Figure 1 (top). Salt marsh along the Wadden Sea at Nieuwlandsreid, the Netherlands (Photo courtesy Jantsje van Loon-Steensma).

Figure 2 (bottom). Dune restoration project along Gulf Coast, Galveston Island, Texas, USA. (Photo courtesy Jantsje van Loon-Steensma).

Figure 3 (page 152, top). Salt marsh at Galveston Island, Texas, USA, with great egret (ardea alba) and watch tower (Photo courtesy Baukje Kothuis).

Figure 4 (page 152 bottom). Recreational use of salt marsh area at Galveston State Park, Texas, USA (Photo courtesy Baukje Kothuis).

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ENHANCING VALUES AND FUNCTIONS OF THE RURAL ENVIRONMENT BY MULTIFUNCTIONAL FLOOD DEFENSES

INSPIRATION FROM THE DUTCH WADDEN SEA REGION AND THE TEXAS COAST

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Multifunctional flood defenses are often considered promising options to deal with spatial scarcity and integrate different stakes in densely populated and intensively used urban areas. In rural areas, as well, interests, values and stakes may compete at the intersection of land and water, and they may also compete for space. For example, many deltaic coastal areas have important natural value, but they are also used for agriculture, recreation, industry, and urban expansion. Not only does human use of the coastal zone affect the coastal habitat and its biodiversity, it also requires protection from storm surges. In these rural areas, the concept of multifunctional flood defenses might also offer an interesting opportunity to combine distinctly different values and functions with flood protection.

To gain insight into the potential of multifunctional flood defenses in rural coastal areas, current practices and ideas for future flood protection were studied along the Dutch Wadden Sea coast and the Texas coast. Of course, there are significant differences between both coasts: They represent different climate zones (temperature and precipitation), have different storm patterns (the Texas coast is hurricane prone), and different tidal ranges (the range along the Texas coast is very modest). However, they also have several similarities: Both coasts are deltaic, comprise a barrier island coast, are the site of oil and natural gas extraction , and host vital petrochemical industries. Furthermore, they both serve an important recreation and tourist function. Comparison of these two cases shows that including wetland habitats in the flood protection could be beneficial for each area, but requires in-depth understanding of the different local conditions and flood risk management strategies.

Flood protection in the Dutch Wadden Sea

The Wadden Sea is a large tidal area, renowned for its sandflats, mudflats and salt marshes (CWSS, 1991; Reise et al., 2010); it has been designated as a Ramsar site and has been on the UNESCO World Heritage List since 2009 in recognition of its unique mudflat ecosystem (CWSS, 2008; UNESCO, 2009). Fauna common to tidal flats flourishes in this system, making the Wadden Sea an important foraging, wintering and resting site for millions of birds on the East Atlantic flyway.

The Wadden Sea region has a very long history of human habitation and flood protection. The first inhabitants settled on the natural high grounds in this tidal landscape. The marshes were used for grazing (by cattle and sheep) and for harvesting hay. About 2,000 years ago, with increasing population, the inhabitants of the coastal area started to raise artificial earth mounds for protection against flooding (Cools, 1948). Starting in the Middle Ages, these mounds were progressively connected by dikes, leading to the formation of rings of dikes protecting the hinterland. As sedimentation on the seaward side of these dikes produced new salt marshes, new dikes were built to reclaim these areas for agriculture (for both grazing and arable land). Centuries of land reclamation caused the boundary between land and the Wadden Sea to gradually shift seawards. The interaction of nature and human activity created a unique flat and open landscape of broad horizons, with extensive dikes along the coasts and semi-natural salt marshes adjacent to them; throughout the landscape, the remnants of historical dikes can be found.

