis in the Netherlands are described and opportunities and limitations of such an approach being used in the Lower Mekong are discussed. Finally, reference is made of a pilot model where the applicability of the Dutch approach is assessed.
http://www.hkv.nl/site/hkv/upload/publication/Economic_Valuation_Flood_Damage_WEBSITE_JW_JL_JH.pdf
accessed on 28.10.14

Multi-criteria analysis

General, overview and theory

Belton V. and Stewart, T.J. (2002) Multiple Criteria Decision Analysis: An Integrated Approach, Kluwer Academic Publishers, Boston

The field of multiple criteria decision analysis (MCDA), also termed multiple criteria decision aid, or multiple criteria decision making (MCDM), has developed rapidly over the past quarter century and in the process a number of divergent schools of thought have emerged. This can make it difficult for a new entrant into the field to develop a comprehensive appreciation of the range of tools and approaches which are available to assist decision makers in dealing with the ever-present difficulties of seeking compromise or consensus between conflicting interests and goals, i.e. the "multiple criteria". The diversity of philosophies and models makes it equally difficult for potential users of MCDA, i.e. management scientists and/or decision makers facing problems involving conflicting goals, to gain a clear understanding of which methodologies are appropriate to their particular context. Our intention in writing this book has been to provide a comprehensive yet widely accessible overview of the main streams of thought within MCDA. We aim to provide readers with sufficient awareness of the underlying philosophies and theories, understanding of the practical details of the methods, and insight into practice to enable them to implement any of the approaches in an informed manner. As the title of the book indicates, our emphasis is on developing an integrated view of MCDA, which we perceive to incorporate both integration of different schools of thought within MCDA, and integration of MCDA with broader management theory, science and practice.

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Department for Communities and Local Government (1999) Multi-criteria analysis: a manual, DCLG, London

Since 2000 it has become more widely recognised in government that, where quantities can be valued in monetary terms, MCA is not a substitute for cost-benefit analysis, but it may be a complement; and that MCA techniques are diverse in both the kinds of problem that they address (for example prioritisation of programmes as well as single option selection) and in the techniques that they employ, ranging from decision conferencing to less resource intensive processes. This manual provides guidance for Government officials and other practitioners on how to undertake and make the best use of multi-criteria analysis (MCA) for the appraisal of options for policy and other decisions, including but not limited to those having implications for the environment. It covers a range of techniques which can be of practical value to public decision makers and are increasingly being used in the UK and in other countries. They are described in this manual as multi-criteria analysis (MCA) techniques. The manual is about techniques which do not necessarily rely on monetary valuations. It therefore complements guidance on those techniques which primarily use monetary valuations, namely financial analysis, cost effectiveness analysis (CEA, and cost-benefit analysis (CBA). These monetary techniques have been extensively used in UK government circles, and are the subject of a number of guides and manuals. One source of confusion to those new to the field is the variety of different techniques, often with rather similar sounding titles, that appear to be
available, such as multi-criteria decision analysis, multi-attribute utility theory, the analytic hierarchy process, and fuzzy set theory. The manual outlines the relationships between the different techniques and indicates the ones which can yield the most fruitful applications, in contrast to those which may be of theoretical interest but little practical value. Chapter 6 shows how to undertake a full multi-criteria decision analysis by involving scoring of each option on each criterion, and then combining the scores by means of a system of weights to yield an overall ranking for each option. Chapter 7 provides some case studies.

Department for Environment, Food and Rural Affairs and Environment Agency (2004) Evaluating a multi-criteria analysis (MCA) methodology for application to flood management and coastal defence appraisals Case studies report, Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme R&D Project Record FD2013/PR1, Risk and Policy Analysts Ltd (RPA), Defra, London

This case study report sets out the work undertaken to develop the MCA-based methodology, its application to two sets of case studies and the implications of the research findings for the production of guidelines for the application of the methodology. The intention of the case studies was to test the methodology to answer two different questions: (a) does the methodology provide information in a format that can be used to inform a range of different decisions? and (b) does the methodology have added value over current approaches, i.e. would it help ensure that decisions are more robust and sustainable and/or can it help to take the views of all stakeholders into account such that conflicts that have arisen can be addressed specifically in the assessment? This report constitutes one of the two milestones identified for the second phase of the MCA project. A second report 'guidelines for the implementation of the MCA-based methodology for flood defence and coastal management' runs in parallel and complements this case study report.

Flood Hazard Research Centre/Risk and Policy Analysis Ltd (2002) Multi-Criteria Analysis in the Context of Flood and Coastal Defence – Scoping Report, Report prepared for the Environment Agency, Bristol

Cost-benefit analysis (CBA) for flood management and coastal defence is well established but there
is growing concern that it fails to take full account of social and environmental factors. One method of including these impacts is by using a MCA approach. A scoping study was therefore undertaken in 2001/02 to look at the existing appraisal and decision framework and whether the use of a MCA approach would be appropriate and acceptable. The conclusion from this study was that flood management and coastal defence appraisal needed the 'best of both worlds'. Any method should retain the rigour of CBA, particularly in regard to demonstrating that the chosen option is a good use of resources, but should also provide a framework within which social and environmental issues can be more explicitly included in the decision-making process.

Greco, S (Ed) (2005) Multiple Criteria Decision Analysis: State of the Art Surveys, Springer, London

State of the Art Surveys is the most comprehensive work available to survey the state of the art in MCDA to date.

Its 24 chapters are organized in eight parts and are written by 49 international leading experts. Each of these parts covers one of the central streams of multiple criteria decision analysis literature. These literature streams are: MCDA today, Foundations of MCDA, Outranking Methods, Multi-attribute Utility Theory, Non-Classical MCDA Approaches, Multi-objective Mathematical Programming, Applications, and MCDM Software.

The handbook presents the most up-to-date discussions on well-established methodologies and theories in the field, while systematically surveying emerging fields in MCDA such as conjoint measurement, fuzzy preferences, fuzzy integrals, rough sets, etc. MULTIPLE CRITERIA DECISION ANALYSIS is a valuable reference volume (more than 2000 references) for the field of decision analysis. It provides graduate students, researchers, and practitioners with a sweeping survey of MCDA theory, methodologies, and applications. It is a handbook that is particularly suitable for use in seminars in Decision Analysis, Decision Support, and Decision Theory.

Huanga, I., Keisler, J. and Linkov, I. (2011) Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends, Science of The Total Environment, Vol 409, Issue 19, 3578–3594

Decision-making in environmental projects requires consideration of trade-offs between socio-political, environmental, and economic impacts and is often complicated by various stakeholder views. Multi-criteria decision analysis (MCDA) emerged as a formal methodology to face available technical information and stakeholder values to support decisions in many fields and can be especially valuable in environmental decision making. This study reviews environmental applications of MCDA. Over 300 papers published between 2000 and 2009 reporting MCDA applications in the environmental field were identified through a series of queries in the Web of Science database. The papers were classified by their environmental application area, decision or intervention type. In addition, the papers were also classified by the MCDA methods used in the analysis (analytic hierarchy process, multi-attribute utility theory, and outranking). The results suggest that there is a significant growth in environmental applications of MCDA over the last decade across all environmental application areas. Multiple MCDA tools have been successfully used for environmental applications. Even though the use of the specific methods and tools varies in different application areas and geographic regions, our review of a few papers where several methods were used in parallel with the same problem indicates that recommended course of action does not vary significantly with the method applied.

Köksalan, M., Wallenius, J. and Zionts, S. (2013) An Early History of Multiple Criteria Decision Making, Journal of Multi-Criteria Decision Analysis, Vol 20, Issue 1-2, pages 87–94, January-April Water management (ISSN 1741-7589) Vol., 161, No.5 261-266

A useful discussion of the origins and early history of multi-criteria decision analysis and its disciplinary roots.

