The Walsoorden pilot project: A first step in a morphological management of the Western Scheldt, conciliating nature preservation and port accessibility

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ABSTRACT: In the framework of the Flemish-Dutch “Long Term Vision” strategy of the Western Scheldt, the Port of Antwerp Expert Team proposed the idea of morphological dredging aiming at steering the estuarine morphology. As a pilot project, the experts proposed a new disposal strategy, where dredged material would be disposed on the eroded tip of the Walsoorden sandbar.

The feasibility of the disposal strategy was investigated at Flanders Hydraulics Research in 2002 and 2003. None of the results of this study opposed the feasibility of the proposed strategy, although final judgement would only be possible after the execution of an in situ disposal test.

At the end of 2004 500,000 m³ of sand was disposed at the tip of the Walsoorden sandbar. After a one-year extensive monitoring of the experiment, it was concluded that from morphological viewpoint the test was a success. The ecological monitoring revealed no significant negative changes in trends due to the disposal test. In 2006 the in situ disposal experiment was continued, with a new disposal of 500,000 m³ of sand.

1 INTRODUCTION

The morphology of an estuary is continually changing, adjusting to the forcing processes which themselves are also changing. No estuary is therefore stable and habitats and the ecological functioning of the estuary will continually change from its present status, even if man didn’t intervene. This implies the need for a detailed conceptual understanding of the estuary system in question. Only such an understanding can lead to proper assessment of the effects of existing and future human activities, such as dredging and disposal, but also the construction of flow regulating structures and dikes. For any estuary there should be a holistic management plan, which takes into account the interests and effects of all uses and users of the estuary in an integrated way.

This paper focuses on the case of the Scheldt estuary, where morphological management is used to conciliate nature preservation and port accessibility. The Scheldt is the aorta to the port of Antwerp, while it is one of the few remaining European estuaries covering the entire gradient from fresh to salt water tidal areas.

2 OVERVIEW OF HISTORICAL EVOLUTIONS

At the end of the Pleistocene, the last ice age, rivers in North-West Europe discharged in the Atlantic Ocean in the vicinity of the Doggersbank, far away from the present shores. With the warming up of the climate, the sea level rose very quickly over more than 100 meters from 20 Kyr BP to about 7 Kyr BP, then slower to become (comparatively) rather stable over past two millenaries. The past rising sea level reshaped strongly the coastal areas and estuaries at the end of the Holocene. Many of these morphological changes are still ongoing.

In front of the actual Belgian, Dutch and German coast an almost continuous series of sandy bars and islands existed (Figure 1). An inner sea was formed, a kind of an extensive lagoon of which remains only the Wadden Sea. The sand barrier between lagoon and open sea was regularly breached during storms, scouring large channels deep into the inner sea. River sediments filled those parts of the lagoon receiving streams with large sand discharges, like the Rhine. In other parts receiving little and more silty sediment loads,
like from the Scheldt river, tidal action penetrated progressively, developing further the sea branches. Import of marine sediments by the tidal currents formed large shoals in the lagoon. Around 1000 A.D., Zeeland had become a patchwork of islands, surrounded by a network of tidal channels. At that time, the river Scheldt discharged in the lagoon near Bergen op Zoom and both the Honte (present Western Scheldt) and the Eastern Scheldt were conducting the Scheldt river water to the North Sea. Till the 11th century, morphological evolutions were significant but fully natural, with almost no human impact.

First signs of human impact on the estuary’s environment become visible in the 11th century: locals reclaimed land that had silted up high enough and started to protect it against flooding. However, inundations due to levee breaching during storm events returned repeatedly portions of land to the river. From the 16th century on, the poldering techniques had become more sophisticated and larger areas were permanently poldered (e.g. for eastern Zeeuws-Vlaanderen 50% of the total poldering occurred during the 17th century).

Poldering was less intensive during the 19th and 20th century because a large percentage of salt marshes had been reclaimed already. However, hydraulic works and storms continued to reshape the area. In 1867 and 1871, the two remaining links (Kreekkrak and Sloe) between the Honte (Western Scheldt) and the Eastern Scheldt were cut-off, modifying drastically the tidal channels network. A catastrophic storm with extensive inundation, in 1953, made the Netherlands decide about executing an extensive flood protection plan “Delta”. From historical data can be concluded that these human impacts such as closure of secondary channels and poldering have strongly influenced the tidal regime of the Western Scheldt. Stronger tidal penetration enlarged the main navigation channel.

