ALTERNATIVE DUMPING STRATEGY FOR THE SCHELDT ESTUARY

REPORT OF WORKSHOP

24TH OF SEPTEMBER 2003, VLISSINGEN

RIKZ

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CHAPTER 1 Background

PAET and alternative strategy

By the end of 1999, the Port of Antwerp called on a team of international experts to provide advice on the feasibility of a further deepening of the navigation route in the Westerscheldt, independently from LTV. In their final report, issued at the start of 2001, the Port of Antwerp Expert Team (PAET) presented their diagnosis, which differed on several points with the outcome of the Long Term Vision. During a meeting with the LTV Morphology Cluster held in Delft in June 2000, the PAET challenged the CELL concept and proposed to work out an alternative strategy to the ongoing dumping in flood channels. (The CELL concept is explained in Chapter 7.)

The dumping in carefully selected shallow areas would help restoring degraded sandbars. The alternative dumping strategy proposed by PAET was presented to the Commission Infrastructure of the Flemish Parliament during the discussion on LTV. Flanders Hydraulics Laboratory of Borgerhout (FHL) was requested to use Walsoorden for a pilot study with scale- and numerical modelling. The PAET was requested to formulate its opinion and analysis before June 30, 2003. However, the report presented to ProSes on September 16th, 2003, does not yet contain all the expected study results. The studies in FHL are expected to be finished end of 2003.

Second opinion

ProSes, the organisation that is responsible for the making of the Development plan of the Scheldt Estuary, asked the RIKZ to organise a second opinion. Therefore the RIKZ invited different experts on estuarine morphology to give:

- A judgement on the feasibility of dumping dredged material on sandbars, as to decide whether further research should be carried out within the research programme of ProSes,
- An assessment of the research report of the PAET to support the proposed strategy,
- Recommendations in general and for the proposed disposal pilot experiment at Walsoorden.

The Second Opinion expert team is only asked to give its opinion on the recent PAET study and on the alternative strategy for dumping, but this should be seen as part of the proposed overall strategy.

The experts received in advance the following documents:

- PAET main report (January 2001);
- PAET addendum to the main report (May 2001) with more detailed presentation of the proposed alternative;
- PAET's study report on the Walsoorden test-site (September 16th 2003).

On September 24th 2003, the Port of Antwerp Expert Team met with this 'Second Opinion Expert Team' in Vlissingen. On September 25th 2003, the 'Second Opinion Expert Team' continued its work with RIKZ and ProSes. For the names of the participating persons, see Annex 1.

The workshop day

The day started with an introduction by Bianca Peters on what is expected of the Second Opinion. Then Jon Coosen of ProSes presented background information on the Long Term Vision that was formulated in 2001, and the targets and plans for the Development Plan that will succeed the LTV. Successively, Marcel Stive, who was involved in the LTV morphological research, gave an introduction on the Scheldt Estuary. Jean Jacques Peters, head of the PAET, then presented a short summary of what had been PAET's advisory work. During the meeting, the PAET was asked for more detailed information and discussions started on possible effects of the strategy (locally and on the estuary scale), on the feasibility of the pilot study and on tools to be used in further research.

This report

This report summarizes the presentations, the information exchange and the lively discussion on the 24th of September. The draft of this report has been submitted to all participants for comments.

In this report the information exchange and the exchange of opinions and insights is separated. After briefly mentioning in what way Flanders and The Netherlands think to develop the Scheldt estuary (subsection 2), first a summary is given of what the PAET really proposes as a strategy (subsection 0). This is followed by study results so far (subsection 4). Then the different facts and insights in the functioning of the estuary are presented (respectively subsection 5 and 7). As a result of that, the plans for the pilot experiment are discussed (subsection 8). The report concludes with remarks during the round up (subsection 9). The comment and recommendations by the Second Opinion Expert Team were formulated after 24th September in their so called *official letter* (An Alternative Strategy for Dumping in the Scheldt Estuary - Comments of the expert team d.d. October 3rd, 2003).

CHAPTER 2 Possible future developments in the Western Scheldt

Jon Coosen presented that in the Long Term Vision it was decided to pursue three goals when developing the Western Scheldt:

- Safety against flooding;
- Navigable accessibility of the ports;
- A healthy dynamic ecosystem.

The Strategic Environmental Impact Assessment and the Societal Cost Benefit Analysis that are being carried out at this moment, look into the effects of among others further deepening and the depoldering of a few adjacent polders.

CHAPTER 3 Morphological dumping and dredging as proposed by PAET

The presentation of Jean Jacques Peters and the responses of the PAET team to explanatory questions by the Second Opinion Expert team, are summarized hereafter.

Better separation between ebb and flood channels
The PAET expects that a better separation between ebb and flood channels could be obtained if some of the eroded sandbar areas are reshaped. This reshaping can be done by disposing dredged material in some well chosen shallow water areas. This would contribute to maintain the multi-channel system. According to studies carried out for the Scheldt Long Term Vision, such a multi-channel system is expected to be in favour of all three LTV objectives (safety, access and ecology).

Complementary technique
The PAET proposes to use the alternative strategy of dumping in carefully chosen shallow areas as complementary to dumping in deeper flood channels, not as a replacement. The PAET emphasizes that this strategy is treating the effects of unwanted morphological evolutions, not the causes. The causes are (among other) related to the hard bordering of the estuary.

The present pilot-test study at Walsoorden considers only one option: to dispose dredged material. Further studies are required for assessing the need for and feasibility of 'morphological dredging' (which implies also alternative dredging besides alternative dumping) and adaptation of the hard bordering and fixed points. One major goal is to obtain a shape of the channel and bar system so that the self-dredging capacity of the flow and the crossing can be increased, by which maintenance dredging could be minimised. 'Morphological dredging' might imply that dredging of parts of sandbars is necessary, instead of just dredging in the navigation channels.

Strategy independent of changes in navigation conditions
The proposal for an alternative strategy for dumping does not depend on the decisions for deepening or widening the channel. The strategy is supposed to be a more sustainable approach than moving the dredged sediment from one part of the estuary to another one, or to export it to the sea.

Three step approach

Having finished the foregoing research, the PAET suggests a three-step approach for researching the alternative dumping strategy:

1. a pilot experiment dumping 200.000 to (ideally) 500.000 m^3 sand at the Western tip of Walsoorden;
2. reshaping of the Western tip of Walsoorden with more dumped sediment and monitoring the effects. (The volume that can be dumped at the Walsoorden sandbar tip is presently estimated at $4 * 10^6$ m^3 to $5 * 10^6$ m^3);
3. analysing the past and present morphological evolutions in the Western Scheldt to identify other locations where similar reshaping of tidal flats would be beneficial for the goals set out in LTV.

The PAET recommends a pilot experiment in which 500.000 m^3 of sediment is dumped in a secondary flood channel at the Western tip area of the Walsoorden sandbar. The suggestion done by ProSes, which was elaborated by AWZ (The Flemish Ministry of Infrastructure), was to have the experiment conducted in the short term, before the end of 2003. As the dredgers have already dredged most of the material that was planned for 2003, an experiment in 2003 could only allow for 200.000 m^3. The PAET felt that an experiment of 200.000 m^3 was still useful. However, now that the experiment is planned in spring 2004, the amount of 500.000 m^3 might be possible. This increases the chances of success for the experiment, with a significant impact on the flow field.