Mendoza, G. A. and Martins, H. Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms, Forest Ecology and Management, Vol 230, Issues 1–3, 1–22

Multi-criteria decision analysis (MCDA) is an umbrella approach that has been applied to a wide range of natural resource management situations. This paper has two purposes. First, it aims to provide a critical review of MCDA methods applied to forest and other natural resource management. The review seeks to layout the nature of the models, their inherent strengths and limitations. Models are categorized based on different classification schemes and are reviewed by describing their general characteristics, approaches, and fundamental properties. The review goes beyond traditional MCDA techniques; it describes new modelling approaches to forest management. The second purpose is to describe new MCDA paradigms aimed at addressing the inherent complexity of managing forest ecosystems, particularly with respect to multiple criteria, multi-stakeholders, and lack of information. Comments about, and critical analysis of, the limitations of traditional models are made to point out the need for, and propose a call to, a new way of thinking about MCDA as they are applied to forest and natural resource management planning. These new perspectives do not undermine the value of traditional methods; rather they point to a shift in emphasis—from methods for problem solving to methods for problem structuring.

Montibeller, G. (2005) From (and To) a New Generation of Multi-Criteria Decision Analysts: An Introduction to the Field and a Personal View on its Future, in Meyer E (Ed.) (2005) Keynote Papers – YOR 14 Conference, University of Bath, 4-6 April, Birmingham: The Operational Research Society (ISBN 0 903440 33 4) accessed at http://personal.lse.ac.uk/MONTIBEL/YOR14_Decision%20Analysis.pdf on 31.10.14

An interesting article which informs about the development of Multi-Criteria Decision Analysis (MCDA) and which should be of interest to those considering applying it to flood risk management. MCDA is now considered to be mature, with several well-developed methodologies, a growing number of real world interventions and a strong society that joins together researchers and practitioners all over the world. We believe that a new generation of multi-criteria decision analysts is emerging – interested in doing research and/or employing MCDA methodologies into practice – and also hope that, somehow, we could engage even more people in forming this new generation. It is within this scene that the paper was conceptualised. It has a dual aim of i) introducing the field to "young" researchers and practitioners, which may be interested in further developing MCDA methodologies, applying them into practice, or combining them with other decision methods; and ii) reflecting on potential further developments of the field that may be pursued by this new generation.

Triantaphyllou, E. (2000) Multi-criteria decision making methods: a comparative study, Springer, US, ISBN 0792366077, 9780792366072

Multi-Criteria Decision Making (MCDM) has been one of the fastest growing problem areas in many disciplines. The central problem is how to evaluate a set of alternatives in terms of a number of criteria. Although this problem is very relevant in practice, there are few methods available and their quality is hard to determine. Thus, the question `Which is the best method for a given problem?' has become one of the most important and challenging ones. This is exactly what this book has as its focus and why it is important. The author extensively compares, both theoretically and empirically, real-life MCDM issues and makes the reader aware of quite a number of surprising `abnormalities' with some of these methods. What makes this book so valuable and different is that even though the analyses are rigorous, the results can be understood even by the non-specialist. The audience for this book includes researchers, practitioners, and students; and it can be used as a textbook for senior undergraduate or graduate courses in business and engineering.

Flood impacts and coastal defence

Ball, T., Black, A., Ellis, R., Hemsley, L., Hollebrandse, F., Lardet, P. and Wicks, J. (2012) A new methodology to assess the benefits of flood warning, Journal of Flood Risk Management, Vol 5, Issue 3, 188–202

A new assessment methodology is presented for the benefits of flood warning that applies both tangible and intangible benefits from warning generation and dissemination using a multi-criteria analysis (MCA). The resulting decision support tool allows benefits to be scored transparently, reinforced by Geographical Information System (GIS) procedures. A wide range of benefits are scored including: protection of key infrastructure, avoided social impacts, timely operation of flood defences and avoided risks to life from the flood hazard. Pilot testing on some 22 sites at a variety of scales (catchments and flood warning areas) showed that the method works effectively when making 'like for like' comparisons, considering a wholly new system for large catchments, or upgrades to warning and dissemination systems in sub-catchment flood warning areas. The methodology promotes consultation and data interchange between the warning organisation and end-users in order to prioritise particular areas of need for new or improved systems.

Chitsaz, N. and Banihabib, M. E. (2015), Comparison of Different Multi Criteria Decision-Making Models in Prioritizing Flood Management Alternatives, Water Resources Management, Vol 29, 8, 2503-2525

Recent increases in life loss, destruction and property damages caused by flood at global scale, have inevitably highlighted the pivotal considerations of sustainable development through flood risk management. Throughout the paper, a practical framework to prioritize the flood risk management alternatives for Gorganrood River in Iran was applied. Comparison between multi criteria decision making (MCDM) models with different computational mechanisms provided an opportunity to obtain the most conclusive model. Non-parametric stochastic tests, aggregation models and sensitivity analysis were employed to investigate the most suitable ranking model for the case study. The outcomes of these mentioned tools illustrated that ELimination and Et Choice Translating Reality (ELECTRE III), a non-compensatory model, stood superior to the others. Moreover, Eigen-vector's performance for assigning weights to the criteria was proved by the application of Kendall Tau Correlation Coefficient Test. From the technical point of view, the highest priority among the criteria belonged to a social criteria named Expected

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Average Number of Casualties per year. Furthermore, an alternative with pre and post disaster effectiveness was determined as the top-rank measure. This alternative constituted flood insurance plus flood warning system. The present research illustrated that ELECTRE III could deal with the complexity of flood management criteria. Hence, this MCDM model would be an effective tool for dealing with complex prioritization issues.

Hall, J. and Solomatineb, D. (2008) A framework for uncertainty analysis in flood risk management decisions, International Journal of River Basin Management, Vol 6, Issue 2, accessed at http://www.tandfonline.com/doi/abs/10.1080/15715124.2008.9635339#.VFPbMvmsXtU on 31.10.14

Modern flood risk management involves responding sustainably to flood risk with portfolios of structural and non-structural measures. Under these circumstances of multi-attribute choice between portfolios of options, the motivation for uncertainty analysis becomes more compelling than ever. Uncertainty analysis is required in order to understand the implications for decision makers of limited data, model uncertainties, changes in the flooding system over the long term, incommensurate scales of appraisal and potentially conflicting decision objectives. In recognition of the importance of uncertainty analysis as an integral aspect of sustainable flood risk management, a new framework for uncertainty analysis within flood risk management decisions has been established. The proliferation of methods for uncertainty analysis can be placed within the coherent framework. As well as estimating the amount of uncertainty associated with key decision variables, the framework supports the decision making process by identifying the most influential sources of uncertainty, and the implications of uncertainty for the preference ordering between options. The challenges posed by severe uncertainty about the potential for long term changes in the flooding system are discussed and robustness analysis is advocated in response to these uncertainties.

Jonkman, S. N., Jongejan, R. and Maaskant, B. (2011) The use of individual and societal risk criteria within the Dutch flood safety policy - nationwide estimates of societal risk and policy applications, Risk Analysis, Vol.31 (2), 282-300

The Dutch government is in the process of revising its flood safety policy. The current safety standards for flood defences in the Netherlands are largely based on the outcomes of cost-benefit analyses. Loss of life has not been considered separately in the choice for current standards. This article presents the results of a research project that evaluated the potential roles of two risk metrics, individual and societal risk, to support decision making about new flood safety standards. These risk metrics are already used in the Dutch major hazards policy for the evaluation of risks to the public. Individual risk concerns the annual probability of death of a person. Societal risk concerns the probability of an event with many fatalities. Technical aspects of the use of individual and societal risk metrics in flood risk assessments as well as policy implications are discussed. Preliminary estimates of nationwide levels of societal risk are presented. Societal risk levels appear relatively high in the south western part of the country where densely populated dike rings are threatened by a combination of river and coastal floods. It was found that cumulation, the simultaneous flooding of multiple dike rings during a single flood event, has significant impact on the national level of societal risk. Options for the application of the individual and societal risk in the new flood safety policy are presented and discussed.

