THIRD ENLARGEMENT PROGRAM OF THE RIVER SCHELDT

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ABSTRACT

The Scheldt estuary is an international seaway that is partly located in the Flemish Region of Belgium and partly in the Netherlands. Large ocean-going vessels travel up and down the estuary to and from Antwerp, a mainport situated at about 80 km of the river mouth.

After two previous deepening exercises (in 1970 and in 1997), a new agreement was signed on March 11th 2005 by the responsible ministers of Flanders and the Netherlands, clearing the way for the third enlargement of the navigation channel in the Scheldt Estuary. Dredging works are planned to start in 2007 and should be completed by the end of 2009. The Scheldt will then offer a tide-independent navigation draft of 13.10 meter, which will allow the Port of Antwerp to offer a better service to post-panamax vessels. The decision by the Flemish and Dutch governments forms part of an all-embracing mutual approach for the Scheldt estuary, as outlined by the 2010 Development Sketch based on three principles : accessibility, flood protection and nature conservation. The enlargement program includes deepening and widening of the navigation channel and the disposal of the dredged material resulting from both the capital and (extra) maintenance dredging works. Extensive studies are now carried out by the Dutch-Flemish CONSORTIUM ARCADIS-TECHNUM (CAT) to examine what will be the effect of the planned activities on the natural environment of the river. The results of these studies will be used to draw up a joint Dutch-Flemish EIA-document, that will serve as a basis for the decision-making process that ultimately should lead to the most environment-friendly solution in dredge and disposal options.

In this paper an overview is given of the methodology followed to arrive at an optimal project solution.

Keywords: Port accessibility, sustainability, dredged material disposal, naturalness, environmental.

INTRODUCTION

In the past few years, the Dutch and Flemish governments have been performing jointly a strategic orientating study to guarantee a sustainable future for the Scheldt Estuary: the Scheldt Estuary Development Sketch 2010. The study focused on improvements in three main areas :

- the safety against flooding ;
- the accessibility of the ports along the Scheldt ;
- the naturalness of the Scheldt Estuary.

Based on the results of this study, both governments took the political decisions concerning mutual ambitions and possible measures in order to realize these goals. In the coming years, the proposed projects and measures will be elaborated and executed.

The subject of this paper is only dealing with the implementation of the second goal of this development sketch : the enlargement of the navigation channel to the Port of Antwerp as a measure to improve the accessibility of the ports along the Scheldt. Another paper presented on this congress will focus more on the other two goals of the development sketch.

In Figure 1 an overview picture of the Scheldt Estuary is given.

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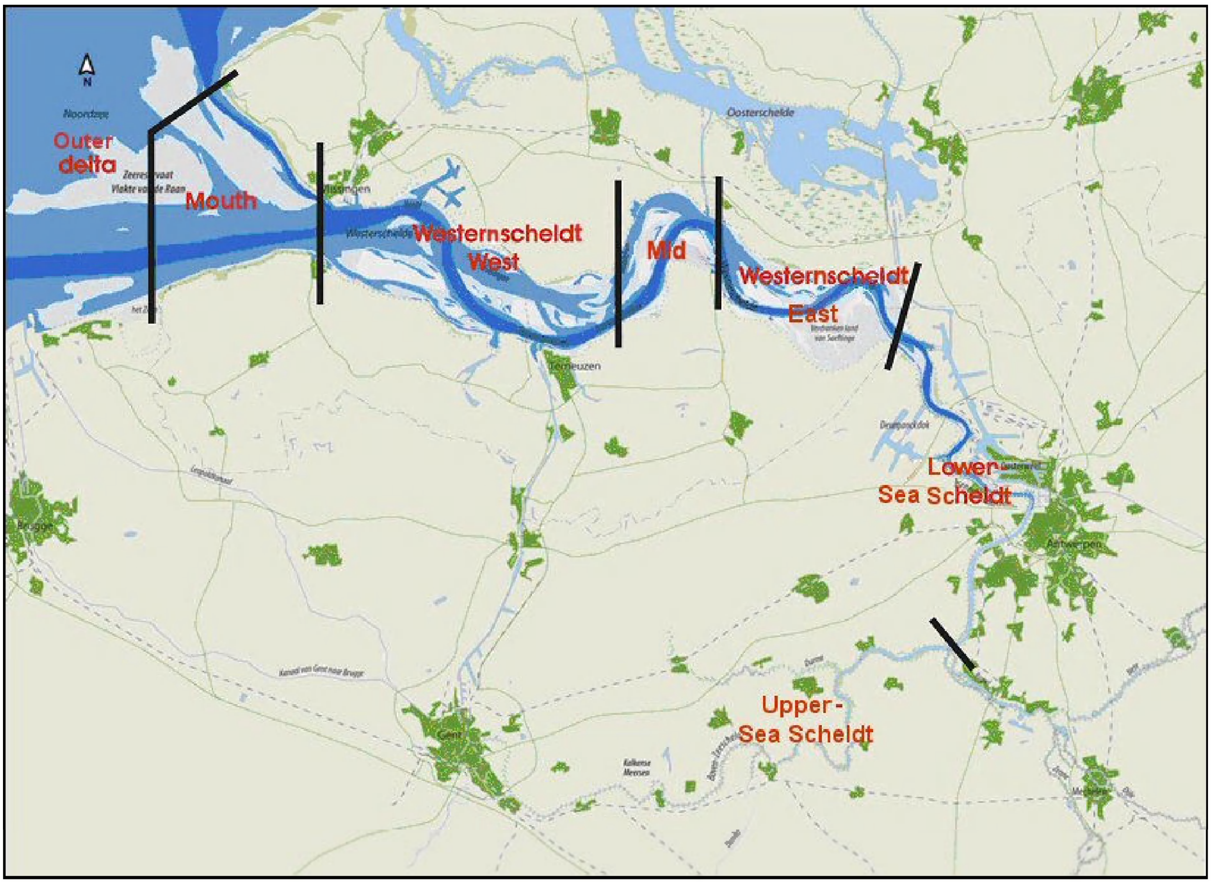

Figure 1. The Scheldt Estuary

SCOPE OF THE THIRD ENLARGEMENT PROGRAM

Planned activities

At this moment the river Scheldt is maintained at a depth of 13,3 m MLLWS (mean lowest low water at spring tide). Taking into account a keel clearance of 12,5%, this means that a tide-independent navigation to the Port of Antwerp is limited to ships with a maximum draft of 11,85 m. Both Flemish and Dutch governments now decided to enhance the port's accessibility for ships with a maximum draft of 13,1 m (tide-independently).

To realize this goal, 11 sand bars and a few shoals in the navigation channel need to be dredged and maintained at a target level of –14,7m MLLWS.

