Building with Nature

EcoShape

Adaptive Monitoring Strategies in dredging;

Historic Case Study Maasvlakte 2 – a review of the monitoring plan with focus on adaptive strategies

EcoShape – Building with Nature

Project:	Adaptive monitoring strategies 2
Report title:	Historic Case Study Maasvlakte 2 – a review of the monitoring plan with focus on adaptive strategies
Report number	C062/11
Authors:	Jacqueline Tamis (IMARES) Martin Baptist (IMARES)
Project manager:	Martin Baptist (IMARES)
Date:	May 27, 2011
Version:	1

IMARES is:

- an independent, objective and authoritative institute that provides knowledge necessary for an integrated sustainable protection, exploitation and spatial use of the sea and coastal zones;
- an institute that provides knowledge necessary for an integrated sustainable protection, exploitation and spatial use of the sea and coastal zones;
- a key, proactive player in national and international marine networks (including ICES and EFARO).

P.O. Box 68
1970 AB IJmuiden
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 26
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 77
4400 AB Yerseke
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 59
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 57
1780 AB Den Helder
Phone: +31 (0)317 48 09 00
Fax: +31 (0)223 63 06 87
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 167
1790 AD Den Burg Texel
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 62
E-Mail: imares@wur.nl
www.imares.wur.nl

Contents

1 Introduction

1.1 Problem definition

Climate change and its consequences like sea level rise and increasing storm frequencies in combination with the growing demand for space will lead to an increased demand for marine and coastal construction schemes in the world. In most cases, marine sand extraction is required. Sand extraction causes disturbances of the seabed (Dankers 2002; Erftemeijer and Lewis 2006).

The extractions often lead to acute removal of floral and faunal assemblages at the borrow site, smothering and burial of organisms in the vicinity (benthos, seagrass, corals), and may alter the sediment characteristics at the location itself, in its vicinity or even in areas further away. Significant changes in seabed morphology may in turn modify the ruling hydrodynamical regimes that govern the transport of chemicals, fine organic material as well as biota including (shell)-fish larvae. During large scale extractions, due to overflow and resuspension, increased suspended sediment concentrations may f notably affect the timing and magnitude of algal growth and consequently shellfish, fish and birds that depend on it (Boyd et al. 2005; Boyd et al. 2003; Phua et al. 2004; Van Dalfsen et al. 2000). The overall effect on the environment will be time and space dependent and relates to the ecological functions of the areas affected.
To protect the environment, specific design rules and norms are laid down for dredging works. From practice, these norms are experienced by the contractors as defensive, strict and limiting project execution. Moreover, in many cases design rules and norms lack a scientific basis. This project, 'Adaptive Monitoring Strategies (AMS) 2', seeks a more flexible way of working with norms, based on scientifically sound knowledge on sensitivity and resilience of ecological receivers. In this project we study monitoring strategies and techniques with an application on sand extraction. The focus is on the adaptive execution cycle of infrastructural works. The basic strength of the adaptive cycle is that the execution of work can be adjusted and / or management actions can be taken during operation in order to reach environmental goals. In this cycle, monitoring of key performance indicators (Langenberg and Troost 2008) is essential, but foremost a sound definition of relevant monitoring parameters on various temporal and spatial scales needs to be given.

The practical application to which this project will lead is a practice or protocol that organises and co-ordinates mitigation, rehabilitation and monitoring measures. This protocol will guide the implementation of a dredging operation and its ongoing maintenance after implementation. The protocol is based on principals, values, standards, or rules of behaviour that guide the decisions, procedures and systems of a (dredging) organization in a way that (a) contributes to the welfare of its key stakeholders and their environments, and (b) respects the rights and wellbeing of all constituents affected by its operations.

1.2 Adaptive Monitoring Strategies (AMS) 2 program

The ambition of the Building with Nature program is to design a science-based, tailor-made control and surveillance process that will allow the adaptive and cost effective management of dredging operations.

The key objectives of the AMS2 program are:

1. To establish sound and scientifically justified monitoring objectives and strategies;
2. To identify key performance indicators for guarding the environmental quality of the marine environment in a number of selected habitats around the world;
3. To construct protocols that allow the evaluation and review of in situ information for quick readjustment of operations (promote cost-effectiveness);
4. To generate guideline documents and operational rules for the implementation of a tailor-made surveillance process that will allow an adaptive and controlled execution of marine sand extraction.

1.3 Historic case study

Various examples of possible adaptive monitoring schemes used in dredging were identified during the kick-off meeting of the AMS2 project: Öresund; Hong-Kong; Singapore; Melbourne; and Maasvlakte 2. The first three cases are various examples of adaptive strategies. The Melbourne case and Maasvlakte 2 case were selected to serve as hind cast example, i.e. how could adaptive execution have helped? This report describes the Maasvlakte 2 case study.

1.4 Readers guide

First, the Maasvlakte 2 monitoring scheme (Chapter 2) and the implemented adaptive strategies (Chapter 3) are described. In Chapter 4, the Frame of Reference, a tool in support of decision making as well as a target for specialist improvement, is applied to the monitoring scheme of the Maasvlakte 2. This aims to identify the information that could lead to improvement of the monitoring program. Conclusions are presented in Chapter 5.

