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Building the deltas of the future

Hydrolink

BUILDING THE DELTAS OF THE FUTURE

BY HENDRIK POSTMA, MARK VAN KONINGSVELD & STEFAN AARNINKHOF

Hoppers of Van Oord (left) and Boskalis (right) working together in the construction of the Rotterdam Port Extension Maasvlakte II.

The Netherlands is home to two of the largest dredging contractors in the world. Both companies have seen a gradual growth over the last 100 years, alongside with a series of iconic hydraulic engineering projects in The Netherlands as well as abroad. Ambitious investment programmes in research and development and continuous equipment innovation have played an important role in keeping the Netherlands ahead as a country known for its hydraulic engineering skill. Recent R&D efforts focused on the development of improved methods for the design and implementation of marine infrastructure, based on the concept of Building with Nature. The latter heavily relies on multi-disciplinary collaboration in the context of the so-called Dutch Diamond, consisting of the private sector, government, NGOs and knowledge institutes. It is our ambition to maintain this leading role and become a key player in Building the Deltas of the Future.

Figure 1 - Impression of the nature of dredging works in the late 19th and early 20th century. 1: construction works on the Noordzeekanaal (1865-1876). 2: construction works on the Eemskanaal near the port of Delfzijl (1866-1876). 3 & 4: construction works on the Afsluitdijk (1927-1932).

The Dutch dredging industry: historic perspective

The history of the Dutch dredging industry is shaped by a culture of innovation and entrepreneurship. The industry finds his roots in the second half of the 19th century, in the villages and cities built in the swampy wetlands surrounding the Biesbosch region just southeast of Rotterdam. Most companies started out as family-owned businesses aiming to make a living with small-scale maintenance dredging and construction of river bank and shore protection schemes. The works were carried out with highly artisanal techniques, and were paused during the cold winter months.

Driven by challenging projects in the Netherlands as well as abroad, the Dutch dredging industry has seen a major scale increase over the last hundred years. This involved both the dimensions and production rates of the dredging equipment, as well as the size of the companies themselves. Persistent consolidation of various smaller companies into larger organizations has nowadays resulted in a small number of major players, of which Boskalis and Van Oord belong to the five largest international dredging contractors worldwide.

These developments can be put in historic perspective along the lines of three major hydraulic engineering project in The Netherlands:

Figure 2 - Overview of large projects that over the years have shaped the development in dredging equipment and vice versa.
1: construction of the Rotterdam port extension Maasvlakte II (Netherlands). 2: construction of the Sand Motor Delfland (Netherlands). 3: sandy strengthening of the Hondsbossche and Pettemer Sea Defence (Netherlands). 4: construction of Palm Jumeirah (Dubai). 5: construction of the West of Duddon Sands Windpark (UK). 6: construction of the Eneco Luchterduinen Windpark (Netherlands).

1. Construction of the Nieuwe Waterweg (1866-1872), a new, man-made entrance to the North Sea that enabled Rotterdam to become a port of international standing. Historic pictures (Fig. 1) reveal the labour-intensive nature of the work, owing to the massive scale of the project and the artisanal work methods in use at the time.
2. Devastating floodings in 1916 lead to the construction of the Afsluitdijk (1920-1932), which dramatically shortened the coastline and turned part of the former Zuiderzee basin into a fresh water lake we now know as IJsselmeer. The project marks the transition from artisanal techniques to science based engineering; it inspired the establishment of world-renowned research institutes Delft Hydraulics and GeoDelft. Both institutes merged into Deltares in 2008.
3. Following the 1953 flood disaster in the Southwest Delta, the Dutch government initiated the Deltaplan that foresaw in the construction of a series of hydraulic engineering infrastructure projects to ensure safety against flooding, improve accessibility of the Delta region and create fresh water reservoirs for agriculture. The Delta Works commenced in 1958 and were completed in 1997. Rather than designing infrastructure to deal with floods witnessed in the past, the Delta Committee proposed to establish safety norms based on an economic analysis optimizing the cost associated with provided safety levels and the economic value in the hinterland. The safety levels reflect the probability of occurrence of the design conditions that the infrastructure should just be able to withstand. The optimal levels are embedded in law. Starting out with 'traditional' tidal closures, growing environmental awareness urged the design engineers to revise the later barriers into open structures, to maintain existing ecological values. As such, the Eastern Scheldt storm surge barrier marks a paradigm shift to multi objective design.

