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Setting the Stage for an Integrative, Adaptive, and Synergistic Approach

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Future-Proofing Flood Risk Management: Setting the Stage for an Integrative, Adaptive, and Synergistic Approach

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Introduction

Globally, flooding is one of the most common and destructive natural perils causing on average US$200 billion annually in damages. Many of our most densely populated areas are in coastal zones and in river catchments prone to flooding. Sea-level rise, economic development, and increased frequencies and intensities of storms will require that we continuously invest in adapting our flood risk management (FRM) systems, including flood protection infrastructure such as levees and dams and urban drainage systems. In the United States, an estimated 100,000 miles of levees can be found of which a large fraction is aging. In many cases, the reliability of these levees is unknown, and the country has yet to establish a National Levee Safety Program (NLSF). A complicating factor for FRM in the United States is that flood damage is not limited to certain areas, as one third of flood damage occurs outside of designated floodplains (Kousky and Michel-Kerjan, 2016). One of the principles that is now gaining ground in federal water resources planning and development (including flood safety) in the United States is "achieving *Co-Equal Goals*," which encompasses a shift from a focus primarily on economic development to a new approach that envisions maximizing public benefits, including economic, environmental, and social goals, with appropriate consideration of costs, for present and future generations.

Adapting to a changing risk of flooding presents a major policy challenge as the upfront costs are high and immediate and the benefits in terms of flood protection are

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uncertain and possibly far off in the future. Traditional FRM approaches are typically a result of reactive responses to flood disasters and are biased toward quick wins driven by political pressure to "do something." Moreover, they are often based on static assumptions about long-term probabilities aimed at optimality and economic efficiency with uncertainties implicitly accounted for through safety factors and other allowances. Mainly driven by economic development and technological innovations, these approaches often result in large-scale engineering responses. The sustainability of these infrastructure systems is currently under pressure as they are not sufficiently resilient to respond appropriately to slowly changing drivers and shocks. In addition, in the developed world, flood protection infrastructure is aging and reaching its design capacity. Although aging infrastructure poses a risk, it also provides opportunities, such as to correct old mistakes and introduce new technological and management approaches to adapt these systems to changing conditions and enhance their overall resilience.

Simultaneously, the global financial crisis has focused attention on the role of infrastructure renewal and development in economic stimulation and has reinforced government efforts to reduce expenditures. In an era of continued austerity, the challenge of governments seems to be to increase infrastructure's capital efficiency. However, cost cutting in the near term can create increased costs in the longer term. For example, as flood defenses also attract asset investments, they can magnify flood risk if not upgraded regularly. Hence, continually investing in risk prevention is sensible as these upfront investments save money later on in terms of damage prevented.

In this article, we discuss some guiding principles that could help drive future-proofing FRM approaches in the United States, as well as the underlying pressures that create incentives for cost-effectiveness, while maximizing robustness. It is inspired by the recent Dutch history in managing flood risk, as the Dutch are setting the stage for an integrative, adaptive, and synergic approach.

Recent Developments in Dutch FRM

The Netherlands, with nearly 60% of its surface prone to flooding, is protected against coastal and river flooding by a system of 3,500 km of primary dikes, storm barriers, and dunes accompanied by 14,000 km of secondary dikes around polders and along canals. A large portion of these dikes does not meet the legal performance standards.

In 1993 and 1995, when the rivers Meuse and Rhine almost flooded, a debate was started on the limitations of our ability to control extreme events solely by technical means, that is, dike systems. This debate was fed by the scientific discourse on the reliability estimates of flood defense systems. An important issue in this debate was the challenge to properly address the uncertainties associated with economic development and climate change in these estimates. Moreover, it became clear that the huge levels of investments and their dependency on the existing defense systems in the Netherlands are so high at present date, that options for radical change are limited and in all scenarios implementation will take at least several decades. These notions prompted a reconsideration of the current FRM strategy.

As of 2008, the central government, water boards, provinces, and municipalities are working together on a new Delta Program to future-proof the country against the long-term effects of climate change. The primary goals are to provide flood safety and to ensure the availability of fresh water, now and for future generations. At the heart of the Delta Program is an integrated, risk-based approach: striving toward striking an appropriate balance between protection, prevention, and preparedness, and promoting environmental, societal, and economic gains. This new approach acknowledges that 100% protection cannot be guaranteed, that dike systems may fail, and that failure should be taken into account in the design to enhance resilience.

In 2014, the Delta Program delivered its first *Delta Works* comprising a pioneering and innovative *multilevel governance process* (Slob & Bloemen, 2014). Instead of the delivery of a major engineering system with belt and braces redundancy, it has resulted in an unprecedented organizational reform to create the time, political commitment, and institutional capacity required to explore and test innovative approaches and technologies, and to allow implementation of measures over a long time frame. It aims to create the conditions under which continual improvement and adaptation can be fostered in a learning-by-doing process. It also includes the installation of a Delta Program Commissioner who is responsible for the implementation of the Delta Program, and the establishment of a Delta Fund to ensure that funding will be available for the major investments required by the program in the long run (Deltacommissaris, 2015).

The Delta Program has a long-term vision and consists of a cohesive set of measures for the short term, medium term (up to 2050), and long term (up to 2100). This phased, adaptive approach to investment decision making was developed to incorporate major uncertainties around future conditions in the selection and design of measures. As a consequence, long-term commitments for the design and implementation of large-scale infrastructure systems have been postponed, as they create inertia and reduce flexibility for the next 50 to 100 years.

