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How "wide green dikes" were reintroduced in The Netherlands: a case study of the uptake of an innovative measure in long-term strategic delta planning

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This article describes and analyzes the reintroduction of the "wide green dike" in the Netherlands. It is a noteworthy example of implementation of an innovation in long-term strategic delta planning. The Dutch Delta Program was central herein. Pursuing its ambition to make the Netherlands climate-proof, the Delta Program invited a diverse set of actors to participate in developing a long-term adaptation plan, and also to propose innovative short-term measures to help realize that plan. The wide green dike was actively promoted by a local water board, with involvement of scientists and nature conservation organizations. A stepwise participatory process resulted in national-level recognition of the potential of the wide green dike, particularly due to its "green" and "adaptability" characteristics. Alignment of flood protection and climate adaptation goals with nature conservation objectives, as well as collaboration with new actors, were all crucial in the reintroduction of this innovation.

Keywords: Dutch Delta Program; long-term adaptation strategy; innovation; new actor coalitions

1. Introduction

Recognition of the inevitable impacts of climate change (e.g., IPCC 2007) has prompted many of the world's delta regions to initiate a search for suitable and sustainable adaptation strategies, and innovative measures to respond adequately to the threat posed by our rapidly changing climate (e.g., Bucx *et al*. 2010, 2014; EEA 2007, 2012; Hinkel *et al*. 2018; IPCC, 2012; Nicholls 2007, Nicholls *et al*. 2014; Syvitski *et al*. 2009). However, uncertainty regarding climate change and its impacts, as well as socioeconomic developments, such as population growth and land-use intensification, has become a major hurdle for adaptation planning and strategy development (Dessai *et al*. 2004; Hallegatte 2009). Numerous studies have examined approaches for elaborating adaptation strategies in the face of uncertainty. These include robust decision-making (Dessai *et al*. 2004; Hallegatte 2009; Lempert and Schlesinger 2001) and

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flexible and adaptive planning (e.g., Kuklicke and Demeritt 2016; Kwadijk *et al*. 2010; Lawrence *et al.* 2013; Reeder and Ranger 2011). Central to these approaches is the need to take a range of changing climate and socioeconomic conditions into account in decisions concerning long-term investments. Against this background, adaptable measures, or a sequence of possible interventions, may be preferred (Hallegatte 2009; Reeder and Ranger 2011).

Throughout history, flood risk management in deltas has been undertaken in an adaptive way; that is, by experimentation, trial and error, and "learning by doing" (Kato and Ahern 2008; Kwakkel, Walker, and Haasnoot 2016; Walker, Haasnoot, and Kwakkel 2013). After extreme events, flood protection works were restored and improved to withstand the most recent extreme conditions. Urbanized deltas, therefore, often have long and established traditions of water management and flood protection, including the construction of dikes and polders (Van de Ven 2004). Precisely because this strategy has proven so effective in enabling development and intensive use of dike-protected areas, it is often difficult to implement innovations or realize changes in entrenched flood protection approaches (e.g., Geels 2004, 2005; Vellinga, Marinova, and Van Loon-Steensma 2009; Wiering *et al*. 2017). Climate change and socioeconomic developments, however, will result in changing boundary conditions and call for new strategies and measures.

Although biophysical and socioeconomic conditions do vary around the globe, all deltas face similar challenges in responding in an effective and timely manner to the issues they face under the uncertainty of climate change and socioeconomic developments (Daniel and Hinkel 2018; Moser, Williams, and Boesch 2012). Initiatives have been started to connect delta regions in networks and in projects where they can share knowledge and experiences (e.g., the Delta Alliance www.delta-alliance.org and the 100 Resilient Cities platform). Various research projects have also commenced, to compare and select adaptation strategies (e.g., Bellinson and Chu 2018; Seijger *et al*. 2017; Suckall *et al*. 2018; Zevenbergen *et al*. 2018). Several countries have made expertise on adaptation and flood risk management available to developing countries. An approach increasingly recognized as promising is the formulation of a long-term vision guiding developments toward a sustainable delta and covering multiple policy domains (Seijger *et al*. 2017). Such a long-term strategic delta plan offers a framework that accommodates and connects diverse policies, programs and projects, and offers space for innovative solutions and, perhaps, the introduction or reintroduction of historic methods (Seijger *et al*. 2017).

The Netherlands – with more than half of the country prone to flooding – is one of the world's frontrunners in the adoption of a long-term strategic delta planning approach (Bloemen *et al*. 2018; Van Alphen 2016; Verduijn, Meijerink, and Leroy 2012). Furthermore, the Netherlands' has formalized its ambition to implement innovative solutions by labeling innovative flood protection strategies for several locations as "promising" and "preferred" (Delta Programme 2014) and by earmarking funds for explorative studies on innovation. However, as far as we know, little has yet been written about the dynamics involved in the implementation of innovations under the new strategic delta planning approach. This is remarkable, since plan implementation is widely recognized as difficult and, indeed, fraught with failure (e.g., Phi *et al*. 2015; Hupe and Hill 2016).

