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Diagnostic studies NOURTEC

Plan for analyses

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delft hydraulics
Diagnostic studies NOURTEC

Plan for analyses
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1 Introduction

In the summer and autumn of 1993 a large shoreface nourishment was placed, approximately 800 m off the coast of the isle of Terschelling. This nourishment was designed to mitigate the structural erosion of the middle part of Terschelling and comprised about 2.5 million cubic metres of sand. As part of the MaST-NOURTEC programme sponsored by the European Union, an extensive monitoring and research programme is being carried out around this and other nourishments in Danmark and Germany. Within this programme DELFT HYDRAULICS acts as subcontractor to RIKZ, the National Institute for Coastal and Marine Management in the Netherlands.

In their letter of 27 July, 1994, RIKZ asked DELFT HYDRAULICS to submit a proposal for a preliminary investigation which should lead to a plan for data analyses and model studies, focused on questions relevant to Rijkswaterstaat. Such questions include the prediction of the effects of the nourishment, in terms of the development of the BKL-zone as a function of time.

After a proposal was submitted by DELFT HYDRAULICS on 6 September 1994, RIKZ commissioned the study by order no. 22942542 of 13 September, 1994.

In the present report the result of this study is described. The study was carried out by Dr. J.A. Roelvink; the approach was discussed during a workshop at RIKZ held on 12 October, 1994. Results of this discussion have been incorporated in the report.
2 Objective of the studies

The design objectives of shoreface nourishments in general are described in the design report of the three NOURTEC test sites:

- coastline stabilization;
- coastal protection;
- creating or maintaining a recreational beach.

For the different NOURTEC sites, different design objectives were defined. In the Terschelling case, coastline stabilization is the only relevant objective. The objective is further specified as:

"To return the Transient Coast Line (TKL) to a position seaward of the Basal Coast Line (BKL) and to ensure that the TKL will not retreat landward of the BKL during the next ten years."

The exact definitions of TKL and BKL are given in the design report; here it is relevant to note that the TKL is based on a linear regression of the developments over the last ten years, and that "the" TKL is computed for each individual profile.

The objective of the present study is related to the general NOURTEC goal, which is to evaluate the effectiveness and efficiency of different nourishment techniques in different environments. The scope of the present study is restricted to the Terschelling site. Here, the experiment will provide information on the behaviour of a shoreface nourishment.

The design objective for the Terschelling site is defined purely in terms of effectiveness; the question is:

"Can the coastline be stabilized by shoreface nourishments?"

Apart from the question whether the overall effect is beneficial, we have to find out:

"Are there negative side effects, and if so, how serious?"

For the present study, a third question is almost as important:

"Is shoreface nourishment more efficient (cheaper per m change in TKL, per km) than beach nourishment?"

Answering these questions is the main objective of the study programme around the experiment. In the following, we will first describe the conceptual model we apply to structure our evaluation of the effects of the nourishment.
3 Conceptual model

In our thinking about the effects of the nourishment, it is convenient to split up the overall problem into smaller problems which are easier to grasp.

First of all, we will separate the direct effect of the nourishment from the indirect effect. We consider the nourishment as initially being some distance away and rather separate from the coast. It is then useful to separately consider:

- the direct effect of the nourishment on the wave and current climate, and hence the morphological developments near the shore; and
- the propagation and dispersion of the nourishment itself which indirectly influences the nearshore area.

A next step is to consider longshore effects and cross-shore effects separately. First we look at cross-shore effects.

For a large part of the nourishment site, the coast including the nourishment can be considered as nearly uniform. This implies that longshore gradients in currents and sediment transport can be neglected, and that morphological changes are due to cross-shore processes only. This greatly facilitates a part of the analysis.

![Diagram](image)

Figure 1 Short-term effect, cross-shore

In considering the cross-shore effects we can analyse both the immediate effect on the beach due to the change in wave climate, and the longer-term effect due to the morphological development of the nourishment.
With respect to longshore effects we consider three mechanisms. The first is the immediate effect on the coast of the nourishment, which may act in part as a submerged longshore breakwater. Since nearshore processes act on a smaller time scale than processes further offshore, we can assume the nourishment to be stable in considering these effects.

The next mechanisms are related to the propagation of the nourishment in longshore direction. Here it is useful to separately analyse the large-scale ("far-field") behaviour of the nourishment and the small-scale ("near-field") behaviour, concentrated around the heads of the nourishment.

The large-scale behaviour can be seen as the propagation of the whole nourishment along the coast. This will influence the section along the coast where the most favourable evolution can be expected.
The small-scale effects near the heads are essentially three-dimensional. Although they may quickly fade away in time, they may cause local disturbances and are therefore worth taking into account.
4 Hypotheses

Based on the conceptual model described above we may now formulate a number of verifiable hypotheses.