Reg Parker explained that the research questions of the experiment at Walsoorden are:

1. What will be the directions and rates of sediment transport?
2. What will be the changes in hydrodynamics due to a reshaped tip of Walsoorden sandbar?
3. Can we achieve a change in the morphology of the sandbar?
4. Can we get finer material at higher altitudes, in the intertidal flats and on the sandbar?
5. Can we monitor sufficiently well the experiment?

If the experiment is successful, the next step is to dump possibly (but not necessarily) up to $4 * 10^6$ m^3 to $5 * 10^6$ m^3, which is the expected maximum storage capacity at the Western tip of the Walsoorden sandbar. Jean Jacques Peters thinks that repetitive deposition is better than dumping all at once. If the experiment with the 200.000 or 500.000 m^3 fails, because the deposited material immediately disappears from the dumping area, this might mean that the experiment should have been carried out with more sediment. It does not necessarily mean that the proposed strategy is not viable.

CHAPTER 4 Study results so far

As for now, the Flanders Hydraulic Laboratory has carried out hydrodynamic simulations with a physical scale model and with SIMONA & Delft 3 D (2D and 3D). Moreover, satellite tracked drogue measurements of flow tracks have been carried out in the field. At three locations stationary sediment transport measurements were done with (among others) the Delft Bottle A test. Multibeam measurements have also been carried out to determine the bathymetry and microtopography. At the moment, in the physical scale model sediment transport simulations with a fixed bed are being carried out. (The Flemish Ministry of Infrastructure financed all field measurements performed in 2003.)

Hydrodynamic numerical simulations not yet fully analysed

In the hydrodynamic numerical simulations, the simulated flow velocity fields were different as compared to the measurements in certain periods of the tidal cycle in some areas. The PAET explained that there was not yet enough time for detailed analysis of these differences. Jean Cunge was already suspicious just from the numerical results, because he had noticed that some flow fields in the numerical model follow grid lines. Jean Cunge explains that the problem with the numerical models used is that the scale at which depths are varying is very small for the type of models used. In particular, numerical models have problems with locations like the intertidal areas, which sometimes are dry and sometimes are wet. Jean Cunge had the impression that in the middle of the channels the velocities were reliable. PAET believes that the model is sufficiently accurate, because the inaccuracy of the model is during slack and then there is hardly any sediment transport.

Hydrodynamic physical scale model simulations finalized

The hydrodynamic simulations with the physical scale model were finalized and reported to ProSes in June 2003. The physical scale model represents the situation in 1990 and is distorted 1:4, which means that the ratio between depth and width is 4 times as large as in reality. Luc Hamm added that the use of such a rate of distortion is common practice in France.

No numerical simulations of sediment transport

There are no numerical simulations planned for sediment transport in the near future, mainly because Flanders Hydraulics Laboratory has not yet set up the software and related models. The PAET, in particular Jean Cunge, has low expectations of such simulations because of the uncertainties concerning the formulas that describe the sediment movements and exchanges between bed, bedload and suspended load. Marcel Stive does not share that opinion and says that nowadays numerical models can at least help to define maximums.

Sediment transport simulations with the physical model

The scale model tests about the dumping of sediment in the selected areas have just started and are expected to be completed at the 31st of October of 2003.

Satellite tracked drogue measurements gave insight in flow tracks

Co van der Kreeke mentioned that he was enthusiastic about the float tracking results.

In situ sediment transport measurements not yet sufficient

The sediment transport measurements that were carried out in 3 positions during one spring tidal cycle, are not yet sufficient to make a Shields plot of the potential mobility of the sediment in the vicinity of the disposal test site. The field survey programme by PAET was considering measurements in 12 positions in total, but it is not yet sure if the other measurements will be carried out. Co van der Kreeke said the Delft bottle measurements seemed very useful.

Multibeam survey practicable during pilot study

The PAET concluded from the Multibeam bathymetric test-survey that the on-line monitoring of bathymetry in the dumping area during and after disposal test is practicable (short, medium and long-term).

CHAPTER 5 Morphological system; facts and historical developments

Bart Kornman, Bianca Peters, Jean Jacques Peters, Marcel Stive and Youri Meersschaut supplied answers on questions regarding the Scheldt morphological system.

Facts and figures

The facts and figures below were mentioned in the workshop (relying on the MOVE-report, RIKZ, 2003, the Scheldt-atlas, *morfologische ontwikkeling Westerschelde 1931-2000*, RIKZ, 2001).

Scheldt estuary

- Maintenance dredging in the Scheldt is on average in the order of magnitude of 11 million m^3/year over the last few years.
- There is still mining for commercial purposes of about 2.5 million/year. Mining removes sediment with particle sizes in the order of 200-300 microns (D50-D90).
- The difference in tidal range in Vlissingen within 18.6-year cycle is 10 to 15 cm.

Walsoorden

- The order of magnitude of the dredging nearby Walsoorden is 0,5 - 2 million m^3/year.
- The tip of Walsoorden is eroding since long (more than 60 years).
- According to the studies for the CELL-concept, the gross sediment transport capacity is about 10 million m^3/year (16 megaton) in the cell of which Walsoorden is a part (N.B. this was mentioned during the workshop, but Figure 2 shows a small CELL of 6 million m^3/year and a bigger cell of 21 million m^3/year near Walsoorden).
- Based on the desired shape of the sandbar, there could be a capacity to store 4 to 4.5 million m^3 of sediment at Walsoorden.

Sediment to be dumped

- The grain sizes of the sediment that is disposed: D50 180-200 microns.
- The amount of silt smaller than 63 microns is less than 2 or 3% of the total amount.

The history

As shown in Figure 1, the intertidal area was halved between 1650 and 1968. The last polderings were done quite recently, in 1968. Poldering reduced the lateral storage of floodwater, which induced a deepening of the main channels.

The estuary extends further and further into the sea. The mouth area has become an integral part of the estuary. These changes at the seaside are very important and are considerably influenced by the Delta works.

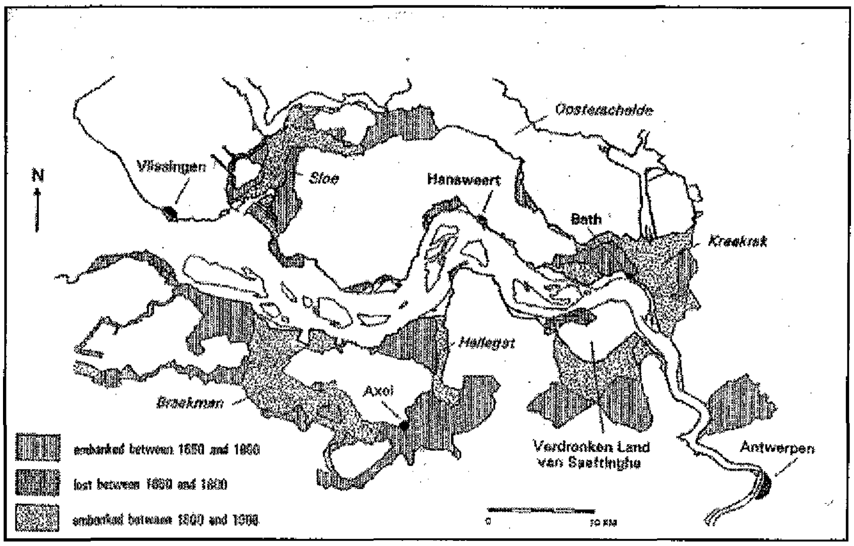

Figure 1 Changes in intertidal area (Van der Spek, 1994, presentation of Marcel Stive)

In 1997 the navigation channel was widened and deepened allowing ships with a depth of 38 feet to enter and exit independent of the tide, 48 feet ships to enter in one tide and 43 feet-ships to exit in one tide. The previous and first time that the Scheldt was deepened and widened was between 1967 and 1978.