The reintroduction of the wide green dike is one of the first examples of the uptake of an innovative measure under the Netherlands' new long-term strategic delta planning approach. Thus, it offers an opportunity to reflect on the implementation process

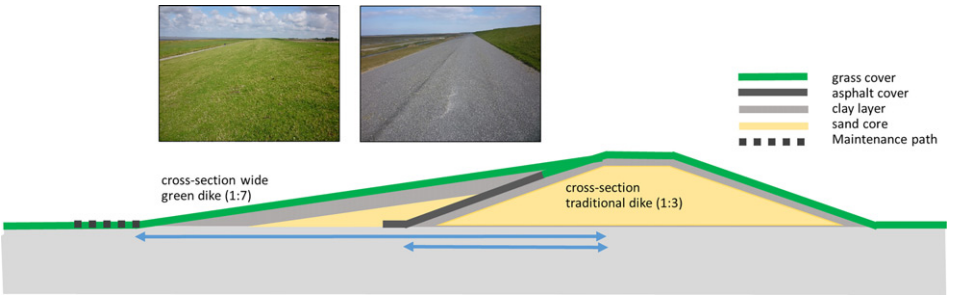

Figure 1. Cross sections of the wide green dike and traditional dike (with an asphalt cover on its seaward slope). Blue arrows (bottom) depict the difference in seaward footprint. Photographs show a wide green dike along the German Wadden Sea coast (top left) and a Dutch traditional dike along the Dutch Wadden Sea coast (top right).

of a real-world adaptation innovation. This article describes and analyzes the steps taken in reintroducing the wide green dike in the Netherlands. Our aim is to identify the main barriers and drivers in our case study and to distil lessons that could be applied in other delta regions facing similar challenges, and in similar processes of transition to a long-term strategic delta planning approach. We use the Hourglass Framework to answer three main questions: (1) what were the important steps in the implementation process of the adaptation innovation in the real-life context? (2) who were the key actors, and what was the role of new actor coalitions? (3) what role was played by shifts in governance under the new long-term strategic delta planning approach? We map and discuss the steps in the implementation of the wide green dike, including the roles of the main actors and actor coalitions. This provides us with a deeper understanding of the main barriers and drivers to implementation of adaptation innovations overall.

2. Case study and methods

This section first introduces the wide green dike case study; then explains how we applied the Hourglass Framework to our case study.

2.1. Wide green dike case study

Our wide green dike case study is located in the Dutch Wadden region. This region is protected against flooding from the Wadden Sea by dikes. The Wadden Sea is a shallow sea, marked by barrier islands, sand and mud flats and coastal marshes (Reise *et al*. 2010). Due to its outstanding nature values, the Wadden Sea was listed as a UNESCO World Heritage site in 2009 (Common Wadden Sea Secretariat 2008; UNESCO 2009). A number of sections of dike do not meet today's safety standards. At the time of writing, a project had begun to transform a section of the existing dike into a wide green dike. The wide green dike is a historical dike design. Wide green dikes use only natural materials, such as clay covered with grass, and have a mildly sloping seaward face that merges smoothly into the adjacent salt marsh (with a slope of around 1:7) (Van Loon-Steensma and Schelfhout 2017) (Figure 1). Under normal conditions, incoming waves are damped by the salt-marsh foreland. Only during storm conditions, when the salt marsh is submerged due to high water levels, do waves reach

the dike. Because of the wave-damping capacity of the salt-marsh foreland and the gentle seaward slope (which reduces wave impact), the grass-covered clay layer is sufficient to protect the dike against erosion during extreme events (Van Loon-Steensma and Schelfhout 2017). 'Traditional dikes,' as built over the past one hundred years in the Netherlands, have a steeper seaward slope covered by asphalt, concrete or stones to resist the design wave loads (this is 1/3,000 years for the mainland coast along the Wadden Sea) (Figure 1).

2.2. Methods

For our case study, we elicited the different steps in the wide green dike implementation process. Our descriptive analysis follows Seijger *et al*.'s so-called Hourglass Framework for strategic delta planning (Seijger *et al*. 2017). The 'hourglass' is formed first by the process of convergence of the ideas and stakes of the various different actors toward a decision, followed by a process of divergence into a variety of policies, programs and projects shaped to realize the long-term vision. It connects the planning, decision-making and implementation phases. We applied this framework to explore the way the wide green dike innovation was put on the agenda, how it became embedded in regional strategic plans and has been implemented within the context of the new strategic delta planning approach. Furthermore, we examined the role of actors and new actor coalitions, the impacts of shifts in governance, and the role of new policies in the various steps toward implementation.

We used mixed methods for the description and mapping of our case study. Based on scientific and grey literature, as well as policy documents, we constructed an overview of flood risk management strategy in the Netherlands and the emergence and adoption of the new adaptive approach to long-term strategic delta planning. The overview enabled us to describe and identify the different stages in the development of the long-term strategic delta planning process. We also positioned the wide green dike concept in this overview, in order to present a broad, historical perspective on the reintroduction of this dike concept. The implementation steps were also traced in the reintroduction of the wide green dike. We identified the main actors involved and their roles, and reflected on the roles of new actor coalitions and shifts in governance.

Alongside scientific and grey literature and various Delta Program documents, we drew on our own experiences, as both authors were extensively involved in research on, and development of, the wide green dike. This yielded a draft map of the implementation steps and the actors involved in the reintroduction of the wide green dike, structured according to the Hourglass Framework.

Next, we discussed our findings on implementation steps, roles of actors and new actor coalitions, and shifts in governance and policies with key players from the water board (1 interviewee), nature conservation organizations (1 interviewee), research institutes (1 interviewee) and the Dutch flood protection program (1 interviewee).

Based on these interviews, we tightened our description of the implementation process and elaborated further on the roles of the main actors and actor coalitions. We also asked the interviewees whether they recognized the different steps in the implementation process for the wide green dike.

Finally, based on the mapped overview of the implementation steps, key actors and activities, and shifts in governance, we reflected on the value of the Hourglass

Framework in facilitating the development of a long-term strategic delta planning approach.