Kabir, G., Rehan, S. and Tesfamariam, (2014) S. A review of multi-criteria decision-making methods for infrastructure management, Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance, Vol 10, Issue 9, 1176–1210

In infrastructure management, multi-criteria decision-making (MCDM) has emerged as a decision support tool to integrate various technical information and stakeholder values. Different MCDM techniques and tools have been developed. This paper presents a comprehensive review on the application of MCDM literature in the field of infrastructure management. Approximately 300 published papers were identified that report MCDM applications in the field of infrastructure management during 1980–2012. The reviewed papers are classified into application to the type of infrastructure (e.g. bridges and pipes), and prevalent decision or intervention (e.g. repair and rehabilitate). In addition, the papers were also classified according to MCDM methods used in the analysis. The paper provides taxonomy of those articles and identifies trends and new developments in MCDM methods. The results suggest that there is a significant growth in MCDM applications in infrastructure management applications of MCDM over the last decade. It has also been noted that many decision support tools based on multiple MCDM

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methods have been successfully used for infrastructure management.

Kubal, C., Haase,D., Meyer, V, and Scheuer, S (2009) Integrated urban flood risk assessment – adapting a multicriteria approach to a city, Nat. Hazards Earth Syst. Sci., 9, 1881-1895

Flood risk assessment is an essential part of flood risk management. As part of the new EU flood directive it is becoming increasingly more popular in European flood policy. Particularly cities with a high concentration of people and goods are vulnerable to floods. This paper introduces the adaptation of a novel method of multicriteria flood risk assessment, that was recently developed for the more rural Mulde river basin, to a city. The study site is Leipzig, Germany. The "urban" approach includes a specific urban-type set of economic, social and ecological flood risk criteria, which focus on urban issues: population and vulnerable groups, differentiated residential land use classes, areas with social and health care but also ecological indicators such as recreational urban green spaces. These criteria are integrated using a "multicriteria decision rule" based on an additive weighting procedure which is implemented into the software tool *FloodCalc urban*. Based on different weighting sets we provide evidence of where the most flood-prone areas are located in a city. Furthermore, we can show that with an increasing inundation extent it is both the social and the economic risks that strongly increase.

Karin Hansson, K., Larsson, A., Danielson, M., and Ekenberg, L. (2011) Coping with Complex Environmental and Societal Flood Risk Management Decisions: An Integrated Multi-criteria Framework, Sustainability, 3, 1357-1380; doi:10.3390/su3091357

An integrated water resource management approach would be beneficial in order to take both the best interests of society and of the environment into consideration. One improvement consists of models capable of handling multiple criteria (conflicting objectives) as well as multiple stakeholders (conflicting interests). A systems approach is applied for coping with complex environmental and societal risk management decisions with respect to flood catastrophe policy formation, wherein the emphasis is on computer-based modelling and simulation techniques combined with methods for evaluating strategies where numerous stakeholders are incorporated in the process. The resulting framework consists of a simulation model, a decision analytical tool, and a set of suggested policy strategies for policy formulation. The framework will aid decision makers with high risk complex environmental decisions subject to significant uncertainties.

Kenyon, W. (2007) Evaluating flood risk management options in Scotland: a participant-led multi-criteria approach, Ecological Economics, Vol 64, 70-81

The characteristics of flood risk management include complexity, large spatial scales, inter-temporal issues, plural values and conflicts of interests. It is argued that issues with such characteristics require public participation in the decision making process. This study builds on existing deliberative processes to develop a new participant-led multi-criteria method to evaluate flood risk management options in Scotland. The results show that participants preferred regeneration or planting of native woodland to other flood management options, and least preferred building flood walls and embankments. The design of the workshops allowed a rich dataset to reveal the thinking behind such results and provided a deeper understanding of why participants came to these conclusions.

Levy, J. (2005) Multiple criteria decision making and decision support systems for flood risk management, Stochastic Environmental Research Risk Assessment, 19, 438-447

Multiple criteria decision making (MCDM) is a collection of methodologies to compare, select or rank multiple alternatives that typically involve incommensurate attributes. MCDM is well-suited for eliciting and modelling the flood preferences of stakeholders and for improving coordination among flood agencies, organisation and affected citizens. A flood decision support system (DSS) architecture is put forth that integrates the latest advances in MCDM, remote sensing, GIS, hydrologic models, and real-time flood information systems. The analytic network process (APN) is discussed with application to short-term flood management options for the middle reaches of the Yangtze River. It is shown that DSS and MCDM can improve flood risk planning and management under uncertainty by providing data displays, analytical results and model output to summarise critical flood information.

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Meyer, V., Haase, D. and Scheuer, S. (2007) : GIS-based multi-criteria analysis as decision support in flood risk management, UFZ-Diskussionspapiere, No. 6/2007

In this report a GIS-based multicriteria flood risk assessment and mapping approach is developed. This approach has the ability a) to consider also flood risks which are not measured in monetary terms, b) to show the spatial distribution of these multiple risks and c) to deal with uncertainties in criteria values and to show their influence on the overall assessment. It can furthermore be used to show the spatial distribution of the effects of risk reduction measures. The approach is tested for a pilot study at the River Mulde in Saxony, Germany. Therefore, a GIS dataset of economic as well as social and environmental risk criteria is built up. Two multi-criteria decision rules, a disjunctive approach and an additive weighting approach are used to come to an overall assessment and mapping of flood risk in the area. Both the risk calculation and mapping of single criteria as well as the multi-criteria analysis are supported by a software tool (FloodCalc) which was developed for this task.

Meyer, V., Scheuer, S. and Haase, D (2009) A multicriteria approach for flood risk mapping exemplified at the Mulde river, Germany, Natural Hazards, Vol 48, Issue 1, 17-39

In this paper we develop a GIS-based multicriteria flood risk assessment and mapping approach. This approach includes flood risks which are not measured in monetary terms; it shows the spatial distribution of multiple risks, and it is able to deal with uncertainties in criteria values and to show their influence on the overall flood risk assessment. Additionally, the approach can be used to show the spatial allocation of the flood effects if risk reduction measures are implemented. The approach is applied to a pilot study for the River Mulde in Saxony, Germany, heavily affected by the hazardous flood in 2002. Therefore, a GIS database of economic, social and environmental risk criteria was created. Two different multicriteria decision rules, a disjunctive and an additive weighting approach, are utilised for an overall flood risk assessment in the area. For implementation, a software tool (FloodCalc) was developed supporting both, the risk calculation of the single criteria as well as the multicriteria analysis.

Papaioannou, G., Vasiliades, L. and Loukas, A. (2015) Multi-Criteria Analysis Framework for Potential Flood Prone Areas Mapping, Water Resources Management, Vol 29, 2, 399-418

A fundamental component of the European natural disaster management policy is the detection of potential flood-prone areas, which is directly connected to the European Directive (2007/60). This study presents a framework for mapping potential flooding areas incorporating geographic information systems (GIS), fuzzy logic and clustering techniques, and multi-criteria evaluation methods. Factors are divided in different groups which do not have the same level of trade off. These groups are related to geophysical, morphological, climatological/meteorological and hydrological characteristics of the basin as well as to anthropogenic land use. GIS and numerical simulation are used for geographic data acquisition and processing. The selected factor maps are considered in order to estimate the spatial distribution of the potential flood prone areas. Using these maps, the study area is classified into five categories of flood vulnerable areas. The Multi-Criteria Analysis (MCA) techniques consist of the crisp and fuzzy analytical hierarchy processes (AHP) and are enhanced with different standardization methods. The classification is based on different clustering techniques and it is applied in two approaches. In the first approach, all criteria are normalized before the MCA process and then, the clustering techniques are applied to derive the final flood prone area maps. In the second approach, the criteria are clustered before and after the MCA process for the potential flood prone area mapping. The methodology is demonstrated in Xerias River watershed, Thessaly region, Greece. Xerias River floodplain was repeatedly flooded in the last few years. These floods had major impacts on agricultural areas, transportation networks and infrastructure. Historical flood inundation data has been used for the validation of the methodology. Results show that multiple MCA techniques should be taken into account in initial low-cost detection surveys of flood-prone areas and/or in preliminary analysis of flood hazard mapping.