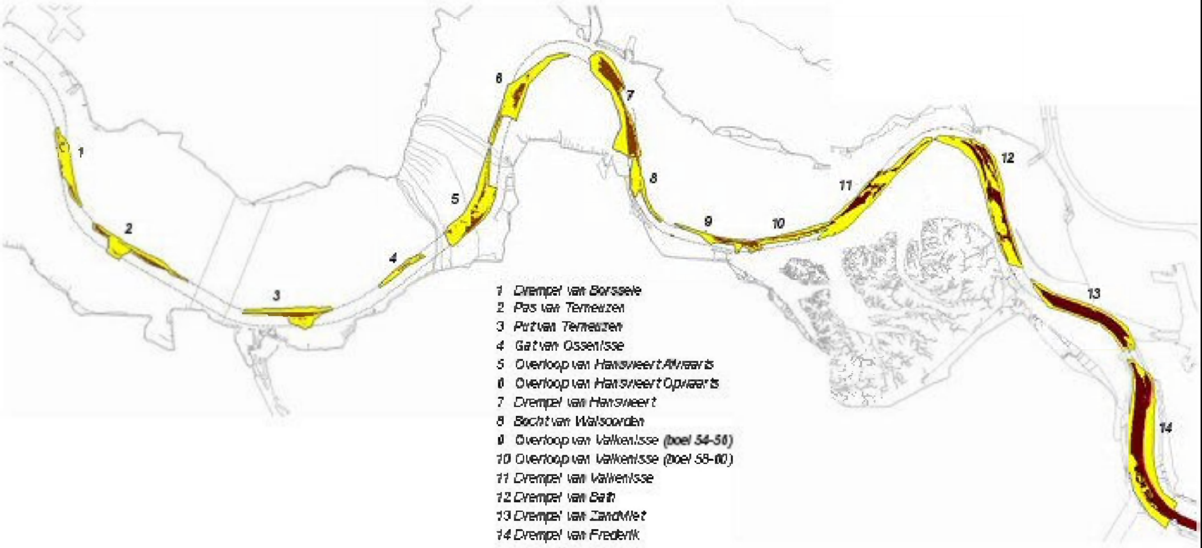

Figure 2. Capital dredging locations.

The total volume to be dredged adds up to approximately 14 million in situ m³. This volume is to be dredged once-only and was estimated based on the profile as shown in Figure 3:

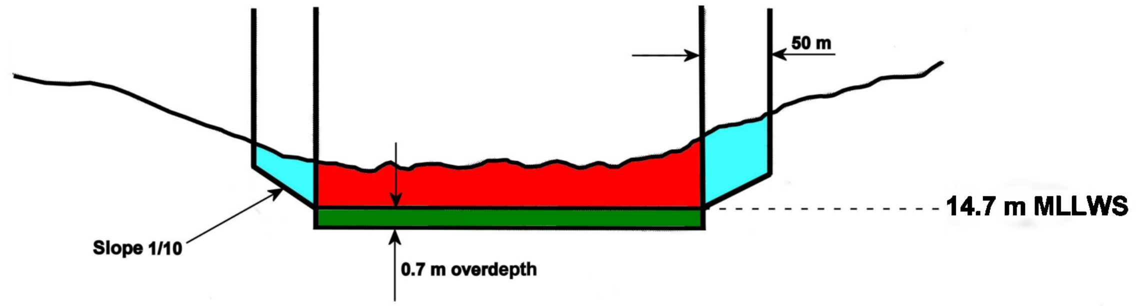

Figure 3. Schematic drawing of the volume to dredge.

This profile consists of a rectangular box profile (in red) with the bottom at the new target depth of –14,7 m MLLWS and a variable width depending on the location along the Scheldt axis. The slope volumes (in blue) were added as well as an overdepth of 70 cm (in green).

The result of this GIS-calculation is summarised in Table 1 :

Table 1. Estimation of the capital dredging volumes

Scheldt Estuary Total	Lower Sea Scheldt	Western Scheldt Eastern Part	Western Scheldt Middle Part	Western Scheldt Western Part
14	6,3	5,2	1,1	1,4

(volumes in millions of m³ in situ ; excl. overdue maintenance dredging ; incl. the 70 cm overdepth as explained in above text)

The disposal of the material resulting from the capital and the (expected increased) maintenance dredging forms also part of the project.

Philosophy

The basic idea behind the Scheldt Estuary Development Sketch is the preservation of the physical characteristics of the estuary. These characteristics are considered to be crucial for the achievement of the objectives for the themes safety, accessibility and naturalness. In future, the morphological management of the estuary will not only be determined by maintenance of the navigation channel and safety considerations, but will also be focused on the preservation of the estuarine characteristics. This pro-active approach pertains to a management that is aiming to an optimisation of the physical and ecological state of the estuary, rather than to a mere compensation for morphological damage.

The new course to follow may well be clear, but finding the best practical implementation of the planned activities isn't that straightforward. To assist the governments in their decision-making, the key step is an EIA in which the main effects of the enlargement with respect to the environment are assessed. An extensive study prior to this EIA appeared however indispensable to supply the necessary information on morphology and dredging to allow a proper assessment of the effects.

THE SCHELDT ESTUARY

Introduction

A detailed description of the Scheldt Estuary is necessary to act as a framework facilitating an objective comparison between the system before, during and after the planned enlargement activities.

First a description is given of the history of the Scheldt Estuary. Historical observations indicate the changes the estuary has undergone. On the one hand this helps to get an idea of the natural variations of the system, which must allow for judgment of the possible effects in the right perspective. On the other hand, human intervention in the past can teach us a lot about the response of the system.

For a comprehensive system description of the Scheldt estuary, is referred to Kuijper, C., Sas, M., Jeuken, M.C.J.L. (2006). This description indicates how the abiotic system has been changed, how human interventions have interfered with this, which evolutions are to be expected on medium long term and how a dynamic sediment management can influence this. Hereafter a summary is given.

The Scheldt estuary comprises the Sea Scheldt and her tributaries that are tidally influenced, the Western Scheldt and the mouth area (the pre-delta). The physical system can be characterized by :

- an open and natural mouth area ;
- a system of main and secondary channels with enclosed shoals and sub tidal areas (Dutch : "ondiepwatergebieden") in the Western Scheldt, the so-called multiple channel system ;
- an estuarine transition area with a lot of human interventions in the Lower Sea Scheldt ;
- a river system with a meandering character in the Upper Sea Scheldt and its tributaries ;
- a large diversity of habitats, especially intertidal areas, salt marshes and sub tidal areas in salt, brackish and fresh water area in combination with natural banks.