3. Steps toward implementation of wide green dikes in The Netherlands

3.1. Development of the Dutch flood protection strategy

The Netherlands has a long established tradition of water management and flood protection, including the construction of dikes (Van de Ven 2004). The first flood protection infrastructure was established here in Roman times, some 2,000 years ago (Van de Ven 2004). In the Middle Ages, Catholic cloisters and monks began to systematically drain peatlands and build dikes to reclaim and protect coastal areas against high seas. In the thirteenth century, local landowners established the first local water management councils, the so-called water boards (Van de Ven 2004). Although many areas of governance were centralized in the seventeenth, eighteenth and nineteenth centuries, local water management, including coastal protection, often based on locally developed best practices in dike design, remained under the authority of the water boards, including financing through taxation, as allowed for in the Dutch constitution of 1848 (Kissling-Näf and Kuks 2004).

Although various floods over the centuries challenged this system of local water boards, the water boards remained relatively autonomous, promulgating a diversity of maintenance practices and dike designs. However, in the twentieth century, after two major coastal floods, the national authorities stepped in. The 1916 flood stimulated scientific research on dike design and gave impetus to a national infrastructure megaproject to build the 30 km long Enclosure Dam (*Afsluitdijk*) which closed off the entire Zuiderzee estuary. In 1953, a dramatic flood inundated the southwestern Netherlands, resulting in nearly 2,000 deaths and major economic losses. Poor maintenance – because most of the relatively small coastal water boards lacked the money to maintain the dikes to an adequate safety standard (Vellinga and Aerts 2013) – and inadequate dike design caused many dike breaches, leading to this disaster (Gerritsen 2005).

Following the 1953 flood disaster and the advice of the First Delta Committee, an entirely new national system of water safety was implemented, based on a rough economic cost-benefit analysis. Strict national safety standards were established and national funding was provided under the so-called First Delta Plan. The responsibilities of the local water boards were reduced to the implementation of national design principles, execution and maintenance of dike works and operational tasks. Flood safety norms were laid down in 1996 in the national Flood Defense Act. In the ensuing decades, extensive dike reinforcements and proper maintenance has yielded a well-protected country (Jorissen, Kraaij, and Tromp 2016). However, recognition of the realities of climate change (Begum, Stive, and Jim 2007; IPCC 2007), alongside near flood disasters in the Dutch riverine region in 1993 and 1995, gave rise to a new policy initiative, "Flood Protection for the 21st Century" (*Waterveiligheid 21^{e} Eeuw*).

Dutch flood protection policy was thoroughly revamped, accompanied by comprehensive research on the expected impacts of climate change in the Netherlands (Ritzema and Van Loon-Steensma 2017) and uncertainties in this regard (e.g., Klijn, Van Buuren, and Van Rooij 2004; Kwadijk and Rotmans 1995). This produced a new shift in flood risk management governance and strategy from 2005 to 2015, premised on the growing awareness that flood risks in deltaic areas are not static, but change with changing hydraulic conditions, particularly under the influence of climate change,

socioeconomic and demographic developments (De Moel, Aerts, and Koomen 2011) and land subsidence. Based on a detailed and updated nationwide economic cost-benefit analysis, a full probabilistic flood protection approach was introduced in 2017 (ENW 2017).

Another key development in the Netherlands was the introduction of the new Water Act of 2009, which changed the balance between national and local funding of primary flood protection works from nearly one hundred percent national to a fifty/fifty split (Adviescommissie Financiering Primaire Waterkeringen 2006). Regional (secondary) flood protection works had to be fully financed regionally (i.e., at the provincial level). This reassignment of financial responsibility sought to create stronger incentives at the regional level for cost-effective water management, judicious spatial planning and sound coastal protection. It was also meant to prevent the availability of national funding from acting as a barrier to more cost-effective innovations for adapting to accelerating sea level rise and land subsidence (Adviescommissie Financiering Primaire Waterkeringen 2006).

Furthermore, the Netherlands adopted a new 'adaptive' delta management plan, based on the recommendations of the Second Delta Committee in 2008 (Delta Committee 2008). To put into effect the new long-term, flexible and integrated delta planning approach, the Dutch Delta Program invited, engaged and connected with regional and local governance actors, including provincial-level government agencies, water boards and municipalities, alongside new actors such as nature conservation organizations (Delta Programma 2010; Delta Programme 2011). These parties were asked to implement the long-term strategic vision on sustainable delta development through their policies, programs and projects. The new approach, which encompassed the domain of spatial planning and the notion of multifunctional land use, was presented as offering major opportunities for innovation and involvement of new stakeholders. With the new strategic delta planning approach and new laws in place, the water boards suddenly became responsible for covering more costs and, at the same time, had greater freedom in land use and design of flood protection measures. This represented a huge shift in water management and flood protection practice, for both the water boards and their stakeholders.

3.2. Latent familiarity with the wide green dike in The Netherlands

The timeline in Figure 2 depicts the development of Dutch flood protection strategy and the emergence of the long-term strategic delta planning approach over the last century. A latent familiarity with the wide green dike concept is evident, as this dike design was implemented in 1984 and then again in 2018.

Implementation of new safety and dike design standards in the 1950s resulted in the need for massive dike reinforcement works and efforts to strengthen the scientific knowledge base on dike design. This led to modifications in historical dike-building techniques and designs, and massive application of asphalt covers on the seaward slopes. In Germany, however, the wide green dike became the preferred dike design (EAK 2002) after observation of its superior performance during the North Sea flood of 1962, compared to dikes with a steeper seaward slope.

