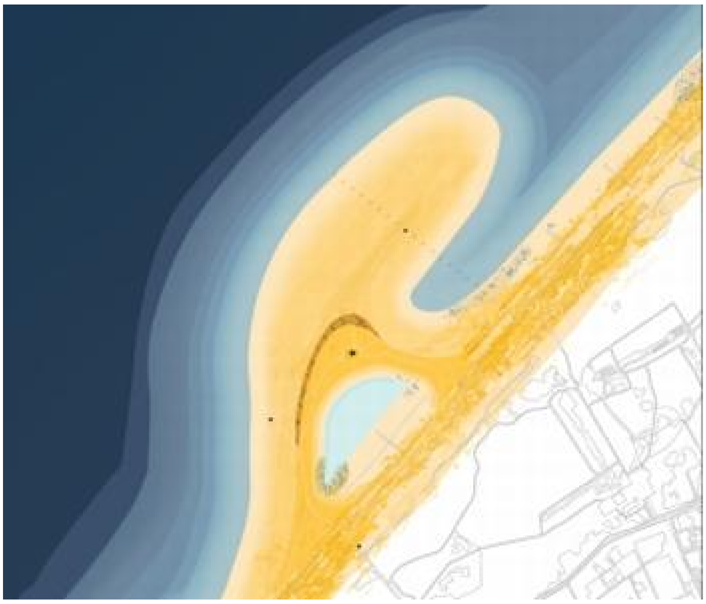
Plan of approach

Integrated model approach for the design of mega-nourishments



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12 Januari 2011

Titel
Plan of approach

Opdrachtgever
Ecoshape

Trefwoorden
Zandmotor, Societal perspective, Model train, Key parameters

Samenvatting
In September 2008 the committee Veerman presented their report, *Working together with water*. The report describes opportunities to change the political policy regarding integral coastal management. Their recommendations and conclusions on behalf of integral coastal management involved the applicability of large-scale nourishments to counter balance for sea level rise and provide coastal protection. The Zandmotor can be seen as a first step for large-scale nourishments to counter balance for sea level rise in combination with space for nature and recreation, from a societal perspective. Because of its uniqueness in integral coastal management the Zandmotor is carried out as a pilot project. If the government wants a project like the Zandmotor to succeed there has to be public support. To achieve this support, uncertainties in relation to swimming safety, siltation, groundwater, etc. need to be investigated. Therefore results from this thesis, like for most reports made so far concerning this project, need to be linked and translated to a societal perspective.

The meaning of this thesis is providing an integrated model approach, in order to improve the design approach for future large-scale nourishments. Focus of this thesis lies within the answering of questions, and to narrow or exclude uncertainties that have emerged from several stakeholders. One of the main goals of the project the Zandmotor is to gather knowledge of its development. The approach for providing integrated model tools can be done by coupling between several numerical models. Hereby advantages of several models can be combined.

Referenties
Ecoshape, Building with nature

Deltares

Titel
Plan of Approach

Opdrachtgever	**Pagina's**
Ecoshape	19

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Versie	Datum	Auteur	Paraaf	Review	Paraaf	Goedkeuring	Paraaf
1	Dec. 2010	T. Pekkeriet					

Contents

1 Introduction

In this work plan insight will be given into the working process of my master thesis regarding an integrated approach to the design of mega-nourishments.

1.1 Motive

1.1.1 Second Delta committee, Building with Nature

Figure 1.1 Overview project site

In September 2008 the committee Veerman presented their report, *Working together with water*. The report describes opportunities to change the political policy regarding integral coastal management. Their recommendations and conclusions involved the applicability of large-scale nourishments to counter balance for sea level rise and provide coastal protection in the future. The Zandmotor can be seen as a first step in large-scale nourishment to counter balance for sea level rise in combination with space for nature and recreation. Through natural forcing, redistribution of sand will provide a gradual build out of the adjacent coastline.

Building with Nature (from here BwN) is a five-year innovation and research program (2008-2012). It provides opportunities to construct by integrating nature in the design and development process. With new insights and knowledge, nature itself becomes the driving force behind the sustainable development of hydraulic engineering infrastructure. The EcoShape Foundation is lead partner in the BwN programme. The Zandmotor is part of the BwN program, enabling insight for long-term coastal management of the Dutch coast.

1.1.2 Zandmotor design

The Zandmotor is a pilot project, which will be carried out as a mega-nourishment near the coast of Delfland. The project site is visualized in figure 1.1.1, near Ter Heijde and Kijkduin. Execution will start in January 2011. In the design process multiple companies and institutes have carried out preliminary studies. Despite the various investigations for design, simulations, forecasts, environmental impact, etc. many uncertainties are still present or have recently come to the surface. For instance, substantial expected changes in groundwater, fresh water production and salt intrusion, swimming safety or siltation. These uncertainties all have relevant societal links with the environment.

1.1.3 Role of stakeholders in design process

To obtain societal support it is important that a project like de Zandmotor is connected to the surrounding and involves a wide range of stakeholders. Therefore besides coastal protection (safety against flooding), also nature and recreation are treated at the same level.