Morphological changes have always existed, but capital and maintenance dredging only became significant after 1972. The "Overloop of Hansweert" has eroded naturally at the end of the sixties and thus became the shipping route (Map nr 9 in PAET, 2001a Improving navigation conditions in the Western Scheldt and managing its estuarine environment - How to harmonize accessibility, safetyness and naturalness). All areas in the Western Scheldt have been changing and are still doing so. The high Plate De Bol near Terneuzen did not exist in 1938 and is, according to PAET, likely the result of a morphological process similar to the one in Walsoorden.

As from 1997 the material dredged in the eastern part of the Western Scheldt is not anymore dumped in a flood channel close to the location were it was dredged. Increasing volumes of dumping in the eastern part were observed to lead to the degeneration of channels, to a diminishing of dynamical processes and to a decrease of areas that are important for ecology. Dredged material is now being dumped in the middle and western part of the estuary, not to withdraw sediment from the estuary.

The maintenance dredging did not increase due to deepening of the navigation channels in 1997. The RIKZ suggested that this might have to do with the fact that a maximum sediment transport capacity is reached. Jean Jacques Peters added that former deposit sites are now opening up. The widening, however, increased maintenance dredging.

Earlier studies have stated that until a few years ago there was net import of material from the sea. Mining was allowed as much as there was net import. The effects of the deepening of 1997/1998 have been closely monitored in the project named MOVE. The recent studies state that, since a few years, there is a net export of sediment of about 2 million m^3/year.

This supposed change from net import to net export was said to have started already before the deepening in 1997. The RIKZ said that this might have to do with the changed dumping strategy of bringing material more westwards (closer to the North Sea).

When the role of hard bordering was discussed, Bart Kornman mentioned that there is a numerical simulation of the area near Walsoorden in which a longitudinal wall (an artificial bank) was considered along the crossing. He mentioned that the study, carried out some 5 years ago, was giving negative effects for the navigation depth. Kornman would supply PAET with the study report.

CHAPTER 6 Definitions

To agree on working definitions, PAET presented four questions with answers (for answers see Annex 2):

1. How would you define the river morphology and its dynamic behavior?
2. What do you understand by autonomous (morphological) development?
3. Do you consider an "autonomous" development is influenced by the riverbanks and which elements would you considered? Do you think these elements are taken care of in the presently available models?
4. What are your views on the importance of the river's geotechnical characteristics (geology of banks and riverbed) for studies about the morphological development of a river?

These definitions were shortly commented. The experts agreed that the first two definitions could be used as a working base, except that there were some comments on the use of the term 'river morphology' instead of 'estuarine morphology'. In reaction on the third and fourth definition the experts agreed that all available research methods (field experiments, numerical models and physical models and empirical models) have their limitations and advantages and can best be used in a complementary way. The influence of riverbanks and hard bordering of riverbed is indeed not well understood, but not neglected.
In the answer to the third question it was mentioned that the zero state is what happens if we do nothing. This was changed into Zero state is what happens if business is as usual, meaning in this case that dredging continues as according to the present strategy.

CHAPTER 7 Insights and conceptual models

Keith Dyer stressed that when trying to achieve the LTV-targets, it is better to work with nature than against it. Everybody agreed. However, the insights of how the morphology of the Scheldt estuary functions and what is most important in this functioning differed (slightly) from expert to expert. In this subsection the insights expressed during the workshop are presented.

PAET did not present an explicit conceptual model of the ongoing changes in the estuary, and the changes anticipated in the future. Keith Dyer mentioned; only after we know how nature wants to develop, can we find out how to combine it with the LTV targets.

CELL concept

According to the LTV studies a multi-channel system is vital in the Scheldt estuary. This means a separation between ebb and flood channels. The researchers of the LTV study, among which Marcel Stive, developed the CELL-concept. The CELL-concept states that large amounts of sediment transport are taking place within geographically defined cells (see Figure 2). The exchange of sediment between cells is only 5 to 10% of that within cells. The amount of sediment that can be dumped in a cell each year, is also 5 to 10% of the total amount of sediment being transported within the cell (Wang, 1996). This will then replace the internal relocation of material. This percentage is based on dumping in the channel, but might be different when dumping in shallow areas to rebuild an eroded sandbar.

Marcel Stive asked Jean Jacques Peters if he expected the CELL concept still to be valid when dredging would be stopped. Jean Jacques Peters said that stopping dredging would decrease the sediment transport by current, but would not reduce it to zero. Marcel Stive shared this opinion. Jean Jacques Peters said that he agreed with the idea that dumping too much sediment in a flood channel may induce the decay of this channel, but that does not mean that he thinks the CELL concept is valid.

Co van der Kreeke said that, supposing the CELL concept was right, the PAET strategy would enlarge the dumping capacity. By forcing the flood flow to go through the Schaar van Waarde and the ebb flow to come back through the Schaar van Valkenisse, more sediment transport would be circulating in the same cell. Thus the gross sediment transport becomes bigger and therefore the 5 to 10% dumping capacity per year becomes bigger.

Jean Cunge explicitly mentioned that he does not believe in the CELL-concept and does not believe the analysis that allows for a well defined limit of 5 to 10% of the gross sediment transport to be dumped in a channel, above which the stability of the cell would be in danger.

(For further explanation of the CELL concept is referred to the paper distributed at the workshop: "A new morphological schematisation of the Western Scheldt Estuary, The Netherlands" by J.C. Winterterp, Z.B. Wang, M.J.F. Stive, A. Arends, C. Jeuken, C. Kuijper & P.M.C. Thoolen published in 2001 in Proceedings of the 2 nd IAHR symposium on River, Coastal and Estuarine Morphodynamics.)

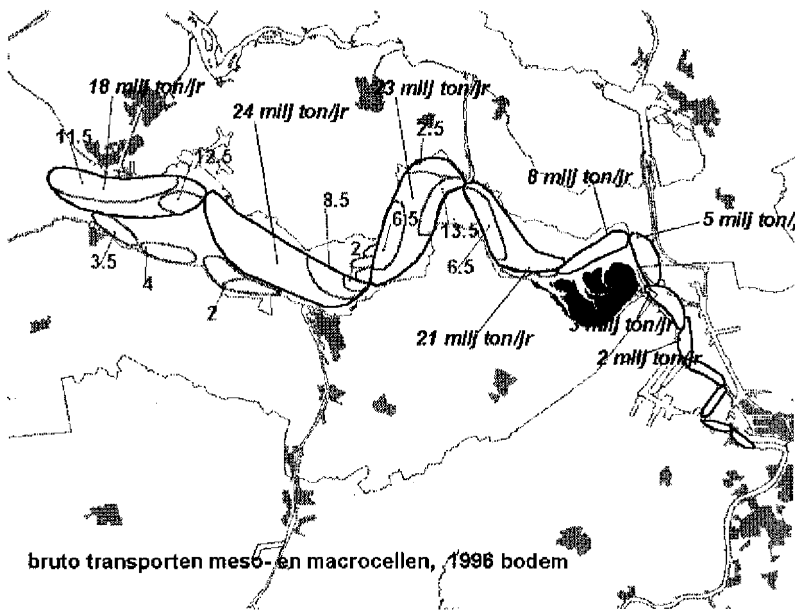

Figure 2 CELLs with annotated their gross sediment transport (presentation of Marcel Stive)

Exponential decay of cross-sectional area along longitudinal axis

Luc Hamm explained that in natural alluvial estuaries there is an exponential decay of the cross-sectional area as a function of the distance along the longitudinal axis from the mouth of the estuary. Outliers in this relationship are most often not sustainable. Hamm said that for both dredging and dumping it is recommendable to attempt to get the new cross-sectional areas (better) fit the exponential decay relationship.