Besides the periodic vertical and horizontal water movement due to the tide, the sea influence is evident by the salt intrusion that can reach beyond Antwerp. The sediment transports induced by the water movement affect non-cohesive sand (order of magnitude 200 µm but varying along the estuary) and mud (smaller than 63 µm) with cohesive characteristics. In the Western Scheldt morphological changes are directed by the (gradient in) horizontal transports of mainly sand. Here silt is only playing a role with respect to the bottom composition of the intertidal areas and salt marshes. However, in the eastern part of the Western Scheldt and in the Lower Sea Scheldt, particularly near the turbidity maximum, the contribution of the silt fraction to the total sedimentation in the channels and ports becomes far more important.

In addition to the "natural" sediment transport, dredging, disposal and sand mining also cause redistribution and extraction of sediments out of the system. The influence of these human interventions is significant and certainly contributory to the morphological changes on a small, local as well as on a large scale.

The Western Scheldt

The multiple channel network in the Western Scheldt can be interpreted as the connection between six so-called macrocells, each of them consisting of the following morphological entities: two main channels (eb and flood), a set of connecting channels (cutting through the shallow areas and linking the two main channels) and the enclosed salt marshes and intertidal and sub-tidal areas. Horizontal movements of the main channels have been restricted by dikes and bank-protection measures ; morphological changes occur therefore mainly due to deepening or shoaling of these main channels.

The preservation of the two main channels is of importance for the shipping traffic. The connecting channels contribute to the morphodynamics of the system. Increase or decrease in shoal area, as well as in sub tidal and inter tidal area, is most likely associated with changes in the behaviour of these connecting channels. The intertidal and sub tidal areas are of great ecological importance since they serve as respectively foraging area for birds and fish breeding ground.

The morphological development of the above mentioned multiple channel system manifests itself in changes in the sand balance, this is the large scale pattern of the long term (decades-centuries) sediment transport and resulting sedimentation and erosion patterns. Long term import or export can lead to siltation respectively inundation of the estuary.

The Lower Sea Scheldt

In the Lower Sea Scheldt, the salt, brackish and fresh water intertidal areas together with the shoals and channels create a unique environment for various communities. The Lower Sea Scheldt is highly dynamic and characterized by a large variety with respect to salinity, current velocities, sediment concentration and turbidity, in space as well as in time (tidal and seasonal variations).

The best ecological indicator (related to the dredge disposal activities) is the turbidity. The concentration of mud in suspension in the Lower Sea Scheldt is mostly limited to a few hundreds of mg/l. Close to the bottom, layers with a higher mud concentration (from a few g/l to several tens of g/l) can be formed. These layers are not very stable during the tidal cycle. Usually they are formed during the change of tide, when the current velocities are so small that the fines can settle.

The analysis of the mud concentration indicates that there is a correlation between this concentration and the seasons. These seasonal influences however do not interfere with the variations that occur during one tidal cycle or during a whole neap tide – spring tide cycle. The seasonal variations can be attributed to a large number of processes that are often inter-connected and can be grouped as follows:

- upper river discharge (affects the shift of the turbidity maximum and results in a larger sediment supply from the non-tidal part of the river basin) ;
- temperature ;
- storm tides.

In the Lower Sea Scheldt, there is a continuous movement of mud. Taking into account the tidal action and the accompanying mud concentrations, this means that on a yearly basis, the tidal action causes 10 to 30 million tons of mud to be transported upstream during flood and a similar amount downstream during eb. In low velocity zones, settlement of mud occurs.

THE INVESTIGATION PRIOR TO THE EIA

Introduction

The complete enlargement project comprises 3 main parts :

1. The execution of the capital dredging works (i.e. deepening and widening of the navigation channel), to be completed in maximum two years.
2. The disposal of the material resulting from these capital dredging works, to be realised in the same period of approximately 2 years.
3. The (increased) maintenance dredging and disposal of the resulting material. This part will be a permanent activity. The goal is to develop a <u>sustainable</u> maintenance strategy.

Because of the complexity of the natural system involved, it was decided to launch an extensive investigation program prior to the actual EIA with as main goals :

1. to indicate the effects on the environment of :
   - the deepening and widening of the navigation channel : these effects are related to the capital dredging and the disposal of the material.
   - the existence (and presence) of the enlarged navigation channel, inclusive its maintenance.
   - to a lesser degree : the effects due to the use of the enlarged navigation channel
2. to find disposal locations for the material resulting from the capital and maintenance dredging. This also includes an assessment of the effects of the different dredging and disposal techniques.
3. to search for a sustainable dump strategy for the disposal of the maintenance dredging material.

4. to supply the necessary information allowing a proper assessment of the effects.

Once the preliminary investigations are completed and all effects are properly described, they will be evaluated by different disciplines in the EIA, as there are ecology, morphology and bottom changes, water, air, space occupation and mobility, sound and vibrations, landscape, external safety etc.

This paper focuses on the morphological elements in the investigation, as morphology is closely related to the dredging activities, the emphasis is further put on the quantification of the effects of the dredging activities.

Basic principles

In this investigation the whole Scheldt estuary is considered one integrated system that is characterized by hydrodynamics, salt dynamics and morphodynamics. Taking into account the proposed enlargement of the navigational channel, there are two important investigation areas to consider :

- morpho-dynamics, mainly applicable to the Western Scheldt and predominated by the transport of sand;
- mud-dynamics, mainly applicable to the eastern part of the Western Scheldt and the Lower Sea Scheldt. (salt dynamics are to be included).

As already mentioned before, the EIA should serve as a basis for the Flemish and Dutch authorities to take the final decisions on the enlargement program and how and where the dredged material from both capital and maintenance dredging can best be disposed. To make these decisions also legally valid, it is necessary to investigate different possibilities (project alternatives and variants). All these investigation variants need to comply with the following basic principles :

- The only enlargement option to be investigated is the one leading to a tide-independent access for ships with a draught till 13,1 m. This means that the economic benefits for the region (Antwerp/Vlissingen) are supposed to be equal in all the investigated project alternatives, so there is no need for a comparison on economic grounds.
- Safety against flooding may not be endangered in any way.
- The multiple channel system of the Scheldt estuary has to be preserved. (a comparison of the risks of degeneration of the multiple channel dynamics should be analysed).
- The naturalness of the estuary should not be influenced and mitigating measures have to be proposed if necessary.

Investigation Means

The earlier described morphological processes are characterised by a cascade of scales with regard to time and space. A profound knowledge of both the area-specific characteristics and the relevant processes is necessary to correctly assess the morphological changes due to human interventions. Part of this knowledge is currently captured in morphological models of the Scheldt Estuary, but not one of them is able of describing accurately all the relevant processes together, let alone at the different time and space scales. It is therefore of utmost importance that morphological experts who have to interpret the results, are fully aware of the possibilities and even more the limitations of these models.