Stating the aspects; coastal protection, nature and recreation, an overview is necessary to have better understanding of the issues that are at hand and related to these aspects. This thesis will commence with an inventory of the daily discussion topics around this pilot project the Zandmotor. The daily discussion between multiple stakeholders will provide insight in questions and uncertainties, for which some are solved and others are still open. Many of the presently open topics from a variety of disciplines need attention, since they form a pressing matter to the involved stakeholders. Investigation will be done to these topics, and if possible some sort of priority list will be made for most urgent matters. For example the safety for swimming can be regarded from the discipline of recreation. From the discipline of coastal protection also erosion processes can be investigated to the down drift coast of the Zandmotor. These are only a few examples of a large list of topics, see paragraph 2.1.

1.1.4 Role and limitations of models (tools)

With an overview of the topics, we want to indicate and quantify these topics enabling further research. Therefore the topics are provided with indicators, e.g. for the topic; *safety against flooding* we have amongst others the indicator *dune area* (paragraph 2.1). Subsequently the indicators will be linked to the available tools that are at hand, for which output can be translated to these indicators. Before going to the tools (the numerical models), there has to be knowledge and understanding of the dominant physical processes that play a role for each indicator. Next, knowledge of the available numerical models is necessary to know their limitations and capabilities. Figure 1.2 provides application ranges on spatial and temporal scale of several tools that will be used. The application ranges are presented with the concerning scale of a mega-nourishment. The figure also provides some model specific indicators that can be handled.

The studies performed in the design process of the Zandmotor are partly based on simulations from numerical models like Delft3D and XBeach. These models are built for hydrodynamic and morphodynamic processes, specified for certain spatial and temporal scale. Forecasting the processes concerning a mega-nourishment requires simulations for the order of 20 to 50 years. Present tools are not able to cope with all processes that can occur in such a period; e.g. Delft3D cannot handle single storm events in a simulation of 20 years. Next to it, new tools have recently come available concerning the application of a vegetation and sand-mud module in Delft3D. Also to model and integrate Aeolian processes are under development. These new tools can play a substantial role in the design approach for future mega-nourishment projects.

