Chapter 83
The Impacts of Megahydraulic Engineering Projects from a Dutch Perspective

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83.1 Introduction

This chapter looks into two megahydraulic engineering works in the Netherlands, how they evolved through time, what has changed the perception on these megaworks, and why they have changed since they were carried out. The Zuiderzee works are a megahydraulic engineering project in the northern area of the Netherlands that has been carried out to close off and partly drain the former Zuiderzee. The megaworks were undertaken between 1927 and 1975. The Delta works are a megahydraulic engineering project in the southwestern part of the Netherlands that was planned to close off the major inlets of the rivers Meuse, Rhine and Scheldt. This project was carried out between 1954 and 1997. Both megahydraulic engineering projects are the result of a long term tradition of water management and coastal management, which can only be fully understood within the framework of the geoarchaeological setting of the Dutch landscape.

This chapter begins with this geoarchaeological setting. Next the megahydraulic engineering projects will be examined by addressing four key questions. (1) What were the initial objectives to build the two megaprojects? (2) When a project was completed, did it meet its initial objectives? (3) How have the perceptions and appreciations of each project evolved since their building and completion? (4) And how will perception of each of these megahydraulic structures change in the near future, especially within the context of expected climatic change and an accelerated sea-level rise?

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83.2 Geoarchaeological Setting

In the western part of the country, which is the most densely populated and economically most important area, people live below sea level. Therefore, an ever-present danger of flooding threatens the area, which generally could be handled, except for single large scale natural events. Below the geo-archaeological history with respect to the development of the coastal zone and its inhabitants is presented as an introduction to the construction of megahydraulic engineering projects in the low-lying countries.

The Netherlands is situated at the southern fringe of the Cenozoic North Sea Basin (Fig. 83.1). Because of the regional tectonic position and sedimentary response the geology as well as the preconditions of coastal hazards differ considerably from neighboring countries and regions. The center of sedimentary deposition is in the present North Sea (Zagwijn, 1989). The thickness of the entire Quaternary sediments can mount to 600 m (2,132 ft) onshore and increase to 850 m (2,789 ft) offshore (De Gans, 2007). This thickness of sediments reflects a history of tectonic subsidence, marine transgressions and regressions. In addition a deltaic position of the Netherlands with respect to large river systems (Rhine, Meuse, and Scheldt) that have been depositing sediments in the basin for over a period of two

Fig. 83.1 Overview of northwestern Europe showing the location of the Netherlands at the southern fringe of the North Sea Basin. Adjacent regions are rich in relief and have older geological formations exposed with respect to the Netherlands (*arrow*). (Source: Google Earth)

million years. These create a unique geological setting with respect to neighboring regions. In essence, the processes of sedimentation due to tectonic subsidence, sediment supply from rivers, as well as relative sea level rise continue until the present day. Sedimentary facies data record changes in coastal evolution controlled by sedimentary processes and variations in sediment supply and accommodation space (Beets and Van der Spek 2000), as well as human impact. In addition the impact of regional variations in subsidence needs to be taken into account (0, 1–1, 0 m/ka (4–40 in/ka)) (Vink, Steifen, Reinhardt, & Kaufman, 2007). These variations may be the causes behind the different landscapes and coastal evolutions in nearby regions.

It has been 250,000 years since the first inhabitants in this region have lived in the southeastern higher part of the province of Limburg (extended part of the Ardennen-massif; Roebroeks, 2005). This province is a hilly area that was at about 200 km (125 m) distance from the unprotected coastal lowland in the western Netherlands, where early hunter-gatherers may have been active. Around 200,000 years ago there is some evidence that people had settled down in the river area in the Central Netherlands prior to the arrival of land ice in the penultimate ice age, the Saalian, which covered the northern half of the Netherlands (Roebroeks, 2005).