Reclamation of tidal flats gives shallow channels before new equilibrium

Dronkers (1998) work, presented by Marcel Stive, claims that the reclamation of intertidal areas will first give shallow channels and then lead to a new equilibrium situation with again deep channels. Figure 3 illustrates the principle of Dronkers. Marcel Stive concluded that the challenge is to force the system into this next equilibrium stage; less intertidal area and deeper channels.

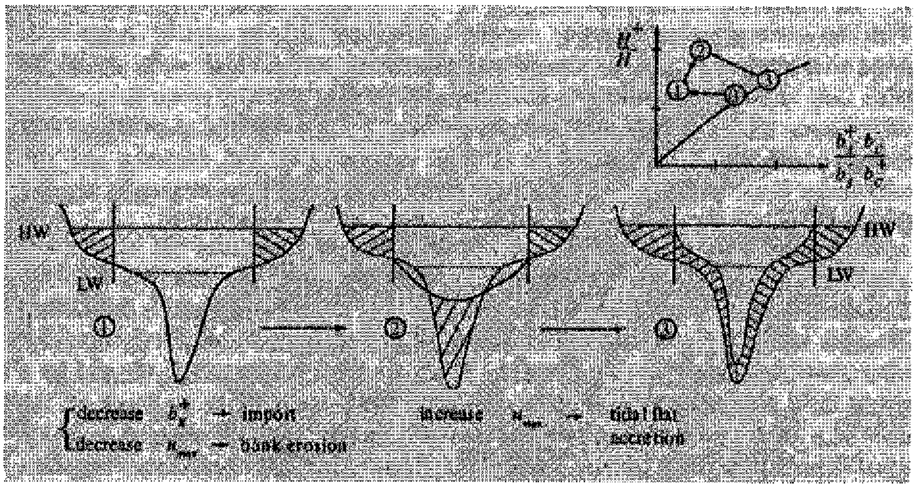

Figure 3 Dronker's model: Different stages of the morphodynamic response to tidal flat reclamation (presentation of Marcel Stive)

Meandering or not meandering?

Jean Jacques Peters claimed that the Scheldt estuary is not a naturally meandering estuary. It was not formed by the sea rise invading a river, rather by a river searching its way through a lagoon in which the sea had created channels during storms. The original estuary was upriver of Antwerp, later on through the Eastern Scheldt.

Marcel Stive, however, showed Van Veen's conceptual model of meandering ebb channels and flood channel branches parallel to the main direction, even if the borders are constrained (1950). He showed numerical models of a virtual simple estuary, where a small perturbation had exactly reproduced Van Veen's model of meandering ebb channels (Hibma, 2000). See Figure 4.

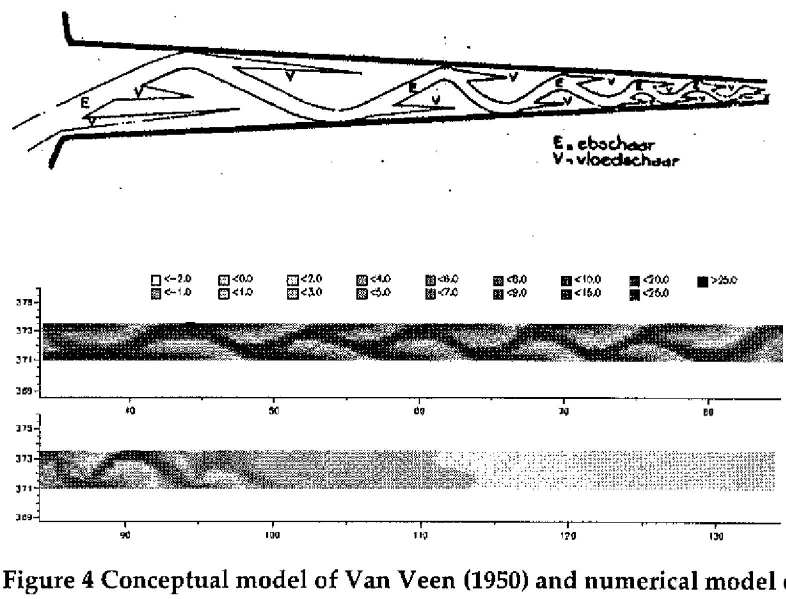

Figure 4 Conceptual model of Van Veen (1950) and numerical model of Hibma (2000); meandering within constrained borders (presentation Marcel Stive)

Important influence of fixed borders

Jean Jacques Peters pointed out that the hard bordering of the Westerschelde was created by building levees for poldering with discontinuities in alignment. He said that it is important to consider and further investigate the relationship between fixed points and the channels. The need for such investigation was confirmed by many of the participants.

Channel switching is natural

Keith Dyer mentioned that channel switching is a common phenomenon in an unrestrained system. Dyer was therefore not surprised that the bank of Baarland moved downstream to the west, making the "Overloop van Hansweert" the new navigation channel. The bank of Baarland might finally get attached to the right bank. This principle of bank movement needs to be applied to the Walsoorden bank in order to anticipate future natural trends.

Jean Jacques Peters mentioned that the cause of this evolution is likely in the morphological changes in the adjoining parts (chain reaction) and that a similar evolution as near Hansweert can happen in the area near Valkenisse; Schaar van Valkenisse can become the shipping route. He also mentioned that the flood channel Schaar van Waarde is already taking more ebb flow now.

Jean Jacques Peters added that he thinks shifts of channels are needed to create a large variety of ecotopes. In his opinion, it was wrong to protect the banks of *slikken*, as the bank protection produces more turbulence, keeping more sand in suspension and then depositing it on the flats, instead of finer material only.

Larger tidal volume gives more channels

Marcel Stive mentioned in his presentation that with a larger tidal volume a natural alluvial estuary generally tends to more channels. See Figure 5 with 1, 2 and 3 channels.

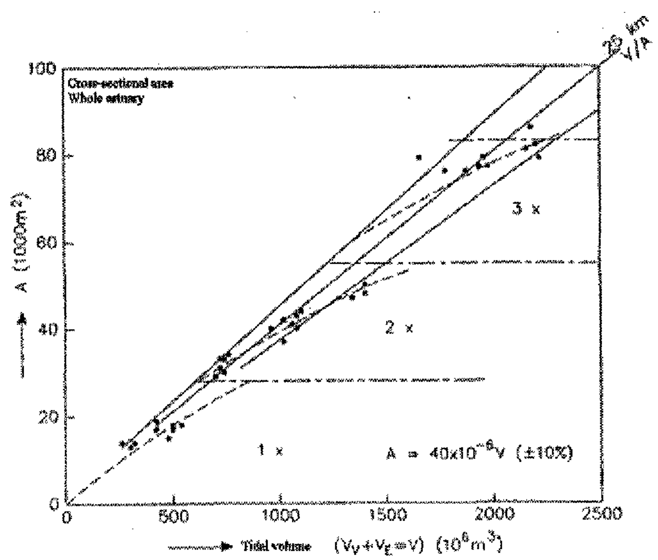

Figure 5 Relation between tidal volume, cross-sectional area and number of channels (presentation of Marcel Stive)

CHAPTER 8 The pilot study

Way of dumping

Jean Jacques Peters explained that in the pilot study the dumping would go on continuously during ebb and flood, as hopper dredges cannot wait and have to deliver their load before returning to the dredging site. The field and model studies showed that the ebb velocities at the dumping site are extremely low. At the initiation of flood they are also low. Only at the end of the flood they are higher than the threshold for initiating bedload.