This remarkable difference in dike design between the Netherlands and neighboring Germany was noted in the late 1970s. At that time, German coastal reinforcement works received a visit from the "Kring of Coastal Engineers" (a yearly gathering of

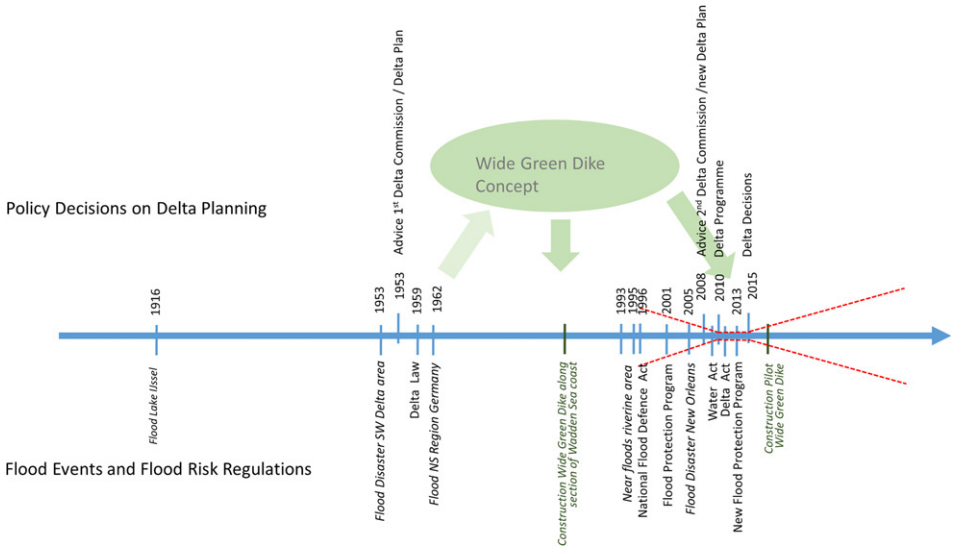

Figure 2. Timeline of flood risk management strategy in the Netherlands over the last century. Emergence and adoption of the strategic delta planning approach is indicated by red dashed lines, and implementation of the wide green dike is indicated by green arrows.

experts from countries bordering the North Sea initiated in the aftermath of the 1953 flood disaster). Here, the Dutch participants learned about the German wide green dike design. Beside a grass-covered mildly sloping seaward face (with a slope of around 1:8), a zone extending some 150 m into the adjacent salt marsh was set apart from the legally protected Wadden Sea conservation area (Hofstede 2003) to enable flood safety-oriented management in this zone. A discussion arose among the experts about the advantages and disadvantages of the various dike designs. Later, Dutch botanists explored the differences in vegetation in the grass cover of the dikes, again comparing the German and Dutch situations (Sprangers and Muijs 1997).

When, in 1984, one of the last stretches of dike along the Wadden Sea had to be reinforced, some experts, who were aware of the German dike design, sought to explore the option of a 'green' dike here. This new interest in more environmentally friendly dike design was the result of an extensive discussion about the positioning of this stretch of dike. That discussion can be seen as a manifestation of the increased emphasis within society on recreation, nature conservation and landscape values, in addition to flood safety, since the 1970s. Regional government advocated a shift in the dike's placement to reclaim land for agricultural purposes, although this would negatively affect some coastal conservation areas. Ultimately, a legal decree was issued to retain the Noorderleeg summer polder outside the official dike ring, to preserve its natural values by allowing occasional flooding of the salt-marsh related habitats. This essentially created the opportunity for a grass-covered dike, as the summer polder formed a relatively high and very broad foreland adjacent to the dike, which through its wave-damping capacity, protected the dike from wave onslaught. This was confirmed by tests performed at a new large-scale wave flume facility (Waterloopkundig Laboratorium 1984).

In this particular example of wide green dike implementation, various factors were important: the presence of an extensive summer polder adjacent to the dike; exchanges

of experiences facilitated by national and international meetings; advocacy of a 'green' dike by early adopters; strong promotion of nature and landscape-oriented interests by conservation organizations; sound scientific evidence of the wide green dike's performance presented by a respected research institute; and issuance of a legal decree to conserve the summer polder. However, this example remained an exception in Dutch dike reinforcement works.

3.3. Growing interest in the wide green dike concept in the initial stage of the Wadden region delta plan

The new Delta Program created regional subprograms tasked to develop regional flood protection strategies (2010–2014) (Van Alphen 2016). The Wadden Sea region was one of these, due to the region's important natural values and because the Wadden Sea region forms a geographical and geomorphological entity with distinct hydrological conditions and challenges. Furthermore, the Wadden region delta program (together with the southwest delta program) was to be coordinated by the Ministry of Agriculture, Nature and Food Quality, in line with this ministry's responsibility for nature development and conservation, landscape quality and agriculture. All other delta subprograms were coordinated by the then Ministry of Transport, Public Works and Water Management (now Ministry of Infrastructure and Water Management).

The Ministry of Agriculture recognized the Delta Program as an opportunity to align climate adaptation strategies and measures with nature development and conservation goals, some of which were legally mandated, in the Wadden Sea region. It also saw the program as an opportunity to connect and reorient the existing wicked range of policies, stakes and actors in the Wadden Sea region. Furthermore, its role brought the involvement of regional departments and representatives of the ministry. Moreover, specialized knowledge institutes linked to the ministry were involved, in addition to the water boards and regional authorities. As a result, expertise on ecological, geomorphologic and climate adaptation strategies and governance were well represented on the initial Wadden region delta program coordination team, alongside expertise on flood risk and water management (as in the other delta subprograms). This initial coordination team formulated the aim of the Wadden region delta program as the development of a long-term strategy to adapt to climate change while also strengthening the Wadden region's unique natural and landscape values (Delta Programme Wadden Region 2011).

