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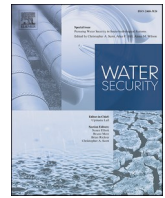
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Towards adaptive asset management in flood risk management: A policy framework

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ABSTRACT

EU Member States invest some €2.5 billion per year in flood protection, yet flood damages continue to increase. A new approach to the planning, design and management of flood protection assets is needed to ensure risks are better managed and asset management is aligned with broader socio-economic policies and supporting governance systems. This paper sets out a policy framework to enable this transition. The framework results from a collaboration of researchers and practitioners from around the North Sea. The findings highlight common challenges and identify four priority Policy Recommendations in response to these: 'Break free of the silo' by aligning planning processes; 'Mind the gap' between strategic and operational choices; 'Prepare for change' by developing multi-functional and flexible plans; and 'Make space for innovation' by seeking to manage risk rather than avoiding it.

1. Introduction

Collectively EU Member States invest around €2.5 billion per year on flood protection infrastructure [7]. But a combination of climate and socio-economic change is increasing the damage caused by flooding. Complex and difficult decisions will need to be taken in response to these threats, especially in coastal regions, as rising sea levels challenge the sustainability of communities and the policies and plans to keep them safe. This is compounded by an ageing asset base and multiple demands on resources across different sectors and countries.

In 2015 the EU funded the Interreg FAIR¹ project that brings together flood protection asset owners, operating authorities, and researchers from across the North Sea Region (NSR) - Fig. 1. Through a process of case studies, expert lead workshops and Peer-to-Peer learning, the

partners in FAIR shared and debated the policy, practice and emerging science of asset management; in particular how best to manage flood protection assets (including built and natural infrastructure assets) and ensure they are appropriately adapted to an uncertain future. Although there is no single solution or response, there is consensus on the urgency of the issues to be addressed and what is needed in order to make progress in ensuring flood protection assets and systems deliver the required flood protection over the long term. To do so requires a multi-functional design response (to ensure the assets deliver outcomes for a wide range of beneficiaries, people and nature) and the capacity for adapting to uncertain future change (in both loading and functional requirements, e.g. [34]).

This paper explores these issues by first presenting the inadequacy of the heuristic approach that has largely characterised the evolution of

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¹ <https://northsearegion.eu/fair>

flood risk management. The continuing and common challenges faced today by those involved in flood management are then distilled and recommended policy responses to address those challenges presented. Throughout examples of emerging practice from across the case study areas are used to illustrate the discussions (with links to the supporting more in-depth case study reports from the FAIR project and broader references provided – [14–18,20,21]). A detailed End Report from the FAIR programme also provides additional detail on the pilot applications [19] and supporting Knowledge Agenda [20].

2. Heuristic learning fails to foresee the future: A change is needed

Conflict between human development and the natural function of floodplains is as old as civilization itself (e.g. [45]). As societies develop,

they invariably take steps to lessen the impact of flooding. At first, these efforts were minimal but in recent centuries have evolved to include audacious structural actions to keep flood waters away from our cities and towns and drain vast areas of wetland for agriculture (e.g. [26,29]). Such measures are often difficult to sustain and are inevitably overwhelmed by the next ‘great flood’ and throughout history flood management practice has evolved in response to these events. This heuristic approach has yielded some important, although largely incremental, advances in both policy and planning, but has also left a legacy of significant and ageing flood protection infrastructure assets.

The demands placed upon these assets are now rapidly changing. Climate change is one driver of change but there are also others, including the expectations of society for flood risks to be well managed, for healthy ecosystems and for socially just investment of public funds [34]. Meeting these expectations requires a change in approach; it is not



Fig. 1. Members of the North Sea Region (shaded) and case studies contributing to the expert lead workshops and Peer-to-Peer learning that underpins the recommendations from FAIR. Note: National leads from the Environment Agency of England contributed advice and approaches.

longer acceptable to assume the climate in stationary (e.g. [30]) or to deliver inflexible mono-functional flood protection assets; more is now demanded of these assets than flood protection alone. Innovation is needed if flood risks are to be managed to acceptable levels at costs that are affordable.