The strong home market enabled the Dutch hydraulic engineering sector to build up a competitive edge in the field of dredging and construction of marine infrastructure projects, thus providing a sound base for international expansion. This started towards the end of the 19th century and in the first decades of the 20th century with the construction of various port and shipping channels in Argentina, Indonesia and the United Kingdom. As of the 1970's Dutch companies became increasingly active in the Middle East in the construction of land reclamations and several ports, such as the Port of Jubail in Saudi Arabia. From the 1990's onward, construction of several very large infrastructure projects, such as the Oresund fixed link project between Sweden and Denmark, the Chek Lap Kok project, in Hong Kong, and the Singapore land reclamations at Pasir Panjang illustrated the trend towards the development of ever larger dredging vessels. These contributed importantly to the construction of Dubai's Palm Islands in the first years of the 21st century. The past decade was coloured by several mega projects in Australia related to mining (iron ore and coal) and LNG processing and export, carried out under the most strict environmental regulations

Recent years have shown a further expansion of the scope of works towards the offshore, including the development of deep sea mining activities and prominent involvement in the installation of Offshore Wind Farms. This culminated into the construction of some of the largest windparks presently in development, including the Eneco Luchterduinen Windpark, the Gemini Windpark (both in the North Sea) and West of Duddon Sands in the Irish Sea. These developments illustrate the permanent need for innovation, while entering new fields and exploring new horizons in the field of hydraulic engineering (see Fig. 2).

Science and innovation in dredging technology

The projects in the previous section illustrate the importance of innovation and increasing scale, both in dredging efficiency and company size. The challenges presented by the increasing scale of infrastructure projects over time, triggered dredging companies to invest primarily in technological development. This mainly resulted in the construction of ever larger, stronger and more efficient dredging and excavation equipment.

Of key importance, for example, was the development of the so-called Jumbo Trailing Suction Hopper Dredge (TSHD), that were able to hold over 40.000 m^3 of sediment in their hopper and reach productions that were roughly two orders of magnitude larger than that of smaller scale models (from approximately 200 m^3/hr of the early models to well over 10.000 m^3/hr for the most modern equipment). This scale step in TSHD equipment enabled a dredging production of well over 1 million m^3/week in projects like the The World in Dubai as well as the construction of the extension of the Port of Rotterdam: Maasvlakte II and the Hondsbossche and Pettemer seadefence. A similar scale increase can be seen in the development of backhoe dredgers, with the backacter, that can haul as much as 25 m^3 of sediment in one haul, as the current pinnacle. Likewise the Cutter Suction Dredger (CSD) was developed over the years, resulting in a one order of magnitude increase measured by cutter power (from approximately 200 kW to well over 7000 kW). Another major innovation was the introduction of the so-called self-propelled CSD. This made these very large vessels much more flexible in terms of deployment and manoeuvrability. Furthermore the increased size of the vessels dramatically increased their workability characteristics.

The Jumbo Trailing Suction Hopper Dredge (TSHD) are able to hold over 40.000 m^3 of sediment in their hopper

The ongoing increase in the capabilities of dredging equipment, initially triggered by challenges presented by large infrastructure development and competition, in turn inspired project developers to think of new projects of a scale that was previously unimaginable. The design and construction of the Palm Islands in Dubai, and more recently the construction of the Suez Canal expansion in a record time, are examples that clearly illustrate the scale at which dredging industry is able to meet project developers' requirements.

Ongoing investments in dredging equipment has turned the dredging business into an asset driven and highly capital intensive industry. As a result, dredging research and technology development has long been focussed on production optimisation. The Dutch dredging sector was early to realise that it would pay off to fund and perform fundamental research on dredging technology together, in order to stay competitive on the world dredging market. The collaboration was effective since the research focussed on pre-competitive knowledge development. Each company retained its own responsibility to translate the research findings into daily practice. For the various Research & Development projects, the dredging companies set up a strategic alliance (SSB), which has been in operation for more than 20 years now and tapped into the knowledge and expertise of available research institutes in the Netherlands such as Deltares and the various technical universities. Topics studied by this research alliance include:

- the operational performance of various types of dredger in different weather and sea conditions;
- computer models for hydraulic transport;
- quality control for process water;
- and design methods for weak soils.

More recently technological developments focus more on societal issues such as the reduction of fuel consumption and CO_2 emissions: cleaner engines, efficient ship hull design, more efficient ways of equipment operation, etc.

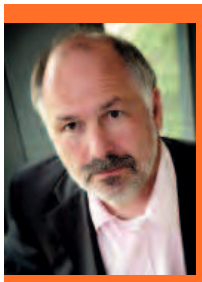
As part of that collaboration the Dutch dredging sector is involved in various doctoral research and graduation projects and even sponsors the chair Dredging Engineering at Delft University of Technology.

Science and innovation in project design: Building with Nature

Around the start of the 21st century Dutch dredging companies where among the first to realize that the ever increasing scale of dredging projects and the increased public awareness of sustainability, in combination with external triggers like climate change and accelerated sea level rise, called for a paradigm shift in the development and design of hydraulic engineering infrastructure.