Due to sea level rise coastlines have moved inland since the end of the last ice age, the Weichselian. Subsidence of the land, e.g., by tectonic lowering of the land surface, and input of ice sheet's meltwater contributed considerably to that sea level rise. About 10,000 years ago people already fought against rising water. Mesolithic hunters and gatherers fled from the quickly filling up of the North Sea basin. The oldest known archaeological features coming from Bergschenhoek, the province of Zuid-Holland, date from 6200 years BP. At this location the surface level was raised with reed bushes by the inhabitants to keep their feet dry. Possibly certain Mesolithic cultures were bound to relative short time periods where sand barriers (early coastal barriers) or elevated river beds offered dry conditions. If after sea level rise or stream channel diversion the once dry locations were flooded, people moved away or adapted to this new situation. In terms of coastal management it can be stated that people at that time were reacting against the threat of the rising water (Fig. 83.2). At 5000 years BP sea level rise was relatively fast as melt water from the ice sheet speeded up the rise in sea level. When finally all ice was melted, only subsidence remained which resulted in a slower rising sea level. From that time on the coast started to secure itself by building up a series of elongated sand barriers that shielded the inland from coastal erosion processes.

The relative sea level rise in the last 3000 years in the southern North Sea cannot be exclusively explained by geological factors. Since then there is growing evidence that humans occupied the coastal zones leaving their imprint on the landscape and since that time humans in the Netherlands have become a major geological factor (De Gans, 2007; Vos & Van Heeringen, 1997). After the introduction of agriculture the forest coverage decreased considerably and at about 3000 BP wide open spaces and heath lands originated on a wide scale (De Gans, 2007). Around 2000 years ago the way people reacted to rising sea level or to the threat of rising water changed. They became proactive in a structural way. There is growing evidence for water

Fig. 83.2 Schematic diagram shows change in reaction of historic humans against rising sea level and coastal hazards. Box 1. Zuiderzee works, Box 2. Delta works

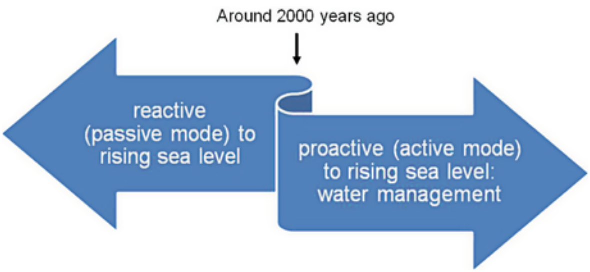

Fig. 83.3 General map of the Netherlands and locations of mega-scale engineering works

management during Roman times and even earlier in terms of infrastructural works carried out, such as dams, dikes, dwelling mounds (terps, the first since 2500–2600 BP) and canals (De Gans, 2007; De Ridder, 2005) (Fig. 83.3).

Within about a thousand years the cultivation and draining of the peat lands with wind-driven watermills, that started about 1400 AD, led to a subsidence in the coastal zone which could mount to about five meter. As this process is an indirect result of settlement and land reclamation, it cannot be considered as a proactive measure with regard to water management! From about 2000 BP sand barrier aggradations at the coast ended and since 1000 AD coastal erosion started again (De Gans, 2007).

The transition from an agricultural to an industrial society during the 19th century accelerated human interference with geological processes. In addition, the importance of water as a defensive system should not be underestimated, a concept that remained valid until the early 1950s. General aims of the period 1850–1950 AD are years in which there was a striving for independence, in particular to secure food supply in order to sustain a growing population and reducing the risks of natural hazards. The growing influence of humans on the coastal landscape after the end of Middle Ages is also evident by data on shoreline shortening: during the 16th century the Dutch coastline measured more than 3,000 km (1,850 mi), with almost all estuaries and coastal inlets open to the sea. In 1840 the coastline was already shortened to 2,000 km (1,250 mi). After building the Closure Dike (Afsluitdijk) in 1932 (one of the key acts of the Zuiderzee works), the entire coastal length was shortened to ca. 1,650 km (865 mi). After completing the Delta works in 1975, the coastline measures ca. 850 km (530 mi).