Historically, the importance of designing in adaptive capacity into flood protection assets, and the acceptance that they will need to adapt as the future unfolds has had limited traction in practice. As a result, investments in capital projects have often been prioritised (e.g. [38]). Budgets for maintenance, monitoring and adapting flood protection assets are often the first to be constrained, and consequently, important asset management measures are often postponed. In the absence of long-term funding agreements, asset management tends to focus on 'patch and repair' corrective maintenance—rather than taking more significant action to keep pace with climate and other changes. Increasing this leads to a widening *adaptation deficit*, which is the difference between the risks faced and the risk considered to be acceptable now and in future (adapted from [22]).

In response, flood protection asset management must evolve towards an adaptive approach that ensures service provision reliably over time, balances whole-life performance, risks and cost (accounting for climate change, deterioration as well as possible changes in use and functional requirements). Achieving this change in practice and overcoming the barriers to adaptation is difficult (e.g. [8]). It will require not only technical innovation (e.g. in design, materials, monitoring etc.), but also innovation in institutional arrangements (to enable joined up action), policy enablers (e.g. [32]), to facilitate funding of multi-functional assets and flexible designs that embed adaptive capacity) and planning enablers (that give space for innovative solutions and link strategy to operation).

There are numerous initiatives that bring together the various domains of societal need, especially in relation to climate hazards and related infrastructure interdependencies, into an integrated strategic approach [37,2]. But, as yet, only a few case examples have been developed and few have been implemented. In particular domains, attempts are being made to deliver adaptive and flexible assets that provide multiple benefits and a range of services, by taking an integrated approach, which in the urban domain is founded in effective land use management. The science and knowledge in this area continues to be developed and lessons learnt. These initiatives need also to be complemented by appropriate supportive frameworks, including facilitating governance, leadership, unambiguous responsibilities for action, incentives, and vision.

In the FAIR project four policy recommendations for advancing towards adaptive asset management emerged (Fig. 2). These recommendations, the challenges they address, and emerging examples of implementation are elaborated in this paper before drawing together the common issues to be addressed to progress towards 'making adaptation happen' in practice.

3. Avoid the silo

3.1. Challenge to be addressed: The institutional context for asset management is often fragmented

Flood protection is necessarily a multi-stakeholder endeavour, bringing together issues of place making through spatial planning, investment, aesthetics, acceptable risks, and others. Flood protection asset management seeks to balance these perspectives and trade-off issues of cost, risk, and performance at multiple scales (from a single asset and to the system of assets, e.g., [42,28]). The demands of local communities for protection and the national desire for efficient investment create policy and priority tensions. Understanding how to leverage local funding and private investment to supplement national sources and to ensure national choices are not simply based on maximum return, but also consider broader issues of social justice and well-being as well as

ecosystem health, are common challenges [34].

The institutional context within which these challenges are responded to and flood protection assets planned, promoted, and managed is therefore crucial. Rarely is one organisation entirely responsible for flood protection asset management throughout all its stages. Roles and responsibilities are dispersed amongst many organisations and any mismatch between these responsibilities and the available capabilities and resources can undermine the provision of flood protection that is most fit for purpose. For example, a self-assessment of asset management approaches by each FAIR partner points to the strengths of a decentralised governance model in terms of coordination and problem solving between the different municipal departments, but also highlights the risks of adding responsibilities to municipalities without sufficient resources or knowledge to deliver [23].

3.2. Policy recommendation #1: Align multiple planning processes within and beyond flood management

There are many complex chains, interacting processes and actors in effective asset management. There will be centralized processes in place and dispersed, localized deliverers and operators. Policies need to ensure that there are effective inter-linking strategies in place for asset planning, delivery, and operation, such that the entire process, from centralized strategies to local delivery is managed as optimally as possible. This will require in many cases, a strategic oversight by one or more responsible authority or process leader who needs to be accountable. However, such oversight should ensure that local and dispersed functionality is appropriately utilised to inform the integrated planning, delivery, and operational processes (Box 1).