2 Monitoring Maasvlakte 2

2.1 Introduction

The Maasvlakte 2 (MV2) is a new location for port activities and industry to be created in the North Sea, directly to the west of the current port of Rotterdam and the surrounding industrial area. The required sand will be taken from carefully selected locations at sea, but will also become available when the port itself is deepened. During the 1st phase construction (2013) 240 million m^3 sand is required. The maximum total quantity of sand required (2033) is 365 million m^3 (Projectorganisatie Maasvlakte 2 2009). Most of the sand that is required for the land reclamation will be extracted from the North Sea (Figure 1) at more than 10 kilometers from the coast, 2 kilometers in western direction from the NAP-20 depth contour (van Zanten et al. 2008).

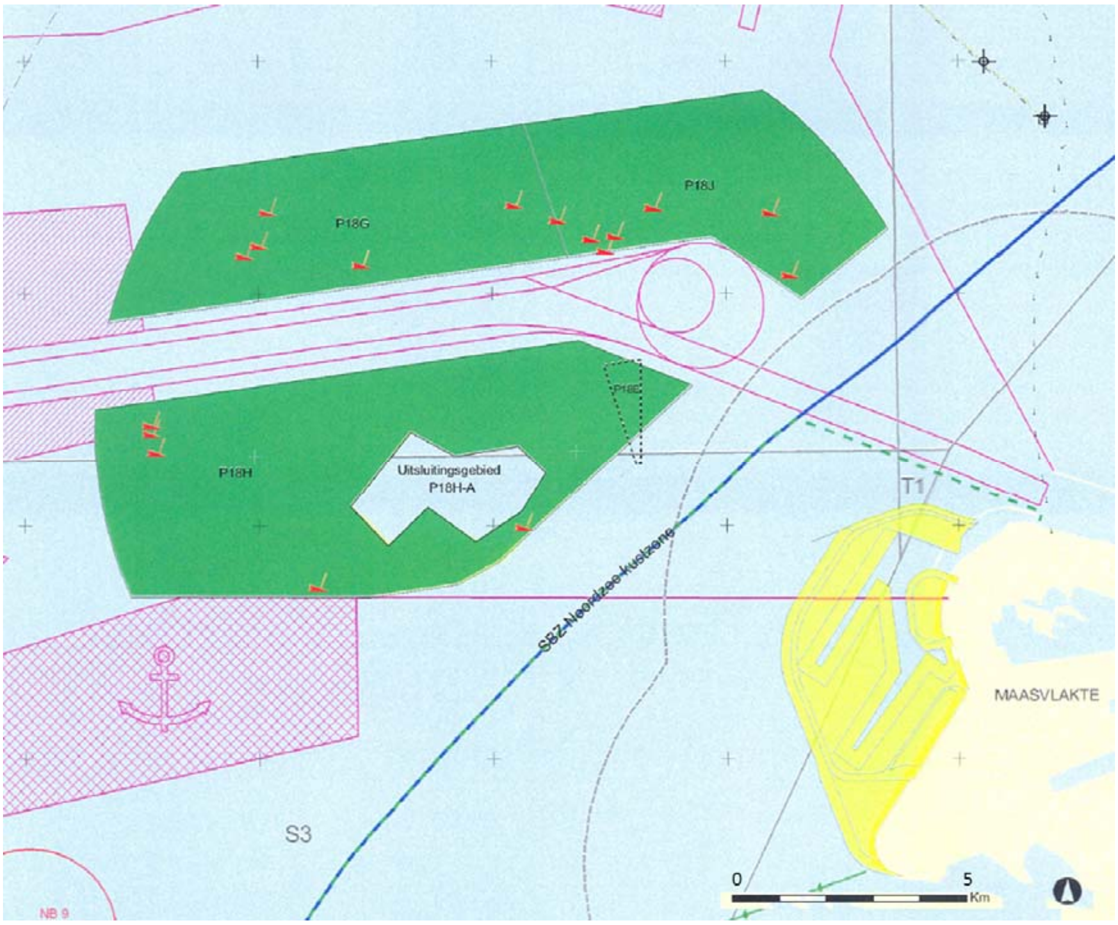

Figure 1 Location of Maasvlakte 2, showing the area for sand extraction in green. Adapted from (Ministerie van Verkeer en Waterstaat 2008).

The land reclamation will cover around 2000 hectares in total. Half of this will consist of infrastructure area, such as sea defences, fairways, railways, roads and port basins. The other 1000 hectares will provide the space for industrial sites (Projectorganisatie Maasvlakte 2 2009).

Two permits are required for the sand extraction: a permit for the construction and presence of the Maasvlakte 2, including the required sand extraction under the Nature conservation law (Ministerie van LNV 2008); and a permit for the extraction of sand under the Mineral Extraction law (Ministerie van Verkeer en Waterstaat 2008). The project is permitted under conditions, among which a monitoring plan is required. The permit requirements, monitoring plan, monitoring execution and - evaluation are described in the following sections.

2.2 Permit conditions

Under authority of the Ministry of EAI [1] (Ministry of Economic Affairs, Agriculture and Innovation)

The permit conditions under the Nature conservation law ('Nb-wetvergunning') include the following monitoring requirements (see for all requirements the MEP (van Zanten et al. 2008)):

A monitoring plan should be submitted for approval to the relevant authorities (i.e. Ministry of EAI), at least 8 weeks before start of the project. The monitoring plan should include a description of all relevant factors to be monitored. A minimum set of parameters is required. The permit allows motivated deviation of these requirements. Annual reporting and, if needed on the basis of the results, ad-hoc reporting is required. If necessary, the monitoring plan should be adapted, but only with approval by the Ministry of EAI. If, 5 years after ending the project, the monitoring results show no effects, the monitoring requirements can be withdrawn or adapted.