The models used in the present investigation are the one-dimensional network-model ESTMORF for the morphology and the DELFT3D-model for the calculation of the water movements, the sediment transport (sand and mud) and the morphology in two and three dimensions.

Another important instrument is the "cell-concept". This cell-concept comprehends a schematisation of the multiple channel system by means of macro and meso cells, representing respectively the main ebb and flood channels and the connecting channels (Winterwerp et al., 2000). This schematisation allowed for a stability analysis of the multiple channel system, making it possible to determine disposal criteria that avoid degeneration of the multiple channel system (Jeuken, 2001; Jeuken et al, 2003; Wang et al, 2002; Wang, 2003 ; Jeuken et al., 2004)

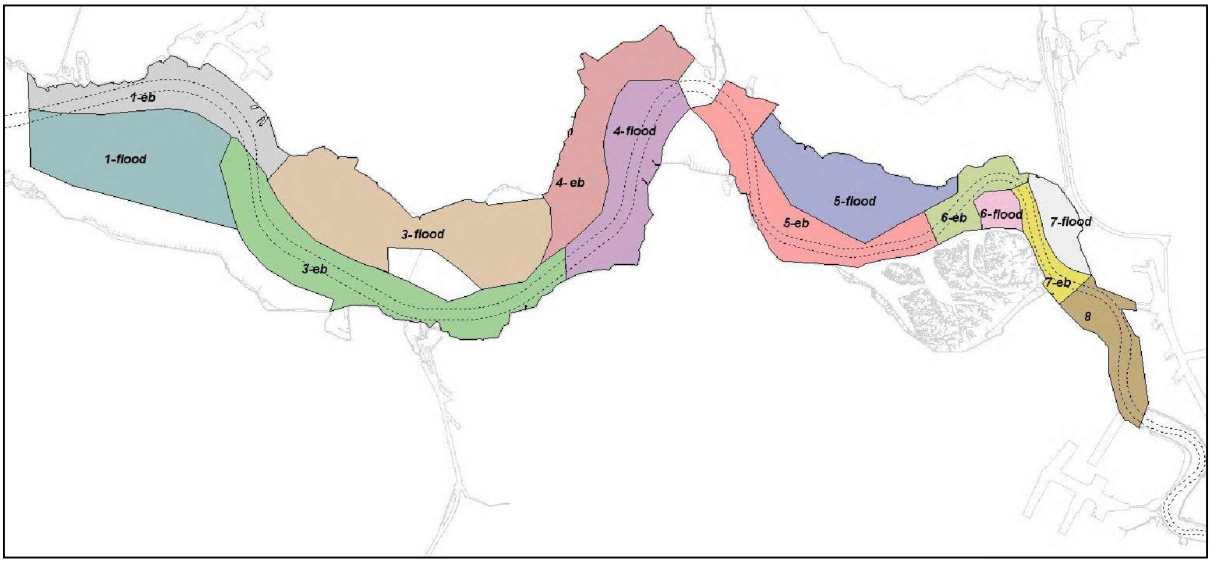

Figure 4. Division of the Scheldt Estuary in macro-cells.

Investigated scenarios

In the EIA five alternatives will be assessed and compared. In the current investigation prior to this EIA, the effects of these five alternatives are examined and described. Based on the comparison it will be determined which disposal variants and possible mitigating measures will lead to the most environment-friendly alternative.

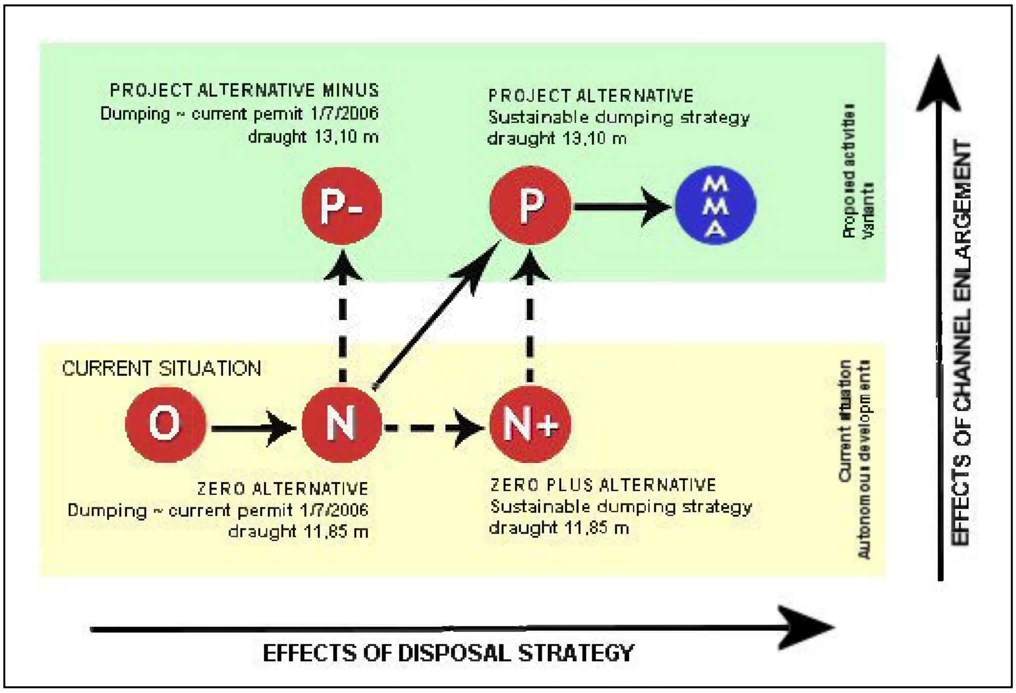

Figure 5. Investigated alternatives.

Zero alternative and zero plus alternative

The zero alternative (also called the reference situation) consists of the current situation plus the autonomous developments that are most likely to happen anyhow, even if the enlargement program would not be executed. Obviously maintenance dredging will still be necessary and will be done in conformity with the current permit granted in july 2006.

The zero plus alternative is the zero alternative plus a sustainable dumping strategy. This means a new, more flexible dumping strategy that can guarantee the preservation of the physical system characteristics of the estuary. This new strategy is called “sustainable dumping”. This dumping strategy will be adopted from the most environment-friendly alternative (cf. below)

Project alternative

There is only one project alternative for the realisation of the enlargement program : the deepening of the navigation channel for ships with a draught of 13,1 m and the widening of the navigation channel till 370 m (from the Europaterminal till 500 m upstream the Deurganckdock in Antwerp). For this project alternative several variants exist with regard to the disposal strategy of the dredged material.