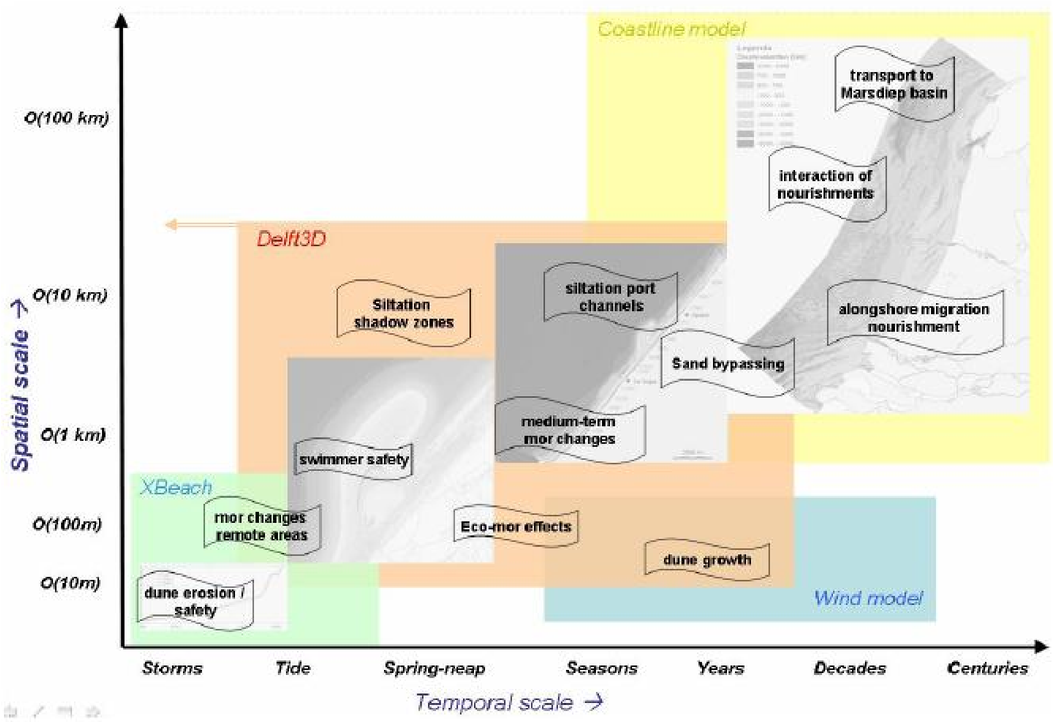


Figure 1.2 Numerical models with their application ranges

1.2 Objective

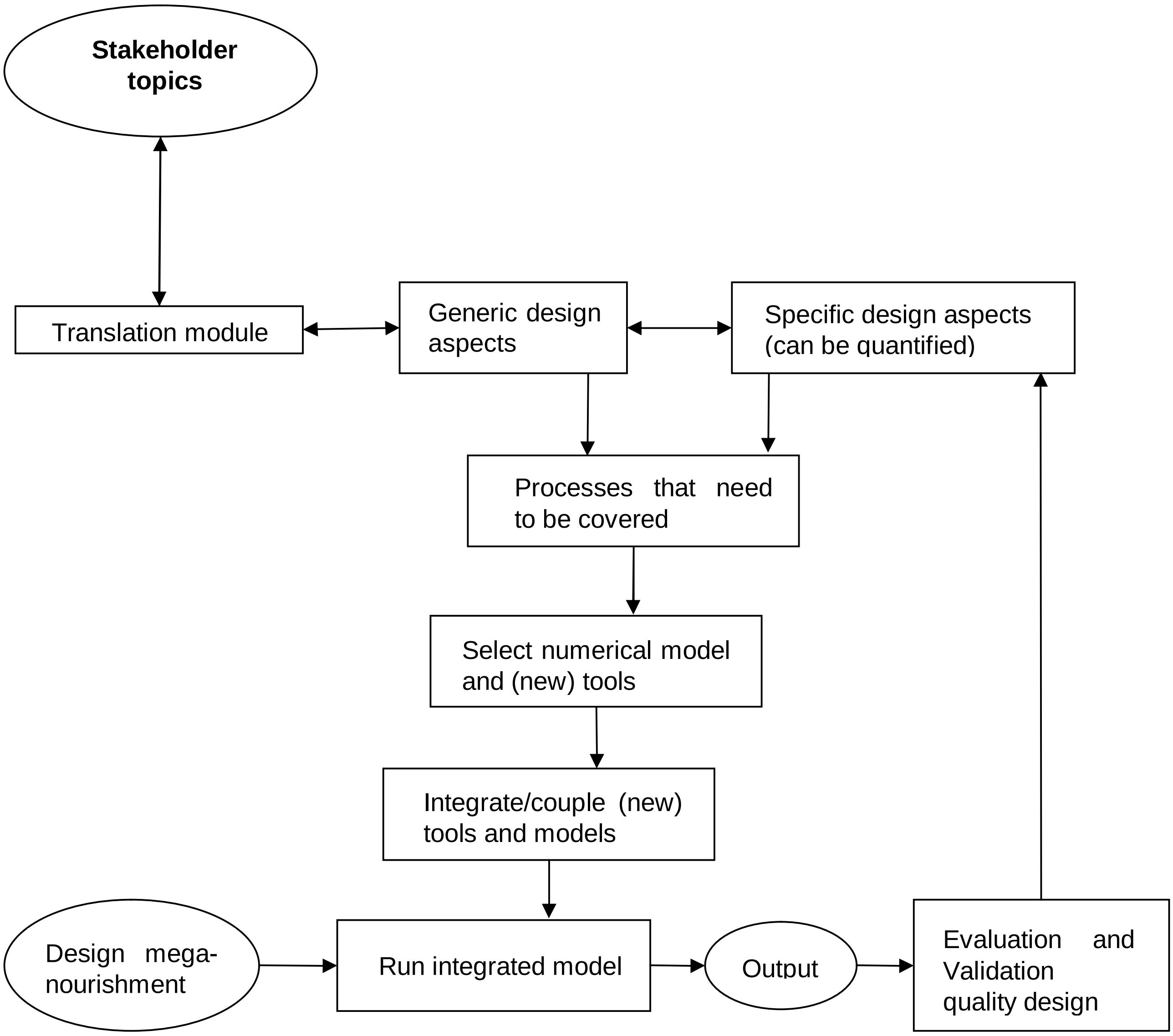
The goal of this thesis is to develop an integrated model approach for the design of mega-nourishments. This will be achieved by coupling and integrate numerical models and new tools, enabling interaction between multiple hydro- and morphodynamic processes on various spatial and temporal scales.

1.3 Reader

In this workplan, first an introduction to the study approach will be given in chapter 2, by providing an inventory of design aspects and describing which aspects are covered in present models. Then in paragraph 2.3 the concept of model integration will be explained. In paragraphs 2.3.1 to 2.3.6 multiple relevant processes will be discussed, concerning the development of a mega-nourishment. These processes are relevant since they are related to the open/uncertain design aspects. In paragraph 2.4 translation of model results to indicators will be discussed. This is followed by an outline of new insight from coupled models. Paragraph 2.6 deals with the explanation of some sensitivity analysis. Chapter 3 provides a long term planning of this thesis. Finally chapter 4 gives an indication of the report structure of this thesis.

2 Study approach

This chapter describes the main phases and work processes of this thesis. Starting with an inventory of the design aspects that are relevant for the design process of a mega-nourishment. In paragraph 2.2 a list is given, which design aspects are covered in present models for the Zandmotor. Next a concept for a model approach is presented for the integration of hyrdo- and morphodynamic processes to cover 'sensitive' design aspects regarding mega-nourishments. These processes are described in detail in paragraphs 2.3.1 to 2.3.6. Followed by a concept of translating model results back to indicators, providing insight for multiple stakeholders. Finally a proposal for evaluation and validation of integrated models and tools is provided in paragraphs 2.5 and 2.6. A global setup of connections between mega-nourishment design aspects is given below. These steps will return and can be recognized in next paragraphs.



2.1 Inventory design aspects

A list of generic and specific topics, concerning the Zandmotor and its area of influence. Five main topics are subdivided into indicators enabling a consistent and comprehensive evaluation during the design process of a mega-nourishment. The indicators provide a proficient tool to be able to quantify generic themes, such values can provide clarity but most of all model results can be translated on behalf of the main topic.
The main topics with their indicators, are worked out in detail, assigned with their unit, processes and order of scale. This list is inserted as appendix, an overview is given below.

