A NEW DISPOSAL STRATEGY FOR THE WESTERN SCHELDT, CONCILIATING PORT ACCESSIBILITY AND NATURE PRESERVATION

by

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ABSTRACT

In 1999, Flanders and the Netherlands agreed to set up a common strategy for managing the Scheldt estuary. In 2002, both parties signed a memorandum of understanding in which was defined a "Long Term Vision" strategy and its objectives. One of these is the preservation in the Western Scheldt of a dynamic flood and ebb channel network, the so-called "multi-channel system". The present trend, a continuation of past natural morphological evolutions combined with human interference (land reclamation and polder building, dredging and other river works) may jeopardise this objective.

An expert team appointed by the Antwerp Port Authority stated the need for morphological management, aiming at steering the estuarine morphology. In a first phase, sediment from dredging works could be used to reshape eroded sandbars where needed, in order for the flood and ebb flows to continue maintaining the multiple channels.

Since 2002, this new disposal strategy is being investigated as a pilot project on the Walsoorden sandbar in the Western Scheldt. An extended research was conducted in 2002 and 2003, combining several tools: desk studies with maps on the historical morphological changes, field measurements, physical scale model tests and numerical models. As a result of the research work executed at Flanders Hydraulics Research, it was concluded that none of the results contradicted the feasibility of the new disposal strategy at the Walsoorden sandbar, 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 during one month with a diffuser in relatively shallow water at the seaward end of the Walsoorden sandbar. The experiment was thoroughly monitored, morphological as well as ecological. One year after the execution of the in situ disposal test, 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 a new disposal test was executed, using the traditional dumping ("clapping") technique with hopper dredgers. Due to practical limitations, the disposal (again 500.000 m³) was spread over 3 months. The new experiment was again thoroughly monitored. Due to larger currents in the disposal area, a higher percentage of the material was transported towards the Walsoorden sandbar. This morphological evolution was seen as positive within the objectives of the disposal strategy. From ecological viewpoint again no significant negative changes in trends have been identified.

Due to the success of both in situ tests, the strategy of morphological disposal will be included in the dredging and disposal operations for the future deepening of the navigation channel. This new disposal strategy will introduce benefits for both the economy (deepening and maintenance of the fairway) and the ecology (keeping the sediment in the estuary, creating new valuable areas without endangering the multiple channel system). Therefore further research work has been carried out in 2007-2008 on how to embed this strategy in the future dredging and disposal policy and the possible use of the strategy on other locations. During execution (planned to start in 2009) an intensive monitoring programme will monitor the morphological and ecological effects of the disposed sediments, allowing adjusting the strategy if necessary. However, this is only part of a morphological management of the estuary, which would also have to include morphological dredging and modifying the hard bordering at some locations.

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1. THE SCHELDT ESTUARY

1.1 Historical evolutions of the Scheldt estuary

The Scheldt estuary has been influenced by human interactions for several centuries (PAET, 2000). The natural system at the start of the Middle Ages consisted of the Scheldt river that connected to the sea branch the Honte near Bergen op Zoom. In the 11th century land reclamation (poldering) started, as dikes were built around area that had silted up high enough. In the early period dikes were regularly breached, but as dike building techniques improved (since the 17th century), the poldering received a permanent character. In the 19th and 20th century poldering became less intensive, but hydraulic works and storms continued to reshape the estuary. In 1867 and 1871, the two remaining links (Kreekrak 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 hydrodynamics (e.g. tidal penetration) and morphodynamics (e.g. migration of sandbars) of the Western Scheldt.

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 (up to 34' tide independent draft) happened in the early 1970’s, with the main part of dredging works located on Dutch territory (3 + 10 Mm³/year). During the late 1990’s, a second dredging campaign (up to 38' tide independent draft) for improving the navigation conditions was conducted.

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

1.2 A long term vision for the Scheldt estuary

In 1998, the Netherlands and Flanders decided to develop a joint long term vision (LTV) for the Scheldt estuary (DZL & AWZ, 2001) and its functions:

- Safety against flooding
- Optimal accessibility of the ports
- Natural ecosystem

The basic idea of the LTV was: “Developing a healthy and multifunctional water system, supporting human needs in a sustainable way”. In 2001 the governments of both countries adopted this overall target and already in 2002 the drawing up of the 2010 Development Outline (DO) for the Scheldt estuary had started. The aim of the 2010 DO was to define those projects and measures which, in a first stage, must be started up no later than 2010 to ensure the realisation of the LTV in 2030. Already in March 2005 the execution of the full 2010 DO was decided upon. The main projects in the 2010 DO are:

- Safety against flooding: implementation of the updated Sigmaplan in Flanders;
- Accessibility: deepening (up to 43' tide independent draft) and widening of the fairway to the port of Antwerp;
- Ecosystem: development of 600 ha of estuarine nature along the Western Scheldt in the Netherlands and 1,100 ha of estuarine nature and wetlands along the Sea Scheldt in Flanders;
- Both countries will jointly monitor the evolution of the estuary and the effects of the implemented projects in order to extend their knowledge of the estuary and to facilitate possible corrections.