England, Strategic oversight and local delivery: Following widespread flooding in 2007 arrangements were put in place to enable more effective working between the main agencies involved in managing risks. The Environment Agency was given the responsibility of strategic oversight of all flood-related planning with delivery devolved to local municipalities designated as the Lead Local Flood Authority (LLFA). LLFAs are one 'department' of a local municipality and therefore local policies and activities need to balance the needs for local flood protection and a range of other activities including: education; public health; crime; highways etc. Overall these arrangements are broadly successful in enabling a more strategic approach to flood risk management [4] when adequately resourced but can be impeded when there is either a lack of resources; differing objectives, priorities and regulatory environments, within and between partners; a mismatch between public expectations and delivery; a lack of the necessary partner skills, capacity and knowledge.

4. Mind the gap

4.1. Challenge #2: Strategic planning and operational processes fail to align

Good asset management requires strategic plans and perspectives to link seamlessly with operational activities and perspectives. This is easier said than done. There is often a 'gap' in responsibility, with organisations tending to be divided between strategic and operational activities, making it easy for those involved to adopt, by default, a standalone process (e.g. [31,37]). Without a clear line-of-sight from operation to strategy and vice versa, strategic objectives are likely to be undermined by operational realities and the operations may fail to reflect the longer-term direction set by the strategy. This mismatch can lead to poor targeting of investment and inappropriate design and maintenance choices.



Fig. 2. Four policy recommendations for progress towards adaptive asset management flood protection.

4.2. Policy recommendation #2: Link strategic planning and operational processes through a tactical handshake

FAIR promotes a continuous collaborative approach to decision making across: strategy (with the focus on adaptive management planning); operational (with the focus on delivering and informing the plan) and tactical (providing the ‘handshake’ between the two, informing the strategy on what bottom-up needs and the operational on the top-down expectations). This continuous process underpins the FAIR planning framework (Fig. 3) and builds on asset management good practice in flood management, (e.g. [25,40,36] and in water and wastewater, and extends these approaches to explicitly consider the central role of the ‘tactical handshake’ in delivering effective, efficient and adaptive asset management in practice.

Establishing a culture of collaboration (inside and outside of any single organisation) is central to the success of this continuous process. But although necessary, this is not enough. A shared understanding of the assets to be managed is vital, including basic information on what and where the assets are, to how they are likely to perform now and in the future. This includes, for example, the adoption of structured assessment processes (methods, monitoring and data bases, e.g. [25]. These can help to progressively refine performance information and enable understanding captured through detailed level assessments to be reused in higher level plans (e.g. [39]). These can also provide insights from strategic assessments to inform more local analysis. FAIR has highlighted several approaches that are emerging to aid this process. These include innovative approaches that allow progressive performance assessment, that enable local understanding to be included without influencing the formal expression of performance (e.g. using fragility functions, [41]) and ‘total expenditure’ (TotEx) approaches that enable whole life capital, maintenance, modification, and eventual removal costs to be assessed [28]. These approaches help bridge the gap between strategy and operation by providing a common assessment framework at each level.

Netherlands, reducing life-cycle costs through a more strategic approach to delivering the statutory protection standards³: The dykes along the river Hollandsche IJssel no longer meet the statutory standard. The river can be isolated from the main River Nieuwe Maas by a storm surge barrier; but the dykes are the responsibility of the regional

water authority (HHSK) whereas the storm surge barrier is the responsibility of Rijkswaterstaat. The barrier controls the hydraulic loads on the dykes. Improving the reliability of the storm surge barrier also decreases the expected hydraulic loading conditions on the dykes; but investments in the barrier are needed to realise this. By working together, it has been possible to trade-off costs and benefits between dyke and barrier improvements operations in a way that reduces whole life-cycle costs without compromising standards; opportunities that a programme focused on dyke strengthening only would have missed.