Safety against flooding (Coastal protection)
- Coast migration, MKL volumes, beach width
- Erosion processes down drift coast
- Dune strength, dune area, dune development

Zandmotor development
- Migration, MKL volumes, beach width
- Shape, short and long term
  - Conservation, frequency maintenance nourishments
- Dune area (aeolian transports)
- Formations of dunes
- Effect due to storm conditions (XBeach)
  - Formations of scarps
  - Overwash
- Effects of near structures (harbor moles or approach channels)
- Effect of vegetation

Recreation
- Swimming safety (rip current, current velocities, eddies)
- Siltation accumulation, low energy areas

Ecology
- Dune-, intertidal- and subtidal area.
- Effect on groundwater and the groundwater level (Dunea, extraction fresh water bubble)
- Water quality
- Biodiversity, benthos and vegetation
- Sand mining (pits)

Technical realization
- Execution
- Dredging possibilities
- Nourishment design
- CO2 emission
- Cost/feasibility

2.2 Design aspects covered in present ZM and present models

By means of the indicators given in the previous paragraph, an overview will be presented. This overview states which design aspects are investigated (in green) in the Environmental Impact Assessment (EIA) for the present Zandmotor design, or have hardly been investigated (in red). Some design aspects have been treated only preliminary or are still uncertain and should be investigated in more detail (in orange), to provide more reliable insight of the impact of mega-nourishments. From stakeholders inventory it is clear that not all design aspects are sufficiently covered in the present Zandmotor design.

	Unit	*EIA*
Coastal protection, safety against flooding (sea level rise)		
Coast migration (BKL, Beach width, MKL volumes)	[m] [m3/m']	[green]
Erosion processes down drift coast (e.g. Born rif)	[m]	[orange]
Dune strength, dune area, dune development	[m2/m']	[orange]
Sand engine development		
Migration, MKL volumes, beach width	[m2]	[green]
Conservation, frequency nourishments	[1/T]	[orange]
Dune area (aeolian transports)	[m3/m']	[red]
Effect due to storm conditions (XBeach)	-	[orange]
Formations of scarps	[m3/m']	[orange]
Overwash	[m3/m']	[orange]
Effects on near structures (harbor moles or approach channels)	[kg/s]	[orange]
Effect of vegetation	[kg/m2]	[red]
Recreation		
Swimming safety (rips, currents, eddies)	[m/s]	[orange]
Siltation accumulation	[kg/s]	[red]
Ecology		
Dune-, intertidal- and subtidal area	[m2/m']	[orange]
Changes in groundwater and fresh water extraction (Dunea)	[m/s] [m3/s]	[red]
Water quality (Salt intrusion)	[kg/m3]	[red]
Biodiversity, benthos and vegetation	[kg/m2]	[orange]
Sand mining (pits)	[kg/s]	[red]
Technical realization		
Execution	[m3/s]	[orange]
Dredging possibilities	-	[orange]
Nourishment design	[m2/m']	[orange]
CO2 emission	[kg/m3]	[orange]
Cost/feasibility	[Euro/m3]	[green]

2.3 Model integration

Providing an integrated model for the design of mega-nourishments can be achieved through coupling several numerical models. Coupling these software packages, characteristic features of each numerical model can be used. This will enable interaction between multiple morpho- and hydrodynamic processes. The new integrated models, are expected to provide new insight of these processes between multiple temporal and spatial scales.

Model coupling will lead to a so called model train, given the second and third picture in figure 2.1. The simulation that already has been generated in Delft3D during the design phase of the Zandmotor project is shown in the first picture. In this research it serves as a reference case.

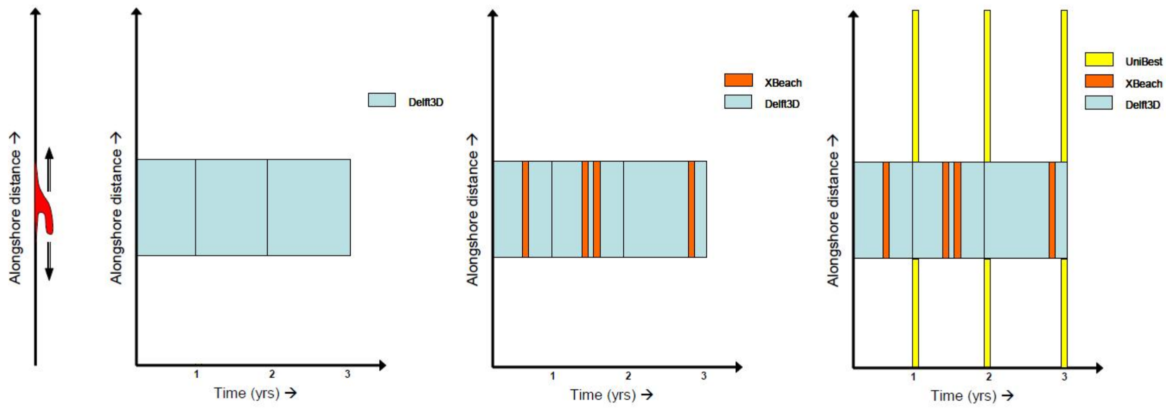


Figure 2.1 Coupling of several models in time and space

A visualisation of several model trains is provided in the figure 2.1. In this figure also the numerical models UniBest and XBeach are presented and are coupled with Delft3D. UniBest is a tool to model longshore sediment transports and morphodynamics of coastlines. XBeach is a process-based (2DH)model that can simulate cross-shore profile changes, associated dune erosion and long shore sediment transport on a time scale of storms up to months [Roelvink et al., 2008]. Delft3D is a 2D/3D modeling tool to investigate hydrodynamics, sediment transport and morphology and water quality for fluvial, estuarine and coastal environments.
The figure on the right can be seen as a model train providing interaction of three numerical models. UniBest can handle large temporal and spatial scale morphological processes, so by coupling the three it can provide insight for a larger domain Delft3D or XBeach is capable of.