Besides these large-scale projects, a considerable number of smaller administrative and legal measures were defined.

2. THE WALSOORDEN PILOT PROJECT

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, in short “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, respecting the preservation of the estuary’s physical system characteristics. 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 for this, rather the always more stringent immobilisation of the main channels and shoals (PAET, 2000; PAET, 2001a). To revert the reduction in dynamic morphological behaviour of the estuary, it was proposed to steer the development of channels and shoals.

PAET stated that disposal is a way to redistribute the sediments in the Western Scheldt, so as to feed, for example, areas eroding too much. This can be applied not only in the flood channels, but also on some parts of intertidal shoals. The expert team worked out a proposal to restore the western tip of the Walsoorden sandbar that has been eroded since several decades (PAET, 2001b). Several millions of cubic meters of sediment could be stored at that place (Figure 1). By disposing material near the eroded tip of the Walsoorden sandbar, the multiple channel system could be sustained in a pro-active way, improving the distribution of the flood currents between the ebb and flood channel. The reshaped tip could also increase the self-erosive capacity of the currents on the sill of Hansweert, reducing the amounts to be dredged. Moreover from ecological point of view, the reshaped sandbar could reduce flow velocities on the sandbar, allowing finer sediments to settle on the intertidal area of the sandbar. Nevertheless, disposing material near this location should only be seen as a curative solution, the cause of the erosion (orientation of the flood currents towards the tip of the sandbar) should be investigated and solved within the philosophy of morphological management of the estuary.

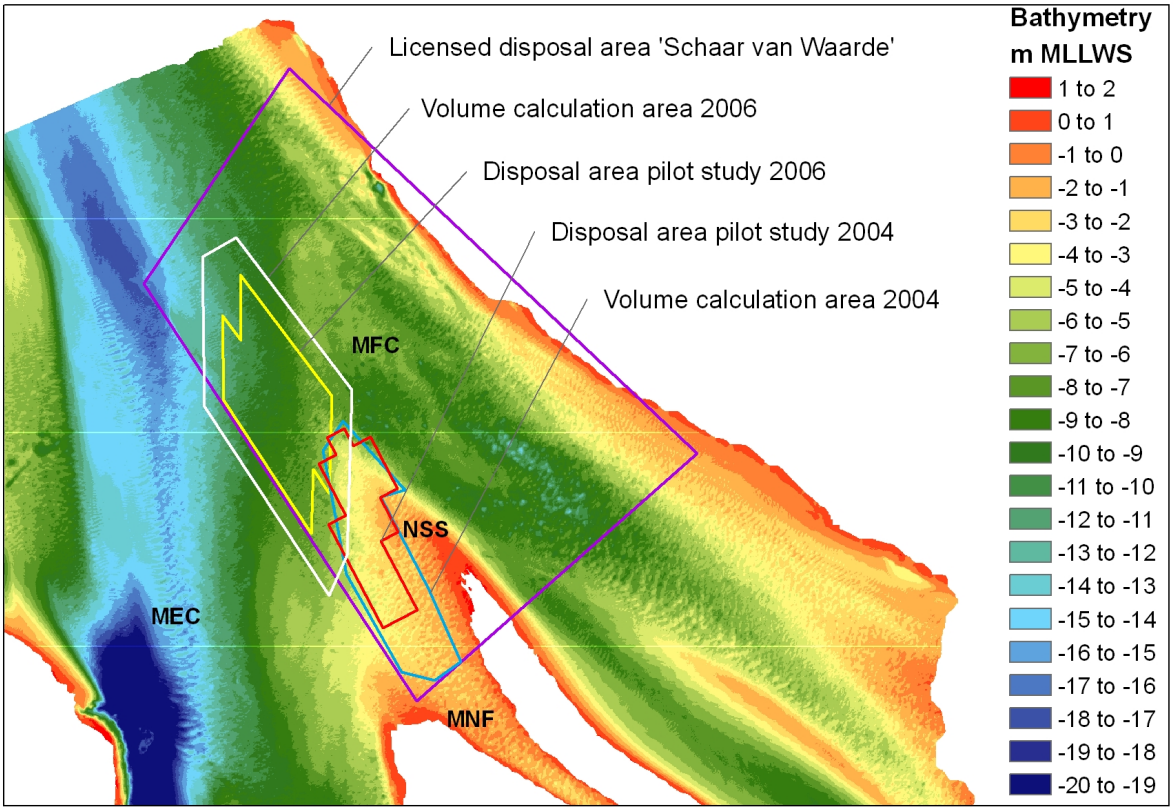

Figure 1: Overview of the licensed disposal area ‘Schaar van Waarde’ at the northern tip of the Walsoorden sandbar, the disposal areas used in the pilot projects of 2004 and 2006 and corresponding volume calculation areas