83.3 Zuiderzee Works

83.3.1 Background

The 1916 storm surge finally determined the discussion about the closure of the former Zuiderzee and partly reclaiming the area. The oldest plans to drain this shallow sea were made by Hendric Stevin already in the late 17th century (Van Duin & De Kaste, 1995: 41). He proposed to close off the Wadden islands and to discharge water towards the North Sea at low tide, but his plans were not carried out. Also in the course of the 19th century many new plans were made (Van Duin & De Kaste, 1995: 40–44). Through the development of science and technology at that time, there was a firm belief that there was an engineering solution to all problems, but that did not particularly apply to the future development of the Zuiderzee.

Three reasons need to be mentioned here. First there was the vast extent of the intended earthwork that could not yet be handled. Building a dike is not only expensive but also risky. In the wink of an eye one gale could jeopardize all investments. The chances of such gales hitting the southern shores of the North Sea were low that only for a few weeks per year were such engineering risks considered acceptable. In was in that short time period that the entire project had to be carried out up to the closure of the last gap in the dike. In order to carry out the project this way, the sheer amount of earth works and additional work were calculated into the number of laborers and working days needed. It was only during the 1860s through the introduction of the first steam-driven dredger operating on the Dutch waterways, that plans to close off the Zuiderzee became more realistic. Still, discussion about the financial realization and uncertainty about the hydrological consequences kept on delaying plans.

In the 19th century land reclamation served an economic interest. It was considered that private investors and not the government should take the initiative, which concept was taken to be valid for the draining of the Zuiderzee as well. However, private investors remained very reluctant because of the huge risks involved. The 1916 storm surge changed the attitude of investors and put the project in another perspective. It shifted the focus from the damage caused by the storm to the special position the Netherlands held during the Great War (1914–1919). During the late 19th century Dutch agriculture modernized and became highly specialized. Dutch farmers increasingly used cheap American corn as fodder to increase stockbreeding. Poultry and pigs produced high quality proteins for the British industrial towns and the growing markets in the Ruhr area in Germany.

From the outbreak of the Great War Holland remained neutral. In order to prevent any given aid to the enemy, the transshipments through the Netherlands were controlled by the nations at war carefully. No more American corn could be imported and this led to a dramatic decline in stockbreeding and consequently to a change from grassland into arable land. Worries about future food supply were very much enhanced by the 1916 storm surge event, which was generally perceived as a national disaster. Vast areas were flooded and became unproductive for a long time. This widespread perception of vulnerability provided the political support needed to impose a special law in March 1918, which anticipated the closure and partial draining of the former Zuiderzee. As a result of this thinking, the Zuiderzee project became a national issue with the Dutch government responsible for financing it. Initially, it was estimated the project would cost some $US 20 million, but in the 1930s the costs already surpassed $US 700 million.

83.3.2 Zuiderzee Works Carried Out

This background explains the initial objectives of the Zuiderzee project. Firstly, it aimed at reducing the risk of flooding through the reduction in the length of sea dikes. Secondly, the project aimed at increasing the arable area in order to guarantee long-term food supply of the Dutch population. Thirdly, the Zuiderzee project was supposed to provide more jobs. Finally, because surrounding areas of the former Zuiderzee faced a growing salt gradient in dry summers, which resulted in lower crop yields, it was aimed to reduce the area's salt gradient to a brackish and eventually fresh water area. The building of the Closure Dike would change the former Zuiderzee into a huge fresh water reservoir that could also be used to replenish drainage canals in the polders of North Holland and Friesland. Moreover, this was considered to enhance both agricultural production and food supply.

As soon as it was decided to carry out the Zuiderzee project, it was not quite clear yet if it was hydrological safe to close off the former sea. Building the Closure Dike would block off the tides and nobody could foresee its consequences in terms of future tidal ranges in the northernmost part of North-Holland and Friesland. Some researchers anticipated an increase of at least 4 m (13 ft). Would dikes be able to withstand these higher tides during heavy storm surges?