In this thesis the processes; storm events, vegetation, siltation, aeolian transports, the impact of adjacent coastlines and hydrology will be addressed. These processes have emerged from the daily discussion of multiple stakeholders and from recommendations topics of previous studies. Each topic will be described by the following structure; objective, hypothesis, model, approach and status. Considering the scope of this thesis, the concept is making multiple model trains to integrate these topics with existing simulations. Given the time scale of this thesis, probably not all topics can be investigated thoroughly. Throughout this thesis choices have to be made for investigation of the mentioned processes, based on priority and opportunity. During the thesis it can be, that one topic is desired to be investigated more thoroughly.
If there is an opportunity to make a relation with other processes as mentioned above, this will be taken into consideration. When one is working with the model train, XBeach and Delft3D,

to provide more insight into the impact of storm events and observes a relation with e.g. siltation, working process can be combined to cope with both issues.

During this investigation, there need to be continuously checking if the model results are plausible. The plausability can be checked in literature, with useful rules of thumb and of course with common sense. In the same line of thinking processes and outcomes have to be in connection with expert judgement.

2.3.1 Storm events

Goal
Build an integrated model tool to provide more insight into the impact of storm events. The interaction between extreme hydrodynamic forcing and long-term morphodynamic processes.

Figure 2.2 Storm nov. 2007 near Delfland coast

Hypothesis
The long term morphological development and migration of the Zandmotor with the adjacent coastline has been investigated by means of a simulation with Delft3D. In this 20 year simulation average hydrodynamic conditions have been implemented. Using averaged conditions, the impact of large storm events has not been included in the simulation. Therefore generated model results can be questionable. The absence of (extreme) storms in the present simulation with Delft3D is an uncertainty for the morphodynamic processes of the Zandmotor. To have insight into the impact of storm events, a study [Van Thiel de Vries et al., 2009] is carried out. This study looked for the consequences of a single storm. Mentioned research shows storm conditions can have substantial impact on the coastal system and especially in a situation like the Zandmotor, that will bring the local equilibrium of balance.

Model description (XBeach)
Storm events will be generated with XBeach because of its ability and capacity for hydro-dynamic storm forcing. It is a process-based (2DH)model that can simulate cross-shore profile changes, associated dune erosion and long shore sediment transport on a time scale of storms up to months [Roelvink et al., 2008]. It is mainly used for computations concerning dune erosion and overwash of dunes. XBeach includes a wave model that is coupled to a flow model. These models compute the propagation of short and long (infragravity) waves, as well as the interaction between the short and the long waves, which is essential for dune erosion.

Approach
The present approach is to substitute generated model results from storm events simulated with XBeach back into the morphological model of Delft3D and vice versa. For example; a period of five years can be simulated with Delft3D, the bathymetry of the Zandmotor after this 5 years can be implemented in XBeach for the simulation of a storm event and after this event the new bathymetry can be implemented back in Delft3D to continue long term simulation. Hence a model train is made, in which storm events are included in a long term morphological assessment (up to 20 years). Research will be performed, looking into the

features of storm events from the perspective of the Zandmotor (length and time scale, bathymetry, etc.). Namely which storm events can occur, their impact and which parameters they have. In addition, a sensitivity analysis can be made that provides insight in the effect and impact of various storm events. One can simulate various storms, in changing the characteristics like frequency, period, magnitude etc. in order to see changes in impact. Research will be carried out for several storm conditions.

Status & planning

A preliminary study into storm events has been done [Van Thiel de Vries et al., 2009]. This study looked for the consequences of a single storm event, and was generated for the initial stage of the Zandmotor. The points discussed in the approach for the topic storm events are scheduled to work on in January and February ; a global overview is given in chapter 3.

2.3.2 Vegetation and benthos (Delft3D-module: delwaq)

Goal

Understanding the impact of vegetation on mega-nourishments, due to implementing a model module that can handle vegetation characteristics. Especially the vegetation hot spots; low energy wet areas and interaction with aeolian transports over the dry beach are of importance.

Hypothesis

Regarding the zandmotor without future nourishment for shape retention and when it is completely at the mercy of nature. Then no substantial effects from vegetation are expected for the long time scale, over 50 years. Because the Zandmotor is expected to be spread out around that time, and the coastline will be uniform and 'smooth' again. See the following figure for visualization [Ye, personal communication].

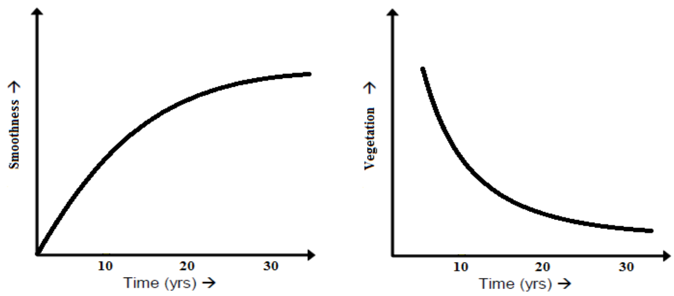


Figure 2.3 Smoothness vs vegetation curve

Substantial effects from vegetation are expected, for the shorter time scale, within the first 10 years. This is because the initial shape of the Zandmotor, during the short term, is still intact. Normally at the uniform Dutch coast no vegetation is present in the foreshore, because of the large hydrodynamic forcing in the foreshore. But in the case of the Zandmotor, the lee side low energy area can provide an area suitable for vegetation to grow or be planted artificially. Keeping the sand in its place, forming a relative hard coastal 'structure' with respect to the down- and up drift coastline. This stabilized part of the Zandmotor, can have significant impact on the forecasts that have been simulated with Delft3D. In this reference case no effect of vegetation is included.
Vegetation plays an important role in the roughness or chezy factor near the profile of the bottom. It can hamper the flow for which sedimentation can occur, but it can also give an increase in turbulence. The balance between these two parameters can determine the state, either erosion or accretion of the bottom bathymetry. Water quality determined by the

concentration of oxygen, nitrate, etc. important for the growth of vegetation, benthos and fish. Water quality will be an issue for the dune lake at the Zandmotor and for the low energy area at the north side of the hooked shape. Vegetation can be an indicator to determine the water quality.