2.1 The feasibility study

In 2002-2003 Flanders Hydraulics Research carried out a research program to evaluate the feasibility of the proposed pilot project at the Walsoorden sandbar. The research program included a field measurement campaign with DGPS-floats, in-situ sediment transport measurements, the use of a physical scale model for both hydrodynamic modelling and mobile sediment tests and the use of a numerical model for hydrodynamic simulations. Each of the used study tools has advantages and limitations. However the combination of these different tools allows a good assessment of the feasibility of the proposed alternative disposal strategy.

None of the results indicated that the idea would not be feasible. Further research was executed to find the location that was most suited for the execution of an in situ disposal test. Therefore a fixed-bed scale model with artificial sediments was used to investigate sediment transport pathways (FHR, 2003). The PAET concluded that the disposal of material as proposed for the morphological disposal strategy, can likely be used to influence the estuarine morphology (PAET, 2003). They insisted on having a small scale in situ disposal test to gain final evidence that the proposed strategy is feasible.

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 in the Scheldt estuary is very valuable and that an in situ disposal test is necessary to remove the remaining uncertainties about the proposed strategy (BERLAMONT ET AL., 2003).

2.2 In situ disposal test 2004

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 “Bayard II” (Figure 2, left). On this pontoon the sand is pumped to a diffuser (Figure 2, right) that disposes the sediment in a precise way on to the bottom.

Figure 2: Pontoon “Bayard II” (left) and diffuser head (right)

From November 17th to December 20th 2004 500.000 m³ of sand was almost continuously disposed in the proposed area. Figure 3 shows the bathymetric data of December 2004, right after the disposal test, and a difference between the bathymetric survey of December 2005 and December 2004.

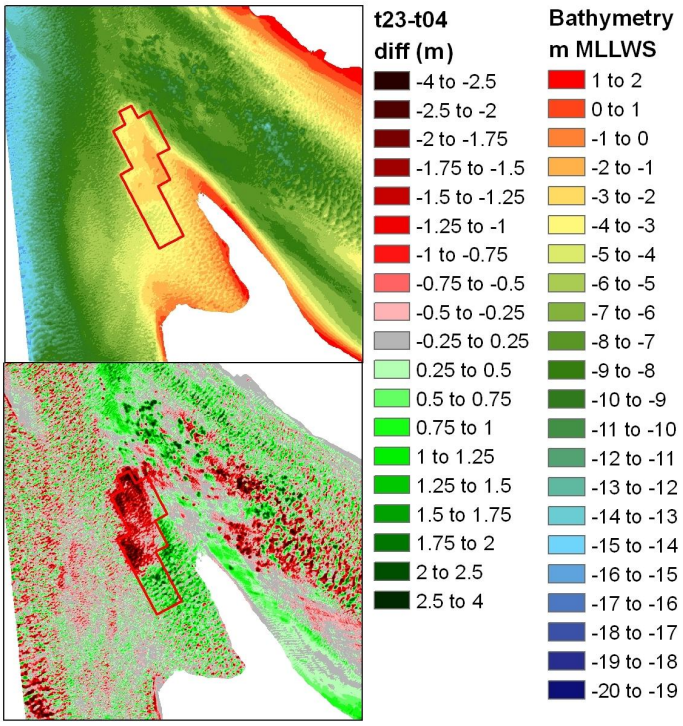

Figure 3: Bathymetric survey December 2004 (above) and difference survey December 2005 minus survey December 2004 (below)

To evaluate the success of the test an extensive monitoring programme was set up. This programme included frequent topo-bathymetric surveys, using multibeam echo sounding (LEYS ET AL., 2006), ecological monitoring, both on the intertidal flats as in the subtidal area, sediment tracing tests and sediment transport measurements. Several criteria, both morphological (to evaluate the stability of the disposed material) as ecological (changes in ongoing natural trends) were defined before executing the in situ test in order to evaluate its success.

From morphological point of view, it can be concluded that the experiment using a diffuser to modify the morphology of the sandbar by disposing precisely dredged material was very successful (FHR, 2006). Despite a small loss of sediment directly after execution of the disposal test, which is probably caused by the transport of the finer sands by the currents (i.e. natural segregation), the amount of material within the control area equalled the disposed quantities. Only after 2 months a decrease of volume was measured, a loss of ca. 10% after 6 months and almost 20% after one year. The main part of the eroded sand is transported during flood towards the Walsoorden sandbar. This evolution is in agreement with the predictions of the feasibility study.