Under authority of the Ministry of Infrastructure and the Environment[2]

The permit conditions under the Mineral Extraction Law ('Ontgrondingenwet') require a monitoring plan in which the following is described (Ministerie van Verkeer en Waterstaat):

- Bathymetry: during active extraction depth measurements of the site and surroundings, at least once a month with a horizontal resolution of at least 2 meter and a vertical resolution of at least 30 cm. After extraction depth measurements of the site and surroundings the first five years after ending the extraction each year and thereafter once each five years until no change is observed, with a horizontal resolution of at least 2 meter and a vertical resolution of at least 30 cm.
- Volume extracted material (m3) and weight, an overview of extraction routes and location and time of the extracted material (monthly basis).
- Granulometric analyses
- Determination of the material, the grain size and the mud content of the seabed within and near the extraction sites through boxcore sampling.
    - During active extraction: sampling is required twice a year near the extraction site;
    - After extraction: sampling is required within and near the extraction sites, once a year during five years.
    - Five years after extraction has ended, sampling frequency can be reduced to once each five years, until no more changes are observed.
- Total Suspended Matter (TSM) in the water column: the concentration of TSM in the water column should be sampled in a frequent and adequate way within the extraction site and the affected area by measuring those TSM

---

[1] The Ministry of Agriculture, Nature and Food Quality (Ministerie van Landbouw, Natuurbeheer en Voedselkwaliteit; LNV) was formerly the ministry of agriculture of the Netherlands. On 14 October 2010, when the Rutte cabinet took office, the department was merged with the Dutch Ministry of Economic Affairs to form the new Ministry of Economic Affairs, Agriculture and Innovation (EAI).

[2] The Ministry of Transport, Public Works and Water Management is now part of the new Ministry of Infrastructure and the Environment.

contents in minimum 3 representative measure verticals outside the active extraction site in representative cross sections in the coastal zone, minimum one vertical measurement each 2 weeks, supplemented by analyses of satellite images for following the variation of TSM contents in the spatial scale.

- Benthos: Determining the species distribution and the biomass of the benthos. A representative sample within and near the site and within the reference areas is required. At least 300 'sleep'- and boxcore samples within the affected area and the reference sites (Petten to Vlissingen) are required previous to extraction. During and after extraction, yearly sampling is required until at least 5 years after extraction has ended. Five years after ending the extraction, and when no further changes compared to the reference sites are observed, monitoring is no longer required.
- Effects of underwater noise on sea mammals: Measurements of noise.
- Determination of possible changes in spring bloom of primary production.

2.3 Monitoring plan

For the entire life span of the Mainport Rotterdam, extensive Monitoring and Evaluation plans (MEP) have been set up, such as the MEP sand extraction and MEP land reclamation. Their goal is twofold: first is verification how do the actual effects relate to the expected scenario's and second is gathering data for filling the gaps in knowledge. Every five years, the monitoring plans are evaluated. If needed, the management plans will be adjusted (Projectorganisatie Maasvlakte 2 2009). As the scope of BwN AMS-2 is marine sand mining, this historic case description of the Maasvlakte 2 focuses on the MEP sand extraction.

Most important effects of the large scale sand extraction on the North Sea are thought to be the destruction of benthos followed by the recovery of the seafloor and benthos at the extraction sites and direct surroundings. Furthermore, potential effects of the increased turbidity (i.e. concentration suspended matter (TSM)) on the natural processes within the food chain and on the abundance of shellfish and birds are expected. The MEP sand extraction is conducted by the Project organization Maasvlakte 2 (Projectorganisatie Maasvlakte 2 2009).

The themes of the MEP sand extraction and corresponding monitoring elements are presented in Table 1 and described below.

Table 1 Themes of the monitoring plan sand extraction MV2, based on (van Zanten et al. 2008)

	Seafloor and benthos	Suspended matter	Underwater noise	Seafloor and benthos	Seafloor structure	Geo-morphology	Hydro-dynamics	Seafloor structure
	Monitoring elements							
	Nature				**Coast and sea**			
Themes	C			P	C	P		
Bathymetry						x	x	
Extracted material								
Seafloor properties	x			x	x			x
Suspended matter (TSM)		x						
Change spring bloom		x						
Species composition benthos	x	x						
Noise measurements			x					

C = Construction
P = Presence

Sand extraction under authority of the Ministry of EAI
Monitoring is conducted as part of the Permit conditions required by the Nature conservation law under authority of the Ministry of EAI. These requirements differ according to the area protected under the Nature conservation law:

- Voordelta
  - Land use (area)
  - Erosion pit
  - Change in tide wave
  - Increased suspended matter (TSM)
  - Noise, ship movements and light emissions
- Kwade hoek
  - Deposition in the dunes
- Haringvliet/Grevelingen/Oosterschelde
  - Effects of increased suspended matter on terns, monitored by TSM measurements.
- Waddenzee and Noordzeekustzone
  - TSM concentrations along the Zeeuwse and Hollandse coast, by use of modelling, remote sensing and field measurements.