It was expected that the choice between these disposal variants will have a clear influence on the morphological developments of the Estuary. Therefore these variants of the project alternative were checked from a morphological point of view. Further in this paper, this matter is addressed in more detail.

Project alternative minus

Although the necessity of a new, flexible dumping strategy is acknowledged, it was chosen to look also at the project alternative that keeps the dumping strategy identical to the existing one. This allows to assess the effects of the enlargement of the river itself, without the proposed change in the dumping strategy.

Most environment-friendly alternative

The final goal of the investigation is to define the most environment-friendly alternative (denoted as “MMA” in Figure 5). This alternative includes a deepening till 13,10 m draught, the proposed widening near Antwerp and the new (optimised) sustainable dumping strategy.

A new maintenance philosophy : “Sustainable dumping”

The main goal of the EIA is to arrive at a sustainable sediment management system, which is necessary to preserve a healthy physical system as a carrier of a healthy ecological system for the whole Scheldt Estuary with its specific morphology characterized by a multiple channel system and variations in shoals, channels, sub tidal and intertidal areas and salt marshes.

Practical experience and morphological investigations have shown that the current dump strategy, applied since 1997-1998, is far from ideal. A rigid continuation of the same practice, would lead to undesired effects that could endanger the multiple channel system of the Western Scheldt.

Aiming for a stable navigation channel, a sustainable sediment management needs to create an equilibrium in between the natural and artificial (due to maintenance dredging) sand transport.

The artificial part of those transports is controllable by man and should allow for an active management of the sediment supplies : the right quantity of sand has to be dropped at the right time at the right spot. This means that flexibility becomes a prerequisite in dealing with quantities, times and locations when a flexible, sustainable dumping strategy is pursued.

Yet “flexible or sustainable dumping” does certainly not mean that the material resulting from the maintenance dredging can be disposed of arbitrarily in the Scheldt Estuary. The EIA will have to define the potential dumping areas and these areas will have to be adopted in the dumping permit; be it with the annotation that adjustment of locations, quantities and times of dumping should always be possible. These adjustments have to be decided based on the results of intensive monitoring in the estuary. Therefore intensive measuring campaigns will have to be integrated in this new maintenance dredging philosophy.

Selection of Potential Disposal Areas

The previous shows that the disposal of the dredged material is a critical element in the investigation. The following points of departure are used to select the possible disposal areas :

- The disposal strategies must be both ecologically and morphologically sound.
- The distances between dredge and disposal zones are to be reduced as much as possible.
- From the environmental point of view, disposal in the river is preferred above disposal on land.
- The material resulting from the capital dredging works will be disposed in morphologically low-dynamic areas in order to minimise recirculation towards the dredging zones.

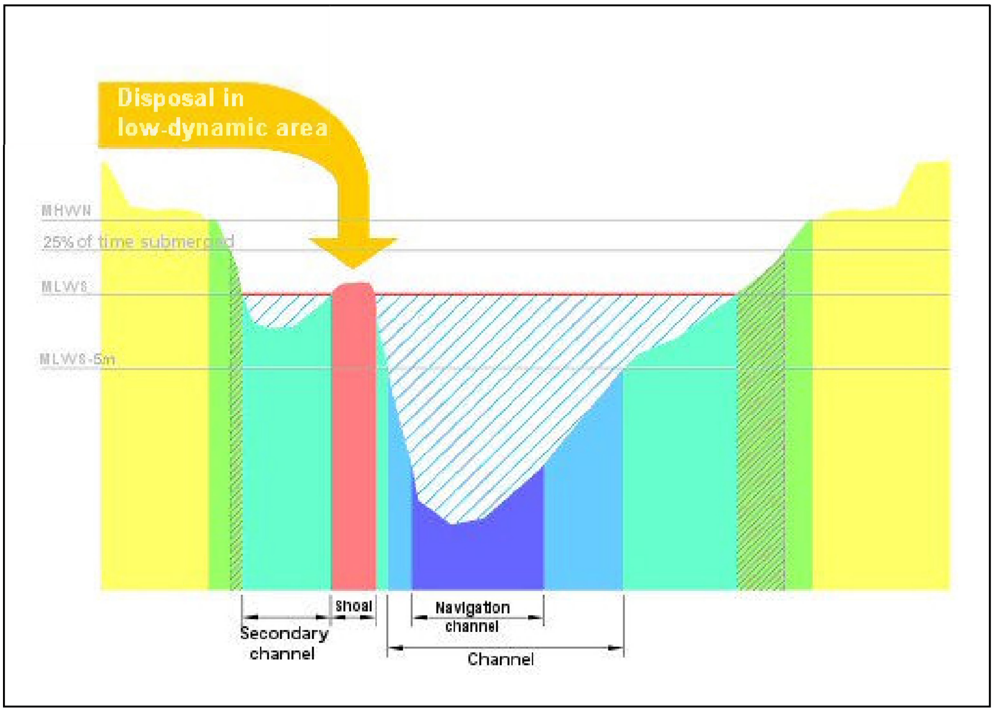

Figure 6. Material resulting from the capital dredging : disposal in low-dynamic areas.

- The disposal of the material resulting from the maintenance dredging works will be done :
    1. preferably in the secondary channels, as long as the stability of the multiple channel system is not endangered ; sand mining will be used as a controlling measure to increase the storage capacity of these secondary channels.
    2. in the deeper parts of the main channel that are part of the same macrocell insofar as the storage capacity of the secondary channel in combination with sand mining is insufficient
    3. in the secondary channel of the adjacent macrocell if the storage capacity of the previous two options is depleted.
- The disposal strategy should aim for minimisation of the need for maintenance dredging after the execution of the enlargement program.