Sediment mining for providing building material started at the end of the 19th century. Since 1958, about 1 to 2 million cubic meters of sediment was mined per year, on average.

At the end of the 19th century, dredging activities were required to improve the accessibility of the port of Antwerp. Until the 1920’s, these activities were concentrated on the Belgian territory (2 Mm³/year). From 1920 till 1960 the quantities on Belgian and Dutch territory were comparable (2 + 2 Mm³/year). The first large deepening campaign happened in the early 1970’s, the main part of dredging works on Dutch territory (3 + 10 Mm³/year). Nonetheless, the increased dredging in the Dutch part did not apparently result in significant changes of the trend in morphology or tidal action. During the late 1990’s, a second dredging campaign for improving the navigation conditions was conducted. The impact of the deepening by 4 feet is monitored (MOVE programme), but no significant negative impact was noticed yet.

3 MAINTAINING ACCESSIBILITY IN A MORPHOLOGICAL DYNAMIC ESTUARY

The morphological evolution of the estuary between 1800 and 2000 (Figure 2) is one of further shoal aggradation and enlargement of the main channels. The estuary is described as a typical multiple flood and ebb channel network. The main and deeper ebb channels have usually sills at the seaward end where they join together with the flood channels. These ones are shallower and have a sill at the landward side, where they join the main ebb channel. There are also many minor channels, the “chute” channels, sometimes called “short-circuit” channels connecting the major ebb and flood channels. The reducing mobility of the channels and shoals is for a large part due to the hard bordering of the estuary (levees, bank protections, groynes, jetties and harbours); sandbars are rising too high, channels deepen, shallow water areas diminish.
Till 1970, dredging was restricted to maintaining depths on crossings in the navigation channel, formed by the main ebb channels. Traditionally, the sediments were disposed in the flood channels with the idea that it would take a rather long time before coming back into the main ebb channel.

With the demand for increased navigation depth, a first deepening started in 1970 and the dredged sediments were still disposed in flood channels. The disposal sites were decided in common by the Dutch and the Belgium administrations on the basis of the assessment of the ongoing morphological changes. The procedures were adjusted due to the increasing concern about environmental aspects and with the regionalisation making the Flanders region responsible in Belgium for public works and infrastructure. In 1995, Flanders and the Netherlands reached an agreement to deepen further the Western Scheldt shipping route. Works were executed in 1997 and 1998. However, the amount of sediment disposed in the eastern part of the Western Scheldt was reduced when aggradation was observed in some flood channels, supposedly because too much sediment had been disposed there. This siltation could eventually jeopardise the existence of the multi-channel system in that reach. Therefore, from 1997 on, more material was moved to disposal sites in the western reach of the estuary.

In 1999, the Dutch and Flemish governments decided to set up a Long-Term Vision (LTV) project with 3 objectives: to ensure maximum safety against flooding, optimal accessibility of the ports within the estuary and optimal nature development. These 3 subjects are all related to the morphology of the estuary. Directly concerned by these issues, the autonomous Port of Antwerp, independent from the Flemish administration, requested a group of experts (called Port of Antwerp Expert Team, or “PAET”) to give an opinion about the prospects for a further deepening and widening of the navigation route, mainly needed for the larger container ships. One of the main questions considered in LTV was where to dispose the large volumes needed for such an enlargement? Dutch researchers had claimed that flood channels would disappear if too large quantities of sediment were to be disposed there. Their conclusions were based on some assumptions and calculations with modelling tools, of which one is based on the so-called “cell-theory” [Wang et al., 1995 – Winterwerp et al., 2001]. PAET consider their schematisation as too simplistic. Based on their analysis of past morphological changes in general and of the (temporary?) decay of some flood channels, they stated that not only disposal of sediments was to be blamed, rather the always more stringent immobilisation of the main channels and shoals. To revert the reduction in dynamic morphological behaviour of the estuary, it was proposed to steer the development of channels and shoals. Recent studies show that the disposal of dredging materials has a much larger impact on the estuarine morphology than the deepening of the channels [ProSes, 2004]. The main attention should therefore go to new strategies for disposal, although PAET believes that dredging may also be beneficial for morphology, e.g. rectifying the shape of sandbars.