Jean Berlamont remarked that he expected it to make a difference if you dump at ebb or flood. Reg Parker supported continuous dumping in this pilot experiment, as it gave the opportunity to monitor how sensitive stability of the dumped material was to the time of dumping.

There was general agreement that ecologists will have to be asked how much they think there can be dumped in shallow areas at once without damaging the environment on the long term. Ecologists probably have a wish on the thickness of the dumped layer that the system can take in a certain amount of time. Jean Jacques Peters added that the question to the ecologists should not just restrict to "how much can you dump in this particular place in this amount of time?", because the ecologists should also consider that it is maybe better to dump somewhat more, for the benefits of the whole ecosystem if larger areas of different ecotopes can be created.

The Second Opinion Expert team agreed with the PAET that 200.000 m^3 is not much for achieving the expected result in an experiment like this and that 500.000 m^3 would probably be more appropriate. The risk of dumping 200.000 m^3 is that changes are too little to monitor, because part of the material will not stay deposited anyway. Jean Jacques Peters added that the risk that the material does not stay should not be overestimated, because the dumping will take place at places where measurements show that velocities are very small. Marcel Stive intuitively also thinks that the sediment won't disappear so easily.

Also there was a discussion about what would be the maximum amount that can be dumped. Marcel Stive suggested using the CELL-concept for this (10%). However, all experts agreed that dumping large amounts could not be done without risks. The question is how far we can go: not dumping too little (no effect, no change in flow field) and not dumping too much (risk of deterioration). Therefore a step-by-step approach during the experimental dumping is necessary.

Bianca Peters mentioned that there is also dumping taking place at the Schaar van Waarde. It should be arranged that this dumping does not take place during the pilot experiment at Walsoorden. Jean Jacques Peters said that coordination is not a problem, as this was already done during sediment measurements in the field.

Way of monitoring

There were different opinions on the minimum requirements for the time that intensive monitoring should continue. Parker and Dyer mentioned that they would at least want to monitor intensively during a spring- neap- spring cycle. Berlamont mentioned that he did not consider the neap so important and rather would have as minimum requirement an average tide and a spring tide. Parker stressed that in an ideal situation it was important to also monitor seasonal differences, particularly the sustainability of the changes in the flats from winter to spring.

Also there was some discussion on the spatial area to monitor. A suggestion was to look at the maximum length a water particle could travel during one tidal cycle.

PAET proposed to use multibeam, LIDAR and sediment transport surveys to monitor the pilot disposal test. The Second Opinion Expert team suggested the following monitoring, in order of decreasing priority:

- **Glauconite tracing** tracked with Medusa, to see sediment transport paths;
- **Multi-beam measurements** at high water, to monitor bathymetry (accuracy 10 to 20 cm according to Jean Jacques Peters);
- **LIDAR measurements** for accurate terrestrial surveys, complementary to the Multibeam bathymetric surveys, especially useful for the intertidal areas. There was a discussion on the usefulness of **LIDAR**. Everyone agreed that **LIDAR** should be accompanied by proper ground truth measurements, as should all remote measurements.
- **Wave action**. The influence of waves on the survey results was discussed. It was mentioned that wave action caused by passing vessels might be stronger than what is caused by the wind. Jean Jacques Peters suggested that the ship records from the Port of Antwerp could be used to identify possible impacts and also annotating during the experiment when a ship is passing will already give an indication of wave action.
- **Extent of the water line at different stages.**

The above list of monitoring does not include the monitoring of the conditions before the experiment starts. All participants consider this very important.

Co van der Kreeke stressed that the experiment and the accompanying modelling does not need to answer the question why the morphology of the area is as it is. The question at the centre of the experiment is if enough material stays where you dump it and if it affects the hydrodynamics as wished. Co van de Kreeke reckoned that monitoring and modelling can be modest.

As for the changes in hydrodynamics as a result of changes in morphology, it was suggested that putting the changed bedform into a hydrodynamic numerical model is sufficient for that purpose. Co van der Kreeke wondered if this would give good results, given the existing differences between numerical model results and the flow measurements in the field.

Keith Dyer added that it is not sufficient to rely on surface flows, as this will give some (possibly up to 20 degrees) difference in direction with the subsurface flows. Van der Kreeke mentioned that, if financial resources allow it, the Ocean Surface Current Radar is very useful.
Keith Dyer said that for modelling it is useful to measure bed shear stress instead of only velocities. This can be done by also measuring turbulence and bedforms.

What conclusions can you draw from such an experiment?
Luc Hamm said that the experiment with a limited volume for dumping (200.000 m^3) would only tell about the possibilities of how to keep the sand there, not on the impact of the reshaping of sandbars for the estuary.

Dyer mentioned that if the pilot study and the initial dumping at the location of Walsoorden are successful, it would still be difficult to extrapolate the results to the implications of reshaping other sandbars. Co van der Kreeke added that if all the material has gone within 2 days, you know you have to dump far more to get it staying.

As for grain size distribution, Co van der Kreeke thought the experiment shows the short-term impacts, but not the long-term impacts. Parker added that biological activity would also influence if smaller particle sizes were getting to higher altitudes.

According to Keith Dyer, the role of modelling is that models give an additional verification of conclusions drawn from measurements. Jean Berlamont said that modelling is necessary for extrapolating to other sites.

Stevens said that no answer to the feasibility question is obtained with only one experiment. More experiments are needed. The pilot experiment will only give an answer about the technical feasibility.

CHAPTER 9 Round up

During the round up, it was agreed that there are still a lot of uncertainties on how the local system in the surroundings behaves, and even more on how the estuary behaves. The conclusion was that the experiment needed to be conducted with care and needed to be properly monitored.

The role of monitoring and modelling caused a lot of discussion during the workshop, but all participants agreed that monitoring, field studies and modelling should go hand in hand. It was emphasized that also other conceptual models than the CELL concept are necessary (see Chapter 7).

As a point of attention, the meeting stressed that a lot of factors influence the stability of the estuary apart from the location were sediment is dumped. The reopening of a polder will certainly affect the morphology.

Jean Jacques Peters thanked the Second Opinion Expert Team for their valuable advice and the open discussion. He and the other members of PAET agreed with the comment made by members of the Second Opinion Expert Team that this meeting would preferably have taken place two years ago, or in a couple of months, when the results of the numerical and physical models are properly analysed.

After the round up, the meeting of the Second Opinion Expert Team with PAET was closed and the Second Opinion Expert Team started preparing its comments after PAET had left.