Currently, the low-lying coastal zone (mainland and barrier islands) is inhabited by some 1.25 Million people. Some 227 km of dikes

defend the islands and mainland against flooding by the Wadden Sea (excluding the Afsluitdijk, the barrier dike that created Lake IJssel in 1932). On the northern side of the barrier islands, facing the North Sea, the primary flood defense consists of dunes (>10 m high) and wide sandy beaches which the Public Works Department of the Dutch Ministry of Infrastructure and Environment actively maintains by dune protection programs and sand nourishment. At present, the dikes along the Wadden Sea coast are variously dimensioned to withstand extreme situations with a probable return frequency of once in 2,000 years - 10,000 years, with crests well above extreme storm surge levels (~4–5 m above NAP, Ministerie van Verkeer en Waterstaat 2007) and expected wave run-up. Because the Wadden Sea has a wave damping effect, flood defenses along the Wadden Sea coastline are designed for much lower extreme wave heights (~1–2.8 m) than the flood defenses (namely, the dunes) on the North Sea side of the islands (~10–11 m, Ministerie van Verkeer en Waterstaat 2007).

However, climate change is altering the hydraulic conditions (e.g., surge level, wave height, wind direction) that are associated with these extreme situations. This, together with the ongoing need to improve the dikes, initiated a search for new flood protection designs and ideas. The 'business as usual' strategy to improve flood protection in the Wadden Sea region has been to raise the dikes, without deliberately integrating other functions into the dike design. Due to the strict national and international nature protection policy concerning the Wadden Sea (including its salt marshes), seaward expansion of the dikes is not allowed. But how about including these salt marshes into the dike design?

Salt marshes provide characteristic and valuable habitats (see e.g., Adam, 1990) and have a natural flood-protection potential because they dissipate wave energy (e.g., Costanza et al., 2008; Gedan et al., 2011; Shephard et al., 2011). Lower wave height and reduced wave energy could have important implications for the required dike dimensions (in particular, dike slope and height) and the need for dike slope and toe protection structures (such as hard revetments and rocks). In addition, the presence of salt marshes could have a favorable effect on other aspects of dike design, such as improving dike stability and reducing piping (Venema et al., 2012).

Integrating the salt-marsh foreland into the dike design thus offers a challenging opportunity to combine or even strengthen the Wadden region's unique nature and landscape values with flood protection. This idea was further explored in the Delta Program Wadden Region (Van Loon-Steensma et al., 2012) and in the MFFD program, and is now included in a major dike research program being implemented by Water Authorities in the north of the Netherlands. Integrating salt-marsh foreland into the dike design implies not only a widening of the physical flood defense, but also a shift towards a broader flood protection concept that includes other functions and values as well.

Flood protection along the Texas Coast

The Texas coastline also comprises an elongated stretch of barrier islands and peninsulas, which form the border between the Gulf of Mexico and several bays and estuaries. The bays and estuaries are fed by numerous rivers that drain rainwater from higher inland areas into the Gulf of Mexico, and are flanked by extensive wetlands consisting of salt, brackish and freshwater marshes, grass meadows, prairies and forested wetland and floodplain forests (Blackburn, 2004). As in the Wadden Sea, the shallow bays and estuaries are highly productive areas, attracting numerous birds and making the area an important stopover area for migrating birds on the Central Flyway (a major route for birds migrating from North America to Middle and South America). Wetlands inundated by coastal flood tides or flooding rivers are protected for their biodiversity and habitat, both in the framework of the Ramsar Convention and the US Clean Water Act.

The Texas coastal area was originally inhabited (very sparsely) by Karankawa Indians. European penetration of the Texas coast started in the 16th century. In the 19th century, the city of Galveston was an important port (and port of entrance for immigrants), connected by rail to the US hinterland, via Houston. After the devastating hurricane of 1900, however, the port facilities were shifted to a more sheltered location inside Galveston Bay (the current Houston port). A channel was dredged to connect the new port with the Gulf, and a seawall was constructed to protect the city of Galveston from future flooding by hurricanes.