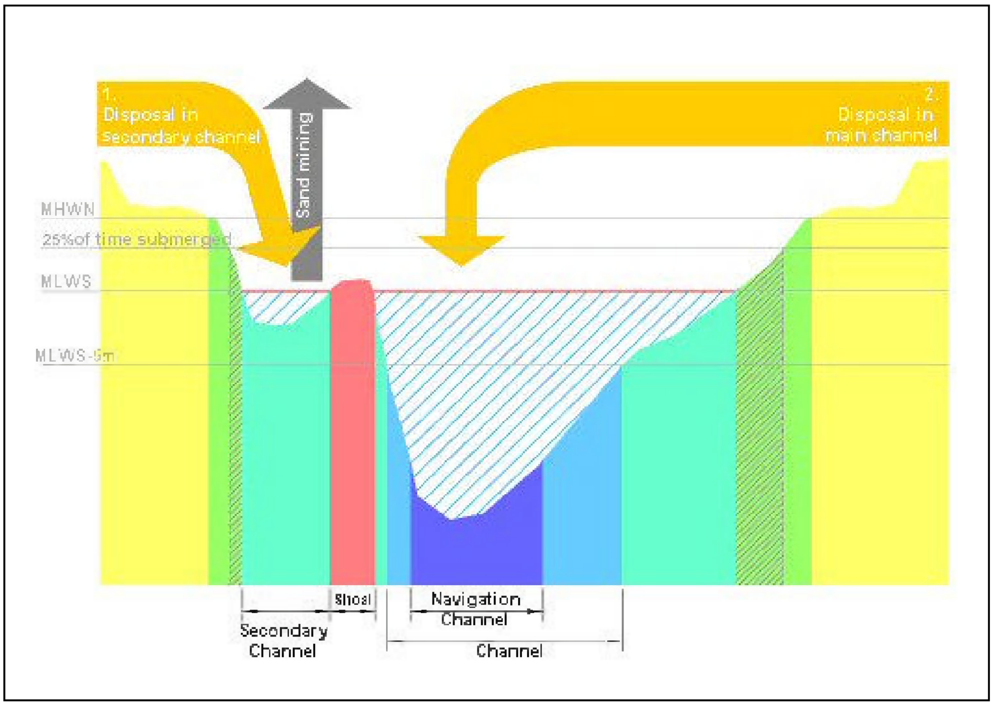

Figure 7. Material resulting from the maintenance dredging : disposal in the secondary and main channel.

Investigated Variants of the Project Alternative

Introduction

As stated before, there is only one project alternative to be evaluated in the EIA. The investigation prior to this EIA, must supply the experts in the various disciplines with the necessary information to allow them to make a proper assessment of this project alternative.

However several variants of the project alternative were investigated. These variants differ from each other with regard to the disposal of the dredged material. Variants for the Western Scheldt were combined with variants for the Lower Sea-Scheldt. The variants were defined based on the points of departure mentioned above and it was aimed to choose them sufficiently distinctive so that a good representation of the complete range of possibilities was achieved.

Disposal of the material resulting from the capital dredging works

For an estimation of the capital dredging volumes one is referred to Table 1. For the Lower Sea Scheldt three variants exist for the disposal of the capital material :

1. in the river ;
2. ashore ;
3. combination of 1 & 2.

Similarly, for the Western Scheldt, three options exist :

1. in the mouth area and on shoals ;
2. in the mouth area and in secondary channels ;
3. on shoals and in secondary channels.

Ultimately three variants have been calculated, each of them being a combination of a disposal variant for the Lower Sea Scheldt and one for the Western Scheldt.

It was expected that each disposal variant would lead to a clearly different macro-morphological development of the estuary. However, the model results showed hardly any difference in the morphological effects. As a consequence, the choice of the variant tobe integrated in the selected project alternative had to be made on different grounds than initially anticipated.

It was decided to let prevail the “sustainability”-considerations. This led to a project alternative, where all dredged material of the Western Scheldt was dumped in the secondary channels. However, by opting for this alternative, there would be no assessment of disposing dredged material on the shoals in the Western Scheldt. Therefore an additional project alternative was defined, in which all the material dredged in the Western Scheldt is dumped on three shoals.

Summarised, the preliminary investigation led to a double project alternative for the EIA with an equal disposal strategy for the Lower Sea Scheldt but two different disposal strategies for the Western Scheldt :

- In the project alternative P4C (<P4-channels) all the material resulting from the capital dredging works is dumped in the secondary channels of the same or adjacent macrocell as where it has been dredged.
- In the project alternative P4S (<P4-shoals) all the material resulting from the capital dredging works is dumped on three shoals in the Western Scheldt, namely the Hooge Plate, the Rug van Baarland and the Plaat van Walsoorden.

For both project alternatives, the material dredged in the Lower Sea Scheldt is to be disposed partly in the Schaar van Ouden Doel (where it is controlled by sand mining), partly in the deeper zones of the main navigation channel and partly on land.

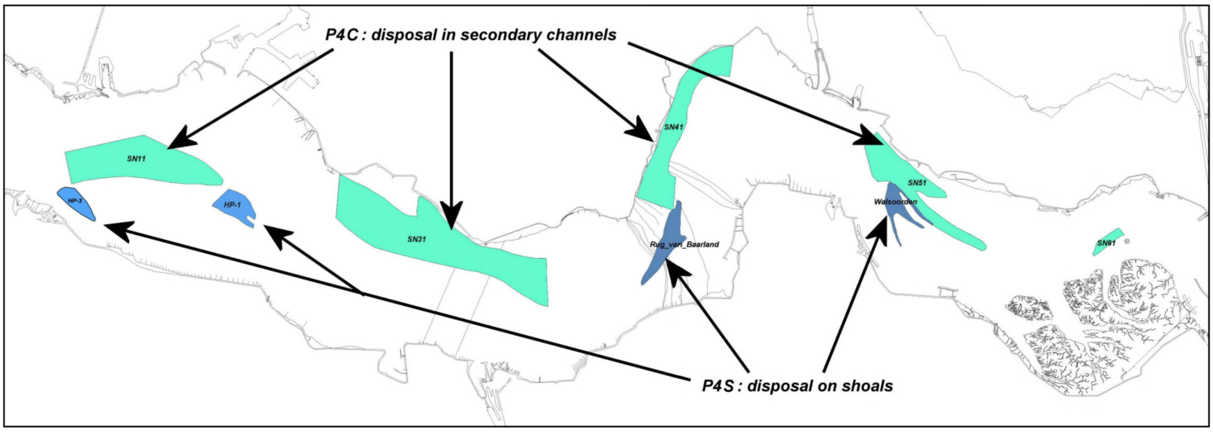

Figure 8. Possible disposal sites Western Scheldt for dredged material < capital dredging.

The disposal on the shoals in the Western Scheldt has to be realised between 0 and –5 m MLLWS ; dumping in the secondary channels is limited to a maximal fill-up level of – 5 m MLLWS and by a disposal criterium based on a stability calculation for the multiple channel system. The deeper parts in the Lower Sea Scheldt can be filled up to a maximum level of –12 m MLLWS.