Sand extraction under authority of the Ministry of Infrastructure and the Environment

Bathymetry and extracted material
As mentioned previously, during active sand extraction the permit requires at least once a month depth measurements of the site and surroundings. The first five years after ending the extraction depth measurements of the site and surroundings are required each year and thereafter once each five years until no change is observed. However, the monitoring plan deviates from this requirement: the frequency of monitoring is lower. Six months after sand extraction has started, the first measurements[3] are to be conducted followed by

[3] The site measurements are conducted according to Standard 1a of the IHO Standards for

yearly measurements. In between measurements, the management of the extraction process could be adapted on the basis of the management administration, i.e. the amount of extracted material in combination with the automatic registration during extraction (indication X. Y, Z-positions of suction tube, etc.). After extraction, the frequency can be reduced in agreement with the authorities. According to the monitoring plan this frequency will be sufficient for an adequate description of the seafloor developments within the area and for determination of the achievement of the equilibrium situation.

Seafloor properties

Sand extraction causes changes in the seafloor composition (material, grain size en mud content) within the extraction site and direct surroundings. This can impact benthos and therewith the rest of the (food)chain (van Zanten et al. 2008). To obtain insight in the change in seafloor composition this needs to be periodically determined during and after extraction. The composition of the top layer (10 cm), including the mud content, is of concern. During active extraction, the seafloor composition is only monitored in the near surroundings of the site. After ending the extraction, monitoring will continue and will also include sampling within the extraction sites (van Zanten et al. 2008). The frequency of monitoring according to the permit conditions is: during active extraction near the extraction site twice a year, after extraction within and near the sites once a year during five years. After that once each five year until no more changes are observed. The monitoring plan however, assumes that yearly monitoring during extraction will be sufficient. After extraction has ended the monitoring frequency will be gradually decreased in agreement with the authorities. It is suggested that measurements in the 1st, 2nd, 4th, and 9th year after ending the extraction will be sufficient to clarify the effects and changes (van Zanten et al. 2008).

Suspended matter and change in spring bloom

The fine particles that are released into the water column during sand extraction required for the Maasvlakte 2 construction works cause a decrease in visibility and increase in turbidity of the seawater and therewith consequences for nature and ecological values. Question is whether this increased turbidity can lead to a change in the spring bloom of algae. This could have effect on the reproduction of shellfish and therewith affect shellfish eating birds. To analyse and clarify occurring effects the distribution of fine particles is monitored. This is divided into two sub themes:

- Mud in the water column (TSM);
- Change in spring bloom.

As described earlier, according to the permit requirements, the concentration of TSM in the water column should be by measurements in the field, supplemented by analyses of satellite images for following the variation of TSM concentration in the spatial scale (Ministerie van Verkeer en Waterstaat). However, the monitoring plan deviates from this requirement: an analysis of satellite images following the variation of TSM concentration in the spatial scale now forms the basis of the monitoring. This is supplemented by use of modelling of TSM and specific in-situ measurements at sea for the verification of the model and, if necessary based on the satellite images, additional measurements (van Zanten et al. 2008). Following the MEP, less sampling is thus expected than initially required according to the permit conditions. The complete monitoring methodology for TSM can be found in

---

Hydrographic Surveys, 5th edition, February 2008, Special Publication no.44, The International Hydrographic Bureau, Monaco (www.iho.int).

the Monitoring Plan for the construction of the Maasvlakte 2 (in Dutch) (van Zanten et al. 2008) .

The following monitoring will be conducted in order to describe the spreading of the TSM and to assess the start of the spring bloom (van Zanten et al. 2008):

- To verify the model the TSM in the water column will be measured by repeating the base line measurements4 in 2007. For this purpose, TSM measurements will be conducted at 100 locations along the coast, in the months of April, July and October. At 25% of these locations, sampling will also include vertical measurements. These samples will supply sufficient calibration data to interpret the field measurements. The first measurements are foreseen in the year 2009 (the second year after start of extraction and TSM production), because the effects of the increased TSM concentrations will occur only after long term exposure.
- After 2009, specific measurements will be conducted only if necessary. The decision will be based on the satellite observations (daily available) together with the assimilated model calculations. For example when large plumes of TSM or unidentifiable patterns are visible for a prolonged period.
- The spring bloom will also be analysed with use of Remote Sensing, based on the Chlorofyl-a concentration. As soon as the spring bloom has been determined, the regular measurements are requested at the Waterdienst to identify the size and growth of the spring bloom. It is assumed that the Waterdienst will adjust the frequency of measurements to the event. Water samples are taken to determine type and species of algae.

Benthos species composition at extraction sites
Sand extraction affects the benthos present at the extraction site and possibly the benthos surrounding the site. The benthos originally present at the site will be removed and the benthos present in the area surrounding the site could be affected when suffering from long term exposure to increased TSM concentrations. After ending the extraction recolonisation of the seafloor will occur. In order to clarify the effects and recolonisation the benthos will be monitored during and after extraction.