The ecological monitoring did not reveal any significant negative impact, neither in the intertidal areas, nor in the subtidal areas (NIOO, 2006). None of the results from this monitoring indicated that the in situ disposal test was responsible for a significant change in ongoing trends. 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. This in situ test confirmed the feasibility of the proposed disposal strategy.

2.3 In situ disposal test 2006

The first disposal test proved that the new disposal strategy is feasible. By disposing sediment near the Walsoorden sandbar, the seaward tip can be reshaped. Where the diffuser allows a very precise disposal, the question was asked whether the traditional “dumping” technique could also be used to dispose the dredged material. Hereby a higher time-efficiency can be realized in execution, using the flood current to transport the material towards the sandbar. Therefore a second in situ disposal test was conducted in 2006, using the traditional “clapping” technique. Since this technique requires larger depths to dispose the material (i.e. the draught of the dredger vessel), research using a validated numerical hydrodynamic model was performed to determine the most suited disposal location for this second test (FHR, 2006).

The second disposal test occurred in two phases: in the first phase (January – March 2006) an amount of 500.000 m³ was disposed, while in the second phase (September 2006 – March 2007) an additional 900.000 m³ was disposed using the traditional disposal technique. These disposals were carried out within continuous maintenance dredging works in the Western Scheldt. Therefore a larger spreading in time is found for this test compared to the test of 2004, where the disposals were concentrated in time.

The extensive morphological and ecological monitoring program, that was started at the beginning of the first disposal test, was continued in time. Moreover the monitoring program is also oriented on the longer term. The same criteria were incorporated from the first test, both morphological (a new control area was defined to evaluate the stability of the disposed material) as ecological.

The topo-bathymetric surveys were continued using the multibeam echo sounder technique. These surveys allowed volume computations for the control area. The evolution of the sediment volume is shown in Figure 4.

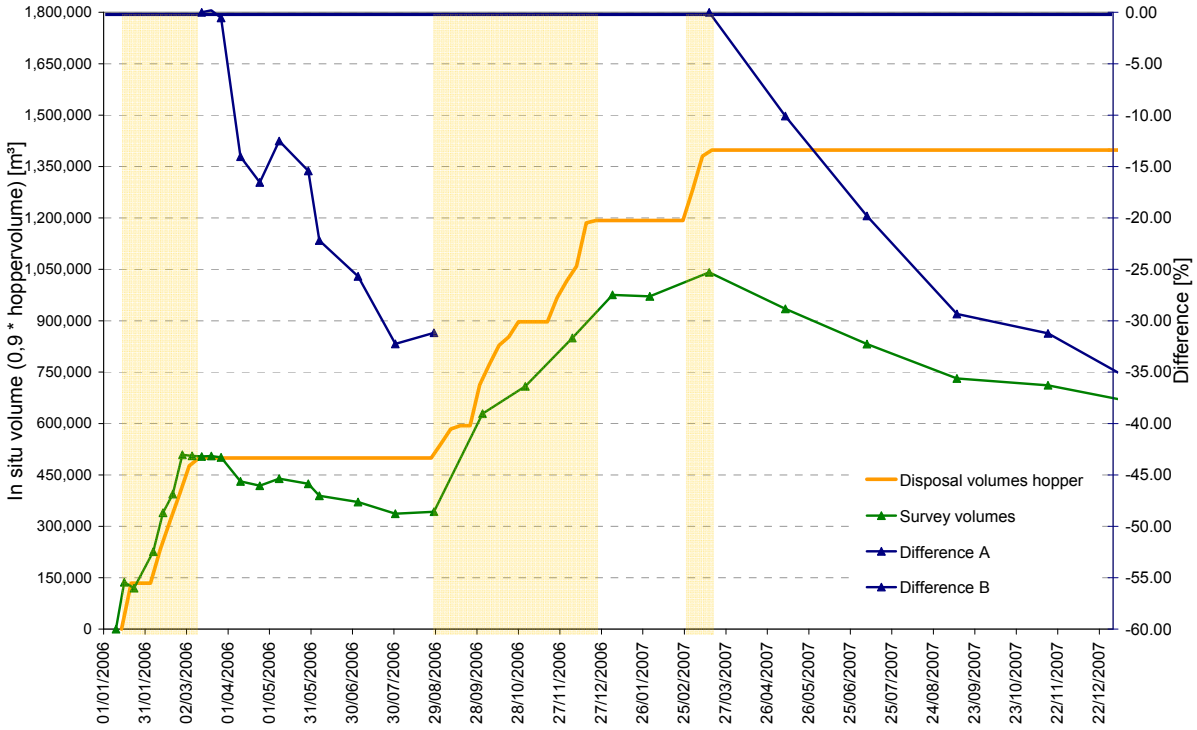

Figure 4: Evolution of the sediment volume for the disposal test 2006. Disposal periods are indicated by an orange color.