In 2002, the Dutch and Flemish governments signed a memorandum of understanding to implement together the Long-Term Vision programme. They set up jointly an organisation called ProSes (Project Direction for the Development Scheme of the Western Scheldt Estuary) funded by both regions and which main task was to establish the development scheme with the objectives to be reached in 2010.

4 MORPHOLOGICAL MANAGEMENT OF THE WESTERN SCHELDT

4.1 Morphological dredging

During a meeting with the LTV’s working group on morphology, in the year 2000, PAET suggested “morphological dredging” as an alternative to the present dredging strategies. It is based on the principles developed for the maintenance and the capital dredging in the navigation route in the Congo inner delta, for example by redistributing the sediment transport and using dredging and disposal to change the plan form of the river.

Disposal is a way to redistribute the sediment in the Western Scheldt, so as to feed, as an example, areas eroding too much. Not only in the flood channels, also on some parts of shoals. PAET worked out a proposal to restore the western tip of the Walsroorden sandbar that erodes since several decades. Several millions of cubic meters of sediment could be stored at that place (Figure 3 – white hatching). As a result of this disposal this eroded sandbar would be reshaped so that the flood and ebb flows would continue to maintain the multiple
channels. Besides making the estuary ecologically and morphologically healthier, the reshaping of the sandbar would also improve the self-erosive capacity of the flow on the crossing and possibly reduce the quantity of material to be dredged. The technique could also be applied in other places along the estuary.

4.2 Technology for morphological dredging

The dredging companies contacted for advice about the disposal of material in controlled way close to the riverbed have developed a system by which the sediment is disposed quietly with a diffuser in shallow water (Figure 4). This technique has already successfully been applied in coastal areas [Goossens & Bosschem, 2002].

4.3 Potential benefits for the environment

A careful choice of disposal sites, based on good field data and possibly completed with modelling, may produce a selective spatial dispersion of the sediments along the sandbar. Some particle fractions will preferentially move in the deeper areas, other moving towards the shallower ones, possibly up to the top of the bar. During the process, the change in morphology by aggrading up some parts of the bar will change the flow patterns and modify consequently the local sediment transport capacities. This will obviously also change the sedimentation pattern, also of the finest particles moving in suspension in the water column. The segregation of sediment fractions of both disposed and natural sediments will result in the formation of different substrata, some more silty than other, creating a variety of ecotopes.

5 RESEARCH ON THE WALSOORDEN PILOT PROJECT

5.1 Study tools

PAET stated from the beginning of the Walsooden project proposal [Peters & Parker, 2001] that field measurements and physical and numerical models needed to be combined, as each of these study tools has advantages and limitations. They must be seen as complementary tools for the assessment of the alternative disposal strategy. The research programme included a field measurement campaign (floats, sediment transport), physical fixed bed scale model tests for both the flow and the bed sediment movement and hydrodynamic numerical model simulations. Flanders Hydraulics Research (Flemish Community) executed this programme with the support of the Port of Antwerp and its expert team.

5.2 Conclusion of the feasibility study

The results derived from the studies concerning hydrodynamics and sediment transport [Flanders Hydraulics Research, 2003] indicated that the placement of material as proposed for the morphological dredging strategy can likely be used to influence the estuarial morphology [PAET, 2003]. Degraded areas and their associated biotopes could be regenerated. PAET insisted on having a small scale in situ disposal test to gain final evidence that the proposed strategy is feasible.

The analysis of the data has also shown that all investigative tools were needed to reach this conclusion and that morphological assessment of the Western Scheldt should not be based on modelling alone. One should realise that our knowledge about and understanding of the physical processes governing morphological changes is still not sufficient to set up trustworthy models. Combining different tools is the only way to reduce the uncertainties.

Where most of the research occurred within the scope of ProSes, a second opinion team was asked to give their comments on the methodology used for and the results gathered from the research. They confirmed that the idea to use dredged material to restore sandbars is very valuable and that an in situ disposal test is necessary to remove the remaining uncertainties about the proposed strategy.