Emerging Principles for FRM

What have the Dutch learned so far? One of the lessons learned is that only by quantifying and acknowledging uncertainty are we better placed to decide how best to manage it.

Flood defense infrastructure systems implemented today will endure for several decades if not centuries. A long-term, strategic view on planning of these investments is essential to be sure that limited resources are being effectively used. The challenge is to maximize the societal benefits, including risk reduction, and minimize the costs associated with building, operating, and maintaining infrastructure at system level. In other words, infrastructure is not only about damage prevention. Infrastructure investments, such as levees, dams, and urban drainage systems, provide wider benefits for society, and current approaches of cost-benefit analysis seem to be inadequate as a tool for evaluating them. A second lesson is that a broad view on costs and benefits is crucial to unlock alternative options for funding and financing. Moreover, it is also necessary to assess and include the value of flexibility and resilience across these systems over the long term.

From the Dutch experience, the following guiding principles to future-proofing FRM approaches have emerged and could have applicability to efforts in the United States to address similar issues:

1. *Monitor and adapt*—to respond dynamically to (unforeseen) changing conditions; FRM is a continuous process of learning that incorporates new knowledge to improve longer term planning and shorter term adaptation. Longer term plans are never fixed and complete but are continuously adapted to changing circumstances. This requires anticipation of possible future circumstances and flexibility to deal with uncertainty and exploit opportunities, which may emerge over time. Building more flexibility into flood defence infrastructure *systems*, to adapt these system to changing conditions and increase capacity, and *strategies*, to swiftly move from one trajectory of alternatives to another and to slow down or increase the pace of implementation of measures. For example, the Delta Program is keeping open the option to adjust the proportion of river discharges between its two major branches under particular scenarios.
2. *Do more with less*—to exploit the potentials of multifunctional use and multipurpose assets. Multifunctional flood defenses, multipurpose storage reservoirs, and water sensitive urban design (low impact developments [LID]) are new concepts that enable optimization of resources. For instance, flood detention basins can also serve the purpose of drought mitigation, and at the same time provide hydropower and/or irrigation. Successful Dutch examples of this category of measures are *Building With Nature* (coastal systems) and *Room for the River* (river systems) using both natural processes and more sustainable land use planning to enhance flood protection and environmental quality.
3. *Seize the opportunity*—to align infrastructure portfolios and to link the investment agendas of programs with those from other sectors when opportune. It needs to look more broadly at project objectives to identify opportunities for leverage and synergies. Urban restoration, regeneration, and modernization can be a key driver but routine infrastructure upgrades in conjunction with dike reinforcement can also play a role. A complicating factor is that different sectors often have different planning and investment periods which will require asset managers to proactively share information about their capital investment works. For example, the river widening measures at Nijmegen funded by national government were combined with the creation of a new island with recreational and ecological functions and the construction of new bridges and urban waterfront developments in cooperation with the municipality, province, and water board.
4. *Design for failure*—to seek to develop a portfolio of measures and instruments based on an understanding of system's interdependency (including failure) and emergent behavior[1] and how these may change over the longer term. This runs counter to traditional approaches that use a single intervention that focuses on a single type or magnitude of a flood "event." Strategies based upon a wide

portfolio of measures foster greater resilience than relying upon a single measure (Sayers et al., 2014). This can help to ensure an acceptable level of performance even when exposed to unanticipated extreme events as it aims to avoid impacts of a type and magnitude from which recovery would be extremely difficult. For example, in Dordrecht, urban planners design elevated roads to serve as evacuation routes and schools as shelters for extreme events, beyond the design flood, without additional cost.

5. *Accelerate uptake of new technology and stimulate innovation*—Technology is an important driver to improve design, planning, and performance of FRM systems and to make them more efficient. Typical examples are sensors in levee system for early detection of failure, visualization tools such as interactive design tables coupled with 3D flood modeling to better inform stakeholders, and advanced rain forecasting systems in support of anticipatory water management. The Dutch government and private sector are spending more than any other nation on water-related R&D to foster innovation in this field to better cope with the huge challenges ahead.
6. *Work in partnerships*—The emerging principles call for new, fit-for-purpose governance arrangements that bring in the commitment, knowledge, and the investments for developing and implementing the strategy and realizing the infrastructure projects. Many different actors will have to be involved such as banks, citizens groups, scientific communities, and environmental and economic interest groups. Government agencies across national, regional, and city levels have started to adopt a way of working in which they actively encourage initiatives from these actors and subsequently help with the realization of those ideas. By doing so, the City of Rotterdam has, for example, stimulated 600 community initiatives for city greening and urban flood management in a period of 1 year.

Lessons for the United States

Even though the Netherlands and the United States are vastly different in size, geography, and political systems and processes, both nations will be affected by climate change, sea-level rise, and the attendant risk of flooding. The Dutch are responding proactively and aggressively to what is recognized as a threat to the entire nation. At the heart of their efforts is a recognition that the future is uncertain and traditional approaches to FRM are no longer adequate; the technical and institutional flexibility to adapt to changing conditions will be the hallmark of future successful efforts. The guiding principles outlined above are both scalable and transferrable and could be beneficially applied to U.S. efforts at all levels of governance to successfully manage its future flood risk.

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Note

1. The advantages of a combination of flood risk management measures are often greater than the sum of the advantages of each measure taken separately.

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