Hamburg, Germany, developing a strategic approach to the management of ‘on demand’ assets⁴: Hamburg is protected from flooding by a range of measures, including a complex array of automated flood protection gates that are required to operate (on average) about 10 h/year and to a very high standard of reliability. Understanding the trade-off between the benefits of a highly automated approach and the potential increased chance of error (due to the complexity of the process) is a challenge. Data and information is central in responding to this challenge and LSBG Hamburg are developing a georeferenced asset information system that not only focuses on geometry and functions but also operational permits, as-built details, and the consequences of failure, to help understand the system behaviour and target maintenance.

5. Prepare for change

5.1. Challenge #3: The future is uncertain but decisions we make today are long-lived

The future will be different from the past; but how it will be different is impossible to predict. Developing flood protection infrastructure in this context presents several challenges, for example how much should be invested today in strengthening and raising assets and where is it possible to delay investments? These are complex decisions when the climate and socio-economic circumstances change (sometimes profoundly) over the lifetime of the decisions being made. Short-term political realities and varying perceptions of risk compound these difficulties, and because of this, maintenance and monitoring typically receive a lower sense of urgency compared with large scale infrastructure investments, renewals, or upgrades. This ‘bias-to-build’ leads to solutions that may be unnecessarily costly or maladapted to the reality of the future as it emerges [33].

Box 1

Aligning planning processes in Sweden and England.

Sweden, integrated city planning, Helsingborg²: The municipality of Helsingborg leads the coordination of all aspects of city planning. This context enables a series of major investments in the regeneration of the seafront and harbour area (including green space and beach access) and improvements to the flood protection standards to be considered simultaneously and plans adjusted in response to resources and changing needs.

² <https://northsearegion.eu/media/13621/helsingborg-pilot-02-06-20.pdf>

³ <https://northsearegion.eu/media/13622/fphij-pilot-02-06-20.pdf>

⁴ <https://northsearegion.eu/media/13620/hamburg-pilot-02-06-20.pdf>

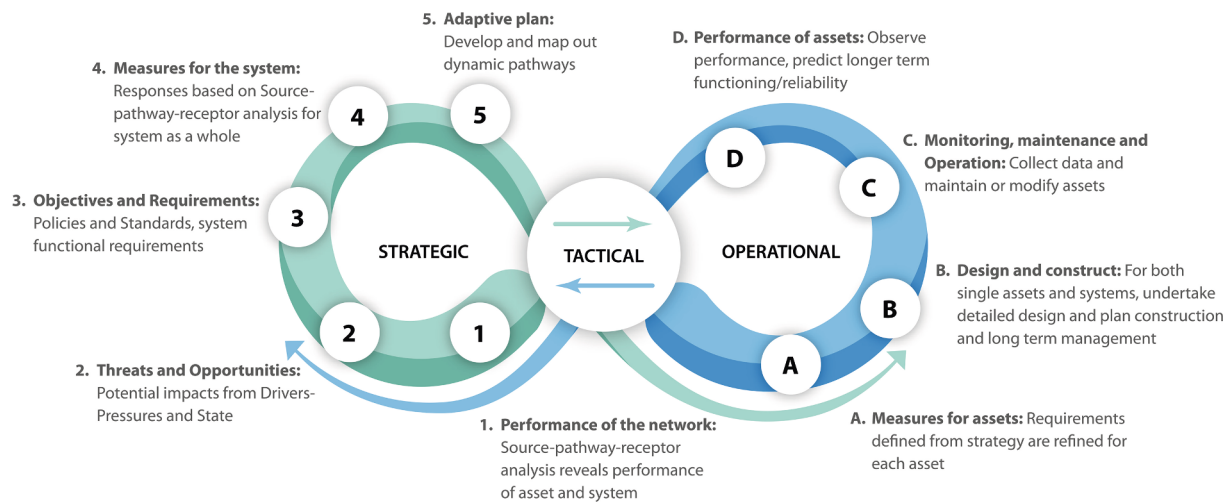


Fig. 3. FAIR framework recognises the importance of a continuous engagement between strategy and operations and the central role of a 'tactical' handshake in linking to two. Source: FAIR End Report [18].