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Schroter, K., Ostrowski, M., Velasco, C., Nachtnebel, H.P., Beyene, M., Rubin, C. and Gocht, M. (2008) Effectiveness and Efficiency of Early Warning Systems for Flash-Floods (EWASE) CRUE Research Report No I-5, CRUE ERA-NET, Prepared by the Joint Project Consortium, Coordinator John Goudie, Defra, London

This is the final report of the EC funded EWASE research project. In this report the wider benefits accruing to flood warning schemes are the subject of qualitative MCA which can be found on pages 103-106. Otherwise the report presents a detailed assessment of the benefits of flood warning. EWASE evaluated the efficiency and the effectiveness of early warning systems (EWS) in small river basins that have short hydrological response times. EWASE provided information for optimal alerts through the analysis of the trade-off between the benefit of an increased lead time and the simultaneous decrease of warning reliability. The increase in lead time may provide valuable time for the completion of preventive measures, whereas the decrease of warning reliability will cause economic loss in case of a false alert. Two study basins in Austria and Spain are presented to illustrate the application of the methodology proposed and to identify the key information required to integrate this approach into comprehensive flood risk management strategies. In this way EWASE synthesises data and experiences to help flood managers in finding better solutions for the operation of early warning systems.

In the light of current knowledge given the assumptions and region of investigation of this study, no FRM strategy appears to be more efficient than the combination of local protection and early warning. Early warning as discussed in EWASE offers a significant potential to transfer responsibilities from the state to the individuals. The extent to which individuals are enabled to care for their safety and to optimise their benefit from the warning depends to a large part on the distribution of the warning. Particularly in the economic sectors high potential benefits can be realised, because of the ongoing presence of people at least during the day. As 60 to 70% of the risk arises in the economic sectors, there is a high potential for damage reduction due to early warning. It is therefore a promising means to implement the EWASE approach on the company level supporting managers to decide about releasing an alert for optimising their benefit from early warning. Early warning systems as a non-structural protection measure induce very low detrimental effects on the natural environment. Therefore the implementation of early warning is a good opportunity to reconcile the Water Framework Directive and the Floods Directive.
Early warning is well in line with the protection of the weak. In fact timely warning may be the only possibility to evacuate the sick, the elderly, the children and the pupils from hospitals, resorts, kindergartens and schools.

Scheuer, S, Haase, D. and Meyer, V. (2011) Exploring multicriteria flood vulnerability by integrating economic, social and ecological dimensions of flood risk and coping capacity: from a starting point view towards an end point view of vulnerability, Natural Hazards, Vol 58, Issue 2, 731-751

In this paper, we present an approach to modelling multicriteria flood vulnerability which integrates the economic, social and ecological dimension of risk and coping capacity. We start with an existing multicriteria risk mapping approach. The term *risk* is used here in a way that could be called a *starting point* view, looking at vulnerability without considering *coping capacities*. We extend this approach by a multicriteria modelling of coping capacities towards an *end point* view of vulnerability. In doing so, we explore a way to differentiate coping capacity from flood risk in each of the dimensions of vulnerability. The approach is tested in an urban case study, the city of Leipzig, Germany. Our results show that it is possible to map multicriteria risks as well as coping capacities and relate them in a simple way. However, a detailed calculation of *end point* vulnerability would require more detailed knowledge on the causal relationships between risk and coping capacity criteria and their relative importance.

Scheuer, S., Haase, D. and Meyer, V (2013) Towards a flood risk assessment ontology – Knowledge integration into a multi-criteria risk assessment approach, Computers, Environment and Urban Systems, Vol 37, 82–94

Flood risk management must rely on a proper and encompassing flood risk assessment, which possibly reflects the individual characteristics of all elements at risk of being flooded. In addition to prevalent expert knowledge, such an approach must also rely on local knowledge. In this context, stakeholder preferences for risk assessment indicators and assessment deliverables hold great importance but are often neglected. This paper proposes to put this body of information into operation in form of a knowledge base, thereby making it accessible and reusable in multi-criteria risk assessment. Selected use cases discuss the advantages of such a semantically enhanced

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assessment approach.

Su, H-T and Tung, Y-K (2014) Multi-criteria decision making under uncertainty for flood mitigation, Stochastic Environmental Research and Risk Assessment, Vol 28, Issue 7, 1657-1670

Designs of flood mitigation infrastructural systems are decision-making which are often made under various uncertainties involving multiple criteria. Under the condition of uncertainties, any chosen design alternative has the likelihood to perform inferior to other unselected designs in terms of the adopted performance indicators. This paper introduces a quantitative risk measure based on the concept of expected opportunity loss (EOL) for evaluating the consequence of making the wrong decision. The EOL can be used to assess the relative performance of multiple decision alternatives and is extended to deal with decision problems involving multiple criteria. In particular, the probabilistic features of the consequences associated with a design alternative is considered and used in the Preference Ranking Organization Method of Enrichment Evaluation (PROMETHEE) MCDM technique. The integration of PROMETHEE and decision making under uncertainty is demonstrated through an example of flood damage mitigation planning.

Sugden, R. (2007) Integrating Cost-Benefit Analysis and Multi-Criteria Analysis of Flood and Coastal Erosion Risk Management Projects R&D Project Record FD2018/PR2, Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme, Environment Agency and Defra, London

In the UK, flood and coastal defence (FCD) projects are subjected to economic appraisal, using the cost-benefit methodology described in Defra's Flood and Coastal Defence Project Appraisal Guidance, Part 3: Economic Appraisal (FCDPAG3). The feasibility of changing this appraisal framework from the traditional 'calculus of social costs and benefits' to the 'calculus of willingness to pay (WTP)' has been examined. The main virtue of the calculus of WTP is that it allows the impacts of a project to be disaggregated between economic interest groups (e.g. government and taxpayers, businesses, households). This makes it easier to consider the distributional effects of projects and to identify the role of contributions from project partners (e.g. property developers), while retaining the essential logic of cost-benefit analysis (CBA). A radically different appraisal methodology, multi-criteria analysis (MCA), is proposed in this report which is a preliminary assessment of the compatibility of CBA (using the WTP calculus) with the kind of MCA proposed by evaluating MCA. The report provides a very useful comparison of CBA and MCA and ways of reconciling these appraisal methods.

Tkach, R. and Simonovic, S. (Not Dated) A New Approach to Multi-criteria Decision Making in Water Resources, Journal of Geographic Information and Decision Analysis, Vol 1, No.1, 25-43 at http://publish.uwo.ca/~jmalczew/gida_1/Tkach/Tkach.htm on 27.08.14

Spatial comparison of floodplain management alternatives in a raster GIS environment is conceptualized as a multi criteria decision making problem. A spatial MCDM technique is developed by combining the conventional Compromise Programming technique with GIS technology. This new technique is referred to herein as Spatial Compromise Programming (SCP). The main contribution of the proposed technique is its ability to address uneven spatial distribution of criteria values in the evaluation and ranking of alternatives. SCP is used to determine the best alternative for each geographic location within the region of interest. The analysis of floodplain management strategies for the Red River Valley region is chosen as a case study to illustrate application of the Spatial Compromise Programming technique.

Yalcin, G. and Akyurek, Z. (Not Dated) Multiple criteria analysis for flood vulnerable areas, at http://proceedings.esri.com/library/userconf/proc04/docs/pap1097.pdf on 29.08.14

This paper integrates the use of Multi-Criteria Decision Analysis with (MCDA) with Geogrpahicla Information Systems (GIS). Cell-based Multicriteria Evaluation (MCE) methods are used to analyse the flood vulnerable areas. In ArcView 8.2 all data are stored and the criterion values are generated for all criteria that are seen as map layers. The criterion maps are converted into grids and the mathematical processes are applied to the criteria with MapCalculater. Ranking Methods are used to rank the every criterion under consideration in the order of the decision maker's preferences and the Pairwise Comparison Method (PCM), which is designed as a user interface to calculate the weights from input preferences with Visual Basic Application (VBA) program embedded in

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ArcGIS 8.2 is used. At the end of the application, the composite maps are created using Boolean Approach, Ranking Method, PCM and Ordered Weighted Averaging (OWA) Method including fuzzy concept on standardization of the criterion values and are compared.