In 2010, the development of the Wadden Sea adaptation strategy commenced with baseline studies (to assess the effect of climate change on future flood risks) and a series of stakeholder workshops. Many of the stakeholders involved had previously participated in programs, projects and activities organized by nongovernmental organizations (NGOs) aiming to protect the Wadden Sea, to integrate economic activities with nature conservation, and to explore new flood protection concepts (e.g., via the European Union's ComCoast project). For instance, the Waddenvereniging, an NGO for protection of the Wadden Sea, in 2009, initiated a series of design workshops to explore the potential of more integrated and nature-based flood protection concepts. This was in response to a recommendation by the Second Delta Committee that the program should pursue sustainable climate adaptation measures. These initiatives also elaborated on the findings and activities of the Trilateral Working Group on Coastal Protection and Sea Level Rise (CPSL 2001, 2005, 2010). Furthermore, in 2008, a

group of contractors, engineering companies, research institutes and NGOs founded "Ecoshape," a consortium to explore the technical and operational aspects of "Building with Nature." Also around this time, the Nature-Based Climate Buffers coalition (*Natuurlijke Klimaatbuffers*) was launched.

In 2011, several innovative and green concepts were launched during early workshops for the Wadden Sea delta program. The wide green dike concept was enthusiastically advocated by a representative of the Hunze and Aa's Water Board, as he was puzzled by the design differences between the dikes along the Dutch and German parts of the Ems-Dollard estuary.

A key player at this stage was the Ministry of Agriculture. In its coordination role, the ministry sought to align the Wadden Sea's nature conservation goals with the ambition to develop a long-term climate change adaptation strategy. Moreover, the ministry introduced ecologically oriented knowledge institutes to the development of flood risk management strategies. Furthermore, the Delta Committee's recommendations, as well as the Delta Program's participatory approach and engagement of new stakeholders, provided a strong impetus for new ideas and new stakeholders in flood risk management, including nature conservation actors and businesses.

3.4. Formulation of the Wadden sea adaptation strategy

The Wadden Sea delta program followed the schedule set by the Netherlands' national Delta Program: exploration of possible adaptation strategies (2010–2011), identification and elaboration of promising strategies (2012–2013) and formulation of preferred strategies (2014) (Delta Programme 2011; Delta Programme Wadden Region 2011). This was followed by five national 'decisions' or priorities formalized in 2015.

After the initial workshops, several explorative literature reviews and modelling studies were performed, among others, on the potential of innovative dike concepts, including the wide green dike (Van Loon-Steensma and Schelfhout 2013a; Van Loon-Steensma *et al*. 2012). The idea of transforming the present flood defenses along the Wadden Sea coast into more environmentally friendly and innovative designs, particularly those based on nature or ecoengineering principles, was well received by regional stakeholders, including the water boards, and by the steering and coordination committee of the Wadden region delta program and the national Delta Program. During regional and national conferences in 2012 and 2013, the wide green dike was presented as a promising adaptation strategy for the Wadden region.

The Hunze and Aa's Water Board succeeded in initiating a pilot study on the potential of the wide green dike along the Dutch part of the Ems-Dollard estuary within the Wadden Sea regional delta program (Van Loon-Steensma and Schelfhout 2013b). Although the research was conducted by national institutes, representatives of Hunze and Aa's were intensively involved. In January 2013, they organized a symposium to inform and consult with a range of stakeholders, among them, local landowners, NGOs and municipalities, as well as Dutch and German experts. These exchanges between Dutch and German experts, underpinned by technical details, as well as the attendance of new and national actors, such as nature conservation organizations, businesses and representatives of the ministries of Economic Affairs and of Infrastructure and Environment (new incarnations of, respectively, the ministries of Agriculture and Transport), helped to launch the wide green dike concept on the Delta Program map of promising strategies for the Wadden region and inspired new actors

to step in. For instance, Ecoshape organized a workshop to explore the potential of an ecoengineering approach to the construction of a wide green dike along the Ems-Dollard estuary. Here, Germany's experience with local clay mining from salt marshes was raised as potentially applicable (Bartholomä *et al*. 2013; Karle and Bartholomä 2008). New studies were also done, for example, on the potential benefits of innovative dike designs and their robustness and flexibility (Van Loon-Steensma, Henkens, and De Groot 2014) and on the feasibility of a wide green dike along the Ems-Dollard estuary (Van Loon-Steensma *et al*. 2014). The latter focused on civil engineering aspects, as well as legal and socioeconomic issues, and in addition to researchers, involved representatives of the water board and a regional government planning institute (*Dienst Landelijk Gebied*).

In 2015, the national Delta Program advocated innovative flood defenses, including wide green dikes, as the preferred approach to mitigate flood risk along the Wadden Sea coast (Delta Programme 2014). However, as no urgent climate adaptation needs were foreseen for the Wadden Sea region, none of the five Delta priorities focused explicitly on the Wadden Sea region, and no funding was earmarked to actually implement innovative flood defenses along the Wadden Sea coast.

The stepwise approach chosen by the national Delta Program, and subsequently by the Wadden regional delta program, extending from exploration via elaboration to preferred strategies and measures, proved important in supporting initial ideas with scientific background information. Furthermore, the Hunze and Aa's Water Board grasped the opportunity offered by the Delta Program to launch the wide green dike concept within the regional and, subsequently, the national strategy, as well as to invite and engage new actors, such as national and international nature conservation organizations, businesses and representatives of ministries.