Model description (Delft3D-module: delwaq)

Recently a software implementation is made for Delft3D in which vegetation can be included, and in which multiple vegetation parameters and species can be chosen. Each with their own features regarding growth, interaction, density, etc. Coupling between the delwaq-module and the WAVE and FLOW modeling is possible in Delft3D.

Approach

Effect of vegetation can be taken into account as a module in one of the model trains. Investigation will be done, which vegetation will be used in the module for the wet and dry areas. A simulation will be generated including vegetation, also the interaction with aeolian transports can be investigated.

Status & planning

Simulating a model train with a vegetation application is scheduled for March.

Figure 2.4 Possible ecological zones at the Zandmotor .

2.3.3 Siltation (sand-mud module in Delft3D)

Goal

Understanding the processes concerning silt accumulation, by means of an integrated model using a sand-mud module in Delft3D.

Hypothesis

It is expected that mega-nourishments like the Zandmotor may result in accumulation of fine sediments at the leeward side of the nourishment. As a result of this, a new ecological zone may develop along the coast. The mud content of the bed is an important parameter for the bottom quality, because nutrients and pollutants tend to adhere to, or be part of, cohesive sediments [Wang, 1996]. The accumulation of fine sediments is especially expected to appear in summer seasons, when hydrodynamics are calm. None desirable events can occur during these seasons with respect to recreation and to the smell in such siltation areas.

Model description (sand-mud module in Delft3D)
In the existing process-based sand [van Rijn, 1993] and mud models [Teisson, 1997], a representative grain size is often used for determining sediment transport rates, and mud content variations in time and space are not taken into account. Moreover, morphological models only exist for non-cohesive sediments. Recently, a morphological model, in which the bed level and bed composition depend on sand as well as mud, was proposed [van Ledden & Wang, 2000].

Approach
To investigate fines to accumulate near the Zandmotor there are two approaches possible. Either to look which waves and currents are present near the Zandmotor and if the order of magnitude is low enough for fines to accumulate. The other possibility is to investigate the conditions for which fines stays in suspension. If the magnitude of the waves and currents in a specific situation is known, conclusions can be drawn if silt stays in suspension or will accumulate. If there are a lot of and frequently incoming waves near the lee side it can provide enough stir up in the low energy area that this will not result in silt and/or mud areas to develop.

Status & planning
Whether it is likely to get siltation surrounding mega-nourishments, and when and where this will happen, is not yet thoroughly investigated. It is scheduled to work on this topic and integrate it as a module to a model train in April.

2.3.4 Aeolian transport (xDune)

Goal
Within Deltares there is still a knowledge gap with respect to wind driven sediment transport in a coastal system. Presently aeolian sediment transport models are usually developed for areas like deserts. Therefore the objective of this topic is to design an integrated tool providing an interaction between aeolian and morphodynamic processes.

Figure 2.5 Texel, de Hors

Hypothesis
Aeolian processes will probably have substantial impact on the morphodynamic processes of a mega-nourishment. All existing numerical models describe morphodynamic processes below the water surface. But the processes that happen above the water surface are poorly simulated. Rules of thumb estimate an annual aeolian transport along the Delfland coast of 30m3/m' on average. Regarding the Zandmotor project (2x1,5km), it is of great importance to have understanding in the interaction between the lower and upper (wet-dry) part of the Zandmotor.

Model description (xDune)
One of the aeolian sediment transport models (called "Dune" of "xDune") is the model of Sauerman & Herrman, 2002. This model claims to be a minimal model for aeolian sand dunes. It combines an analytical description of the turbulent wind velocity field above the dune with a continuum saltation model that allows for saturation transients in the sand flux.

Approach
In the same period of this thesis, another thesis will be initiated to analyze the effect of aeolian transport. Investigation will be done for the xDune model to identify which hypotheses and calculation methods are used. The xDune model is not a product of the TU Delft or Deltares, there is no prior experience with this program so the content and the structure have to be examined in order to use the model properly. The next step is to set up the model for the case of the Zandmotor, this includes generating input like the bathymetry but more importantly is to determine the wind conditions an speeds that drive the calculation. The final step is to incorporate the model into a model train consisting of several software packages like Delft3D, XBeach and Unibest.

Status & planning
The present status is making sure the numerical xDune simulation has a solid (physical) foundation, factors that determine the sediment flux will be studied. This will be done in an extensive study of literature. The result will be an overview of physical parameters and there relative influence on the sediment transport model. Following steps are described in the approach of this topic. The coupling of a wind module with a model train is scheduled to begin with in April and May.