ANNEX 1 Participants of workshop

PAET = Port of Antwerp Expert Team
ET = Second Opinion Expert Team
RIKZ = National Institute for Coastal and Marine Management
ProSes = Scheldt Estuary Development Project
FHL = Flanders Hydraulics Laboratory (Borgerhout)
ARCADIS = consultancy company which facilitates this meeting

Participants 24th of September:

1. Harm Albert Zanting (ARCADIS, chairman)
2. Marieke de Groen (ARCADIS, secretary)
3. Marieke van Nood (ProSes)
4. Jon Coosen (ProSes, only morning)
5. Bianca Peters (RIKZ)
6. Bart Kornman (RIKZ, only morning)
7. Marcel Stive (ET)
8. Keith Dyer (ET)
9. Jean Berlamont (ET)
10. Co van de Kreeke (ET)
11. Luc Hamm (ET)
12. Jean Jacques Peters (PAET)
13. Jean Cunge (PAET)
14. Reg Parker (PAET)
15. Mike Stevens (PAET)
16. Yves Plancke (Antwerp Port Authority)
17. Youri Meersschaut (FHL)
18. Kristof Verelst (FHL)

Participants 25th of September:

1. Harm Albert Zanting (ARCADIS, chairman)
2. Marieke de Groen (ARCADIS, secretary)
3. Marcel Stive (ET)
4. Keith Dyer (ET)
5. Co van de Kreeke (ET)
6. Luc Hamm (ET)
7. Marieke van Nood (ProSes)
8. Bianca Peters (RIKZ)

Jean Berlamont could not participate 25th of September

ANNEX 2 Working definitions of PAET

Given the complexity and difficulty of the problem the Port of Antwerp Expert Team (PAET) suggested that the Second Opinion expert team commented on the PAET definitions of the following terms, see subsection 6.

1. Q: How would you define the river morphology and its dynamic behaviour?

PAET: A river's morphology has to be seen as the 3-dimensional geometry of the river, including all bed features (e.g. bedforms and other). It is the result of many processes, which relate to the following sciences: hydrology, hydraulics, sediment transport, geology, geography, geotechnics, biology and ecology (fauna and flora). The studies of the morphodynamical behaviour of a river must be based not only on hydraulics and sediment transport theories; they must also take into account the other sciences mentioned above.

2. Q: What do you understand by autonomous (morphological) development?

PAET: The autonomous morphological development of a river is how a river system changes naturally in absence of any disturbance induced by human actions. It is the result of a series of processes among which hydraulics and sediment transport are only part. Difficult to predict because small influences may have strong effect (it is merely a stochastic process rather than a deterministic one. One cause (event) may have different possible outcomes. It is a bit a theoretical definition because there always will be humane perturbation, which effects can last for very long. But the definition is useful because it is analogous to "zero state" in Environmental Impact studies, as reference: what happens if we do nothing.

3. Q: Do you consider an "autonomous" development is influenced by the riverbanks and which elements would you considered? Do you think these elements are taken care of in the presently available models?

PAET: Yes, riverbanks and "hard" bordering of the riverbed play a major role on the development of channels and bars or islands. The exact nature of these impacts is not yet well-understood and neglected in studies and modelling about river behaviour. In numerical modelling some attempts are made to simulate the phenomenon, especially including bank erosion, but it is still at research level.

4. **Q: What are your views on the importance of the river's geotechnical characteristics (geology of banks and riverbed) for studies about the morphological development of a river?**

PAET: The geotechnical characteristics of riverbed and –banks have a major influence on the autonomous development. Even small changes in bed material characteristics may have significant influence on the rate of bank erosion and the disturbed bank shape therefore may influence the guidance of the flow. These elements are not well taken into consideration in the models.

ANNEX 3 Powerpoint presentation by PAET

COLOPHON

ALTERNATIVE DUMPING STRATEGY FOR THE SCHELDT ESTUARY

REPORT OF WORKSHOP

CLIENT:

RIKZ

STATUS:

Final

AUTHOR:

Marieke de Groen
with comments by various participants

CHECKED BY:

Harm Albert Zanting

RELEASED BY:

Harm Albert Zanting

8 October 2003
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Alternative strategy to dispose the material dredged in the Westerschelde
Pilot study Walsoorden

Report by an expert team appointed by the Port of Antwerp to assist Flanders Hydraulics Laboratory (FHL) and RIKZ in the ProSes study

Background

- Proposal was formulated during preparation of LTV and included in ProSes programme (for the Environmental Impact Assessment)
- The alternative is valid for any chosen navigation channel depth
- The strategy aims at satisfying part of the LTV objectives: maintaining the multi-channel system, satisfying navigation, environmental and safety requirements

Study methodology and tools

- Combined use of
  - ✓models (reduced scale - & numerical models)
  - ✓field investigations
  - ✓expertise within the team
  - ✓pilot disposal-test
- Modelling done in FHL
  - ✓scale model (situation 1990)
  - ✓SIMONA & Delft3D (2D and 3D)

Status study on 24/09/2003

- Hydrodynamic simulations in scale model finalized; sediment transport (fixed bed) just started and completion expected 31/10/2003
- Hydrodynamic modelling still ongoing; no sediment transport simulation foreseen
- Field surveys: float tracks + limited (for 3 out of the 12 proposed positions) sediment transport surveys completed

Outcome studies on 24/09/2003

- Differences in velocity fields have been observed between models (scale and numerical) and field; they will be evaluated
- Model velocity patterns in combination with field observations give enough evidence about the hydrodynamic behaviour in the proposed dumping zone, especially during periods with sufficient sediment transport

Outcome studies on 24/09/2003

- Field measurement data confirm expected sediment transport pattern in the dumping area and the practicability of sediment transport monitoring during pilot-test
- Multibeam bathymetric test-survey confirm the practicability of on-line monitoring of bathymetry in the dumping area during and after disposal test (short, medium and long-term)

Implementation

- ProSes agrees implementing a disposal pilot-test (200 000 m^3), planned in spring 2004
- Dredging contractors confirm the availability of the technology for a local and controlled disposal of sediment
- Monitoring is an absolute requirement during and after the disposal pilot-test (multibeam, LIDAR and sediment transport surveys)

Conclusions

- Combining all 3 tools (models and field) is needed for assessing the technical feasibility
- PAET considers having now enough evidence about the practicability of the alternative disposal strategy
- A pilot-test will give information to assess morphological dredging as a management tool for the Westerschelde

ANNEX 4 'Official letter '

An Alternative Strategy for Dumping in the Scheldt Estuary - Comments of the expert team.

1 Introduction

The PROSES Bureau asked RIKZ to organise a workshop with a team of international experts (ET) to express a second opinion on a draft report prepared by the Port of Antwerp Expert Team (PAET), which addressed the feasibility of an alternative dumping strategy (REF 1). This strategy has been elaborated for a specific location, the Plaat van Walsoorden, but it is suggested that it may well apply to other locations. The ET has had the opportunity to discuss the draft report and associated reports and to exchange views with the PAET. The definition of morphology was discussed in the Second Opinion meeting and no essential disagreement occurred (see report of workshop: ARCADIS, 2003). This document expresses the opinion of ET on the alternative dumping strategy in general, on studies carried out for the Plaat van Walsoorden to assess the appropriateness of this location and on a proposed pilot experiment. Suggestions are given to further investigate the feasibility of the alternative dumping strategy.

2 Broader perspective

2.1 Long Term Vision (LTV) Project

Preceding the present PROSES Project a joint Flanders-Netherlands project, the LTV Project, was conducted, in which an agreed view on the preferred functioning of the system was developed. Within the three policy requirements:

- safety against flooding,
- navigable access to the harbours,
- and naturalness,

the perceived functioning was described as that of 'a dynamic, multiple channel estuary'. It was acknowledged that the present dynamic state is strongly impacted by a range of historic and present human interventions such as land reclamation, defence and training works, channel deepening, and sand mining. It was emphasised that any further interventions should not endanger the preservation of the existing, although constrained, dynamic (natural) evolution of the multiple channel estuary. In order to make the concept of a multiple channel estuary more clear the so-named cell-concept was introduced, in which the channels were ordered in macro- and meso-multiple-channel cell systems, with gross and net sediment transport estimates (REF 2, REF3). Theoretically, an estimate was derived of the maximum capacity of adjacent channels to receive volumes of dredged sediment without the danger of choking, as well as the degree of interaction between cells.