In order to address this question, in 1918 a committee was installed to investigate this problem. The committee was chaired by Nobel Prize winner H.A. Lorentz. Nobody anticipated that it would take this committee eight years to resolve the matter. At the time hardly anything was really known about the working of the tides in between the Wadden Islands and outside the inlets in the North Sea. The impact of storm surges and how well the bottom of the sea resisted the incoming and outgoing tides was not very well understood too. That is why it took the committee a long time to collect all the necessary data. It took still longer to process all the data into science-based models about tidal movements. This approach has indisputably proved it usefulness in carrying out the Delta project at a later stage.

In late 1926 the committee published its findings, which led to the start of the Zuiderzee project (Table 83.1 and Fig. 83.4). In August 1930 the Wieringermeer fell dry as the first polder and in 1932 the Closure Dike was finished (Fig. 83.5). In less

Table 83.1 Areal and temporal dimensions of dikes and polders of the Zuiderzee works

Project	Length (km)	Size (km^2)	Carried out
Wieringermeer	18	200	1927–1930
Afsluitdijk	32	–	1927–1932
Noordoostpolder	55	480	1936–1942
Eastern Flevoland	90	540	1950–1956
Southern Flevoland	70	430	1959–1967
Houtribdike	28	–	1963–1975

Fig. 83.4 Map shows location, nature and size of the different projects of the Zuiderzee Works in the central north of the Netherlands that were carried out between 1927 and 1975. (Cf. Table 83.1)

Fig. 83.5 The final stage of completing the Closure Dike (Afsluitdijk) in 1932

than five years time the Zuiderzee changed into a fresh water body. In order to discharge the new IJsselmeer, two groups of locks were built in the Closure Dike. The western locks were named "Stevinsluizen," named after the first engineer to suggest the closing off of the Zuiderzee, and the eastern locks were called "Lorentzsluizen." In 1942 the Noordoostpolder fell dry, but in terms of water management it proved to be a mistake to have connected this polder to the headland of the eastern neighboring province. As draining the Oostelijk Flevoland (completed in 1957) came next and a specially developed bordering lake (Veluwerandmeer) between this polder and the southern headland was formed. This was also carried out south of Zuidelijk Flevoland, which became dry in 1968. In the early 1990s it was decided to not drain any further the last polder to be created: Markerwaard. Thus, it becomes clear that the perception of the Zuiderzee project changed in the course of the 20th century.

83.3.3 Assessment

There is no doubt that the Closure Dike has significantly reduced the risk of flooding the northern area of the Netherlands (Fig. 83.6). Except for the 32 km (20 mi) long Closure Dike, a length of 320 km (200 mi) initial coastal defense changed into secondary dikes. However, in of the process of Europe unifying and globalizing, the reclaimed land has become significantly less important in terms of national food supply. At the start of the 20th century nobody could foresee this kind of development. This is also true with respect to the process of urbanization in the Netherlands, which accelerated especially after the Second World War. A fast

Fig. 83.6 The 32 km (20 mi) long Closure Dike has not really changed shape since the completion in 1932, in spite of modern busy traffic as this photograph from 2006 shows

growing population, a growing need for more space per inhabitant and a strongly improved infrastructure, caused this development. At the same time industry and services became much more important and occupied more space than previously. Through the realization of a building program and the development of vast industrial areas, the polders of Flevoland contributed significantly to the economic potential of the northern area of the Randstad (the most developed economic region in western Netherlands).

83.3.4 Solution/Outlook

Next to the reduction of risks, the IJsselmeer (123,000 ha; 303,933 acres) is now considered to be the most important advantage of the Zuiderzee project. Presently, this vast fresh water reservoir plays a key role in reducing the salt gradient and improving the water quality in large parts of the Netherlands, it will become more important in the future. Because of the vast space available from abandoning arable land, ecology, nature building and town development could be generously compensated.

Moreover, future climatic change will lead to a further sea level rise, which will result in much more increasing pressure from sea water upon lower lying parts of the country. Climatic change is also expected to result in a more irregular river discharge and the occurrence of longer dry spells in summer. Inhabitants, farmers and industries will become increasingly dependent on the fresh water reservoir in the IJsselmeer. Finally, there is a growing interest in the Ijsselmeer as a nature reserve and recreational area.