- The middle part of the nourishment can be treated as uniform alongshore.  
  (Test: is volume change negligible?)

- Due to a reduced wave climate, especially in rough conditions, the beach will show a tendency to accrete or steepen.  
  (Test: survey data, model exercises)

- The nourishment is part of a very active profile; hence its effect through morphological adjustments will be felt within a short period of time.  
  (Test: survey data, model exercises)

- The nourishment as a whole will move in easterly direction due to increase of transport on top of nourishment.  
  (Test: survey data, EMF data, model exercises)

- Due to decrease of longshore transport nearshore, there will be a tendency for increased erosion at west end and increased accretion at east end.  
  (Test: survey data, model exercises)
5  Methods

The following methods can be applied to test the hypotheses and to answer the questions pertaining to the efficiency of the nourishment.

5.1  Survey analysis

The survey data are given at approximately 3-months intervals and have a good spatial resolution. From the first few surveys we can distinguish a number of zones in longshore direction (see Fig. 5):

- autonomous regions on either side, each having a rather uniform behaviour;
- regions affected by head effects; we divide these regions into zones just on top of the nourishment and beside it;
- the middle region with a nearly uniform nourishment.

![Coastal units](image)

**Figure 5  Coastal units**

In cross-shore direction, a natural division to make is between the nourishment region and zones seaward and shoreward of it.

By averaging profiles over each longshore section we hope to obtain a clear picture of the mean cross-shore behaviour of the autonomous and nourished zones. Especially of interest are differences in their behaviour.

By computing the mean depth over each cross-shore section and by plotting it as a function of the longshore distance, we may obtain information on the extent of the area influenced by the nourishment, migration rates of the nourishment and affected areas and of the severity of head effects.
Of course, it must be kept in mind that there are a number of problems which will be encountered when carrying out this analysis:

- The autonomous regions may be different from that of the middle section prior to the nourishment. This can perhaps be taken into account, based on earlier developments.

- There are gaps in the surveys, especially between LW and some distance seaward.

- The natural fluctuations are large, even compared to the nourishment volume.

- The data available will cover little over a year following the nourishment, whereas answers are required regarding the behaviour over a 10-year period.

- The survey analysis will provide some quantitative answers but relatively little understanding of the system.

5.2 Analysis of process measurements

The process measurements provide information on the surface elevations (wave heights etc.), near-bed currents (tide-, wind- and wave-induced), sediment concentrations and sediment sizes.

The measurement campaigns are focused on providing a good spatial resolution in cross-shore direction. However, also some information along longshore sections will be available. At present, high-quality data from the T0 campaign (before the nourishment) and the T2 campaign (May-June 1994) are available.

The data gathered serve several purposes:

- to assess the relative importance of different processes;
- to investigate the changes in these processes due to the nourishment;
- to provide boundary conditions for mathematical models;
- to enable calibration and verification of models;
- to provide insight into the question of how to improve the models and to give clues to new model concepts.

Although the insight gained by the process measurements may already substantially help in understanding the observed morphological developments, modelling is required to quantitatively link the processes to these developments, and to estimate the answers to the questions raised before.
5.3 Models

Two types of process-based models are available to support the analyses.

5.3.1 Profile models

The first type includes UNIBEST-TC and UNIBEST-LT models. The basic assumption underlying these models is that the coast is almost uniform in alongshore direction. This implies that the depth contours may be considered as straight and parallel, which greatly simplifies the description of wave propagation and dissipation.

Other assumptions are that horizontal diffusion effects are neglected, and that the current is assumed to be quasi-stationary. This means that inertial terms in the tidal motion are neglected, a point which must be considered with care in comparing model results with data.

The main differences between UNIBEST-TC and UNIBEST-LT are related to their application: TC is meant primarily for time-dependent cross-shore computations and LT for use in combination with a coast-line model. Since the process description in TC is the most advanced and since it computes cross-shore and longshore transport simultaneously, most simulations will be based on TC.

The state-of-the-art in coastal profile modelling is not such that absolute predictions can be made of the behaviour of a coast section. The model should rather be used as a diagnostic tool. It is a formalisation of our combined knowledge of cross-shore processes; it is capable of quantifying the relative importance of processes, and we can use it for a comparative analysis of the situation with or without for instance a nourishment.

Of course, the extent to which we rely on the outcome of such analyses depends on the model’s capability to describe the natural behaviour of the system. This includes the behaviour of sand banks, the longer-term tendency towards an equilibrium close to the existing state and the dynamic response to changes in conditions.