The following monitoring will be conducted (van Zanten et al. 2008):

- To provide insight into the effects of increased mud deposition on benthos of the area surrounding the extraction site, the baseline measurements of 2008 (300 locations along the coast from Petten to Vlissingen sampled with box-cores and 'sleepmonsters') will be repeated. The first measurement was suggested to be conducted in 2010, when sufficient TSM will be introduced into the water system for possible effects to be visible. Based on the validated field measurements an assessment will be made whether the additional TSM has impact on the benthos. When effects are observed, the measurements will be repeated yearly. If not, adjustment of the frequency will be requested at the authorities.
- To provide insight into the recolonisation of the extraction site the above described monitoring on site will be denser, i.e. a statistical representative number of monitoring locations will be added. The exact number will be based on the benthos present but is thought to be 30 to 50 additional locations. The total number of monitoring locations within and around the

[4] Suspended matter measurements along the Dutch Coast, including the (future) extraction site, the area potentially affected and reference site. It comprises the area between Petten and Vlissingen, up to ca. 30 km from the coast.

extraction site will be approx. 100. The additional locations will be divided into four areas, each 1 x 1 km, of which two are inside and two are outside the extraction site. The latter two will be used as reference sites. Base line measurements at the four sites will be conducted in 2009.
It is suggested to gradually reduce the monitoring frequency during and after extraction even when the previously described monitoring between Petten and Vlissingen is not required anymore. It is suggested to conduct these measurements after the 1st, 2nd, 4th and 9th year after ending the extraction and each five years following. All measurements and locations should be included to be able to describe the species composition and biomass of the benthos in the area. The locations within the extraction site will only be sampled after ending the extraction because then recolonisation is relevant.

Noise measurements
The extraction and transportation will introduce underwater noise. In order to assess possible consequences from this noise on marine mammals it is important to quantify the level of noise. It is noted, that due to a lack of knowledge and experience there is no established assessment framework available to assess the effects of underwater noise. This emphasizes the need for monitoring the level of noise during extraction at the Maasvlakte 2, which is part of the monitoring program. Only the level of noise will be measured. No effect monitoring will be conducted.

The following monitoring will be conducted (van Zanten et al. 2008):
A monitoring plan will be developed to measure the underwater noise (i.e. establishing the source strength) from "sleephopperzuigers" in action during different stages of the work. Based on these measurements and a model of the surroundings of the Maasvlakte 2 the noise contours of the different stages can be calculated. These will be compared to the predictions of the noise contours assessed by EIA.

2.4 Monitoring achievement

In April 2006 the first baseline monitoring study was started (Vertegaal et al. 2007). For all subjects as described in the section above, baseline studies have been conducted. The Monitoring Plan (van Zanten et al. 2008) provides an overview of these studies, including the monitoring locations .

2.5 Monitoring reports

Monitoring is required as permit conditions under several laws. The main monitoring requirements are obligated by the Nature conservation law, under authority of the Ministry of EAI and the Mineral extraction law, under authority of the Ministry of Infrastructure and the Environment. Both the Ministry of EAI as the Ministry of Infrastructure and the Environment demand periodical reports.

All monitoring results will be validated, analysed and reported by the constructor (i.e. the Mainport Rotterdam). The results and findings of all measurements completed in one year are summarized in an integrated annual report to be submitted to the authorities. This report includes at least an overview of the conducted monitoring, a description of the findings and conclusion of the analyses and interpretation of results. The results will be related to the predictions made in the EIA (Ministerie van Verkeer en Waterstaat).

The exact format of the annual reports and the format and frequency of possible interim sub-reports will be established per monitoring theme in consultation with the authorities. The 'Ontgrondingenwet' requires reporting each 6 months. The extraction progress should be reported each month, including the amount of material extracted, locations and time of extraction and results of granulometric analyses (Ministerie van Verkeer en Waterstaat).

The permit under the Nature Law states that each year before the 15^{th} of July the results of the monitoring should be submitted to the Ministry of EAI. If necessary, interim reporting could be required (van Zanten et al. 2008).

3 Adaptive strategies within the monitoring plan of Maasvlakte 2

3.1 Introduction

The Maasvlakte 2 is a huge project conducted over many years. The complete project is to be finalised in 2033. The 1st phase construction, from 2008 to 2013, requires 240 million m^3 of sand. According to the status of January 2010, a total of 80.5 million m^3 of sand has already been extracted from the North Sea for this purpose (Projectorganisatie Maasvlakte 2 2009). The current MEP (van Zanten et al. 2008) is focussed on this first phase of the project, because the main effects are expected in this phase. For the second phase (after 2013), the MEP will be updated based on results from phase 1, including incorporation of learning points. Before implementation of the new MEP, it will be submitted to the authorities for approval.

Considering adaptive monitoring strategies, there are two types of evaluation that can be distinguished: (1) structural evaluation of the complete MEP and (2) periodically evaluation of results within themes.

3.2 Structural evaluation of the MEP

According to the website of the MV2 project (accessed on January 29, 2010), the MEPs are evaluated every five years. If needed, plans will be adjusted (Projectorganisatie Maasvlakte 2 2009). However, the MEP construction (van Zanten et al. 2008) does not refer to such a structural evaluation of the complete MEP. Only periodical evaluation of monitoring plans per theme is included in the MEP. Furthermore, the MEP notes that within the Projectorganisation Maasvlakte 2, a separate working group for conducting the monitoring program has been established (van Zanten et al. 2008). Under this construction, it is possible to maintain an adequate information exchange between the authorities and the constructor. According to the MEP it is preferred to have periodically meetings to discuss progress and results of the monitoring. Also suggestions for adaptation of the monitoring could be discussed at these sessions, such as adjusting frequency or conducting additional monitoring.