83.4 Delta Works

A second megascale project referred to as the Delta Works has been carried out since 1954. In many respects this megaengineering project changed the southwestern delta area thoroughly. As it took about four decades to complete it, major changes were already carried out during its construction.

On the eve of 31 January 1953 a northwestern storm surge hit the southern North Sea area very hard (Fig. 83.7). As the event continued for two successive high tides many dikes finally breached (De Kraker, 2006). A coastal area stretching from Antwerp (Belgium) to Rotterdam (The Netherlands), as well as further eastward along the many tidal inlets, suffered heavy damage: 1920 km^2 (475,000 acres) of land were flooded, 47,000 cattle died, 3000 houses and 300 farms were destroyed, over 250 mi (402 km) dike were destroyed and 72,000 people were evacuated of which 1836 were drowned. In terms of money the total amount of damage was estimated over $US 1.7 billion (Lammers, 1955).

The devastating effect of the 1953 flooding disaster cannot entirely be attributed to the storm surge. For decades the State Department of Public Works (Rijkswaterstaat) had warned about the top levels of dikes being too low, however, no measures were taken. Money was spent on rebuilding the post-war economy instead of dike maintenance. Moreover, the large number of over 300 small water boards proved to be too inefficient to take immediate and adequate measures. Furthermore, communication broke down very quickly which made fast national coordination of large-scale rescue operations difficult. Only two helicopters were operating in the area. Once flooding occurred and tides moved in and out of polders, buildings began to collapse, because of their poor construction. Finally, many

Fig. 83.7 Impact of the 1953-flooding disaster in Zeeland causing about 400 km (250 mi) of dike to breach and flooding at least 1,920 km^2 (475,000 acres)

people fleeing to rooftops were killed when buildings collapsed or just died from cold, because on 1 February the temperatures dropped below 0°C (32ºF).

Many people were evacuated during the following days. Vast areas were declared no-go areas in order to prevent the outbreak of contagious diseases, theft and further chaos. Meanwhile aid arrived from many countries. As soon as the Dutch government realized the extent of the disaster, measures were taken to close as many breaches as possible. Before the end of 1953 closure of these gaps was completed. Meanwhile the government prepared new legislation.

83.4.1 The Delta Works Carried Out

In 1957 the "Deltaplan" was issued (Fig. 83.8). This special law anticipated the building of large scale hydraulic engineering works. As safety-first was the key objective of this new law, all tidal inlets in the southwestern delta area had to be closed. As this was impossible because the "Nieuwe Waterweg" gave access to Rotterdam harbor and the Western Scheldt gave access to Antwerp harbor, alternative measures were required. Furthermore, it was deemed necessary to reorganize the body of small water boards into a large-scale merger. Finally, a warning system was put into operation (Van de Ven, 2004).

Fig. 83.8 The location, nature and size of the different projects of the Delta works in the Southwestern Netherlands and shows the years when they were completed

The expedition of the Delta project is considered as part of a single chain of innovations according to technical criterions: each stage or separate hydraulic-engineering work required a unique approach. Because of the many inlets in the coastal area penetrated far eastward, the tidal flow was much too strong to close them off in the west only. In order to reduce the energy of the incoming and outgoing tides, closing-off started with the smaller inlets and those at the far end in the larger ones. Moreover, closing-off an inlet still required great care because of the strong water flow through the last remaining gap.

At one stage three islands were connected with dams. The Veersegatdam and Zandkreekdam were built of sand and partly of concrete caissons. At slack tide caissons were put into position with tugs after which they were very quickly filled with gravel and stones in order to be finished as dikes with earth, grass and tarmac serving as roads. At other locations the bottom of the inlet was leveled over the entire width with big boulders of concrete placed there by cableways built across the inlet (Brouwersdam and Grevelingendam). As the bottom was gradually raised, the tidal flow stopped automatically. Next the boulder dam was likewise finished. In order to accommodate shipping between Antwerp and Rotterdam the Haringvlietdam at the far end of the inlet had locks built in (Ferguson, 1970).