6 THE 2004 WALSOORDEN IN SITU TEST

6.1 Execution of the disposal test

The execution of an in situ disposal test had to bring final proof of the feasibility of the alternative disposal strategy. The idea of the in situ test was to dispose quietly and precisely 500,000 m³ of sand with a diffuser on the bottom. The dredging vessel (self-discharging hopper dredger) was connected to a floating pipeline through which the sand is transported to a pontoon. On this pontoon the sand is pumped to a diffuser (Figure 5) that disposes the sediment in a precise way on to the bottom.

The amount of 500,000 m³ was chosen because it is on one hand large enough to affect significantly the bottom morphology, however on the other hand small enough to be reversible if something would go wrong. The choice of the disposal location was based on the
results of the feasibility study. The float measurements, the results of the numerical simulations and the physical scale model tests with moveable material on fixed bed indicated that an area between the northern sand spit and the tip of the plate was most suitable for an in situ disposal test (Figure 6).

From November 17th to December 20th 2004 500,000 m$^3$ of sand was almost continuously disposed in the proposed area.

6.2 Monitoring of the disposal test

To evaluate the success of the test an extensive monitoring programme was set up. This programme, which was executed over a period of one year, included bathymetric surveys, ecological monitoring, sediment tracing tests and sediment transport measurements. Several criteria were defined before the test to evaluate its success. One of them stated that 2 weeks after finishing the disposal execution of the test, at least 80% of the disposed sediment should stay within the control area (this was defined as the disposal area, extended slightly towards the sandbar of Walsoorden). Also the ecological parameters should not indicate a change in ongoing natural trends.

6.3 Bathymetric surveys

The bathymetric surveys were executed using the multibeam technique, producing high resolution bathymetric charts. Where a frequency of weekly surveys was achieved during the first months, this was reduced to once every month 6 months after disposal. Beside this possible impact area, a larger zone was measured every 2 months, to capture possible larger scale influence of the in situ test. These surveys allowed volume computations for the control area. The evolution of the sediment volume in the control area is shown in Figure 7. The amount of disposed sediment should be corrected due to the differences in density in the hopper and in situ. Therefore a correction factor 0.9 was applied to the hopper volumes. As can be seen in Figure 7 the first survey after the execution of the disposal test shows a smaller volume measured in situ than what was disposed. This small difference (25,000 m$^3$) represents the sediment losses during the disposal of the sand, where a fraction (finer sands) was transported by the currents.

During the first 2 months the volume within the control area was even higher than after execution of the test, probably due to natural processes. Afterwards a decrease of volume was measured, a loss of approximately 10% after 6 months, almost 20% after one year. The main part of the eroded sand is transported during flood towards the Walsoorden sandbar (Figure 8). This evolution is in agreement with the predictions of the feasibility study. It may be concluded that the disposed sediments stay well in place, and the imposed criterion was successfully fulfilled.

6.4 Ecological monitoring

The ecological monitoring programme included both intertidal as subtidal measurements. Ecologists feared
increased sedimentation, especially of coarser sediment on the sandbar, which could have a negative impact on its biotopes.

The intertidal monitoring comprised of several stations on the Walsoorden sandbar (see Figure 9) where erosion-sedimentation, sediment composition and macrobenthos were measured. None of the results from this monitoring indicated that the in situ disposal test was responsible for a significant change in ongoing trends.

The subtidal monitoring was focussed on sediment composition and macrobenthos samples, using the BACI-technique (Before-After-Control-Impact). Beside the disposal area (yellow area on Figure 11), 2 control areas were chosen: one at the traditional disposal site “Schaar van Waarde” (green area), the other (red area) where no influence from disposal activities should be expected. For the subtidal samples an initial decrease in mud-percentage was found for the impact area. This is explained by the absence of finer mud material in the dredged sediments that were disposed. The macrobenthos samples did not show deterioration (biomass, diversity and density) for the impact area compared to the 2 other control areas.