Other relevant documents, such as the EIA (Vertegaal et al. 2007) and the conditions of the extraction permit (Ministerie van Verkeer en Waterstaat), do not address structural evaluation of the complete MEP.

Permit conditions allow adaptations of the monitoring plan only when approved by the authorities.

3.3 Evaluation of monitoring plans per theme

The basic two conditions included in the MEP that allow adaptation of monitoring are:

- Evaluation of a monitoring plan is performed after new results are analysed;
- Opportunity for discussion of the monitoring program with the authorities and, if necessary and approved, adjustment of the monitoring program.

Monitoring as required by the Ministry of EAI

The monitoring as required by the Ministry of EAI (Nature law) is focused on the abiotic effects (van Zanten et al. 2008). As long as the abiotic effects remain under the limits as determined within the "Passende Beoordeling", the same can be assumed for the biotic effects. As potential biotic effects are the result of changes in abiotic conditions and "worst case" assessments are made, this is considered sufficient. According to condition 27 of the Nature Law Permit, the monitoring program can/should be adjusted when monitoring results show that the (abiotic) effect is larger than expected or any indication that this might occur (van Zanten et al. 2008) If this is the case then additional monitoring will be suggested.

Monitoring as required by the Ministry of Infrastructure and the Environment

According to the permit conditions the monitoring plan should include per theme:

- a motivation of the monitoring parameters, - locations, and – frequency;
- criteria for adaption/deviation of those ;
- and possible measures in case this is necessary (based on e.g. the impact-effect chains as described in the EIA) (Ministerie van Verkeer en Waterstaat).

The planned periods for monitoring are set to the periods when effects are expected. The monitoring frequency is determined as such, that the collected monitoring data will provide sufficient insight in the effects. In consultation with the responsible authorities (i.e. the Ministry of Infrastructure and the Environment) and with their approval, the monitoring frequency will be adjusted if the analyses of the monitoring results provide reason (van Zanten et al. 2008).

The monitoring program is set-up in such a way, that by use of statistic analyses, possible deviations caused by change in tidal currents, wave height and depth can be detected (i.e. natural variation). For example, the monitoring results may depend on the time of measurement, e.g. tidal influence. Monitoring results can thus be corrected for natural variation. Determination of correlations is also possible (Vertegaal et al. 2007).

The criteria for adaption/deviation of the monitoring plan per theme, as included in the MEP, are presented in Table 2 and discussed below.

Table 2 Adaptations in the monitoring program for sand extraction (based on van Zanten et al. 2008)

Theme	Adaptation*	Criteria	Already executed?
Bathymetry	Reduce frequency and size of monitoring area	Based on the change in bathymetry (effects); Based on a stable situation in (part of) the area; Endpoint is total stable situation	No
Extracted material	No adaptations included	Not relevant	Not relevant
Seafloor properties	Reduce frequency	Based on granulometric analyses (including mud content) of the sediment samples	No
TSM	Reduce number of sampling locations	No observed link between TSM and juvenile fish; Spatial correlation shows redundancy of locations (the number of locations can be decreased from 100 to 50).	Yes
	Raise number of samples taken at each location	Temporal correlation is only relevant in case of more frequent sampling (the samples taken at each location are raised from 3 to 6 (i.e. from 3x100 to 6x50)	Yes
	Reduce frequency	Relevant after 2010; Data required for model validation and RS-images is sufficient	No
	Additional measurements	When multiple results (e.g. from RS images) show higher TSM concentrations than expected, and a reasonable link between the relatively high TSM concentrations and the MV2 activities can been identified	No
Change in spring bloom	No adaptations included	Not relevant	Not relevant
Benthos	Reduce frequency	No observed effects on benthos; Endpoint is total stable situation	No
	Location and size of monitoring area	The TSM distribution: for the second benthos baseline (2008) the original (2006) monitoring area was adjusted to new insight into the TSM distribution. The benthos monitoring area is adjusted to the TSM distribution	Yes
Juvenile fish	Stop monitoring	No relationship between TSM concentration and the stomach content of juvenile fish could be determined	Yes
Noise measurements	No adaptations included	Not relevant	Not relevant

* Adjustments are only made under agreement by the authorities

The area subjected to monitoring of **bathymetry** can (in consultation with- and under agreement of the authorities) be adjusted (reduced) when results show that a stable situation has occurred in parts of the area. The monitoring will continue after ending the sand extraction until a stable situation has occurred. Depending on the observed changes in bathymetry, the frequency of monitoring could be adjusted (reduced).

When conducting the baseline monitoring, learning points and new insights are taken as input for future measurements (van Zanten et al. 2008).
The baseline **TSM** measurements have been conducted in 2007 by use of the Siltprofiler. In 2009 this should be repeated, with possible adaptations to the baseline TSM monitoring. The MEP (van Zanten et al. 2008) describes the following criteria on which the frequency in time and space of TSM monitoring is adjusted:

- Monitoring has shown that there is no relationship between TSM concentration and juvenile fish
- Some locations appear to be redundant based on spatial correlation of 2007 measurements
- Temporal correlation is only relevant in case of more frequent sampling.