The final act of the Delta Project, already begun in 1967, was the closing off of the mouth of the Eastern Scheldt (Bijker, 2002). Beforehand, a series of technical problems had to be solved as well as one of a political nature. The political problem appeared to be the most difficult one to solve. While the building of the Delta Works was nearly two decades underway, another tide had changed too. Gradually public opinion turned against a complete closing-off of the Eastern Scheldt. It was argued that fisheries and nature interests should be taken care of as well. Traditionally, the Eastern Scheldt was important because of its oyster, mussel and cockle farming providing several hundreds of people a livelihood. Closing off the tidal inlet would make the tides disappear and therefore also the shellfish. As public protest increased, the government gave way. In 1975 it reconsidered the initial plans (Parma, 1978). The solution was simple: the Eastern Scheldt would only be partly closed. Now it was up to the technicians to find the best technical approach to this political decision.

The solution they provided was just as simple. A Storm Surge Barrier would be built with a number of large slides held in between piers which could be moved. Normally, the slides would be lifted in order to reduce the tides' impacts, except for extra high tides or during severe storm surges when the slides would be entirely lowered (Fig. 83.9). The problems the technicians faced were the following. The inlet had two major deep channels with a sandbar in the middle. The bottom was too weak to carry any heavy concrete construction. It was estimated that large quantities of building blocks had to be made, and that transporting them from distant places would be too expensive as well.

First a deep lying polder was built on the local sandbar ("Werkeiland Neeltje Jans") where the large concrete building blocks were made. Also special means of transportation were designed to carry them or to perform part of the construction process. Because the bottom of the inlet was too weak, the sandy top layer

Fig. 83.9 Delta Works: The Storm Surge Barrier is built with a number of large slides held in between piers which can be moved. Normally, the slides are lifted in order to reduce the tides' impacts, except for extra high tides or during severe storm surges when the slides can be entirely lowered (Courtesy Rijkswaterstaat)

was removed. Even down to 15 m (49.2 ft) the sub layers had to be re-enforced, then on top of that layers of gravel with a concrete mat would form the foundation of the Storm Surge Barrier. Because it is hard to transport 18,000 tons of concrete piers, the construction site was flooded. Then the partly submerged pier became less in weight and could be moved to its final position. After placement of all piers, the large steel slides were fit in. Finally, a new road was built on top of the Storm Surge Barrier. One extra pier was not used and it remains an icon of the Delta Works up to the present day. In 1986, the Storm Surge Barrier was officially opened.

Meantime another technical innovative barrier was built. With two large mobile slides on rails, this Maeslantkering could close off the "Nieuwe Waterweg." Only the Western Scheldt could not be closed off, so the dikes on both banks had to be rebuilt into Delta dikes. These dikes have a wide base and a top level of 10 m (33 ft) above Amsterdam Ordnance Datum. The last stretch of this work was completed in 1992.

83.4.2 Assessment

Did the Delta Project meet the initial objectives? One of these was safety. Since the 1953 storm surge no other natural hazard has hit the area yet. The storm 1976 surge only hit the Belgian area, which had not carried out similar projects. Meanwhile, the large number of small water boards has merged in two large ones in Zeeland, one on the Brabant side and one around Rotterdam. Moreover, the warning system, installed on the Storm Surge Barrier works perfectly, only having lowered the slides a dozen times, while dikes at risk are being watched by especially trained personnel during heavy gales. So on the sides of safety, the Delta Works were and still are a big success. Additional consequences have been the many extra jobs created during the construction of the engineering works and the many new and quite original engineering innovations being applied. Furthermore, the salt gradient has been reduced significantly in large parts of the Zeeland area.

Initially, after being no major objective at all, the closing off of inlets by a number of south-north running dams has radically, but positively changed, the infrastructure of the Zeeland area. A third positive consequence of the Delta Works is the large numbers of tourists visiting them each year which provides much additional income. When looking at the preservation of nature and ecology of the inlets, the story is rather different. On the one hand, shellfish farming in the Eastern Scheldt has not only to hold its own, but has even managed to expand seriously. On the other hand some inlets have changed slowly from a salt-water area into a brackish and fresh water area (Doornbos, 1982; Groenendijk, 1987). Because tides are not active anymore, there is a need now for active flowing water in order to better clean the water and to make blue-green algae completely disappear. In the former Eastern Scheldt there is only a reduced impact of the tides, which has led to a gradual filling of the former channels. Eventually, the reduced tidal impact will make the sandbars disappear into the channels and changing the former sea bottom into a vast flat sandy bottom, which is not able to sustain marine life to its former glory.