2.3.5 Adjacent coastlines (UniBest)

Goal
Understanding the impact of mega nourishments on larger spatial and temporal scales. Creating such a model train upon which Unibest can interact with Delft3D and XBeach.

Hypothesis
If the Zandmotor pilot project will result in a good alternative for present nourishment policy, it is possible more mega-nourishments will be implemented in future coastal management. To cope with this coastal management we have to look at a large temporal and spatial scale. To anticipate this option preliminary research can be executed with interaction of Unibest.

Model description (UniBest)
UniBest-CL+ is a tool to model longshore sediment transports and morphodynamics of coastlines. UniBest-CL+ is a sediment balance model with which longshore transports computed at specific locations along the coast can be translated to shoreline migration. If required the effect of cross-shore phenomena can be included by importing the results of the UniBest modules UNIBEST-TC and UNIBEST-DE.

Approach
In figure 2.3.1 the numerical model UniBest is presented and linked with XBeach and Delft3D. It is planned that a workable model train containing XBeach and Delft3D is operationable before starting with an integration including UniBest. The approach is creating a workable model train, providing interaction of the three. UniBest can handle large temporal and spatial scale processes, so by coupling the three it can provide insight for a large domain.

Status & planning
Currently some research is executed for the impact of mega-nourishments on larger temporal and spatial scale. But the approach to look at it with an integrated model is a new concept. This topic is scheduled for June.

2.3.6 Hydrology (Modflow)

Goal
Set up a model enabling insight in the interaction of onshore groundwater near a mega nourishment concerning a peninsula.
Hypothesis
In December 2008 coastal strengthening started along the Delfland coast. A new seaward dune ridge was constructed along the resorts Ter Heijde and Kijkduin. Near these areas problems occurred regarding the ground water levels. This resulted in some minor flooding of nearby dwellings. The area between Ter Heijde and Kijkduin still had to be reinforced. This area is called Solleveld and contains a freshwater extraction site. The occurred events leaded to a different execution approach to counter problems with groundwater levels and salt intrusion. The Zandmotor is expected to give similar problems on short term, on long time scale mega-nourishments can enhance fresh water extraction. This can be visualized from the idea that mega-nourishment give rise to the dune area and hence the fresh water ‘bubble’.

Model description (Modflow)
Modflow is a three-dimensional finite-difference groundwater flow model. It is used to simulate systems for water supply, containment remediation and mine dewatering. Modflow is a modular finite-difference flow model, which is a computer code that solves the groundwater flow equation. The program is used by hydrogeologists to simulate the flow of groundwater through aquifers.

Approach
Starting with research to the changes in groundwater levels and salt intrusion near a mega-nourishment or peninsula. Set up a model that can handle these changes and provides insight of the impact on fresh water extraction sites.

Status & planning
This topic is under investigation from the moment they encountered these problems during the coastal strengthening. From perspective of mega-nourishments it is therefore a not yet fully understood topic. This topic is scheduled for July.

2.4 Translation model outcome to indicators

If the government wants a project like the Zandmotor to succeed there has to be public support. To achieve this support, uncertainties in relation to swimming safety, siltation or groundwater, as subscribed in paragraph 2.1, need to be investigated. Therefore results from this thesis, like for most reports made so far concerning this project, need to be linked and translated to a societal perspective. This translation is necessary in order to prevent that a technical study will be delivered which cannot be implemented for practical use. A technical study with a societal perspective can for instance lead to measures that will limit public resistance or to provide insight for monitoring plans and/or forecasts upon better decisions can be made overall.

When a certain amount of themes are treated by means of several model trains a sensitivity analysis can be made. The simulation generated with Delft3D, can be used as a reference case in this sensitivity analysis. Furthermore outcomes from the several model trains can also be compared bilateral. The comparison can concern the end results, after a 20 year period, as well temporary model results. The sensitivity analysis is expected to provide more insight into short and long term morphological processes. Results from this sensitivity analysis can provide recommendations for future large-scale nourishments.

In order to provide these recommendations a translation has to be made. A translation regarding the step from model output to understandable recommendations for the involved stakeholders. In the master Thesis from F. Achete a number of translation methods will be developed, see paragraph 3.1 for an overview.

2.5 Evaluation of coupled model simulations

When an integrated model train is operationally, simulations can be generated. Subsequently analysis can be made over the newly generated outcomes. These analyses will provide new insight in the coupled models and their features. In chapter 3 a long term planning of this thesis is presented that provide a link with the separately topics and a period of evaluation, in which new insight can be analyzed. The topics from paragraph 2.3.1 to 2.3.6 are described below, giving their new expected insight with respect to the indicators mentioned in paragraph 2.1.

Effect of storms on long-term morphology.
Indicators
- Coast migration (BKL, Beach width, MKL volumes)
- Erosion processes down drift coast (e.g. Born rif)
- Dune strength, dune area, dune development
  - Formations of scarps
  - Overwash

Effect of Vegetation on short- and long-term morphology.
Indicators
- Biodiversity, benthos and vegetation
- Dune strength, dune area, dune development
- Coast migration (BKL, Beach width, MKL volumes)

Effect of siltation near a mega-nourishment.
Indicators
- Dune-, intertidal- and subtidal area (fine sediments)
- Biodiversity, benthos and vegetation

Effect of aeolian transport on long-term morphology.
Indicators
- Dune strength, dune area, dune development
  - Formations of scarps
  - Overwash
- Coast migration (BKL, Beach width, MKL volumes)
- Erosion processes down drift coast (e.g. Born rif)