The ecological monitoring program, with both subtidal as intertidal monitoring, of the first pilot study is continued considering both the first and the second disposal area as an impact zone. A new control area was defined with similar hydrodynamic characteristics as the disposal areas.

The volume calculations reveal that the sediment disposed during both phases of the second disposal test is less stable than the sediment disposed during the first test in 2004 (FHR, 2009). For the first phase of the disposal test, 6 months after the execution of the test ca. 30% of the sediment is transported out of the polygon. For the second phase ca. 35% of the disposed material is transported out of the control polygon after 10 months. The fact that a higher percentage of the disposed material is transported out of the polygon, can be explained by several factors. The disposal location of the 2006 test has a larger depth (necessary for the trailing suction hoppers dredger), and is therefore located further from the sandbar. It is characterized by a higher dynamism, both hydrodynamic (currents) as morphodynamic (sediment transports). On the other hand, the traditional disposal technique has a lower disposal efficiency compared to the diffuser. This is confirmed by a comparison between the amount of dredged material (in hopper) and the amount of material (in situ) found based on volume calculations between topo-bathymetric surveys. It can be noted that the correction for density differences was not applied for this comparison. The diffuser technique has an efficiency of ca. 85%, while the traditional disposal technique has an efficiency of 75-80%.

An analysis was performed to investigate in which direction the disposed sediments of the 2006 test were transported. It was found that part of the material is transported towards the Walsoorden sandbar. The volume calculations in the major zones (Figure 6) show erosion in the disposal zones further from the sandbar and sedimentation in the zones near the Walsoorden sandbar. In the 2004 disposal area, an increase of the sediment volume is found of ca. 220.000 m³. Although part of the sediment is transported towards the Walsoorden sandbar, a mediocre amount (25%) of the sediment is eroded out of the area. Based on the historical bathymetric evolutions of the seaward tip of the Walsoorden sandbar, the erosion found 6 months after the in situ disposal tests is of the same order of magnitude (500.000-750.000 m³ per year) as these of the historical erosion.