3.5. Implementation stage of wide green dikes

The Delta Program set national priorities in 2015, and the process moved into the implementation phase. Responsibility for further developing and implementing short-term measures to achieve the long-term adaptation strategy was transferred from the national to the regional and local governance level. The regional water boards were now mandated to put the long-term delta strategy into practice by aligning pending dike reinforcement projects and maintenance activities with the long-term vision. For the water boards, however, the legal task of flood risk management still had primacy. Furthermore, they were bound by earlier obligations to reinforce substantial stretches of the Wadden Sea dikes in a 'business as usual' way. Thus, involvement of a group of water board representatives in the national and regional process of strategic delta planning, it appeared, was insufficient to bring about rapid and rigorous implementation of the ambitions of the national Delta Program and the priorities it had set.

However, in parallel to the Delta Program, a new Dutch flood protection program (*Hoogwater Beschermings Programma,* or HWBP) had commenced in 2013. HWBP became part of the Delta Program, meaning that it now had to carry out its dike reinforcement activities in compliance with the Delta Plan's long-term strategy (www.Deltacommissaris.nl). By applying the new funding rules of the Water Act and, at the same time, offering funding for research on the fastest, cheapest and most sustainable ways to reinforce dikes, a series of joint studies was carried out (in Dutch termed *project overstijgende verkenningen*, or POVs). These explored the innovative dike designs

promoted by the Wadden Sea water boards (https://pov-waddenzeedijken.nl). Thus, the innovative dike concepts developed in the national Delta Program came to be considered feasible short-term measures to fulfil the legally mandated dike reinforcement obligations. In addition, new actors, such as local consultancy firms and regional NGOs, became involved in plan development and study elaboration. Although the wide green dike was selected as one of the joint explorative studies (POVs), with the Hunze and Aa's Water Board as project leader, real implementation of this dike design remained far from certain. Next to high initial costs, Hunze and Aa's foresaw serious hurdles, not least, restrictions arising from national and international nature conservation regulations and opposition from local landowners. Indeed, the wide green dike needs substantially more space than a traditional steep dike (see Figure 1), and this bigger footprint could affect biodiversity in the adjacent, protected salt-marsh area (Van Loon-Steensma and Schelfhout 2017).

Hunze and Aa's used the Delta Program's explorative studies on the wide green dike to highlight this design's potential value for the Wadden Sea coastal landscape. It was considered a more sustainable design than the traditional asphalt-covered dike. The additional required clay was estimated to cost less than the asphalt cover (Van Loon-Steensma *et al*. 2014). Finally, the wide green dike could benefit salt-marsh pioneer species – if the required clay could be mined from the adjacent foreland. The water board organized several excursions to Germany to observe a real wide green dike. It also visited a pilot project on clay mining from an adjacent salt-marsh foreland, inviting German experts to share their knowledge with their Dutch colleagues, nature conservation NGOs and private owners of salt-marsh forelands. The water board asked the Ministry of Economic Affairs' regional ecological stimulation program "Towards a Rich Wadden Sea" (*Naar een Rijke Waddenzee*) to host several regional consultations. Furthermore, the water board promoted the wide green dike via press releases and presentations at regional events and by inviting interested scientists, consultancy firms, businesses, NGOs and inhabitants to learn about the wide green dike concept. This all led to broad social support for the reintroduction of the wide green dike and helped raise funding for a pilot.

Simultaneously, Ecoshape, in collaboration with Hunze and Aa's Water Board, the Province of Groningen, the National Public Works Department (*Rijkswaterstaat*), Groningen Seaports and a regional NGO, developed an ambitious plan for experimental clay mining from several suitable locations near the foreseen location of the wide green dike pilot. The project (termed a *kleirijperij* in Dutch) involved ripening and drying dredged Ems-Dollard silt such that it could, in time, be used as solid clay for construction of a wide green dike. Using silt in the form of dredged material from the Ems-Dollard estuary would improve the water quality and, therefore, the ecological quality of the estuary. The Ems-Dollard estuary currently does not meet the standards mandated by the European Water Frameworks Directive and Natura 2000 legislation, due to high sediment loads, among other things (Stuurgroep E&E 2016).

Because of the pending legal requirement to implement dike reinforcement and the innovative character of the plans, HWBP provided partial funding for construction of a wide green dike on a 1 km stretch along the Dollard. Moreover, because of the green character of the pilot, *Waddenfonds* contributed supplementary funds. *Waddenfonds* is a foundation set up in 2006 with revenues from natural gas extraction from the Wadden Sea, to compensate for the negative effects of gas extraction on Wadden Sea nature. *Waddenfonds* also funded a substantial part of the clay-mining pilot, with