In the version of UNIBEST-TC used in the design phase, the model was quite far from representing a fair natural behaviour. This is not entirely surprising since the profiles at Terschelling are very much flatter than in most places elsewhere. Apparently, the conditions here radically differ from those, for instant, at the Holland coast.

In the summer of 1994, UNIBEST-TC underwent a substantial upgrading of a number of processes. The wave breaking and roller description have been improved; the sediment transport formulation by Ribberink and van Rijn (1994) has been implemented; the vertical profile of the cross-shore and longshore current has been reformulated. These formulations have been tested extensively against a set of large-scale laboratory data gathered within the framework of the EU Large Installations Plan (LIP 11 D) and MaST-G8M. The model has been applied in practice to provide estimates of the yearly-averaged longshore transport rates along the Holland coast. Here it was found that transport rates were predicted which were not in contradiction with the observed large-scale trends in the sediment budget.

In view of these changes, there are reasons for assuming that with this upgraded version we can calibrate the model against the prototype data in such a way as to provide a reasonable "base case" simulation.
The application of the model then comprises the following elements:

- calibration of the model; this includes a rough check on hydrodynamic parameters, but is focused on representing the natural morphological system;
- estimating the effect of the nourishment on the nearshore wave climate, longshore and cross-shore transport;
- establishing a "base case" simulation of cross-shore autonomous behaviour;
- estimating the dynamic behaviour of the profile with nourishment as compared to the simulated autonomous behaviour;
- comparison of simulated cross-shore behaviour with survey analyses;
- simulation of a (limited) number of alternative nourishment schemes in order to test the efficiency of the present scheme in terms of sand volumes.
- estimating the large-scale ("far-field") longshore migration of the nourishment;
- comparison of simulated longshore behaviour with survey analyses;
- critical evaluation of the assumptions and results.

Parallel with these activities, a thorough verification of all processes incorporated in UNIBEST-TC against the process measurements will be carried out.

5.3.2 Coastal area model

The coastal area model to be applied in this study is DELFT2D-MOR, a successor to the COMOR model. DELFT2D-MOR is a fully operational model based on the modules TRISULA (flow), HISWA (waves), TRANSP (bottom, suspended transport due to waves and current) and BOTTOM (morphological changes). The model has been tested for a number of situations in 2DH (depth-average\(\omega\)) mode. At present, a quasi-3D transport module based on the same formulations as in UNIBEST-TC is being tested.

The model can be employed for various applications:

- to provide a synoptic view of all processes involved, for a limited number of interesting cases. It can then be used as the link between individual measurements;
- to investigate local developments which are essentially 3D in character.
- to predict the development of the nourishment in the case that longshore and cross-shore mechanisms cannot be treated separately; in this case a full area model must be applied.

The actual use of the model should depend on the conclusions drawn from the profile model studies.

In order to generate accurate boundary conditions for this model, an accurate overall hydrodynamic model of the Dutch Wadden Sea is essential. Such a model, similar in detail to the KUINSTROOK model, is being built at RIKZ. This development should be strongly supported.
6 Plan

The activities discussed under Profile Models cover the subtasks 3.nl.2.2 and 3.nl.2.3 in the NOURTEC proposal. DH will carry out these subtasks. This part of the study will contain two phases:

- a calibration phase, where a rough check of predicted hydrodynamics will be carried out, and where the general morphological behaviour of the model will be calibrated against the existing situation. The objective of this study is to obtain a reasonable "base case" computation;
- the actual simulation phase, where the model will be applied in a diagnostic manner to understand the observed morphodynamic behaviour and to predict the various effects of the nourishment over a 10-year period.

The second phase is subject to a successful calibration of the model. The approach may have to be changed if this proves to be impossible.

In the analysis of survey data related to this modelling, RIKZ (Sharon Westlake) and DH will cooperate. The main part of this work will be carried out by RIKZ.

The verification of UNIBEST-TC against process data is not an objective of the NOURTEC programme. It will be carried out by R. Bakker at RIKZ, in close cooperation with K. Houwman at RUU, and under guidance of Dr. J.A. Roelvink. Data from the T2 campaign will be used. The UNIBEST-TC program is also available for further analysis of process data.

Execution of subtask 3.nl.2.4 (application of a coastal area model) will be specified after finishing previous subtasks. An accurate overall curvilinear Wadden Sea model to nest detail models is essential for success.
main office
Rotterdamseweg 185
p.o. box 177
2600 MH Delft
The Netherlands
telephone (31) 15 - 56 93 53
telefax (31) 15 - 61 96 74
telex 38176 hydel-nl

location 'De Voorst'
Voorsterweg 28, Marknesse
p.o. box 152
8300 AD Emmeloord
The Netherlands
telephone (31) 5274 - 29 22
telefax (31) 5274 - 35 73
telex 42290 hyvo-nl