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River basins and deltas

Water Systems and Port Economies in Times of Climate Change: Rhine, Yangtze and Mississippi

Introduction: not just climate change

River basins and especially delta areas are currently confronted with climate change, which leads to changing conditions and to greater vulnerability to flooding, salt intrusion, but also to problems such as drought and freshwater shortages. However, it would be a mistake to look for the causes of these problems in climate change alone. In the search for effective long-term strategies, the changes in the physical conditions of river basins and delta areas, especially caused by human hands during the last century and a half, must also be considered. Although there were good reasons for these changes (economic development, urban growth and prosperity), the downside is that the resilience and dynamism of the natural system in these areas has declined sharply. The effects of climate change, such as rising sea levels and increasing peak discharges of rivers, can have a greater impact on river basins and delta areas due to this reduced resilience.

The working conference/workshop that PBL, TNC and CCICED want to organize in the autumn of 2022 is based on the observation that the transformation of river basins and delta areas during the 19th and 20th centuries can be considered a 'game-change': the game changed from a dominating role of the dynamics of natural systems to a dominating role of man-made land-use patterns, manipulating the natural systems with an overload of engineering. The central hypothesis, which we want to explore more carefully, is that we need a second game-change, which gives priority to restoring the dynamics and resilience of natural systems in river basins and delta areas. The working conference aims to discuss and determine whether such an approach is possible and effective. The question is what consequences such an approach has/could have for economic and urban development, and how this approach can be combined with strategies for energy transition and making our economies, cities and landscapes more sustainable.

To get a clear understanding of the current, second game-change, it is necessary to discuss also the first game-change: in order to understand the deep consequences and character of such a game change, and to learn from it.

A concrete proposal for the structure of the working conference follows in the last paragraph. First we will discuss the backgrounds and character of the first and second 'game changers'.

The dynamics and formative power of the delta's natural system

The world of the 21st century is facing the enormous challenge of a complex combination of adaptation to climate change, of preventing an acceleration of climate change through energy transition, and of restoring biodiversity and the resilience of natural systems. This complex combination of tasks occurs to an extreme extent in the catchment areas of the major river basins and in particular the delta areas, where the rivers flow into the sea and where the greatest economic and urban growth has taken place worldwide over the past 150 years and is still ongoing. The major rivers and especially their deltas are at the heart of the logistics process of production, transport and consumption of modern industrial societies.

It is true that this development has a long history. Nevertheless, we can say that the last century and a half, from the mid-19th to the end of the 20th century, is the period in which most river basins and delta areas experiencing a 'boost' of large-scale transformations that served to accommodate economic and urban growth. The Rhine, Yangtze and Mississippi deltas are striking examples.

These transformations not only resulted in a reclassification and functional change of the territory of the delta, but also had a strong influence on the dynamic and formative character of the delta. Deltas are the result of dynamic processes of rivers and sea, with regular and irregular changes in currents, tides, wave action, sediment transport and sedimentation, vegetation, wind, precipitation. Most deltas owe their present shape largely to the way in which these processes took place in the last 12,000 years, after the last Glacial Period. The large amounts of sediment that were brought in by rivers and the sea and subsequently became overgrown with vegetation, led to dynamic processes of land formation (Kleinhans 2010; Jarriel et al. 2021).

The dynamic nature of the natural system of deltas gave rise to three main characteristics of deltas: first, extraordinarily rich ecosystems. According to some, deltas and estuaries contain the richest ecosystems, with the most 'ecosystem services' of any ecosystem in the world (Costanza et al. 1997). Deltas include important intersections of migratory fish and migratory birds, which use deltas for foraging, spawning, and breeding.

Second, the dynamics of the delta led to the continuous formation of new (wet)land, which increasingly served as a protective buffer in the coastal landscape. It is true that these processes were erratic and in various places they also led to erosion and flooding of land. But the net result over the centuries was that the land in the delta grew with or even grew faster than the sea level rise (Seybold et al. 2007).

Third, the dynamics of water and sedimentation lead also, with some regularity, to structural changes in the course of the main river discharge and thus in the shape of the delta. The development of the Mississippi Delta shows several 'delta lobs', which are the result of changes in the course of the main river discharge since the last Glacial Period

(Campanella 2006; Blum, Roberts 2012; Giosan, Freeman, 2014). These changes occur once every few hundreds or thousand years and are the result of the silting up of the estuary by sediment supply and deposits by the river itself and the sea. Now as the riverbed of the main discharge starts to silt up, it starts to act as a blockage, and the water tries to find another, easier way to the sea, especially in the case of huge peak discharges. The development of the Rhine/Meuse delta shows a similar process. The main discharge of the Rhine has moved south in several steps over the course of 12,000 years (Vos 2011).