In Annex 1 the cell-concept as developed sofar is described more elaborately. The ET remarks that the PAET has expressed general doubts about the cell-concept. It would be valuable if these doubts were specified, and alternatives were suggested.

2.2 Present dredging and dumping strategy

The dredging and dumping strategy has been to dredge sills and width constraints in the navigation channels and to dump the dredged material in adjacent, nearby channels. Initially most of the material was dredged and dumped in the eastern sections of the Western Schelde estuary, where the channels were most limited in depth. Increasing volumes of dumping were observed to lead to degeneration of channels, to a diminishing of dynamical processes and to a decrease of areas that are important for ecology. In a quantitative sense these limiting volumes were in order-of-magnitude agreement with theoretical estimates (REF 3 and 4). The initial strategy has been changed since the increased deepening of 1997-1998 and dredged material in the eastern sections was dumped in more western located secondary channels. The underlying strategy has been not to withdraw sediment from the estuary. Nevertheless, sand mining takes out about 2.5×10^6 m^3 yr^{-1}.

2.3 Future dredging and dumping strategy

Current information in relation to the critical dumping volumes in secondary channels indicates that it is not unequivocally certain that there is space for a further increase of dredging and dumping material within the same management concept, i.e. preserving a dynamic multiple channel system (LTV) and not withdrawing sediment from the estuary by dumping in secondary channels (REF 5). Hence, the development of alternative strategies is necessary. However, since there is a number of other natural and human developments of which the impacts are uncertain, viz. sea-level rise, the estuary's outer delta (Vlakte van de Raan) development and sediment extraction, a change in morphological management of the estuary has to be introduced with utmost care. Careful monitoring, process studies and pilot experiments specifically focused on this issue are essential.

3 Comments on Present PAET Studies and Alternative Dumping Strategy

The present report and the studies associated with it (REF 1, 6 and 7) are useful in that they highlight a major possible problem with the current development and dredging strategy in the Scheldt Estuary. The contention is that the estuary, given extrapolation of the current dumping strategy, is likely to develop into a single channel system, and that this is an unhealthy state and would lead to deterioration in the navigational and environmental characteristics of the estuary as a whole.

It is therefore opportune to consider alternative dumping strategies. The PAET has developed such a strategy. It concerns the dumping of sediment in relatively shallow areas close to intertidal flats where sufficient storage capacity is expected to exist and where sediment is thought to be only moderately mobile.

3.1 General comments

- Unfortunately, so far not all of the available information has been assembled in support of the thesis that extrapolation of current dredging management strategy leads to disintegration of the multiple-channel estuary. There are bathymetric charts of the long time series of surveys, but they have not been analysed and interpreted in a comprehensive way so that a picture of development of the estuary appears and a conceptual model can be constructed which can be applied to prediction of future developments. The conceptual model would need to have several elements. The cell concept (REF2) is considered to be a good model for the present sedimentary system of the estuary, but it gives little insight into how it might develop in the future. It needs to be integrated with a conceptual model of how the cells might develop. Additionally, a conceptual model is needed to describe the existing changes within the cells, and how the tidal flats may change in form and location. Of particular concern is the possibility that there are progressive changes that may lead to major bank and channel shifts.
- Because of the lack of a well-described concept, it is possible that there are other strategies, which could prevent the deterioration of the estuary. Also, it makes the risks associated with the present proposals difficult to assess. Such an analysis of historic bathymetric charts would be of great help in determining the trend of changes and the justification for the proposals.
- Evaluation of the state of the estuary would have been helped by using an empirical modelling approach, based on dimensional distributions of e.g. along estuary cross-sectional areas, which often display an exponential form. These may be used as indicators of estuarine equilibrium.
- The present dumping practice is well known, but it is not well spelled out in the report. It is apparent that up to 11 million cubic metres sediment per year is dredged from a number of critical shallow points in the estuary and is deposited primarily on the sides of ebb-channels and centrally in flood-channels, taking the tidal stage into acount. Quantification of the distribution would assist interpretation of cause and effect scenarios.
- There is also a problem with both time and space scales, in that it takes the estuary a long time, possibly years to decades, to respond to changes, such as capital dredging of channel deepening, sea level rise, poldering, etc. This aspect needs to be addressed by a conceptual model of future evolution.

3.2 Comments on the alternative dumping strategy

Following the discussions between both expert teams the ET interprets the PAET concept to contain the following elements:

- sediment is dumped at locations on the fringes of intertidal flats where it is expected to have residence times sufficient to realize significant delays in re-siltation of nearby channels and channel sills;
- the dumping sites are given a geometry such that they are expected to impact positively on the current pattern, i.e. to stimulate a multiple-channel system and to reduce maintenance dredging;
- the strategy is elaborated for the Plaat van Walsoorden, but is expected to be applicable to other sites in the estuary as well.

The critical locations are those where the sediment is crossing the estuary at channel intersections, where the transport direction changes from ebb to flood. An area is defined at the western end of the Walsoorden tidal flat where the flood current is coming round the bend below (Hansweert) and attacks and erodes the downstream end of the tidal flat. The hypothesis is that there is not enough sediment available to stop the erosion and that if it were to continue, the flood channel may disappear and a single channel remains.

The ET comments:

- The hypothesis that guiding of the flow can be used beneficially to stop the channel deteriorating to a single channel would require several actions, not only sustaining and enhancing the form of the tidal flat. For instance fixed bank realignments might be necessary.
- The report does not make clear how much modification is necessary to achieve the required effect. The hypothesis that guiding of the flow can be used beneficially to stop the channel deteriorating to a single channel

should be supported by proper arguments and studies linking the short-term hydrodynamic changes with the long-term morphodynamic feedback of the system.

At the moment the strategy is presented in a very empirical and qualitative sense, rather than in a quantitative sense. The absence of a proper quantitative assessment makes it very difficult if not impossible to judge the feasibility of the PAET concept, certainly in its full extent of storing some 4 million cubic metres of sediment at the Plaat van Walsoorden. Yet, the concept is sufficiently promising that it needs careful quantification. Hence it is worthwhile to investigate the feasibility by a stepwise empirical and theoretical approach.

3.3 Comments on methodology

A certain number of studies have been undertaken to examine the situation round the Walsoorden flat and to develop an understanding of its present state. These studies comprise field measurements, physical scale model investigations and numerical modelling, which ideally should be complementary. However, they have not been used and carried out fully following this philosophy.

The ET makes the following specific comments:

- Float tracking has shown the near surface trajectories of the water flow, and these show the patterns of flow on both flood and ebb tides. However, these may not be representative of the near bed flow or the movement of sediment. The flow patterns after any dumping may be different, but significant flow pattern changes are likely to arise if large quantities are dumped. It is unclear what degree of tidal flat modification is required to be beneficial.
- While the feasibility of measuring sediment transport rates in the field was investigated, it has not yet led to a useful dataset. ET thinks the Delft Bottle method gives useful results.
- The physical (laboratory) model may be useful for an overall description, but it is unclear what its future usefulness may be. Also, there are scaling problems, especially for sediment transport simulation. If a role for the physical model is established, it needs to be allied to numerical process-based models.
- Numerical models are not extensively used to their best. Differences between the measurements and the physical modelling should be evaluated. Numerical models could have explored the relationship between the shape of the tidal flat, the flow and the likely sediment transport pathways in an assessment for the pilot experiment. A morphological model would have been a useful additional guide to assist expert judgement.