In the 19th century, the area was already recognized as a good agricultural area, for crops such as cotton and sugar cane; this attracted new settlers and entrepreneurs and resulted in the development of the coastal area around Galveston Bay. The low-lying area around Texas City was purchased around 1890 for the purpose of developing a port and industrial center (Campbell & Moncla 1998). A channel was subsequently dredged and a railway connection added, and the population steadily increased. In order to prevent the channel from silting, between 1910 and 1915 a dike was constructed that would divert the silt-bearing current from the channel. This dike would later be improved to protect the petro-chemical industry that developed steadily from 1930 on. Huge petro-chemical industries have since developed around Houston and other locations along the coast, such as the Freeport industrial area. This area is protected from surges by a dike, as are some other industrial areas and settlements. As flood protection is currently designed for a 1/100 year event and flooding occurs with each major hurricane passing the region, several ideas have been proposed to protect the Houston-Galveston Bay Region from flooding; these include different structural measures such as the Ike-Dike on Galveston island, and dams and barriers along the Houston Ship Channel.

Apart from these intensively urbanized and industrialized locations, until recently, extensive stretches of the Texas coastal fringe have remained almost pristine. The seaward side of the barrier islands and peninsulas consists of a beach with low sand dunes (1-5 m), while the bay and estuarine side have grass meadows and marshes (sometimes grazed by cattle). The coastal fringes on the mainland side of the bays and estuaries, also have extensive marshes and grass meadows, which transform landward into prairies with patchy vegetation of grass and bushes. The river floodplains also often contain bottomland forest. A substantial part of the wetland area and bottomland forest along the Texas coast is currently federal or state protected. The majority of the prairie land, on the other hand, is privately owned, primarily used for ranching, but with some homes interspersed. Some wet prairies are also farmed for rice, which requires an actively managed water system. Because of the modest tides in the area, the extensive flat, low lying coastal rural area is only inundated by seawater during extreme conditions associated with hurricanes. No structural flood prevention measures are in place in these areas, though a hurricane evacuation route is indicated by signs.

The sandy strip adjacent to the Gulf is a popular recreation and tourism destination. Especially on Galveston Island and the Bolivar Peninsula, both being close to Houston, numerous beach houses have been constructed very close to the beach. These houses are built on stilts to protect them against coastal flooding caused by hurricanes. Sometimes the owners of these vacation houses have tried to stimulate dune formation in order to protect their houses. The trend of building beach houses is continuing, resulting in an increasing transformation of former natural beach and dune area into a recreational and residential area. Even the marsh area along the bays and estuaries near Galveston is increasingly being used for housing, transforming these wetlands into recreational and residential areas as well.

Although building on stilts and stimulating dunes provides some protection against flooding, a substantial number of beach houses is severely damaged each time there is a hurricane. However, such damage has not hindered development of the coastal fringe, because flood damage is generally covered by flood insurance. Concern about the flood risk associated with these developments and their negative impact on nature values has led to the idea to preserve the coastal zone with its mosaic of wetland habitats for nature conservation purposes and to mitigate hurricane damage, at the same time providing the greater Houston area with opportunities for outdoor recreation for (Blackburn, 2013).

Including wetland habitats in flood protection

Currently there is an increasing interest in integrating natural habitats in flood defense schemes in both the Wadden Sea region and the Texas coastal region. Nevertheless, there are major differences between the approaches suggested, rooted in the different flood hazards and natural features of the regions, but also in differences in policy, governance structure, and attitude toward flood risk.

In the Netherlands, preventing floods still forms the core of the Dutch flood safety management strategy. This flood prevention strategy is the result of centuries of flood protection practices and lessons learned from historical flood disasters. The size of dikes is determined based on a cost-benefit analysis, with crests built well above the expected extreme storm surge levels and wave run-up. Integrating salt-marsh foreland into the dike design would only result in adjusted dike dimensions (in particular, dike slope and height) and affect the need for dike slope and toe protection structures (e.g., hard revetments and rocks). Nevertheless, such a multifunctional design for a wider dike zone would be beneficial for both nature and landscape values of the Wadden Sea region.

In Texas, on the other hand, the idea to include wetland habitats in the flood protection strategy for rural areas favors a spatial flood risk strategy. Assigning coastal wetlands, prairies and bottomland for nature conservation could prevent their becoming built up. With no permanent construction or vacation homes (beach houses) present, the risks associated with a flood would diminish substantially. However, this implies a shift from a narrow recovery based strategy (based on insurance) towards a broader multifunctional spatial planning strategy across the coastal zone.