These processes continued in most deltas until about the mid-nineteenth century, when large series of major interventions are started that radically change the hydrological system and the spatial structure of the deltas.

The first game change: From dynamic system to controlled mechanism

Two important developments during the nineteenth century are responsible for a fundamental 'game change' in the systems of river basins and delta: technology and the rise of nation-states. These two developments created the conditions for the era called 'the Anthropocene' (Sijmons 2014).

The technological revolution of the nineteenth century includes the invention of the steam engine and later the electric and gasoline engine, and the discovery and use of coal and later oil and gas as energy sources. The new energy sources and technical equipment created the necessity as well as the possibility of major adjustments to the water systems of deltas and rivers. The steam engine allowed for larger ship sizes; the larger ships required deeper waterways, which were made possible by steam and diesel-powered dredgers. Riverbed narrowing also took place on a large scale, resulting in deep waterways on the one hand and more available land for agriculture and urbanization on the other. The waters that mainly serve as a transport corridor are separated from the land by high dikes, where urban, agricultural and industrial development can take place. Due to intensive drainage of the swampy lowland, subsidence is occurring behind the dikes, increasing the vulnerability to possible flooding.

The new nation-states of the late 18th and 19th century created the institutional conditions for the large-scale, cross-regional interventions in the river basins, like Rijkswaterstaat (National Water Management Agency) in the Netherlands and the US Army Corps of Engineers in the USA (O'Neill 2006; Lonnquest et al., 2014; Meyer 2017).

The deltas of the Rhine, Yangtze and Mississippi all three show this development. It is true that there are many differences between the characteristics of these three deltas, but essentially the development process of each of these three deltas has the same characteristics. If you compare the maps of the three deltas from ca. 1850 with those of 2022, you will not only see a spectacular increase in urban and industrial land use, but also the consequences of large-scale river rectifications and normalisations, of new land reclamations, of countless waterworks such as new canals, dikes, dams, locks, of roads, railways, pipelines. We also see what has disappeared: many tens of square kilometres of intertidal areas: wetlands, mud flats, salt marshes, sandbanks, beaches, dunes.

What took place during this period, which began with the deployment of the first steam-powered ships, dredgers and drainage pumps, and has in fact still not ended, can be called a first fundamental game-change. With the rise of the fossil fuel based industrial society, compared to the previous centuries, a fundamental change of the game has taken place, with new players, new rules and new outcomes.
The net result is that, during the last century and a half, delta areas have been drivers of explosive economic growth and prosperity. Not only have the delta areas themselves become centers of economic growth and wealth, but this development has also been crucial for the hinterland. The Mississippi has become the main transportation corridor of the United States since the mid-19th century; 90% of what is shipped across the Mississippi and its tributaries goes to or comes from ports in the Mississippi Delta (O'Neill 2006). The Rhine basin is the economic artery of Europe, or the 'Blue banana' according to the French geographer Roger Brunet (1989). For the development of the Rhine into a Blue banana, the transformation of the Rhine delta into an efficient transshipment and distribution center played a key role (Klemann, Wubs 2013).

In China, the Yangtze Delta and the Pearl River delta are the two most densely urbanized regions of the national territory; together they are responsible for 40% of the GDP of China.

However, the flip side of this development is that the delta has changed from a natural system to something resembling a mechanical system. The entire water system of the river and delta has taken the form of an industrial machine. This also creates the illusion that rivers and their deltas can be controlled and monitored like an industrial machine. The toll that must now be paid for this illusion is threefold.

Firstly, we must note that the 'mechanisation' of the delta has led to a large decline in biodiversity. In some deltas, the specific features of the delta ecosystem have largely or even almost completely disappeared. Not only did this lead to a considerable impoverishment of fauna and flora in the delta landscape itself; this also has major implications for life on Earth in a much larger context. With the disappearance of large parts of delta nature, an essential link in the food chains of countless birds, fish, shellfish and plants in our rivers, seas and oceans has disappeared.

Directly linked to this is the second major problem: the disappearance of a large part of the formative capacity and thus of the resilience of the natural system of the delta. Instead of processes of siltation, land accretion and soil raising, other processes have come to dominate: erosion, subsidence, ever higher water levels in the river mouths and a saltwater tongue penetrating deeper and deeper into the land. And insofar as there is still a supply of sediment, as the most important building block for land formation, it is dredged away to keep the rivers at their depth for shipping (Ericson et al. 2006; Tessler et al. 2015; Hoitink et al. 2020).

