Journal of Hydrology 519 (2014) 2652–2659

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Operationalising resilience to drought: Multi-layered safety for flooding applied to droughts

Jeroen Rijke [a,b,c,*], Jennifer Vessels Smith [a], Berry Gersonius [a,b], Sebastiaan van Herk [a], Assela Pathirana [a,b], Richard Ashley [a,b], Tony Wong [b], Chris Zevenbergen [a]

[a] Flood Resilience Group, UNESCO-IHE, PO Box 3015, 2601 DA, Delft, Netherlands
[b] Cooperative Research Centre for Water Sensitive Cities, Monash University, VIC 3800, Australia
[c] Triple Bridge BV, PO Box 1360, 3500 BJ, Utrecht, Netherlands

ARTICLE INFO

Article history:
Available online 5 October 2014

Keywords:
Efficiency
Flood safety
Multi-layered safety
Resilience
Redundancy
Water security

SUMMARY

This paper sets out a way of thinking about how to prepare for and respond to droughts in a holistic way using a framework developed for managing floods. It shows how the multi-layered safety (MLS) approach for flood resilience can be utilised in the context of drought in a way that three layers of intervention can be distinguished for operationalising drought resilience: (1) protection against water shortage through augmentation and diversification of water supplies; (2) prevention of damage in case of water shortage through increased efficiency of water use and timely asset maintenance; (3) preparedness for future water shortages through mechanisms to reduce the use of water and adopt innovative water technologies. Application of MLS to the cities of Adelaide, Melbourne and Sydney shows that recent water reforms in these cities were primarily focused on protection measures that aim to reduce the hazard source or exposure to insufficient water supplies. Prevention and preparedness measures could be considered in defining interventions that aim to further increase the drought resilience of these cities. Although further research is needed, the application suggests that MLS can be applied to the context of drought risk management. The MLS framework can be used to classify the suite of plans deployed by a city to manage future drought risks and can be considered a planning tool to identify opportunities for increasing the level of redundancy and hence resilience of the drought risk management system.

1. Introduction

Scientists and policy makers increasingly call for resilience to deal with the uncertainties and complexities of risks that are induced by future change (e.g. Gersonius et al., 2012; Vlachopoulou et al., 2014; Zevenbergen et al., 2008). In order to achieve resilience in water management, integration with other domains is needed; particularly with land use planning and urban development, but also with other urban services and interdependent systems (Francis and Bekera, 2014; Scheuer et al., 2012; Yovel, 2013). Such integration is reflected in concepts such as multi-layer safety (MLS; Van Herk et al., 2014) and Water Sensitive Urban Design (WSUD; Ashley et al., 2013) that recently have emerged to inform resilient water management systems.

As a response to the EU Floods Directive, MLS was developed in the Netherlands to operationalise flood resilience by distinguishing three safety layers: (1) protection against flooding; (2) prevention of damage and casualties in case of floods; (3) preparedness to adequately respond to floods (Gersonius et al., 2011; Hoss, 2010; Van Herk et al., 2014). A similar framework has been developed in Flandres (Cauwenberghs, 2013). The MLS concept is based on the premise that a portfolio of interventions across these layers is required to effectively enhance the overall system's flood resilience (Gersonius et al., 2011). It is increasingly applied in policy making processes and has structured policy debates around climate change adaptation in, for example, the Netherlands, USA, Vietnam, Indonesia and Bangladesh (Zevenbergen et al., 2012).

The term Water Sensitive Urban Design (WSUD) is used widely in Australia to reflect a new paradigm in the planning and design of urban environments that is 'sensitive' to the issues of water sustainability and environment protection. The concept is an Australian construct and has evolved from its early association with stormwater management to provide a broader framework for sustainable urban water management (Brown et al., 2009; Wong and Brown, 2009; Wong et al., 2013). WSUD is a multi-disciplinary approach to water management that emphasises the interconnections between water resources, urban liveability and land use (ibid). With respect to drought resilience, WSUD advocates access

* Corresponding author at: Flood Resilience Group, UNESCO-IHE, PO Box 3015, 2601 DA, Delft, Netherlands.
E-mail address: j.rijke@unesco-ihe.org (J. Rijke).

http://dx.doi.org/10.1016/j.jhydrol.2014.09.031
0022-1694/© 2014 Elsevier B.V. All rights reserved.

to a diversity of water sources underpinned by centralised and decentralised infrastructure including urban stormwater, rainwater and recycled wastewater (Wong et al., 2013).

The recent Millennium Drought (2001–2009) in Australia has revealed that a clear framework for combining multiple water resources is needed to structure policy making for drought resilience. The drought triggered a suite of adaptation measures, including augmentation of water supplies through desalination, large water recycling schemes, decentralised systems such as stormwater harvesting, reuse schemes and rainwater tanks, stimulation of water efficient appliances and public campaigns to promote water use reductions. The key realisation from the drought was that more sustainable and innovative solutions require substantial incubation time owing to their diffuse nature and also due to their requirement for public and professional acceptance and substantial institutional reform. As a result, significant investments were made in augmentation of what is largely a traditional focus on large centralised schemes.