Box 2

Innovative approaches to performance assessment in England, the Netherlands and Germany.

England, Environment Agency have translated ISO 55,000 to the flood asset context, recognizing that good flood management is an asset management task.

5.2. Policy recommendation #3: Develop strategies that are flexible and asset designs that are capable of being modified.

Policies and associated appraisal processes should provide a platform for the development of strategies that proactively plan for an uncertain future and can be modified as new evidence and insights emerge (e.g. [38,27,24]). Investments in monitoring and evaluation (assets, the loading conditions and the socio-economic setting) underpin the continuous process of updating both the strategy and operational delivery to ensure flood risks are well-managed and plans can be adapted in a timely manner.

Developing the capacity for future flexibility is not simply 'wait and see' but is a process of purposeful preparation and often comes at a price today (e.g. the cost of securing land for future set-back of a dyke line or to strengthen foundations in preparation for future raising). Various tools and techniques are available to help develop adaptation options [35] - Fig. 4), visualise adaptive pathways and value adaptive capacity (e.g. [1]).

Using these tools and approaches can help asset managers balance performance, risk, and cost over the short and longer term by maximising societal value and avoiding solutions that may be unsuitable for future conditions as illustrated in Box 3.

The Netherlands and England, visualising and valuing adaptive pathways: New guidance and tools are being used to both visualise and value the flexibility offered by adaptive approaches. The guide includes advice on considering adaptive approaches at different stages in appraisal and formally valuing the adaptive capacity [10]. Software tools are also being used to visualise and explore alternative pathways in an interactive way together with stakeholders, providing insights into the adaptation options available, the sequencing of options over time, potential lock-ins, and path dependencies.

Denmark, embedding flood and erosion in local planning⁵: In 2013 Danish municipalities were required to prepare climate adaptation plans that integrate erosion and flood protection within their long-term strategic planning processes (including urban development, wastewater management and environment). Despite not being required to revise the plans, the importance of doing so is widely recognized and many municipalities continue to work with national organizations to reflect better evidence on present and future risks and potential adaptation options within local planning decisions.

6. Make space for innovation

6.1. Challenge #4: Innovation is often not embedded in standard working procedures

The UK's Chief Scientist's Annual Report 2014 [44] stated that to be successful, a society must learn to manage risk and not simply seek to avoid it. Innovative solutions, and how to generate the political momentum to deliver these, remains a central barrier to progress. For example, the policy in recent years within England and Wales has been guided by the principle of 'Making Space for Water' [5], and in the Netherlands by providing 'Room for the River' [6]. Across the NSR the role of nature-based approaches as legitimate flood assets is increasingly recognised and the sentiment of these policy goals is clear; but often at odds with the local political and public response that prefers conventional, tried and tested, solutions. Consequently, asset managers face challenges in promoting and delivering more innovative solutions that challenge accepted norms.