For the monitoring of TSM more focus will be put on the relation time-space and the frequency of 3 times 100 locations in 2007 will be adjusted to 6 times 50 locations in 2009 (van Zanten et al. 2008). From 2010, in consultation with the authorities, the frequency of TSM measurements will be reduced as much as possible to the data that is required for model validation and the TSM from RS-images.
In the EIA (Vertegaal et al. 2007) it is stated that the range duration and concentrations of the TSM distribution and increased mud deposition (including related nutrients) will be described based on monitoring results. Furthermore, it is stated that if necessary, the monitoring frequency could be increased to continuous monitoring of TSM concentrations for a limited number of locations (e.g. 4 to 8) (Vertegaal et al. 2007). This possibility of continuous monitoring of TSM concentrations has not been found in the MEP. The MEP however, notes that additional monitoring could be relevant when multiple results show higher TSM concentrations than expected. A reasonable link should be made between the relatively high TSM concentrations and the MV2 activities based on spatial patterns of the TSM (van Zanten et al. 2008).

The new insights regarding the TSM distribution and monitoring (as described above) have also been used in the evaluation of the **benthos** monitoring. For the second benthos baseline (2008) the original (2006) monitoring area was adjusted to the TSM monitoring area.

The baseline monitoring of **juvenile fish** could not determine a relationship between the stomach content of juvenile fish and the concentration of TSM. Therefore, no further monitoring of juvenile fish is required.

The adaptive execution cycle is presented in Figure 2, showing examples of the monitoring program MV2 (see blue text).

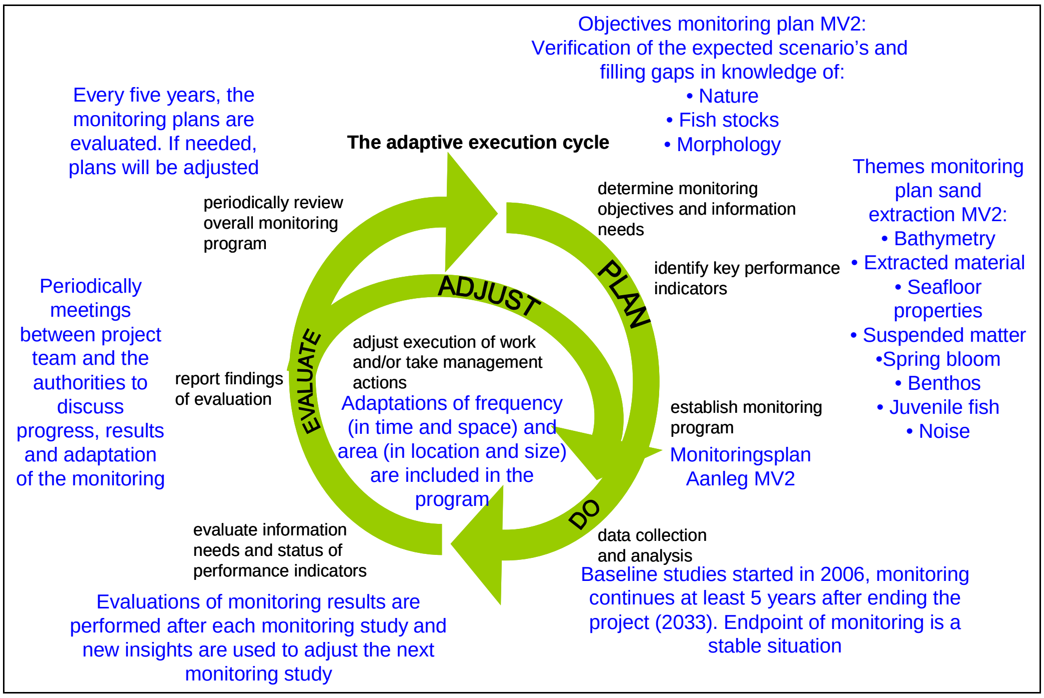

Figure 2 Adaptive execution cycle with examples of monitoring MV2. The general aspects are presented in black. The aspects specific for MV2 are presented in blue.

4 The frame of reference

4.1 Methodology

The frame of reference (Van Koningsveld 2003) is a guideline or template combining the essential components of coastal decision making. The 'basic' frame of reference, derived in an iterative problem driven manner, provides a useful tool in support of decision making as well as a target for specialist improvement. As such it provides a communication tool supporting efforts to rationalise the use of specialist knowledge in coast related decision processes (Van Koningsveld 2003). A key element in this methodology is to take the end user's information need as an explicit starting point for knowledge development and to continually match specialist research with the information need of end users. Effective interaction is needed to prevent or postpone the seemingly inevitable divergence of end user's as well as specialist's perceptions on what is relevant knowledge.