Thirdly, the attempt of optimal control and fixation of the river and delta has led to the natural process of displacement of the estuaries appears to have come to an end. We emphatically state that this process '*appears* to have come to an end', as we see that water management authorities over the past hundred years have been forced to build more and more engineering works in the river system in order to maintain the existing main drainage

riverbed. In the Mississippi Delta, a series of dams, spillways and flood ways have been created around the connection between the Mississippi and Atchafalya Rivers to counteract the natural system's tendency to divert the main drainage to the Atchafalaya River. Nevertheless, it is feared that the time will come when this tendency will no longer be countered, with disastrous consequences for the city of New Orleans and the surrounding area (Barnett 2017; Day et al. 2014). In the complex network of river courses of the Rhine/Meuse delta, a series of interventions have also taken place that counteract the tendency of the Rhine and Maas rivers to discharge more and more water via the Haringvliet and force this discharge out to sea increasingly via the Nieuwe Waterweg near Rotterdam (Vellinga et al. 2014).

More than fifty years ago it became clear that maintaining this approach to the river system is harmful and unsustainable. The first large-scale protests against the loss of river and delta nature date back to the 1960s and have led to the first major adjustments in the Netherlands, such as the cancellation of the complete closure of the Oosterschelde and the construction of the Markerwaard. Not coincidentally, the report for the Club of Rome, The Limits to Growth (1972), was published during this period.

Although the main aim of these protests and changes was to prevent the disappearance of the delta nature, the need for a fundamental change in economic growth was already hinted at as a guiding principle in the development of natural landscapes (Buelens 2022). The American landscape architect Ian McHarg introduced an analysis and design method for wetland landscapes in the 1960s, in which he introduced the need to make a distinction between slow (climatic, geological, geomorphological, hydromorphological) change processes and faster, often human-initiated, change processes such as infrastructure development and urbanization (McHarg 1969). His position was that it is important to take good account of the slow processes, to offer sufficient space for this, and to adapt infrastructure and urbanization accordingly. In practice, he saw exactly the opposite happening, with disastrous results. This method was later elaborated in the Netherlands and became known as the 'layer approach', which was advocated in various government memorandums of the 1990s and 2000s (Meyer 2017).

The relevance of this layer approach became apparent from the 1990s, when the first signs of climate change emerged and it became clear that the channelled river courses did not have sufficient capacity to discharge the increasing amounts of melt and rainwater due to climate change. The Dutch *Room for the River* program (2005-2015) was the first important implementation of the layer approach. Restoration of the river ecosystem was combined with the task of increasing the discharge capacity of the rivers and restoring and strengthening the resilience of the natural system (Sijmons et al. 2017).

Also, in and around the Mississippi Delta, the first ideas for major modification of the river drainage system date back to the 1990s and gained momentum after the 2005 Hurricane Katrina disaster. The wetlands of the delta have been subject to severe erosion since the 1930s. As a result of the channelling of the Mississippi river, all the tributaries that fed sediment- and nutrient-rich freshwater into the wetlands were dammed. The wetlands form a buffer that dampens the force of hurricanes. Erosion of these wetlands is catastrophic to the survival of the city of New Orleans (Campanella 2006; Barnett 2017).

However, with the latest insights and predictions regarding climate change and sea level rise (IPCC 2022; Deltares 2018), the question is whether the changes in the Rhine/Meuse delta, Mississippi delta and Yangtze delta are sufficient. The restoration of nature and especially the restoration of the dynamics and the shaping capacity of the deltas requires a significantly more radical 'game change'.

Towards a second game change: restore the dynamics and resilience of the natural system in combination with energy transition

The need of a new ‘game change’, giving priority to nature-based solutions in delta areas, has already been addressed frequently (Costanza 1997; Temmerman, Kirwan, 2015; Day et al. 2014). However, the major task in delta areas is twofold: to restore the resilience of the natural system and provide room for its dynamics, and to shape the transition from fossil to non-fossil energy sources. This means a combination of maximum mitigation as well as adaptation.

One of the main driving forces behind these changes in deltas is the port and shipping industry. In many cases, and certainly also in the deltas of Mississippi, Rhine and Meuse and Yangtze, the transshipment, storage and processing of fossil fuels plays a central role. Port development and shipping were the basis for the radical spatial and hydrological transformation of the delta, but also for the fact that the deltas have become central hubs in an economic system based on fossil energy sources. Due to the large amount of space required and the many infrastructural systems, the port and shipping system also appears to be the most difficult to change. Because of this strategic role of ports and shipping in the delta areas, and to make the discussion more concrete, the consequences for ports and shipping will have to be explicitly discussed when discussing possible future prospects for these delta areas.