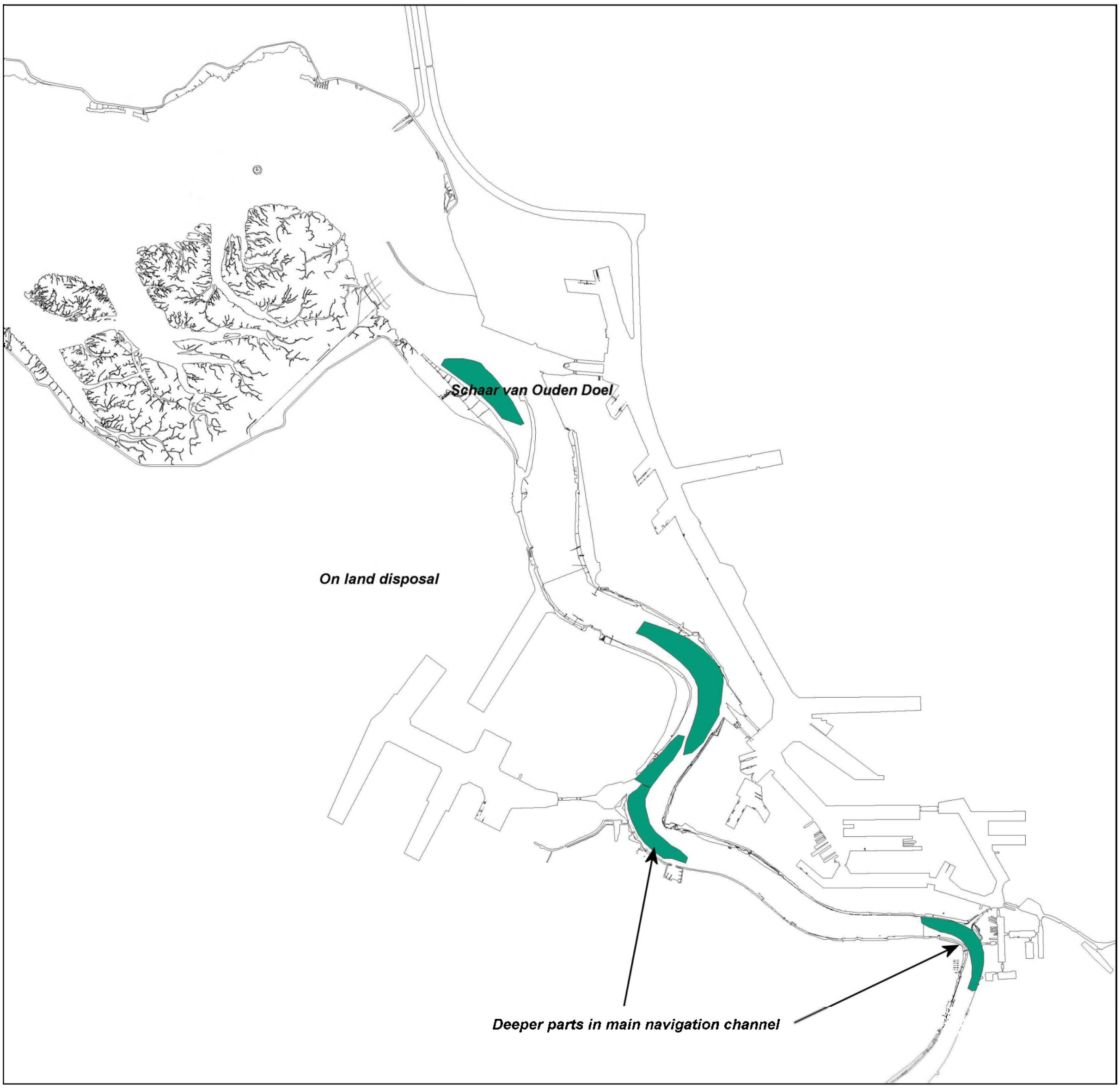

Figure 9. Possible disposal sites Lower Sea Scheldt for dredged material < capital dredging.

Disposal of the material resulting from the maintenance dredging works

Each variant for the capital dredging works creates a need for additional maintenance dredging, characterized by a maintenance dredging volume and location.

It was not possible to determine a priori the characteristics of this maintenance volume, nor to select the best disposal strategy for these volumes. The amount and location of the maintenance volume expected in both scenarios needed to be estimated through modelling of the two variants for capital dredging. This in order to see what morphological changes on medium-long term will be induced by that particular dredging and disposal scenario. Only then a disposal strategy for the expected maintenance volume could be selected, based as much as possible the new philosophy of "sustainable dumping".

As already mentioned in the description of the Scheldt Estuary, morphological changes in the Western Scheldt are mainly governed by the (changes) in horizontal transport of sand. Thus the maintenance volumes for the Western Scheldt will consist mainly of sandy material. On the contrary, in the eastern part of the Western Scheldt and in the Lower Sea Scheldt, it is mainly mud that contributes to the sedimentation in the channels and ports. The maintenance volume in this part of the Scheldt is therefore mainly composed of mud. At the time of writing this paper, only the sand transport calculations have been completed; the mud transport calculations are still ongoing. Therefore an adequate estimate of the total maintenance volumes for the Scheldt Estuary is not yet available at this moment.

The concept of a double project alternative is kept for the disposal of the material resulting from the maintenance dredging. For the Western Scheldt this means that in the maintenance variant P4C, the total volume is divided over the main navigation and secondary channels. In the "shoal" variant P4S, 20% of this quantity is disposed on the shoals in the Western Scheldt and the rest is again divided over the main navigation and secondary channels. For the Lower Sea Scheldt the results of the mud transport calculations have to be awaited to get an idea of the total maintenance volume to be expected.

Impact of the Dredging and Disposal Activities

Introduction

Once the dredging and potential disposal areas have been selected, and all volumes are estimated, a suitable dredging and disposal scenario is selected for all project variants. These scenarios serve to help the EIA experts to gain insight in the effects of the extra dredging and disposal activities necessary for the enlargement program.

It needs to be emphasized that the proposed dredging and disposal scenarios are certainly not to be considered as the "only possible solution" for the problem. The main goal is to give an idea of orders of magnitudes and at the same time to provide insight in the (in)sensitivity of the results for the different input scenarios (different dredging/disposal volumes/locations, depending on the project alternative variant)

"Results" means primarily the number of extra ship movements (traffic) and the total execution time of the works, which should allow each of the experts of the different EIA-disciplines to make a realistic assessment of the effects that the capital and resulting maintenance dredging will have on the natural system of the Scheldt Estuary if one of the proposed scenarios will be implemented.

Practical implementation of the dredging and disposal scenarios

In practice a dredging and disposal scenario for a certain chosen investigation variant consists of the following parts:

1. determination of the different routes (source, destiny and followed trajectory of the different partial volumes[4] of the dredged material) and corresponding sailing distances.
2. selection of the most appropriate execution method for each partial volume. An execution method is called any combination of a specific dredging, transport and disposal technique.
3. calculation of the mean cycle time to dredge and dispose a partial volume (corresponding with the chosen execution method and taking into account the nature of the material to be dredged).
4. determination of the total execution time and the number of ship movements (or trips) per dredging and disposal scenario (one or more per investigation variant).