6.5 Conclusions in situ disposal test

From morphological point of view, it can be concluded that the experiment using a diffuser for modifying the morphology of the sandbar by disposing precisely dredged material was very successful. The ecological monitoring did not reveal any significant negative impact, neither in the intertidal areas, nor in the subtidal areas. This in situ test confirmed the feasibility of the proposed disposal strategy.

7 THE 2006 WALSOORDEN IN SITU TEST

7.1 Execution of the disposal test

In the beginning of 2006 a second disposal test was executed, using the traditional clapping technique with hopper dredgers, instead of the diffuser. Because the disposal test was fitted in the continuous maintenance dredging works of the Scheldt estuary, the disposal of 500,000 m$^3$ was spread over a 3 months period. The disposal location was just downstream the disposal location of 2004 (Figure 6).

7.2 Ongoing monitoring of the disposal test

To evaluate the success of the test an extensive monitoring programme was set up. This programme, which will is executed over a period of one year, includes bathymetric surveys and ecological monitoring, similar to those executed after the 2004 disposal test. Again morphological and ecological criteria were defined to evaluate the success of the in situ test.

The preliminary results of the bathymetric monitoring show that the second in situ test can be described as a success from morphological viewpoint. After 6 months only 32% of the dumped material has been moved out of the control volume (Figure 10). Preliminary analysis of the surveys indicate a transport of the material towards the Walsoorden sandbar. Material dumped in 2006 has reached the 2004 control area, leading to a nourishment of this area.

The ecological results will become available during around June 2007, with the preliminary results not showing any negative impact.

7.3 Preliminary conclusions in situ disposal test

Although the results of the monitoring campaign are only preliminary, the second disposal test seems to be a success as well. Although further investigations are necessary, these results are very satisfactory towards a further implementation of the continuation
of the disposal strategy as was proposed by PAET. In total an estimated volume of 3 to 5 million m$^3$ could be disposed near the Walsoorden sandbar to reach the proposed objectives. This amount covers 50% of the dredging quantities (7 Mm$^3$ in total) necessary for a further deepening of the navigation channel in the Western Scheldt.

8 CONCLUSIONS AND RECOMMENDATIONS

For a long time dredging operations have been considered as producing only negative impacts on the environment. The Western Scheldt is one of the last relatively natural estuaries with a dynamic multi-channel system and exceptionally valuable eco-systems. A management with broader objectives that includes accessibility, safety and nature preservation progressively replaces the past management of the maritime access route to the Port of Antwerp, which was based almost exclusively on an engineering approach. In 2001 an international expert team appointed by the Port of Antwerp authorities, set forward new ideas about the morphological management of the estuary by using dredging and disposal of dredged material to steer the morphological behaviour of the estuarine multi-channel system. As a pilot project to demonstrate this new disposal strategy the location at the sandbar of Walsoorden was selected by the Port of Antwerp Expert Team on the basis of expertise. Reshaping the tip of this sandbar by morphological dredging might improve the self-dredging capacity of the crossing of Hansweert, reducing finally the dredging effort.

The feasibility of this project was studied by Flanders Hydraulics Research, combining desk studies, scale modelling, numerical modelling and field surveys. None of the results of this extensive study opposed the feasibility of the proposed disposal strategy at the Walsoorden sandbar. To finally prove the proposed disposal strategy, an in situ disposal test was conducted. At the end of 2004 500,000 m$^3$ of sand was disposed at the seaward tip of the Walsoorden sandbar. In 2006 the situ disposal test was repeated, using a different disposal technique. Both experiments were intensively monitored, morphological as well as ecological.

Taking into account the results of both disposal tests, it can be concluded that a new morphological dredging and disposal strategy could be successfully embedded in the future morphological management of the Western Scheldt. However, as stated by the Port of Antwerp Expert Team, the new ways of dredging and disposing sediments should be combined with other measures, such as adapting the hard bordering of the estuary and finding alternatives to the traditional protection works of banks and shoals.

The Walsoorden experiment also confirmed the need for building the capacity of the professionals in morphological assessment techniques, giving sufficient room to expertise and visual analysis of charts, maps and remote sensing observations. A further collaboration between engineers, biologists and ecologists is needed to develop further the idea of morphological dredging and the strategies to manage the morphology of estuarine systems.

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