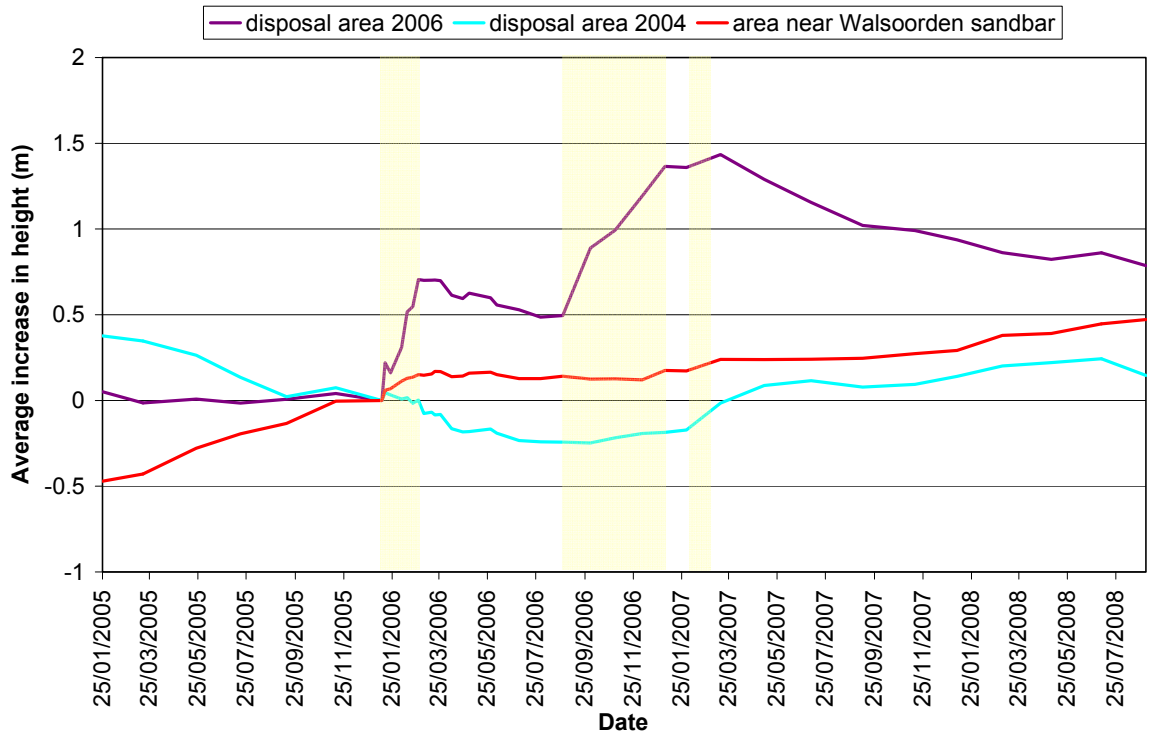

Figure 5: Volume calculations in some major zones for both in situ disposal tests

Additionally cross-sections were defined in the secondary (flood) channel Schaar van Waarde. Although a small reduction of these cross-sections was found, the main cause of this evolution is the ongoing morphological changes in the secondary channel and the disposal of maintenance dredging at this location.

The ecological monitoring program showed no significant changes in the ongoing trends for the sedimentation on the Walsoorden sandbar, the percentage of finer sediments on the intertidal zone and the macrobenthos (NIOO, 2007). The macrobenthos community is an important indicator in the ecological evaluation, because of its essential role in estuarine ecology and its sensitivity to environmental changes.

3. A NEW DISPOSAL STRATEGY FOR THE WESTERN SCHELDT

3.1 A further deepening of the navigation channel

One of the projects within the DO 2010 is a further deepening of the navigation channel to guarantee optimal port accessibility. An environmental impact assessment (RWS & MOW, 2007a) was carried out by an external consortium, studying the optimal way to deepen the navigation channel without endangering the ecological system. One of the alternatives was based on the positive results of the pilot project near the Walsoorden sandbar. Within this scenario sediment is disposed near several sandbars in the Western Scheldt. One advantage of this proposal is that the additional volumes produced by the capital dredging works required for a further improvement of the navigation route could be kept within the estuary instead of exporting it out of the estuary, into the sea.

Within the appropriate assessment (RWS & MOW, 2007b), it was concluded that disposing dredged material near sandbars in the Western Scheldt could create benefits for the ecological system. Besides the Walsoorden sandbar (0, Figure 6), 3 other locations in the Western Scheldt were appointed to dispose material from the capital dredging required to deepen the navigation channel: (1, Figure 6) Rug van Baarland, (2, Figure 6) Hooge Platen Noord and (3, Figure 6) Hooge Platen West.

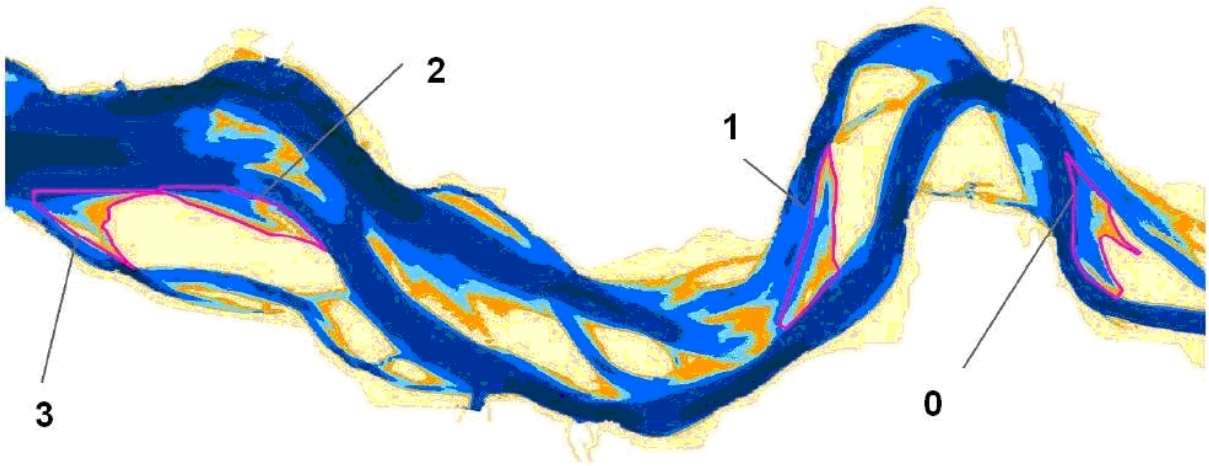

Figure 6: Disposal locations along sandbars studied in the environmental impact assessment of the deepening of the fairway to the port of Antwerp

3.2 Determining the disposal strategy

Where the environmental impact assessment and the appropriate assessment concluded that disposing material from capital dredging works near sandbars is the most valuable alternative, further research was necessary to determine more into detail the disposal strategy at these new locations. The goal for the new disposal strategy is to maximize the creation of ecological valuable ecotopes, i.e. subtidal and intertidal areas with low currents. The experience gained near the Walsoorden sandbar was used to investigate the optimal disposal strategy at these locations. Therefore an extensive research program was carried out, using field measurements (both GPS-floats and sediment transport) and hydrodynamic numerical models. An extra model validation was performed for the flow velocities on the intertidal area of the sandbars, to improve the correspondence of the patterns of ecological valuable ecotopes.