Discussions are ongoing in both the Netherlands and the Mississippi Delta about the most effective and desirable strategies for making the delta resilient to sea level rise. In the Netherlands, three approaches seem to emerge in the Sea Level Rise Knowledge Programme: (1) continue the development of the past century, with even stronger civil engineering works and on a larger scale, (2) a 'retreat' of cities and economic activity to higher grounds, and (3) more room for restoration and reinforcement of the natural system, in the expectation that this will also lead to processes that make the delta less vulnerable to sea level rise and higher peak discharges (Haasnoot et al. 2019).

Also, in the Mississippi Delta there seems to be a balancing of comparable alternatives, as was reflected in the design competition 'Changing Course' (website of 'changing course'). The first option (reinforcement of the existing system) only seems to cause more problems in both deltas in the longer term. Maintaining an increasingly large-scale 'armor' to protect low-lying territory will encounter increasing technical, managerial and financial problems. It seems much too early for the second option ('retreat'); hopefully it doesn't have to come to that. To prevent this option, something will have to be done in the delta areas.

That is why, during the working conference, we propose to seriously examine the possibilities for a fundamental game change based on a new priority for space for the natural system.

The seminar October 11 – 12, 2022

The foregoing argument can be summarized with the following figure:

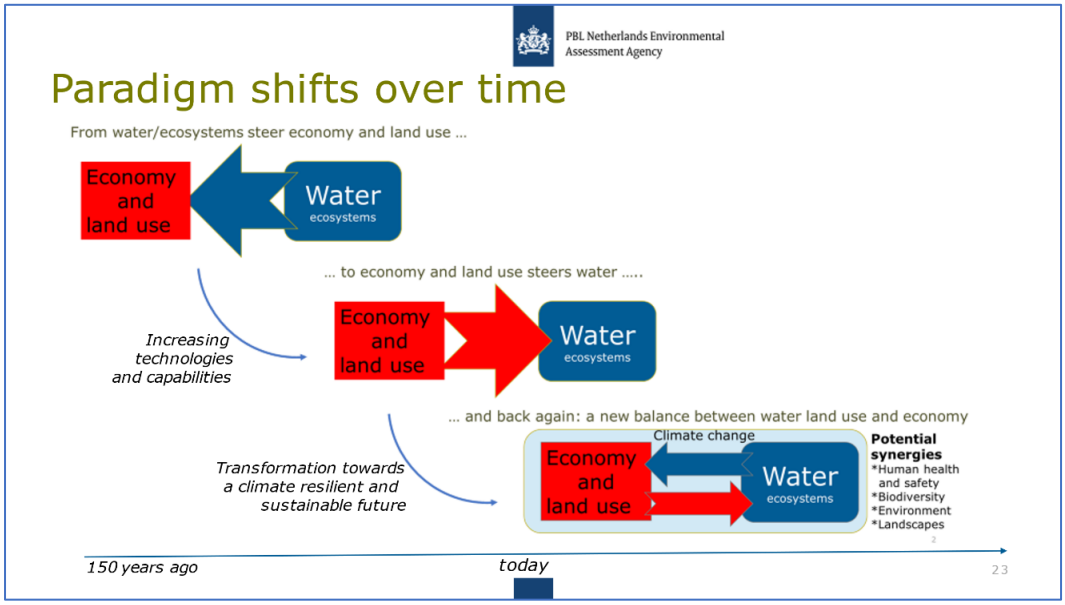

Figure 1. Paradigm shifts over time

Source: Ligtvoet et al. website river-basin-delta-tool

The transition of the upper relationship diagram between water and economy to the middle diagram represents the first game change: from a system in which water is leading, and economic and urban development is following, to a system in which economics and urban development are dominant, resulting in adaptations of the water system. The transition from the middle relationship diagram to the bottom one reflects the current task: a new 'game change', leading to the implementation of a hybrid system in which the water system on the one hand and the economy and land use on the other hand find a new balance.
The seminar '*River basins and deltas - Water Systems and Port Economies in Times of Climate Change: Rhine, Yangtze and Mississippi'* aims to investigate to what extent the idea of the first and second game change is relevant for these three river basins and deltas, and in what sense it can give direction to a new approach for a new balance between economic and environmental development.

In particular, attention will be focused on:

a) the precise nature of the dynamics and shaping forces of the three delta regions;
b) how these dynamics and formative forces were dealt with in the period late 19th century – early 21st century, and what effects this had on the physical conditions of the delta;
c) what options are available to use 'nature-based solutions' to create space for the dynamics of the delta and to use it to restore the resilience of the natural system;
d) what possibilities there are for combining energy transition, sustainable economic development and new land use patterns with more room for delta dynamics.

These four questions will be addressed on both days by three experts on the three deltas. Subsequently, a panel of experts in the field of water management, urban development,

ecology and port economics will reflect on the potential consequences of the proposed strategies for these four fields.

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