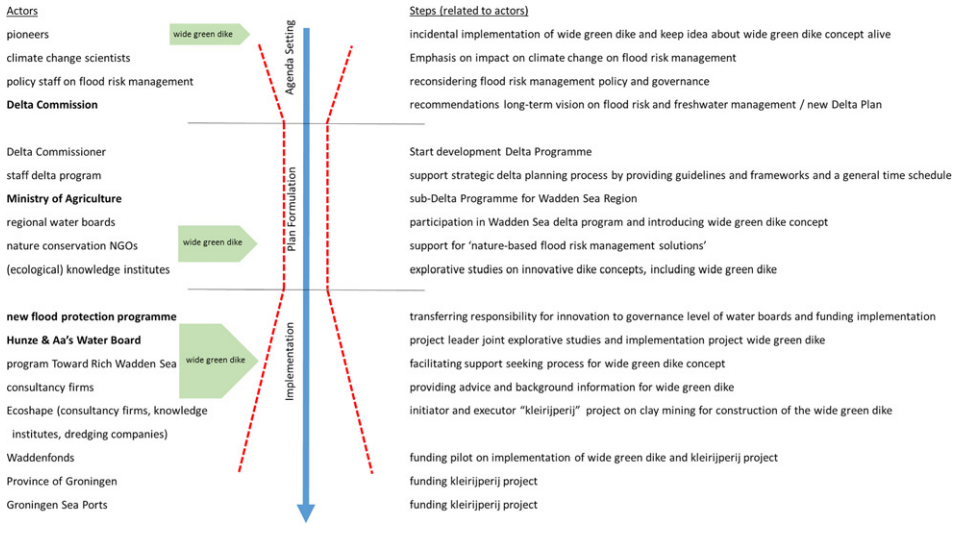

Figure 3. Steps toward implementation of the wide green dike in the Dutch flood risk management strategy (blue arrow) and main actors (key actors are in bold) based on the Hourglass Framework applied to long-term strategic delta planning (red dashed lines).

additional funding provided by the water board, to become available through guaranteed purchases of the clay produced.

In these early years of Delta Plan implementation, the new funding rules under the Water Act (2009), as well as the facilities provided by HWBP, proved key to the reintroduction of the wide green dike. In providing funds for innovation, HWBP in fact transferred the responsibility for innovation to the governance level of the water boards. Precisely because of insufficient funding, the water board had to look for new business approaches and form coalitions with other policy domains and new actors. This opened a window for innovation.

4. Discussion

Figure 3 summarizes the steps toward implementation of the wide green dike and the main Dutch actors involved in flood risk management and in long-term strategic delta planning. Our descriptive analysis of all the steps involved (including tools and the introduction of innovations) and actors demonstrates the crucial roles played by many in implementation of the wide green dike. Although our study is limited to one case it yields important insights, showing that a systematic and detailed description based on a conceptual framework can reveal key information about the dynamics at work in the implementation of innovations.

First, introduction of the new strategic delta planning approach opened a window of opportunity for change and innovation in the already well-developed and established Dutch flood risk management strategy. In particular, adoption of a long-term vision on sustainable development in a changing environment invited participants to think beyond strict Dutch design standards and the 50-year planning horizon for dikes (100 years in built-up areas). The search for robust and adaptable solutions thus began. The Delta Program stimulated this search through its exploration of possible adaptation strategies, following baseline studies to assess the effect of climate change on future

flood risk (e.g., Vellinga *et al*. 2008). Similar to the Thames Estuary project (TE2100), where a series of possible interventions was proposed that could cope with a range of changes until 2100 (Reeder and Ranger 2011), this yielded a portfolio of innovative solutions for the Wadden region (Van Loon-Steensma, Schelfhout, and Vellinga 2014). Such a suite of adaptation options fitted the new adaptive approach, and implied that decisions on measures to achieve the long-term vision would be made over time and in line with emerging developments and insights (Haasnoot *et al*. 2013; Hallegatte 2009; Klijn *et al*. 2015; Kwadijk *et al*. 2010; Kwakkel, Walker, and Haasnoot 2016). The explorative studies (2010–2011), which turned up a set of possible innovative solutions, were immediately followed up by identification and elaboration of promising strategies (2012–2013) and formulation of preferred options (2014) under the Dutch Delta Program (Delta Programme, 2014). Innovative flood defenses, including wide green dikes, were now advocated at the national level as the preferred approach to flood risk management in the Wadden region. The national HWBP offered funding for the regional water boards to conduct further explorative studies on innovations. This led to elaboration of the best short-term measures to achieve the long-term adaptation ambition. In practice, this meant that pilots could be initiated to gain more insight into the performance of innovations.

Second, the introduction of innovative adaptation measures was facilitated by a compelling process that actively engaged regional flood risk managers and new actors and stimulated new ideas. Regional actors were invited to participate in the annual national delta conferences where the latest scientific insights were presented and regional actors could connect with other actors and share experiences. This all contributed to the development of new networks and the strengthening of existing contacts, which proved to be important in advancing long-term delta planning strategy and finding, channeling and utilizing new funding mechanisms (Bellinson and Chu 2018; Geels 2004). Furthermore, during the agenda setting and plan formulation phases, dedicated workshops and excursions were organized to collect local knowledge, to develop shared knowledge and to discuss intermediate findings of the Delta Program's research projects. This helped the Hunze and Aa's Water Board to build a shared perception, to garner trust between the actors and to recognize mutual dependencies (Pahl-Wostl 2007). Especially influential were the 'green' and the 'adaptability' characteristics that emerged during the process. The wide green dike was thus framed as an attractive means to reinforce the dikes along the Dutch Wadden Sea coast to meet the new safety standards and prepare for the effects of climate change, while also enhancing the natural and landscape values of the Wadden region. The participatory process resulted not only in framing and growing support for the reintroduction of the wide green dike, it also helped identify possible implementation issues (Phi *et al*. 2015). Signs of possible tensions and misalignments (Geels 2004), and insights into the motivations and technical, financial and institutional abilities of the actors concerned, stimulated the water board to involve crucial actors in the implementation phase. All these participatory activities in the early phases of the strategic planning process contributed to overcoming hurdles in implementation (Hupe and Hill 2016; Phi *et al*. 2015).