In an effort to develop a new method for project development and operation, Dutch dredging companies Van Oord and Boskalis took the initiative for the Building with Nature (BwN) innovation programme. Starting from the natural system and making use of nature's ecosystem services, BwN attempts to meet society's needs for infrastructural functionality, and to create room for nature development at the same time. By including natural components in infrastructure designs, flexibility, adaptability to changing environmental conditions and extra functionalities and ecosystem services can be achieved, often at lower costs on a life-cycle

Figure 4 - Presentation of the Building with Nature book at the final congress of the first phase of the innovation programme in 2012 (from left to right: Harry Baayen (managing director of Deltares), Jan Schaart (director of Van Oord Nederland and member of the EcoShape supervisory board), Huib de Vriend (scientific director of Deltares and managing director of EcoShape) and Renske Peters (director of Water at the Ministry of Infrastructure and Environment)



Hendrik Postma **graduated as a coastal engineer from Delft University of Technology and has more 30 years of experience in the field of dredging. He held several management positions on Boskalis projects worldwide. At this moment Hendrik is director at Boskalis Netherlands. Besides his role at Boskalis, Hendrik is chairman of the Supervisory Board of the Foundation EcoShape | Building with Nature, chairman of the Vereniging van Waterbouwers and chairman of the Kernteam Delta Technology, which forms part of the Top Sector Water.**

Mark van Koningsveld **studied at the University of Twente in Enschede, the Netherlands, where he received an MSc (1998) and subsequently a PhD degree (2003) in Civil Engineering. After several years of working for Deltares he joined Van Oord (2008) where he currently is Manager R&D Engineering and Lead Engineer Environmental Engineering. Besides his role at Van Oord Mark actively participated in the Building with Nature programme, among others as program manager and Management Team member of the Foundation EcoShape | Building with Nature. Finally Mark is Secretary of the Top Team of the Top Sector Water, representing the business node of the Dutch Diamond (government, research institutes, businesses, NGO's).**

Stefan Aarninkhof **is deputy manager of Hydronamic, the in-house engineering department of Boskalis. He graduated as a civil engineer from Delft University of Technology in 1996. He subsequently received a PhD, also from Delft University, and worked for 10 years at Delft Hydraulics (nowadays Deltares) before joining Boskalis in 2006. Stefan worked on a variety of projects worldwide, including the Khalifa Port and Coastal Zone project (UAE) and the Zandmotor (NL). Until recently, Stefan held the position of program manager and Management Team member of the Foundation EcoShape | Building with Nature. In his present capacity, Stefan is, amongst others, responsible for the environmental engineering group.**

Figure 5 - Restoration of mangrove shorelines in Demak (Java, Indonesia). In March 2015, the Indonesian and Dutch government launched a comprehensive five-year multi million public-private partnership initiative for enhancing coastal safety at the North Coast of Java. It aims to build stable, natural coastlines with reduced erosion risk through a unique integration of mangrove restoration, small scale hard-engineering and sustainable land use. The large-scale pilot project in Demak district focuses on safety against flooding along a 20 km stretch of coastline and sustainable revitalization of 6000 ha of aquaculture ponds. The approach includes a combination of technical and socio-economic measures, as well as creating an enabling environment through stakeholder dialogues and capacity building. The ultimate goal is to enable replication and up-scaling of the concept, for incorporation in a variety of urban and rural development programs.

basis than 'traditional' engineering solutions. To achieve public support, project development was to be seen as a process of co-creation where people from different disciplines work together to come to appropriate project designs.

The BwN programme, which is run by the EcoShape foundation, has now entered its second phase. The first phase ran from 2008 – 2012. The program received funding from the Dutch government, the EU, municipality of Dordrecht and private industries (all cash), as well as in-kind contributions from consultancies, research institutes and universities. The total programme budget for Phase 1 amounted to approximately € 32 million. Key outcomes of Phase 1 include, amongst others, various full scale pilot applications with associated monitoring programmes, a wiki based guideline to support the development and design of Building with Nature solutions, a glossy booklet (Fig. 4) outlining the basic philosophy of Building with Nature, 19 PhD theses and a wide range of scientific articles and technical reports.

The second phase of the EcoShape Building with Nature program runs from 2013 – 2018. The current programme budget is approximately € 38 million and funded from similar sources. A major difference, though, is that this funding was to be secured on a project by project basis. This yields a much wider range of funding sources, which make the programme's governance more complicated, but also increases the basis of support for Building with Nature.

Key to both the first and the second phase of the BwN programme is the realisation that all partners of the so-called Dutch Diamond, viz. the private sector, government, NGOs and knowledge institutes, should be involved in the development of the new design method to ensure that is achieves its maximum potential. A key example of a project that follows this approach is the mangrove restoration pilot in Demak, Java, Indonesia (Fig. 5).

In summary

Over the years, challenging hydraulic engineering projects worldwide have inspired Dutch contractors Boskalis and Van Oord to develop a competitive edge in the field of dredging and marine infrastructure construction. This position was maintained through continuous innovation and development. Initially, R&D efforts focused on the improvement of dredging technology, which lead to a scale increase in dredging equipment – and subsequently the infrastructure projects involved. More recently, the R&D scope was expanded to include the development of sustainable methods for the design and implementation of marine infrastructure, based on the concept of Building with Nature. It is our ambition to maintain this leading role and become a key player in Building the Deltas of the Future