Yazdandoost, F . and Bozorgy, B. (2008) Flood risk management strategies using multi-criteria analysis, Proceedings of The Institution of Civil Engineers and Water Management, Vol 161 (5), 261-266

The concept of 'resilience', also introduced in other research, is appropriately addressed. The application of multi-criteria decision making in flood risk management is demonstrated in a case study of the lower Rhine River. Flood risk management strategies other than the current strategy are defined, some based on the concept of resilience, and ranking of the strategies based on the flood risk management evaluation criteria is presented. The results are supported by uncertainty analyses. Flood risk management is investigated in the context of a decision making problem. Various flood risk management strategies are considered and evaluated using multi-criteria analysis.

Environmental focus

Brown, K., Adger, W. N., Tompkins, E., Bacon, P. and Shim, D. (2001) Trade-off analysis for marine protected area management, Ecological Economics, Vol 37, 3, 417-434

This paper outlines an approach to natural resource management that incorporates multiple objectives for protected area management within a decision-making framework. Both regulators and other major stakeholders are directly incorporated into the approach to enhance decision-making processes. We call this approach trade-off analysis. The approach uses a framework based on multi-criteria analysis (MCA) but involves stakeholders at all stages. This holistic approach is appropriate for multiple use, complex systems such as marine protected areas (MPAs), where many different users are apparently in conflict and where linkages and feedbacks between different aspects of the ecosystem and economy exist. The paper applies trade-off analysis to the case of Buccoo Reef Marine Park (BRMP) in Tobago. Stakeholder analysis is undertaken, and social, economic and ecological criteria identified. The impacts of four different development scenarios are evaluated for these criteria. Stakeholders are asked to weight different criteria and then the outcomes of different stakeholder weightings in the MCA are used to explore different management options. For BRMP, the MCA suggests consensus around development options characterised as limited tourism development for the area surrounding the park in association with the implementation of complementary environmental management. The approach has been used to enhance stakeholder involvement in decision-making and develop consensus-based approaches to management of the MPA.

Cinelli, M., Coles, S. R. and Kirwan, K. (2014) Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment, Ecological Indicators, Vol 46, 138-148. ISSN 1470-160X

Sustainability assessments require the management of a wide variety of information types, parameters and uncertainties. Multi criteria decision analysis (MCDA) has been regarded as a suitable set of methods to perform sustainability evaluations as a result of its flexibility and the possibility of facilitating the dialogue between stakeholders, analysts and scientists. However, it has been reported that researchers do not usually properly define the reasons for choosing a certain MCDA method instead of another. Familiarity and affinity with a certain approach seem to be the drivers for the choice of a certain procedure. This review paper presents the performance of five MCDA methods (i.e. MAUT, AHP, PROMETHEE, ELECTRE and DRSA) in respect to ten crucial criteria that sustainability assessments tools should satisfy, among which are a life cycle perspective, thresholds and uncertainty management, software support and ease of use. The review shows that MAUT and AHP are fairly simple to understand and have good software support, but they are cognitively demanding for the decision makers, and can only embrace a weak sustainability perspective as trade-offs are the norm. Mixed information and uncertainty can be managed by all the methods, while robust results can only be obtained with MAUT. ELECTRE, PROMETHEE and DRSA are non-compensatory approaches which consent to use a strong sustainability concept, accept a variety of thresholds, but suffer from rank reversal. DRSA is less demanding in terms of preference elicitation, is very easy to understand and provides a straightforward set of decision rules expressed in the form of elementary “if … then …” conditions. Dedicated software is available for all the approaches with a

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medium to wide range of results capability representation. DRSA emerges as the easiest method, followed by AHP, PROMETHEE and MAUT, while ELECTRE is regarded as fairly difficult. Overall, the analysis has shown that most of the requirements are satisfied by the MCDA methods (although to different extents) with the exclusion of management of mixed data types and adoption of life cycle perspective which are covered by all the considered approaches.

de C. Infante, C. E. D., de Mendonca, F. M., Purcidonio and Valle, R. (2013) Triple bottom line analysis of oil and gas industry with multicriteria decision making, Journal of Cleaner Production, Vol 52, 289-30

A few years ago became notorious the inclusion of environmental and social issues in economic decisions, which led to a new strategic framework for organizations. Thus, it is of fundamental importance to know the present limitations and new paradigms in the operational and tactical developing of organizations, aiming at less striking and balanced actions. Thus, the objective was to develop an integrated interpretation of economic, environmental and social issues of the main companies in the oil and gas sectors in the world, featuring their activities through sustainability indicators covered in the three pillars of development (Triple Bottom Line). For the research robustness the decision support multicriteria analysis (AMD) was used as methodology, which in the application of the method ELECTRE III was possible to verify the ranking of companies according to direct sustainable reports. It was concluded that sustainable strategies allied to the Triple Bottom Line are a corporate and operational differential. Thus, it is expected to contribute to the deepening of enterprise policies across all strategic decisions focused on sustainability.

Hajkowicz, S. and Higgins, A. (2008) A comparison of multiple criteria analysis techniques for water resource management, European Journal of Operational Research, Vol 184, 1, 255-265

Multiple criteria analysis (MCA) is a framework for evaluating decision options against multiple criteria. Numerous techniques for solving an MCA problem are available. This paper applies MCA to six water management decision problems. The MCA methods tested include weighted summation, range of value, PROMTHEE II, Evamix and compromise programming. We show that different MCA methods were in strong agreement with high correlations amongst rankings. In the few cases where strong disagreement between MCA methods did occur it was due to presence of mixed ordinal-cardinal data in the evaluation matrix. The results suggest that whilst selection of the MCA technique is important more emphasis is needed on the initial structuring of the decision problem, which involves choosing criteria and decision options.

Higgins, A.J., Hajkowicz, S. and Bui, E. (2008) A multi-objective model for environmental investment decision making, Computers & Operations Research, Vol 35, 1, 253–266

Investment in landscapes to achieve outcomes that have multiple environmental benefits has become a major priority in many countries. This gives rise to opportunities for mathematical programming methods to provide solutions on where investments could be made on the landscape, to maximise multiple environmental benefits. The problem was formulated as a multi-objective integer programming model, with objective functions representing biodiversity, water run-off and carbon sequestration. We applied a multi-objective Greedy Randomised Adaptive Search Procedure (GRASP) as an evolutionary programming method to find solutions along the Pareto front. This allows the decision maker to explore trade-off's between the objectives. A 142,000 ha case study catchment in eastern Australia was used to test the methodology and assess the sensitivity of the different and often competing environmental benefits.

Løken, E. (2007) Use of multicriteria decision analysis methods for energy planning problems, Renewable and Sustainable Energy Reviews, Vol 11, 7, 1584–1595

Most decision making requires the consideration of several conflicting objectives. The term multiple criteria decision analysis (MCDA) describes various methods developed for aiding decision makers in reaching better decisions. Energy planning problems are complex problems with multiple decision makers and multiple criteria. Therefore, these problems are quite suited to the use of MCDA. A multitude of MCDA methods exists. These methods can be divided in three main groups; value measurement models, goal, aspiration and reference level

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models, and outranking models. Methods from all of these groups have been applied to energy planning problems, particularly in the evaluation of alternative electricity supply strategies. Each of the methods has its advantages and drawbacks. However, we cannot conclude that one method generally is better suited than the others for energy planning problems. A good alternative might be to apply more than one method, either in combination to make use of the strengths of both methods, or in parallel to get a broader decision basis for the decision maker. Until now, studies of MCDA in energy planning have most often considered energy networks with only one energy carrier. More advanced energy systems with multiple energy carriers have been neglected, even though this field ought to be suitable for use of MCDA due to its high complexity, many decision makers and many conflicting criteria.