83.4.3 Solutions/Future

After more than half a century the southwestern part of the Netherlands faces ecological changes that have not been anticipated. Moreover, the growing focus on nature preservation of the recent decades very much calls for new changes. These changes might range from allowing more tidal impact in the Eastern Scheldt again and opening up some other dams on a very limited scale to flooding some polders in the Western Scheldt area in order to retain areas. Although the Zeeland area is in still very much in the midst of this discussion, the ecological and nature issues have become more complex than ever. There is also a need for changing the Western Scheldt estuary to meet the demands of lager sea-going bulk and container carriers. This problem can only be solved through international negotiations with Belgium. However, most uncertain is the expected climate change, which will lead to a serious sea level rise in the area.

83.5 Conclusion

This chapter looked into the issue of how the Dutch have dealt with a growing sea impact on the low lying coastal zone through time in general and how they have dealt with that problem in the recent century by carrying out two specific megaprojects. In addition, an answer needs to be given to the question whether these megaprojects are still as much appreciated as they were at the start.

In the geological history of the Netherlands it is shown that within the last 10,000 years the first deposition cannot keep up pace with fast sea level rise, then sea level rise slows down, deposition becomes more important and can keep up pace with land subsidence with the consequences being that the coastal areas become a safer place to live for man.

Looking back at the building of the two Dutch megahydraulic engineering projects of the 20st century it is fair to say that from its start until the early 1970s, hydraulic engineers have determined coastal management and, therefore, the building of the Zuiderzee works and the Delta works. Prior to that the only land reclamation remained a valid objective for the Zuiderzee works, while reducing the risk of flooding and the salt gradient remained valid for both projects. But as the guarantee of providing a food supply as prime objective for land reclamation became less important, while at the same time there was a growing awareness for environmental and ecological issues and preserving nature, these changes also had an impact on the building of both megaengineering projects. For the Zuiderzee project, this change led to the cancellation of draining the Markermeer. Abandoned arable lands were partly changed into nature and recreation areas (Veluwerand Meer). Initially, while not an original objective, the reclaimed polders of the former Zuiderzee provided much space for town building (Almere, Lelystad). Moreover, because of the high quality of the fresh water body of the IJsselmeer, there is no need for further change and hardly anyone questioned the need for all parts of the Zuiderzee works to be implemented.

For the Delta works the shift in perception of initial objectives led to the building of a half-open Storm Surge Barrier to allow a reduced tidal impact in order to guarantee the shellfish industry and additional environmental interests. Because guaranteeing safety and reducing salinity were the only initial objectives aimed at, dams and dikes cannot easily be removed to improve water quality. Nor can this objective prevent the continuously changing Easter Scheldt sea bottom from becoming a channel-less horizontal sand dessert in which shellfish will gradually disappear. The environmental issues or the interest of nature seem to be incompatible with those of safety. Therefore the new generation of hydraulic engineers has changed into engineers of nature. However, more space for water and marine life and more appreciation for environmental issues has already led to again an increase in the salt gradient. In spite of the fact that the Delta works have significantly improved the infrastructure and enhanced tourism as well, many question the validity of all of its projects in terms of environmental issues and issues that concern nature.

By living in the coastal low lands of the Netherlands, either in the Delta works area or in the Zuiderzee works area, the Dutch will eventually also have to face expected climate change. A continuous rising sea level and more rainfall will increase the pressure. Are we going to discover the prefect civil or hydraulic engineers that can cope with all these problems at the same time in future? Dutch society has often shown its vigilance, resilience and resourcefulness during the past, so there seems to be hope for the future.

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