The study (FHR, 2008a; FHR, 2008b; FHR, 2008c) revealed that fundamental differences exists between the 4 proposed locations. On one hand both the locations near the Walsoorden sandbar and the Hooge Platen West are located near the seaward tip of a sandbar, attacked by flood currents. It is expected that sediment disposed at these locations, will be gradually transported towards the sandbar. On the other hand the location near Rug van Baarland and Hooge Platen Noord are located along a sandbar, guiding the currents. It is expected that sediment disposed at these locations, will be rather transported along the sandbar. Another difference was found in the flow dynamics: the 2 locations near Hooge Platen are characterized by far more dynamic conditions, both hydrodynamic (factor 1.5 for flow velocities) as morphodynamic (factor 2,5 for sediment transport) in comparison with the location Rug van Baarland and Walsoorden sandbar. A site specific disposal strategy is proposed for each location (Figure 7).

For the Walsoorden sandbar, the disposal strategy aims at creating a subtidal macro-dune which will migrate towards the sandbar under influence of the flood-dominated currents. This macro-dune will be created using both the traditional disposal technique and the diffuser technique. A total amount of 6,5 million cubic metres of sandy sediments will be disposed at this location over a period of 5 years.

Near Rug van Baarland the disposal strategy aims at constructing a sand spit near the southern tip of the sandbar. This new sand spit, in combination with the existing sand spit in the northern part, aims for the creation of an underwater barrier reducing the currents between the barrier and the sandbar, creating a low dynamic shallow water area. A total amount of 5 million cubic metres of sandy sediments will be disposed here over a period of 5 years.