⁵ <https://northsearegion.eu/media/13398/ribe-pilot-v7.pdf>

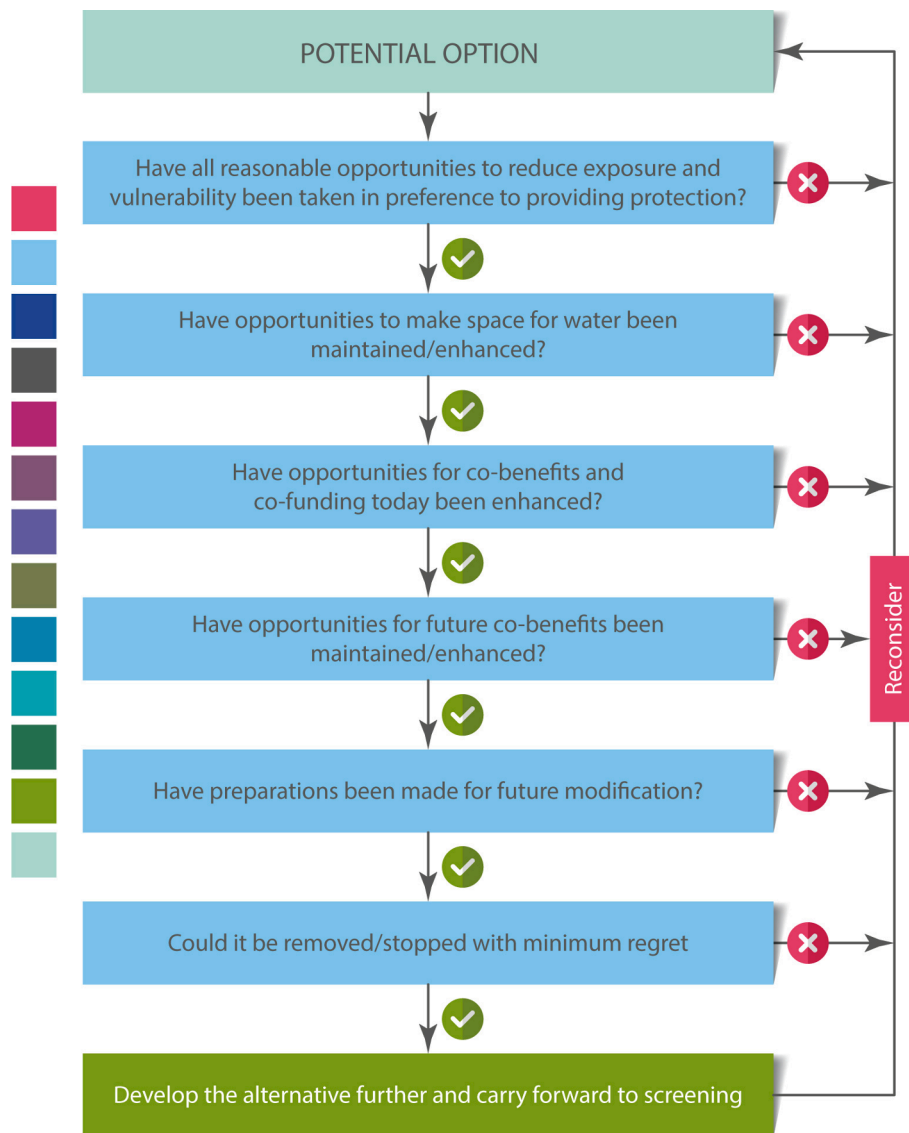


Fig. 4. Guiding the development of adaptive management options. .
Source: [35]

Box 3

Developing adaptive plans in England, Netherlands, and Denmark.

England, developing an adaptive plan for the Thames Estuary. The Thames Estuary 2100 project (TE2100) was established in 2002 with the aim of developing a long-term tidal flood risk management plan for London and the Thames estuary. The resulting TE2100 Plan [9] sets out a management strategy that can be adapted in response to future change including climate and socio-economic change (e.g. [11,43]).

6.2. Policy recommendation #4: Accept that with new approaches comes risk, managing rather than avoiding such risks can lead to innovative solutions.

Policies should provide the platform for the inclusion of innovation – from ideas to implementation, regulation to analysis and in the role of institutions and stakeholders. Central to the successful delivery of innovative solutions is to challenge the wisdom of conventional approaches and be positive in promoting new ways of working. This means rewarding innovation, through, for example, ring fenced innovation and pilot funds, as well as giving space to innovators from industry and

academia to transition novel approaches into practice by accepting the potential for greater uncertainty (Box 4).