Marinoni, O., Higgins, A., Hajkowicz, S. and Collins, K. (2009) The multiple criteria analysis tool (MCAT): A new software tool to support environmental investment decision making, Environmental Modelling & Software, Vol 24, 2, 153–164

This article describes a decision support software system referred to as the multiple criteria analysis tool (MCAT). MCAT identifies a portfolio of decision options that return a maximum aggregated benefit under a constrained budget. Benefits scores of decision options – which we will refer to as projects – are computed using multiple criteria analysis whereas in a subsequent step, binary combinatorial optimisation is employed to identify the combination of projects that return a maximised aggregated benefit subject to a constraint. MCAT has primarily been developed to be used in natural resource management contexts. Though we illustrate MCAT through three Australian natural resource management case studies its use is explicitly not restricted to environmental decision problems. Wherever multi-criteria analysis (MCA) is regarded to be a suitable approach to evaluate decision options subject to a budget constraint, MCAT can be applied. We therefore believe that MCAT has potential for widespread application. It can help improve the transparency, analytic rigour and auditability of investment decisions.

Tiwaria, D.N., Loofb, R., and Paudyalc, G.N. (1999) Environmental–economic decision-making in lowland irrigated agriculture using multi-criteria analysis techniques, Agricultural Systems, Vol. 60, Issue 2, 99-112

The continuing debate about sustainability has raised wide concerns towards integration of environmental and economic aspects into the development decision-making process. This paper develops a framework for environmental–economic decision making that includes the environmental and economic sustainability criteria, and local people's preferences in the context of a lowland irrigated agriculture system using multi-criteria decision-making techniques. Several criteria, such as land capability/suitability, energy input/output ratio, water demand and environmental costs, are considered as environmental sustainability criteria. Economic sustainability is measured from farmers', governments and societal viewpoints using extended cost-benefit analysis. The Geographic Information System (GIS) technique has been used to evaluate spatial sustainability criteria. The involvement of local people at various levels of the decision- making process is emphasized and their opinions are sought in the decision-making process using a two-stage field survey. The results of the multi-criteria analysis combining both environmental and economic sustainability criteria are discussed, and economic incentives for sustainable intensification of lowland irrigated agriculture are outlined.

International and case study focus

Costa, C., da Silva, P. and Correia, F. (2003) Multi-criteria evaluation of flood control measures: The case of Ribeira do Livramento, Working Paper LSEOR 03.62, Department of Operational Research, London School of Economics and Political Science, London ISBN 07530 16842

This paper describes the multi-criteria process used to evaluate flood control options for the Livramento Creek in Setubal peninsular, Portgual. Environmental, social and technical dimensions are identified. The MACBETH approach – Measures Attractiveness by a Categorical Based Evidence Technique – was employed to construct a quantitative evaluation model based on qualitative value judgements formulated by a group of experts from diverse fields. This model allows the overall benefits accruing to each option to be estimated and extensive sensitivity analysis to be performed.

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Ghanbarpour M. R., Salimi, S. and Hipel, K.W. (2013) A comparative evaluation of flood mitigation alternatives using GIS-based river hydraulics modelling and multi-criteria decision analysis, Journal of Flood Risk Management, Vol 6, Issue 4, 319–331, December

A multi-criteria framework is developed for the selection of optimal flood mitigation and river training measures in a selected reach of Zaremroud River in Northern Iran. A river model, Hydrologic Engineering Center River Analysis System, combined with geographic information system analysis is used to simulate water levels for steady, gradually varied flow and mapping inundated flood extents. The modelling is performed for four different alternatives, considering various channel modifications with different dimensions and levee construction. Flood inundation area, flood level, flow velocity and stream power on the downstream and outside of the river bend are used as decision criteria for each alternative. Economic analysis is conducted to evaluate the cost-effectiveness of each alternative. The decision analysis method, technique for order of preference by similarity to ideal solution, is used to compare different flood hazard mitigation measures based on risk, and environmental and economic impacts criteria. The findings of the analysis are that a levee construction at the right side of the river bank adjacent to the residential area is superior to the other three alternatives, which is confirmed using a scenario analysis of different flood mitigation measures.

Hallegatte, S.,Green, C., Nicholls, R.J. and J. Corfee-Morlot (2013) Future flood losses in major coastal cities, Nature Climate Change, Letters, Published Online 18 August 2013

Flood exposure is increasing in coastal cities owing to growing populations and assets, the changing climate, and subsidence. Here the authors provide a quantification of present and future flood losses in the 136 largest coastal cities. Using a new database of urban protection and different assumptions
on adaptation, we account for existing and future flood defences. Average global flood losses in 2005 are estimated to be approximately US$6 billion per year, increasing to US$52 billion by 2050 with projected socio-economic change alone. With climate change and subsidence, present protection will need to be upgraded to avoid unacceptable losses of US$1 trillion or more per year. Even if adaptation investments maintain constant flood probability, subsidence and sea-level rise will increase global flood losses to US$60–63 billion per year in 2050. To maintain present flood risk, adaptation will need to reduce flood probabilities below present values. In this case, the magnitude of losses when floods do occur would increase, often by more than 50%, making it critical to also prepare for larger disasters than we experience today. The analysis identifies the cities that seem most vulnerable to these trends, that is, where the largest increase in losses can be expected.

Kuba, C., Haase, D., Meyer, V. and Scheuer, S. (2009) Integrated urban flood risk assessment – adapting a multi-criteria approach to a city, Nat. Hazards Earth Syst. Sci., 9, 1881–1895

Flood risk assessment is an essential part of flood risk management. As part of the new EU flood directive it is becoming increasingly more popular in European flood policy. Particularly cities with a high concentration of people and goods are vulnerable to floods. This paper introduces the adaptation of a novel method of multi-criteria flood risk assessment, that was recently developed for the more rural Mulde river basin, to a city. The study site is Leipzig, Germany. The “urban” approach includes a specific urbantype set of economic, social and ecological flood risk criteria, which focus on urban issues: population and vulnerable groups, differentiated residential land use classes, areas with social and health care but also ecological indicators such as recreational urban green spaces. These criteria are integrated using a “multi-criteria decision rule” based on an additive weighting procedure which is implemented into the software tool FloodCalc urban. Based on different weighting sets we provide evidence of where the most flood-prone areas are located in a city. Furthermore, we can show that with an increasing inundation extent it is both the social and the economic risks that strongly increase.

Meng, Y., Xin, Q,, Yuchao, Z., Jinbao, S., Dengle, S. and Yi, G. (2011) Spatial Multicriteria Decision Analysis of Flood Risks in Aging-Dam Management in China: A Framework and Case Study Int J Environ Res Public Health. May 8 (5), 1368–1387. Published online May 4, 2011. doi: 10.3390/ijerph8051368 consulted on 28.9.14

Approximately 30,000 dams in China are aging and are considered to be high-level risks. Developing a framework for analysing spatial multi-criteria flood risk is crucial to ranking management scenarios for these dams,

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especially in densely populated areas. Based on the theories of spatial multi-criteria decision analysis, this report generalizes a framework consisting of scenario definition, problem structuring, criteria construction, spatial quantification of criteria, criteria weighting, decision rules, sensitivity analyses, and scenario appraisal. The framework is presented in detail by using a case study to rank dam rehabilitation, decommissioning and existing-condition scenarios. The results show that there was a serious inundation, and that a dam rehabilitation scenario could reduce the multi-criteria flood risk by 0.25 in the most affected areas; this indicates a mean risk decrease of less than 23%. Although increased risk (<0.20) was found for some residential and commercial buildings, if the dam were to be decommissioned, the mean risk would not be greater than the current existing risk, indicating that the dam rehabilitation scenario had a higher rank for decreasing the flood risk than the decommissioning scenario, but that dam rehabilitation alone might be of little help in abating flood risk. With adjustments and improvement to the specific methods (according to the circumstances and available data) this framework may be applied to other sites.