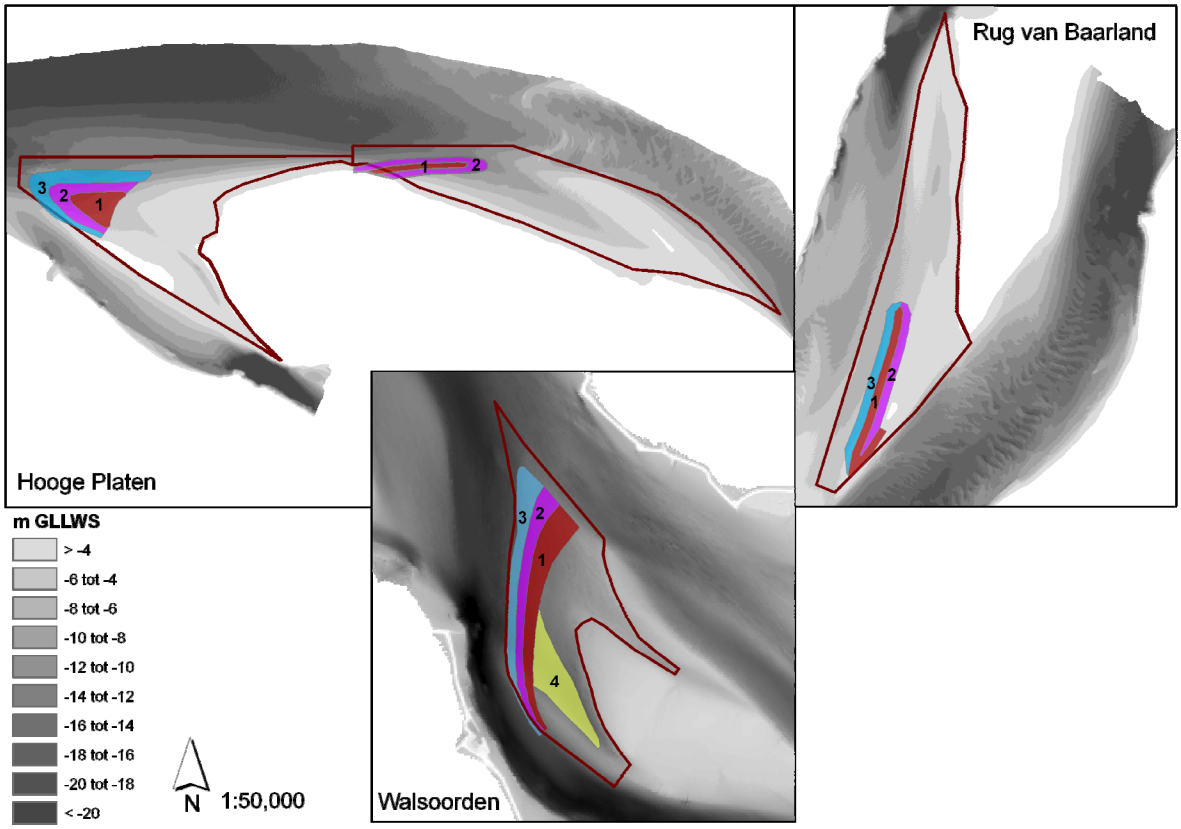

Figure 7: Site specific disposal strategies for Hooge Platen (upper, left), Rug van Baarland (upper, right) and Walsoorden (under) sandbars

For the Hooge Platen Noord the disposal strategy is similar to the Rug van Baarland and aims at constructing a sand spit. For the Hooge Platen West the disposal strategy is similar to the Walsoorden sandbar and aims at constructing a subtidal macro-dune. For both locations near the Hooge Platen, a total amount of 8,2 million cubic metres of sandy sediments will be disposed over a period of 5 years.

Beside the new disposal locations near sandbars, the future disposal license will include larger disposal zones in the secondary channels and in the deeper parts of the navigation channel. This will allow the Maritime Access Division (Flemish government), responsible for managing the dredging and disposal works, to anticipate to morphological evolutions in the estuary and adapt the disposal strategy within the limitations of the disposal license.

To evaluate the possible effects of the deepening of the navigation channel, including the new disposal strategy, an extensive monitoring programme was set up (SCHRIJVER ET AL., 2008). A special protocol, composed of several morphological (stability of disposed material) and ecological (evolution of ecotopes) criteria, is appended to the disposal license to, quasi continuously, evaluate the monitoring data. An independent group of experts ("Commission Monitoring Western Scheldt") will supervise the evaluation of the monitoring and give at least every 2 years an advise on the disposal strategy.

4. CONCLUSIONS

The Long Term Vision for the Scheldt estuary presents a view on the preferred functioning of the system, accepted by both the Dutch and the Flemish government. The LTV acknowledges that the dynamic state of the estuary is strongly impacted by a range of human interventions including land reclamation, defence and training works, channel deepening and sand extraction. The LTV states that further interventions should not endanger the preservation of the existing dynamic evolution of the multiple-channel estuary.

The Port of Antwerp expert team (PAET) also recognises the essential role of morphology to harmonize safety, accessibility and naturalness. Morphological diversity in the Western Scheldt can be attained by a well-considered morphological management, of which a new disposal strategy should be

an essential part. A thorough understanding of morphological behaviour can only be obtained by a thorough analysis of historical data and of experience gained by field observations and measurements, supported by the interpretation of physical and numerical modelling results.

During the Walsoorden pilot study (2002-2003), all these investigation tools were combined to assess its feasibility and the results sustained the concept of the alternative disposal strategy as proposed by PAET in 2001. The execution and extensive monitoring of two small-scale in-situ disposal tests was needed to confirm this proposal. From morphological viewpoint the 2 disposal tests are a success, with relative large amounts of the disposed material remaining in a control polygon. Part of the sediment was transported towards the Walsoorden sandbar, in agreement with the results from the feasibility study. The ecology revealed no changes in the ongoing natural trends due to the tests. Therefore it was concluded that the new disposal strategy has been validated.

This new disposal strategy will be applied on a large scale during capital dredging works of the deepening of the Scheldt's fairway and during the maintenance dredging works thereafter. This step-by-step assessment of a new disposal strategy shows that the realisation of a new concept needs many efforts for validation and acceptation. Though, the approved new disposal strategy is not the only tool for attaining morphological diversity in the Scheldt estuary. Research for other alternative dredging and disposal strategies should continue. Also the possibilities for adaptation of river training works must not be forgotten, because river training works determine the boundary conditions for the future morphological development.

5. ACKNOWLEDGEMENT

The research presented was conducted through a close collaboration between Flanders Hydraulics Research and the Port of Antwerp Authority, partly as a project under the Dutch-Flemish ProSes direction. It was funded by ProSes and by the Flemish Ministry of Environment and Infrastructure. Monitoring was organised with the collaboration of the Maritime Access Division, DAB Fleet, the Dutch Rijkswaterstaat and the contractors.

The authors acknowledge the effective support of the Port of Antwerp Authority, which funded the expert team, also the participation of the members of the Port of Antwerp expert team, Jean Jacques Peters from Belgium, Reginald Parker from the U.K., Jean Cunge from France, Bob Meade and Michael Stevens from USA.

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