The drought has invoked intensive public and scholarly debates in which the measures sometimes seemed to be considered as competing rather than complementary. For example, Environment Victoria perceived the Victorian Governments plans for the construction of a desalination plant immediately after the extremely dry year of 2006 as *"a knee jerk reaction to the lack of rain"* whilst *"less impacting alternatives [i.e. increased water recycling, rain and storm water harvesting, catchment protection] have not been exhausted or in some cases even considered"* (Environment Victoria, 2008; p. 1). Others referred to the desalination plant as *"maladaptation"*, partly because they argued that it would *"reduce the portfolio of adaptation options in the future"* (Barnett and O'Neill, 2010; p. 212). With this paper, we aim to contribute to more structured policy debates about integrated approaches to drought risk management. We translate the MLS framework for flood resilience into the context of drought and discuss the implications of MLS on policy debates about integrated approaches to drought resilience. First, the background theory behind the MLS framework for floods is summarised to identify the general characteristics of each of the layers of the MLS framework (Section 2.1). Secondly, these characteristics are used to construct a provisional MLS framework for the context of drought risk management (Section 2.2). Thirdly, the applicability of the provisional framework is illustrated by structuring interventions that are recently realised or planned to mitigate drought risks in three major Australian cities (Section 3). Fourthly, the implications of the MLS framework are discussed in the context of drought (Section 4.1) and compared with the application in the context of floods (Section 4.2). Finally, we draw conclusions and recommendations for the application and implications of using the MLS framework in policy debates about integrated approaches to drought risk management (Section 5).

2. Theory

This section discusses the theoretical background of the multi-layered safety (MLS) framework for managing flood risks (Section 2.1) and translates the existing MLS framework from flood risk management to a context of drought (Section 2.2).

2.1. The MLS framework for managing flood risks

MLS is a framework for implementing both a risk-based approach (efficiency through optimising costs and benefits) and a resilience-based approach (redundancy through diversification of strategies and measures). It involves not only reducing the probability of a flood through protection with e.g. dikes or dams, but also spatial planning and disaster mitigation, with the aim of limiting casualties and economic losses in the event of a flood. It also adopts the practice of combining different types of strategies into flood risk management (Fig. 2.1), including protection against flooding (e.g. through: dikes layer 1), prevention of damage in case of flooding (e.g. through spatial measures; layer 2); and preparedness for future flooding (e.g. through emergency management plans; layer 3).

MLS represents an important shift in Dutch thinking about flood risk management. Yet, risk-based approaches aimed at a diversification of strategies are also appearing elsewhere. The EU Flood Risk Directive (2007/60/EC) and the UNIDSR Hyogo framework ask for a diversification of flood risk management strategies, together with new governance arrangements to support implementation. These strategies are meant to address all phases of the risk management cycle, but focus particularly on the pre-event phase:

- *Protection*: taking measures to reduce the likelihood of floods, such as building flood defences;
- *Prevention*: using spatial planning and adaptation of buildings to reduce damages;
- *Preparedness*: improving organisational preparation, such as emergency plans, risk maps, and insurance;
- *Emergency relief*: providing emergency relief, such as evacuating communities, and providing help;
- *Recovery and lessons learned*: mitigating impacts on affected communities, and undertaking surveys.

The logic behind the use of the term MLS is to represent the relationships between the different phases or strategies as a parallel system rather than a serial system (Jongejan et al., 2012). This implies that the different layers are not as weak as the weakest link - as falsely suggested by the widely used term 'safety chain'. It also implies that it will be most efficient to invest in the layer(s) with the highest return on investment, and to omit or minimise the use of the other layers.

Hoss et al. (2011) have developed a MLS framework (Table 2.1) after Haddon's ten strategies to prevent a hazard from harming an object (Haddon, 1973). Each strategy in Haddon's model corresponds to a stage that the hazard passes through before it reaches its full impact. By translating Haddon's ten strategies to flood risk management, Hoss et al. (2011) have classified different possible measures into three categories: those reducing the hazard source (e.g. water flow), decreasing the exposure to that hazard (e.g. flood) or decreasing the vulnerability (e.g. flood damage). The added value of using this framework is that it provides insight into the effects and scales of impact of different types of flood risk management measures, for example on maximum water flows or on the potential damages. This, in turn, makes it possible to implement MLS efficiently. In practice, the efficiency of a combined strategy will depend on the level of interaction between the different types of flood risk management measures. Protection measures make floods less likely and reduce the need for better prevention and preparedness. Prevention and preparedness measures make the receptors less susceptible to flood damage and lessen the need for large-scale protection.

2.2. A provisional multi-layered framework for managing drought risks

Before the MLS concept can be translated from a context of floods to droughts, it is important to note the characteristics of each hazard including similarities and differences. Obviously, flooding relates to too much water, whilst drought relates to too little availability of water. Whilst a flood can be defined relatively simply as "the temporary covering by water of land not normally