All the investigated scenarios opt for a trailing suction hopper dredger (TSHD) as dredging and transport technique. This TSHD transports the dredged material in its own hopper to the final destination. Additionally the following assumptions were made :

- All dredging is done in a regime of 120 h/week, as it is also the case for the actual maintenance dredging works.
- An efficiency coefficient of 90% is assumed for the production estimates.
- For delays due to ship traffic an extra down-time factor of 10% is assumed.
- Three "typical" TSHDs were defined with a hopper capacity of respectively 3000m^3, 5000m^3 and 8000m^3. These correspond with the TSHDs that are defined as base equipment in the current maintenance dredging contract.

As disposal techniques, the following options are considered :

- dumping through bottomdoors
- rainbowing
- spraying with spray pontoon
- pumping ashore

[4] a partial volume is a certain quantity of material, dredged on location A and then transported to and disposed at a given location B.

and the choice between these different techniques is based on an evaluation taking into account :

- total time consumption of the disposal operation
- hindrance for the ship traffic
- increase of turbidity
- minimal required waterdepth

Results

At this moment the dredging and disposal study for the Western Scheldt is finished. For both remaining project variants (P4S and P4C) a realistic dredging and disposal scenario has been selected for capital and maintenance dredging. For the Lower Sea Scheldt the development of a maintenance scenario is still pending because the mud transport calculations have not yet been completed.

Although incomplete at the time of writing this paper, Table 2 gives already an idea of the outcome of the above-described exercise :

Table 2. Overview of possible practical implementation dredging and disposal scenarios

	CAPITAL DREDGING				MAINTENANCE DREDGING							
Investigation variant	P4C		P4S		0		N+		P4C		P4S	
Dredging area[5]	WES	BEZ	WES	BEZ	WES	BEZ	WES	BEZ	WES	BEZ	WES	BEZ
million m^3 in situ	7.7	6.3	7.7	6.3	6.5	3.8						
Total # weeks	42	26	56/73/81	26	48	48					Option 1/2/3	
Total # trips	1719	1418	1719	1418	1440	1920						
Sailing distance per trip[6]	15	4	24	4	23	14						
cycle time (hr)	2.4	1.7	3.2/4.2/4.7	1.7	3.2	2.4					Option 1/2/3	
# trips per day	8	11	6/5/4	11	6	8						
# ships per day	1	1	1	1	1.9	1.1						
mean hopper capacity [m^3]	5000	5000	5000	5000	3000	3000						

Once the above table will be completed, a comparison of the project alternatives with the zero and zero plus alternative will be possible, and consequently an indication can be given of the “impact” due to the extra dredging (and disposal) activities that will be involved with the enlargement program.

The numbers for the zero alternatives are made available by the “problem owner” (Maritime Access Division of the Mobility and Public Works Department of the Flemish Government) and represent the maintenance dredging activities in the Scheldt Estuary for the year 2005. Regarding these numbers, an important remark needs to be made about the indicated maintenance volume for the Lower Sea Scheldt. As already mentioned before, this maintenance volume is composed for the greater part of mud with a much lower in situ density than the sand yearly dredged in the Western Scheldt. The mud volume included in the total maintenance volume for the Lower Sea Scheldt mentioned in the table (3,8 million m^3) is obtained by recalculation of the hopper volume to an equivalent reference volume with a reference density of 2.0 t/m^3. This should allow for comparison of this number with the maintenance volumes in the Western Scheldt and with the capital dredging volumes (both mainly consisting of sandy material).

Clearly the total execution time (# weeks), the mean cycle time (hours) and the number of trips per day for a certain scenario will depend on the chosen disposal technique. Therefore in the P4S-scenarios in the table above, each time 3 different figures (in blue) are given for these three parameters: the first, second and third value respectively for dumping, rainbowing and spraying as disposal technique.

[5] WES = Western Scheldt ; BEZ = Lower Sea Scheldt

[6] Distances are one-way and expressed in km

Indeed it is the intention in both the P4S capital and maintenance dredging variants, to dispose the dredged material on the shoals in the Western Scheldt between 0 and –5 m MLLWS (mean lowest low water spring). With a maximum tidal range of approximately 4.5 m at Vlissingen (near the mouth of the Estuary) and 6 m at Antwerp and a mean draught of a typical mid-size fully (with sand) loaded hopper of 7 m, it is clear that not all of the dredged material can be disposed by mere dumping. At lower water levels rainbow and/or spray(pontoon) techniques will have to be used or, if possible, alternative disposal sites at greater depths should be called on.

A few preliminary conclusions can be drawn from Table 2 :

- The total maintenance volume in the Scheldt Estuary for the year 2005 was 10,3 in situ million m^3 (of sand and mud). The total capital dredging volume is estimated at about 14 million m^3 (of mainly sand), which is only 35 % more than the annual maintenance volume.
- Currently the maintenance dredging works on the Scheldt require about 3 TSHDs per day. The capital dredging works for the enlargement can be realised by deploying one extra mid-size hopper during maximum 2 years.
- In the above planning no extra time is yet foreseen for “environmental windows” that could possibly be proposed as mitigating measure later on in the EIA. In this case certain dredging or disposal areas could be excluded from operations during a predefined period of the year because of specific habitat needs (for example : breeding season). If however the total execution time of the capital dredging is really limited to two years max, more or larger TSHD’s can be used to meet this requirement.
- In the P4S-scenarios sailing distances are much larger than in the P4C-scenarios. This means fewer trips per day, but also longer total execution times.

More conclusions will follow as soon as also the mud transport calculations will be finished and maintenance scenarios for the Lower Sea Scheldt can be completed. In the EIA the consequences for man, fauna and flora of the effects described in the preliminary investigation will have to be evaluated.

CONCLUSION

The third enlargement program of the Scheldt Estuary includes the widening and deepening of the navigational channel and the disposal of the dredged material resulting from the capital and maintenance dredging works afterwards. An extensive investigation prior to the EIA is performed. This investigation should provide the EIA-experts with sufficient information to properly assess the effects of this enlargement. The main goal of this joint Dutch-Flemish EIA-study is to achieve an enlargement project that not only contributes to an improvement of the accessibility of the ports on the Scheldt, but also to the naturalness of the whole Scheldt Estuary. It is hoped that with this project is illustrated that dredging can lead not only to economic gains but also to environmental benefits.

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