Meyer, V., Scheuer, S. and Haase, D.A. (2009) Multi-criteria approach for flood risk mapping exemplified at the Mulde river, Germany, Natural Hazards, Vol 48 (1), 17-39

A multi-criteria approach for flood risk mapping exemplified in the Mulde river, Germany The approach is applied to a pilot study for the River Mulde in Saxony, Germany, heavily affected by recent floods, most notably in 2002. Various flood damage reduction measures are evaluated. A GIS-based multi-criteria flood risk assessment and mapping approach is developed. This approach includes flood risks which are not measured in monetary terms. A GIS database of economic, social and environmental risk criteria was created. Two different multi-criteria decision rules, a disjunctive and an additive weighting approach, are utilised for an overall flood risk assessment in the area. For implementation, a software tool (FloodCalc) was developed supporting both, the risk calculation of the single criteria as well as the distribution of multiple risks, and it is able to deal with uncertainties in criteria values and to show their influence on the overall flood risk assessment.

Mosadeghi, R., Warnken, J., Tomlinson, R. and Mirfenderesk, H. (2012) Uncertainty analysis in the application of multi-criteria decision-making methods in Australian strategic environmental decisions, Journal of Environmental Planning and Management, Vol 56, 8, 1097-1124

Multi-criteria decision-making techniques have become increasingly widespread in strategic environmental decision making. In Australia, these techniques are used to integrate both conservation and development aspects of natural resource use. MCDM can also evaluate the effects of uncertainties at each stage of the decision-making process and examine the sensitivity of results to the inputs. This paper reviews the potential uncertainties in environmental management decision-making procedures and explores how uncertainty analysis in the framework of MCDM can address some of these uncertainties. It then examines the application of MCDM in 16 Australian case studies to determine how uncertainty has been addressed in practice. Results demonstrate that appropriate use of MCDM can address uncertainties associated with decision-makers' preferences and from using different techniques (epistemic uncertainty). Results also highlighted the need for incorporating visualising techniques, such as GIS and simulation algorithms (e.g. Monte Carlo simulations), to examine the effects of uncertainty on the spatial pattern of the outcomes. This approach also presents promising ways to gain an understanding of the effects of some dimensions of stochastic uncertainty, and assists in increasing the transparency of the decision-making process.

Musungu, K and Motala, S. (2012) Participatory Multi-Criteria Evaluation and GIS: An Application in Flood Risk Analysis, FIG Young Surveyors Conference - Workshop 1.2, 6204 1/14, Knowing to create the Future Rome, Italy, 4-5 May

Many of the rural-urban migrants in Cape Town have settled in informal settlements because they cannot afford to rent or buy decent housing. A number of these settlements are however located on poorly drained land that is often prone to flooding after prolonged rainfall. However, current flood risk management techniques implemented by the authorities of the Cape Town City
Council (CTCC) are not designed to support informal settlements. In fact, owing to inadequate information about

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the levels of flood risk within the individual informal settlements the CTCC has often implemented inappropriate remedies within such settlements. This study sought to investigate
a participatory methodology that the CTCC could use to improve flood risk assessment in informal settlements. This study responded to calls in various research papers calling for the adoption of participatory methodologies in developing a Geographic Information System (GIS). Using a case study of an informal settlement in Cape Town, this study proposed a methodology involving sourcing and integrating of community-based information into a GIS that can be used by the CTCC for risk assessment. Also, this research demonstrated the use of a participatory multi-criteria evaluation
(MCE) for risk assessment. The MCE method of choice was the pairwise comparison method. Risk weights were subsequently calculated using pairwise comparisons for each household and mapped in the GIS to show the spatial disparities in risk between the households.

Musungu, K., Motala, S., and Smit, J. (Not Dated) Using Multicriteria Evaluation and GIS for Flood Risk Analysis in Informal Settlements of Cape Town: The Case of Graveyard Pond at http://idl-bnc.idrc.ca/dspace/bitstream/10625/49834/1/IDL-49834.pdf on 30.8.14

Rural-urban migrations have contributed to the steady increase in the population of Cape Town.
Many of the migrants have settled in informal settlements because they cannot afford to rent or buy decent housing. Many of these settlements are however located on marginal and often poorly drained land. Consequently, most of these settlements are prone to flooding after prolonged rainfall. Current flood risk management techniques implemented by the authorities of the Cape
Town City Council (CTCC) are not designed to support informal settlements. In fact, owing to a lack of information about the levels of flood risk within the individual settlements, either the CTCC has often been uninvolved or it has implemented inappropriate remedies within such settlements.
This study sought to investigate a methodology that the CTCC could use to improve flood risk assessment. Using a case study of an informal settlement in Cape Town, this study proposed a methodology of integration of community-based information into a Geographic Information System (GIS) that can be used by the CTCC for risk assessment. In addition, this research demonstrated the use of a participatory multi-criteria evaluation (MCE) for risk assessment. A questionnaire was used to collect community-based information. The shack outlines of the informal settlement were digitised using CTCC aerial imagery. The questionnaires were captured using spreadsheets and linked to the corresponding shacks in the GIS. Risk weights were subsequently calculated using pairwise comparisons for each household, based on their responses to the questionnaires. The risk weights were then mapped in the GIS to show the spatial disparities in risk.

Penning-Rowsell1, E.C., Yanyan, W., Watkinson, A.R., Jiang, J. and Thornes, C. (2013) Socioeconomic scenarios and flood damage assessment methodologies for the Taihu Basin, China, Journal of Flood Risk Management Taihu Basin Foresight Project Special Issue, Vol 6, Issue 1, 23–32

The assessment of flood risk is now widely recognised to need research and data on both the probability and the consequences of flooding; the research reported here concentrates on the latter data input. Building on the UK Foresight Future Flooding project, this paper describes the development of future scenarios through which to assess possible future flood risk in the Taihu Basin area of China. In addition, we describe the flood damage assessment model that was developed there to build on these scenarios so as to calculate anticipated risk. Acknowledged methodological limitations remain, but some important developments have resulted. First, the pre-existing flood loss data that were available from Shanghai meant that this aspect of the risk model's input was more regionally appropriate than would otherwise have been the case. Second, the damage assessment has been related both to constructed scenarios and to an agreed National Plan, so that the two can be compared. Third, the scenario construction was linked in Taihu to the statistical base contained in the 2006 Yearbook and the Fifth National Socio-economic Survey data, giving a sounder ‘base case’ of current flood vulnerability than used in the UK Foresight Future Flooding project. Finally, much more attention was given here to agricultural production and flood risk, given the importance of agriculture in the Chinese economy and its focus on food production for a growing population.

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Raaijmakers, R.J.J. (2006) A spatial multi criteria analysis methodology for the development of sustainable flood risk management in the Ebro Delta : A FLOODsite case study. University of Twente MSc Thesis, at http://essay.utwente.nl/57138/ on 26.08.14

This thesis derives a methodology which combines spatial multi criteria analysis with risk assessment in order to support decision making for sustainable flood risk management of coastal zones. A trade-off is made between the reduction of tangible and intangible damage and the conservation of commodity (CO) and non-commodity output (NCO), for risk management strategies. In this case these strategies are land use changes. This is a trade-off between risk and benefit, where a reduction of risk often implies a reduction of benefit. This trade-off is often influenced by the perception of risk, which influences the preference for one of the opposing interests. Flood risk management policy scenarios are judged on the criteria, reduction of tangible and intangible damage and conservation of COs and NCOs in a spatial multi criteria analysis. Worry, awareness and preparedness, three parameters for risk perception are used to determine the weighting of the first two criteria versus the last two. Afterwards pairwise comparison can be used to fine tune the weighting. The methodology should guide a policy maker toward sustainable flood risk management but not make the decision for the best flood risk management policy alternative itself.