Interaction of adjacent coastlines and mega-nourishments.
Indicators
- Coast migration (BKL, Beach width, MKL volumes)
- Erosion processes
- Dune strength, dune area, dune development

Impact of a mega-nourishment on Hydrologie.
Indicators
- Water quality (Salt intrusion)
- Effect on groundwater and the groundwater level (Dunea, extraction fresh water bubble)

2.6 Validation

2.6.1 IJmuiden

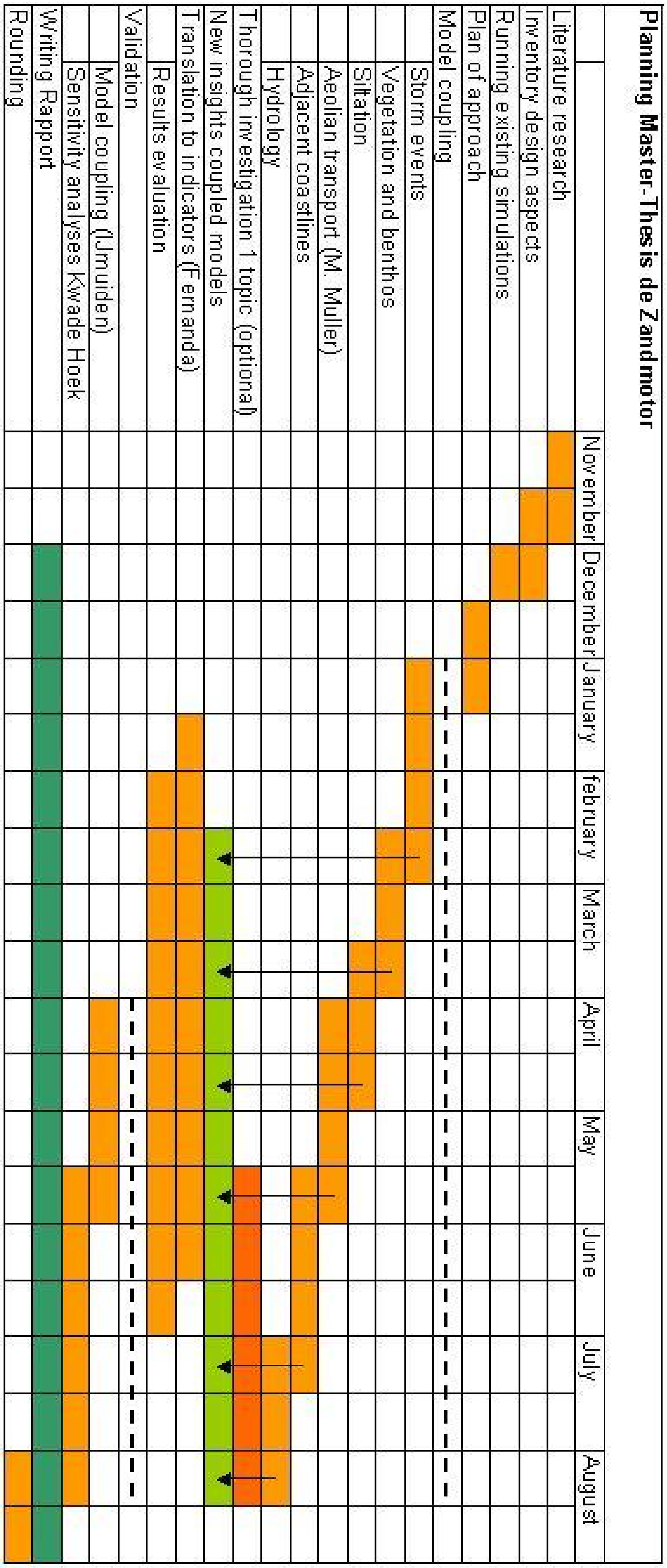
When an integrated coupling between numerical models is operational, the competence of the interaction between the numerical models can be validated. To examine the technique of the coupling which can be established in a similar case concerning IJmuiden. This will not be part of this thesis, but can be carried out under another project.

2.6.2 Kwade Hoek / Born rif

For (Dutch) coastal management the model trains can provide a new integrated design tool. Logical will be the question for its forecasting capabilities. Therefore a next step is possible by creating a predictability analysis. In this analysis, outcomes of the different model trains can be validated with a similar existing case. Look-alikes are for instance the Born rif situation near Ameland or the Kwade hoek case near Goerree. With a validation analysis the state of accuracy can be determined for the new integrated model trains.

3 Organization and planning

3.1 Long term view



4 Report structure

In this chapter an overview of contents is given, but the final version may deviate from this.

1. INTRODUCTION (Project motive and objective)

2. CHARACTERISTICS OF THE HOLLAND COAST

3. Daily discussion Zandmotor
   - 3.1. Stakeholders
   - 3.2. Development Zandmotor in combination with coastal protection
   - 3.3. Recreation
   - 3.4. Nature, ecology
   - 3.5. Technical realization

4. Numerical models
   - 4.1. DELFT3D MODEL
   - 4.2. XBeach model
   - 4.3. UniBest model

5. Model coupling
   - 5.1. MODEL TRAIN
   - 5.2. Overview model settings
   - 5.3. Overview addresed topics

6. Evaluation MODEL TRAINS

7. Sensitivity analysis MODEL TRAINS
   - 7.1. Validation morphology
   - 7.2. Sensitivity analysis hydrodynamics

5 References

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