Helsingborg, ‘innovation of the year’: The Municipality awards an annual prize to the most innovative project initiated during the year. There is even a prize for the ‘failure of the year’ that goes to an innovative project that did not necessarily turn out as expected. The purpose is to reward those that challenge the conventional approaches and encourage staff to embrace innovative solutions across all aspects of their work (e.g. from conception to implementation and from public engagement to funding).

Netherlands, innovative techniques proactively encouraged:

Box 4

Making space of innovation across the NSR.

England, natural flood management: Promoting the role of natural features to slow the flow of flood waters through catchments and urban spaces, and realignment of the coast to maintain littoral processes are being proactively pursued across the UK and widely considered to offer multiple benefits. Based on limited quantified evidence [2] on their ability to manage flood risk, pilot studies and demonstration projects have been funded by central Government to encourage take-up and develop the evidence base [3].

The opportunities provided by innovative approaches to dyke strengthening and emerging monitoring technology are widely available. For example, the national Dutch Flood Protection Program provides support funding for the development and testing of innovative dyke reinforcement techniques. Asset owners are also encouraged to use innovative sensor technologies to gain insight into dyke strength and performance (often in real-time) to maximise safety and optimise maintenance activities (Fig. 5).

7. Conclusions

In recent years, our world has been changing faster than our thinking – policies and approaches that rely on an assumption of stationarity (in climate, funding, societal preferences etc) remain in place (either explicitly or implicitly). Accepting a non-stationary and uncertain future will have profound impact on the choices we make (e.g. [13,12]). Through the FAIR project we have examined and set out here common barriers to adaptive asset management and the need for a policy framework that promotes innovative, whole system, long term thinking. The recommendations highlight the importance of political structures that support and reward those who are willing to pursue innovation and adopt cross sectoral approaches, such as in Helsingborg Municipality where (experimental) failure was not penalised but rewarded. Sometimes failure may only lead to lessons learnt, but otherwise to cost savings or improved outcomes. Appropriate budgeting processes capable of providing security of support but also offering flexibility as part of a leadership structure that is capable of providing strategic oversight (as the role played by the Environment Agency in England).

This paper is not solely about flood management. Flood management is in a pivotal (although perhaps not leading) position to influence change across multiple planning processes. *The success* of the policy recommendations set out, however, will fundamentally depend on the willingness and ability of those involved to make the case of adaptive asset management. This will require all those involved (from policy to operation) to break free of their own silo and actively seek collaborative ideas both within and external to the asset management system. Flood managers must become better at envisioning and visualising the future, using storylines and other aids to garner buy-in to an alternative (perhaps innovative) course of action (such tools exist but are seldom used routinely). We must be prepared to address the hard choices. To date, adaptation has tended to happen ‘at the edges’, *focusing on* easy wins. Addressing the hard choices is more difficult, such as for coastal realignment, or in towns making largescale space available for functioning floodplains. Addressing these issues today underpins the notion here that adaptation is a purposeful process, not simply an opportunity to ‘kick the can down the road’ but one that invests today for future flexibility. But how much short-term political capital we are prepared to risk on this, and how much we are willing to pay remains unclear.

Although we know much, we do not of course know everything, and never will. Good adaptation does not require perfect knowledge; given perfect knowledge, an adaptive approach would not be required (a simple linear staging of planned modifications would suffice). Delivering adaptation is a continuous process of adjustment, in policy, institutional and the flood defence assets themselves, underlying all of the recommendations here - you can’t get ‘adaptation done’ as it continues to



Fig. 5. Investment in innovative monitoring and performance understanding for a dyke reinforcement programme. Courtesy: Rijkswaterstaat.

be a process.

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CRediT authorship contribution statement

Paul Sayers: Conceptualization, methodology, writing-original draft; **Berry Gersonius:** Conceptualization. **Frank den Heijer:** Conceptualization. **Ulf Radu Ciocan:** Conceptualization. **Jeroen Rijke:** Conceptualization. **Philipp Jordan:** Conceptualization. **Peter Frohle:** Conceptualization. **Bart Vonk:** Project Administration. **Richard Ashley:** Writing-review.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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