Raaijmakers, R., Krywkow, J., and van der Veen, A. (2008) Flood risk perceptions and spatial multi-criteria analysis: an exploratory research for hazard mitigation, Natural Hazards Journal of the International Society for the Prevention and Mitigation of Natural Hazards 10.1007/s11069-007-9189-z at http://link.springer.com/article/10.1007/s11069-007-9189-z/fulltext.html on 29.08.14

The conventional method of risk analysis (with risk as a product of probability and consequences) does not allow for a pluralistic approach that includes the various risk perceptions of stakeholders or lay people within a given social system. This article introduces a methodology that combines the virtues of three different methods: the quantifiable conventional approach to risk; the taxonomic analysis of perceived risk; and the analytical framework of a spatial multi-criteria analysis. This combination of methods is applied to the case study 'Ebro Delta' in Spain as part of the European sixth framework project 'Floodsite'. First, a typology for flood hazards is developed based on individual and/or stakeholders' judgements. Awareness, worry and preparedness are the three characteristics that typify a community to reflect various levels of ignorance, perceived security, perceived control or desired risk reduction. Applying 'worry' as the central characteristic, a trade-off is hypothesized between Worry and the benefits groups in society receive from a risky situation. Second, this trade-off is applied in Spatial Multi-Criteria Analysis (SMCA). MCA is the vehicle that often accompanies participatory processes, where governmental bodies have to decide on issues in which local stakeholders have a say. By using risk perception-scores as weights in a standard MCA procedure a new decision framework for risk assessment is developed. Finally, the case of sea-level rise in the Ebro Delta in Spain serves as an illustration of the applied methodology. Risk perception information has been collected with help of an on-site survey. Risk perception enters the multi-criteria analysis as complementary weights for the criteria risk and benefit. The results of the survey are applied to a set of scenarios representing both sea-level rise and land subsidence for a time span of 50 years. Land use alternatives have been presented to stakeholders in order to provide the regional decision maker with societal preferences for handling risk. Even with limited resources a characteristic 'risk profile' could be drawn that enables the decision maker to develop a suitable land use policy.

Van der Veen, A., Raaijmakers, R. and Krywkow, J. (Not Dated) Flood Risk Perceptions Applied to a Spatial Multi-Criteria Analysis in the Ebro Delta in Spain at **http://www.newater.uni-osnabrueck.de/caiwa/data/papers%20session/B1/riskPaperCAIWA01.pdf accessed on 27.08.14**

The conventional method of risk analysis (with risk as a product of probability and consequences) does not allow for a pluralistic approach that includes the various risk perceptions of stakeholders or lay people within a community or region. In river basins, it is often an expert-based economic analysis of land use values that serves as the underlying estimation of costs. Intangibles such as nature development, biodiversity and cultural heritage are difficult to include in the calculation. Yet, local knowledge can be used to develop a realistic approach to outweighing tangibles and intangibles of land use values, as well as developing new approaches to risk

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management. This can be important to find appropriate solutions for the mitigation of risk. This presentation introduces a methodology that combines the virtues of three different methods used for risk analysis: the quantifiable conventional approach to risk, the taxonomic analysis of perceived risk and the analytical framework of a spatial multi-criteria analysis. The combination of these methods is applied to the case study 'Ebro Delta' in Spain as part of the European 6th framework project 'Floodsite'. The new approach using this combination is the incorporation of risk perceptions and its application and operation in a multi-criteria analysis. Risk perception is derived from the psychometric paradigm that distinguishes a variety of risk characteristics. Due to a number of similarities among these risk perceptions all known risk characteristics can be condensed into three higher order risk characteristics - awareness, worry and preparedness. This reduction of risk characteristics enables scientists to employ them as weights in a multi-criteria analysis. Risk perception information has been collected with help of an on-site survey. The result is significant levels of 'worry' and 'awareness' of the flood risk with an increasing demand for 'preparedness'. Risk perception enters the multi-criteria analysis as complementary weights for the criteria risk and benefit. The results of the survey are applied to a set of scenarios representing both sea level rise and land subsidence for a time span of fifty years. Land use alternatives that are based upon the given scenarios have been presented to stakeholders and evaluated. For effective land use policy in flood prone areas it can be useful to compare land use alternatives based upon their performance with respect to risk and benefit. In this way the regional decision maker has been given an overview of preferences for handling risk. Even with limited resources a characteristic 'risk profile' could be drawn that enables the decision maker to develop a suitable land use policy or at least provide a basis for further social learning processes.

Yahaya, S. (Not Dated) Multicriteria analysis for flood vulnerable areas in Hadejia-Jama'are river basin, Niigeria at http://www.asprs.org/a/publications/proceedings/portland08/0088.pdf accessed on 27.08.14

Flood disaster is considered as a major natural hazard due to its devastating effects on the affected area. Multicriteria Evaluation (MCE) methods are used to analyse the flood vulnerable areas. Geographical Information System (GIS) is integrated with Multicriteria Decision Analysis (MCDA). The aim is to provide more flexible and more accurate decisions to the decision makers in order to evaluate the effective factors. Some of the causative factors for flooding in the watershed are taken into account: annual rainfall, basin slope, drainage network, land cover and the type of soil. In this study two main MCE approaches employed in GIS are used, namely Boolean and Weighted Linear
Combination (WLC). In MCE, two methods, pairwise comparison method (Analytical Hierarchy Process-AHP) and Ranking Method are used to calculate the weights of each factor. Using AHP the weightage derived for the factors were, Rainfall 33.9%, Drainage network 25.5%, Slope of the river basin 19.7%,Soil type 15.2% and Land cover 5.7%.A case study of flood vulnerable areas determination in Hadejia Jama'are River Basin, Nigeria is employed to illustrate the different approaches. At the end of the study a Map of flood vulnerable areas in the river basin was generated with a view to assisting decision makers on the menace posed by the disaster.

Yazdandoost, F. and Bozorgy, B. (2008) Flood risk management strategies using multi-criteria, analysis, Proceedings of the ICE - Water Management, Vol 161, Issue 5, 01 October, 261 –266

Flood risk management is investigated in the context of a decision making problem. Various flood risk management strategies are considered the alternatives; the evaluation criteria of such strategies, previously defined in other research, are considered the decision criteria. The concept of 'resilience', also introduced in other research, is appropriately addressed in this regard. The application of multi-criteria decision making in flood risk management is demonstrated in a case study of the lower Rhine River. Flood risk management strategies other than the current strategy are defined based on the concept of resilience, and ranking of the strategies based on the flood risk management evaluation criteria is presented. The results are supported by uncertainty analyses to show the effect of uncertainties on the ranking order of the strategies.

Yilmaz, B. and Harmancioglu, N.B. (2010) Multi-criteria decision making for water resource management: a case study of the Gediz River Basin, Turkey, Water SA, Vol 36, 5, 563-576

In this study, a water resource management model that facilitates indicator-based decisions, with respect to environmental, social and economic dimensions in a multiple criteria perspective, is developed for the Gediz River Basin in Turkey. The basic input of the proposed model is the quantity of surface water that is mainly

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allocated to irrigation purposes. The model has been applied under 3 different hydro-meteorological scenarios that reflect baseline as well as better and worse conditions of water supply and demand, not only to reach a comprehensive assessment of the water budget in the Gediz Basin, but also to evaluate the impacts of proposed management alternatives under different conditions. The Water Evaluation and Planning (WEAP) software is used as a simulation and evaluation tool to assess the performance of possible management alternatives; performance is measured by 9 indicators representing economic, social and environmental sustainability. The study has delineated the best management alternative on the basis of 3 different multi-criteria decision making (MCDM) methods, including simple additive weighting (SAW), compromise programming (CP) and technique for order preference by similarity to ideal solution (TOPSIS). Each method is also applied with 7 different sets of criteria weights that represent objective judgements as well as subjective preferences of decision makers. The results of the study indicate that the decision on the best alternative is basically independent of the MCDM method used, but slightly sensitive to the weights assigned to the criteria as well as the data used in the analyses.

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