In conclusion, it is obvious that not enough is known about the detailed sediment transport around the tidal flats and the interaction of the flow with an evolving morphology, and this might be greatly helped by a well prepared and carefully executed field trail (pilot experiment) in which dumped material in the area considered crucial is carried out. Although a definite answer should not be expected, the pilot experiment is expected to provide additional insight on the feasibility of the strategy of modification of the tidal flats in preventing deterioration of the estuary to a single channel, and making best use of the dumped material in enhancing the estuary.

4 Recommendations on the Pilot Experiment

Extensive discussions between PAET and ET were held regarding the minimum size requirements for the experiment to be successful. The experiment depends crucially on there being sufficient material dumped that there is likely to be enough change in the bed levels to be detectable and provide sufficient information on the interaction between the flow and a developing morphology.

Within the present authorisation a pilot dumping of 200.000 cubic metres can be executed on the short term. Both ET and PAET question whether this is sufficient. The opinion was that the volume should be as large as possible but less than a million cubic metres to reduce the chance of the flood channel being choked. This is however based on estimates of the quantities available. It is highly recommended that the actual minimum and maximum amounts be defined by the PAET using a limited modelling effort allied to the conceptual model that is essential as a guide to the changes expected. The modelling effort could include running existing models on the short term to help in the design of this experiment as presented by PAET, i.e. to check whether current patterns are modified as expected and whether the deposit is stable enough. If nevertheless a pilot of 200.000 cubic metres is decided on, there are risks that the experiment might not give the expected results, and that the reasons for failure may not be apparent.

Some more detailed comments by ET are as follows:

- The timing of the experiment needs further consideration. From ecological considerations it might be better to do the experiment before wintertime. However, sediment mobility is likely to be greater in the winter.

- Minimum technical requirements are use of tracer material, Medusa and multibeam measurements, with a good definition of the baseline situation covering spring-neap-spring cycle.
- There is a necessity for near bed measurements of velocity profiles allied to hydrodynamic modelling.
- If practically feasible, efforts should be undertaken to establish a relationship between sediment mobility, bed forms and friction. This is important for full interpretation and use of the tracer results. In this respect the assessment of the vertical distribution of the horizontal velocity may be a better approximation.

5 Recommendations for Further Research

5.1 Implementation of the strategy

Following the discussion with PAET, we recommend a step-by-step approach to evaluate the proposed dumping strategy. This approach includes the following five steps:

- Pilot experiment, (provided that the recommendations in chapter 4 are taken into account)
- Refinement of the strategy, incorporating a conceptual model of the morphological response of the bank and of the whole cell,
- Larger pilot experiment,
- Implementation of the reshaping of the tidal flat (4 million m^3),
- Generalisation of the approach to other locations.

It is advised that a refinement of the strategy including the development of a conceptual model is initiated simultaneously with (preparations for) the pilot experiment.

The ET emphasizes the large importance of the refinement of the strategy, which should lead to the development of a conceptual model for wider application. This model should at least be based on three elements:

- analysis of historical maps;
- evaluation of past and present practices at each dumping site;
- monitoring of the pilot experiment.

5.2 Analysis of historical maps

Using the bathymetric maps as presented in the final report of PAET and its addendum (REF5 and 6), the ET recommends plotting cross-sectional areas versus distance, focusing on the 50 last years. From this it might be possible to determine a general trend in space, the evolution of the tidal prism and trends in bank movement. Areas that deviate considerably from the trend might be considered for reshaping by appropriate dumping. An analysis of the cross-sectional areas and shapes in time could also reveal insight in the dynamics of particular locations. The ET recommends that due account is given of lunar nodal tide effects.

5.3 Evaluation of past and present practices

We recommend analysing more precisely the difference bathymetric maps at each dumping site to compute the deposited and eroded volumes and compare these to the dumped volumes. Conclusions should be drawn on the local impact of the dumping on the morphology.

5.4 Development of a conceptual model

Analysis of the historical data together with the monitoring of the pilot experiment should provide enough information to develop a conceptual model. At a local scale it could be a simple sand balance for the dumping site. At estuary scale it is a more elaborate description of the morphodynamics of the estuary as a whole, aiming at preparing the next step of implementation of the new strategy. Because of the lack of a well-described concept, it is possible that there are other strategies, which could prevent the deterioration of the estuary. These should be discussed and evaluated.

5.5 Expected impacts

If the conclusion can be drawn that the proposed alternative dumping strategy is a feasible concept, PAET has to attempt making a quantification of the expected advantages and to consider both local, short term impacts and system, long term impacts.

Local, short term impacts concern:

- flat-channel interaction processes, with respect to the residence time and hence the influence on natural capability of restoring dynamic equilibrium (resilience);
- impact on sediment composition of both the dumping material and the flat sediments, with respect to the ecological impacts of the interaction of these two;
- impact on the ecology with respect to the dumping activity in itself (disturbance of the benthos, changes in turbidity, loss of biomass).

System related, long term impacts concern:

- the existing dynamics of the system and the concern whether the strategy does not work against the "natural" dynamical trends, but rather with it, to speed up movement to an acceptable equilibrium;
- the morphodynamic resilience –or the natural capability of restoring (capacity to restore) interventions- is expected to have a quantitative limit (compare the traditional dumping maxima). These limits will have to be assessed with a combined model/concept and an empirical approach;
- the concerns have to be considered in relation to the other developments, such as sea-level rise, the interaction with the Vlakte van de Raan and sediment extraction. Also the effect of possible adjustments of the (now fixed) riverbanks should be considered.

5.6 Recommendations about modelling

A numerical and a physical scale model have been used in the latest study and difficulties appeared, as reported in the PAET report (2003). Proper use of numerical and physical hydrodynamic, sediment transport and morphodynamic models can be useful in determining the sensitivity of the conceptual models for different geometries and parameters. Given the expertise of the PAET however, we recommend the collaboration is necessary in the use of models in the step leading to the overall predictive conceptual model.

5.7 Soundboard group

The PAET would benefit from liasing with a 'soundboard' group being familiar with different complementary techniques and different estuaries in order to help generalise the results.

Prof. Jean Berlamont
Prof. Keith Dyer
Dr. Luc Hamm
Prof. Co van de Kreeke
Prof. Marcel Stive

October 3, 2003

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Annex 1 The cell concept

This concept has been elaborated following several steps:

a) The definition of cell systems at meso- and macro-scales based on the analysis of bathymetric maps following observations and analysis by Van Veen (1950). The method used is general and can be applied to the different bathymetries available. There is no need for a numerical model to define these cells on maps,

b) A qualitative description of how a cell is functionning i.e. recirculation of the sediment mainly inside a cell with flood and ebb currents with second order exchanges between cells. Here again, empirical observations suggest this description,

c) A quantification of the intensity of the recirculation using a numerical model in which assumptions on sediment grain size, distribution of velocities, effects of river floods and wave agitation are made to get a mean annual gross and net sediment transport. This quantification is specific at present to only two bathymetric situations (REF 2) and has not been fully validated against comprehensive field measurements so far,

d) The development of a stability concept with numerical simulations to predict the impact of deepening a channel or filling it. This is a major refinement of the cell concept , a kind of second module, which could be discussed and improved without modifying or rejecting the "first module" described under a) to c). The validation of this concept is described in REF 3, 4 and 5.