Third, new actors, such as the Ministry of Agriculture and nature conservation organizations, were important for innovation (e.g., Geels 2004, 2005; Vellinga, Marinova, and Van Loon-Steensma 2009). The Ministry of Agriculture stepped in during the Delta Plan development phase, when it was agreed that the Wadden region delta program would not be coordinated by the Ministry of Transport but by the

ministry more aligned with nature and environmental policy domains. The Ministry of Agriculture's ambition to align climate adaptation strategies and flood mitigation measures with nationally and internationally mandated nature development and conservation goals for the Wadden Sea region, created a new dynamic in Dutch delta planning. In particular, nature conservation organizations saw the Delta Plan as an opportunity to enter the arena of water management and explore potential synergies between nature conservation and flood risk management more explicitly. These dynamics were a manifestation of a continually changing mixture of competing institutional cultures which, according to Rayner (1991), is common to all countries and arises at different scales. Furthermore, a major shift in nature policy and management and budget cuts precisely at the start of the Delta Program contributed to the new interest in synergies with other policy domains, and the mixture of institutional cultures. This all created a niche for innovation (e.g., Geels 2004, 2005; Vellinga, Marinova, and Van Loon-Steensma 2009). Nature conservation NGOs organized design workshops to explore, with the help of local residents and other stakeholders, the potential of more integrated and nature-based flood protection concepts tailored to the local situation. This yielded a variety of innovative ideas, which were further explored in studies commissioned by the Wadden region delta program. Because the Ministry of Agriculture coordinated this regional delta program, these studies gained contributions from ecologically oriented knowledge institutes linked to the ministry, in addition to the consultancy firms and knowledge institutes that were normally involved. The Delta Program's participatory approach and the involvement of new actors, not least, the Ministry of Agriculture and ecologically oriented knowledge institutes, thus resulted in a broader scope of 'green,' innovative and historically derived solutions and in new coalitions between flood risk management and nature development goals. This concurs with the observations of Hajer *et al*. (2015) on collaboration and alignment of different policy domains. Such collaboration and alignment in our case proved crucial at many points in the implementation of the innovation.

Fourth, changes in Dutch flood risk management strategy and in the room for innovations were accompanied by shifts in governance and funding schemes. Similar to the First Delta Plan, which brought about the major change of introducing national standards and central governance in flood risk management, the Second Delta Plan was triggered by another shift in governance. Just before the launch of the Delta Plan, it was agreed that a considerable share of the cost of flood risk management would have to be borne by the local or regional water boards through tax revenues (Adviescommissie Financiering Primaire Waterkeringen 2006). This stipulation was formalized in the Water Act (2009), which paved the way for a more or less equal say for the local or regional water boards in the development of the new Delta Plan. The transfer of governance in flood risk management and changes in funding were facilitated by the Delta Program.

For the actual realization of the wide green dike, funding emerged as decisive. Here, HWBP stepped in, anchored in the national flood protection strategy and the Water Act. The obligatory nature of the dike reinforcement task, paired with the innovative character of the plans and the robustness and flexibility of the solution presented (which was aligned to the long-term strategic vision), underpinned the choice to explore the potential of the wide green dike. Precisely because the funding was not sufficient, the water board had to look for new business approaches and for coalitions with other policy areas and new actors. This opened a window for innovation.

Finally, especially as flood risk strategies were well entrenched and an extensive legal framework of safety standards was in place, sound scientific information on the performance and collateral benefits of an innovation (or historical solution) was key for implementation of the innovative measure. Indeed, adaptation of flood-related infrastructure is costly and the planning horizon and lifetime of flood-related infrastructure often entails many decades. Impacts on the environment can also be long-lasting, or even irreversible. Therefore, in the new long-term strategic planning context, it became important to account for change and uncertainty during, and even beyond, the lifetime of the infrastructure. This concerned both the impacts of the changing environment on the infrastructure, as well as the long-term consequences of the interventions on the environment. Studies on the impacts and uncertainties of climate change on hydraulic boundary conditions were addressed by the Delta Program at the national and regional levels (Delta Committee 2008). For the wide green dike case, however, the question also arose of whether this dike design, which relies on the wave-damping capacity of the salt-marsh foreland, could provide adequate safety in the changing climate. In this regard, some studies on the wave-damping performance of the foreland have commenced (based on site-specific boundary conditions), although uncertainties still abound regarding the nature and effectiveness of such created ecosystems in general (Temmerman *et al*. 2013). Long-term monitoring of developments in the semi-natural salt marshes, and experiments with different maintenance regimes along the wide green dike, could reduce uncertainty and contribute to wider implementation of such nature-based adaptation innovations in suitable coastal settings.

5. Conclusion

The Hourglass Framework (Seijger *et al*. 2017) served as a useful tool for detailed description of the strategic delta planning steps that led to the reintroduction of a historic flood protection measure (innovation) and the role of actors in the process. More generally, it helped us to understand the dynamics involved in the implementation of such an adaptive innovation. In the context of Dutch flood risk management strategy, we could clearly identify the agenda setting, plan formulation and implementation phases of the strategic delta planning approach, as well as in the emergence of the wide green dike concept. This yielded important insights:

- A long-term vision on sustainable delta development can open a window of opportunity for change and innovation.
- A participatory approach initiated at the national level can engage regional flood risk managers and new actors and stimulate new ideas, which facilitate both the emergence and implementation of innovative adaptation measures at the regional level.
- The Dutch Delta Program's long-term vision and participatory approach catalyzed new coalitions between policy domains and between actors, which contributed to the alignment of policy areas, the development of innovative concepts and the emergence of new sources of funding.
- Although a long-term strategic Delta Plan presents an appealing and convincing instrument for change, shifts in governance and the funding of flood risk management measures need to be anchored in policies and laws to become effective.

- Sound scientific information on the performance and collateral benefits of an innovation (or historical solution) is key for implementation.

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