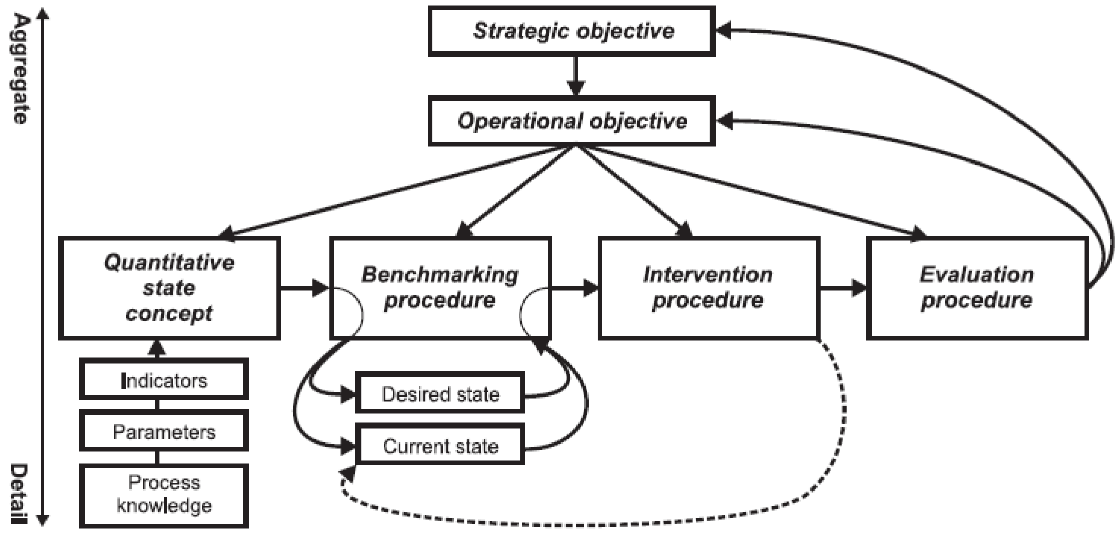

Figure 3 The 'basic' frame of reference (Van Koningsveld 2003).

A 'basic' frame of reference should include the following elements (see Figure 3):

- a strategic objective;
- an operational objective;
- a decision recipe containing a foursome of elements, viz.:
    1. a quantitative state concept;
    2. a benchmarking procedure;
    3. an intervention procedure;
    4. an evaluation procedure confronting the operational as well as the strategic objective.

Below, the elements of the Frame of Reference are described according to the thesis of Van Koningsveld (2003).

Strategic management objective
Strategic objectives provide the long term context for policy and management. They express the vision on the interdependencies of the natural and the socio-economic system and on the role of the human species therein. Strategic objectives tend to vary slowly. Nonetheless they do have a profound impact on the kind of policy and management that is required and acceptable.

Operational management objective
The operational objective expresses our vision on how to *handle* the interactions between the natural and the socio-economic system. As such it is a concrete implementation of the strategic objective. Operational objectives are assumed to be related to the status of values and interests. As such the operational objective should include an explicit indication regarding the temporal and spatial scales involved. It may take many operational objectives to cover all scales intended in the strategic objective. Simultaneous management of different operational objectives can easily lead to conflicts. What is good for one objective might harm another. What works on the short term could adversely affect the long term. As a result, evaluation of management activities should not be restricted to the operational objective but include a critical review with respect to the strategic objective. Evaluating the interaction between different operational objectives and minimising the amount of conflicts are crucial elements of an integrated approach to management.

Decision recipe
From the strategic and operational objective follows our vision on potential and acceptable human interventions. A fully developed decision recipe for intervention, coherently addresses the following elements:

1. Quantitative state concept
To enable objective and reproducible decision making, a quantitative concept needs to be developed that describes the state of the system or certain aspects thereof in an appropriate form. The appropriate form with respect to usefulness in decision processes is determined by the strategic and operational objective as well as by the next steps in the decision recipe. With respect to practical effectiveness there is a strong link with knowledge of the system's behaviour. A wealth of literature available regarding indicators, indexes, etc.

2. Benchmarking procedure
A benchmarking procedure is necessary, so that we can systematically and objectively determine when to intervene in the system. Intervention is required when a discrepancy between the current system state and a desired or reference system state surpasses some predefined threshold. Implicit differences in the desired system state often trigger passionate discussions on what is in the interest of the management objectives and what is not. To facilitate useful discussions, the current as well as the (implicitly) desired state should be made explicit, preferably expressed in terms of the chosen quantitative state concept. This element of the decision recipe often relies on measured or predicted trends in state descriptions, costs and benefits.

3. Intervention procedure
An intervention procedure specifies how we should manipulate (part of) the system in order to bring it to a desired state. It specifies not only the type of intervention but also the method to determine its design. Knowledge of the system, in particular regarding physical processes, plays a crucial role in this element. The design procedure should use the quantitative state concept as one of its primary building blocks. It should at least facilitate significant manipulation of the system's 'current' state, towards its desired state identified in the previous step.

4. Evaluation
The decision recipe and the effects of its application should be evaluated. This evaluation should take place in the development stage of a measure (expected effects), as well as after some period of application (actual effects). First of all, one needs to assess whether or not the operational objective is being sufficiently achieved. If this is not the case, the decision recipe may have to be changed. If the operational objective is satisfactorily achieved, it is still necessary to evaluate the management efforts, but now against the wider perspective offered in the strategic objective. This may trigger modifications in the decision recipe but, but it may also result in an adaptation of the current operational objective, or the formulation of a new one.

The communication process may be guided by assuming that *'ideally'* all elements of the 'basic' frame of reference, as described above, need to be made explicit. An assessment of the elements that have *'actually'* been made explicit reveals so-called *'white spots'*. These 'white spots' represent the remaining information that is needed to develop a successful and coherent approach.

As an example of the implementation of the Frame of Reference, the general Frame of Reference of the Building with Nature program is shown (Table 3).

Table 3 Frame of Reference for BwN (https://public.deltares.nl/display/BWN/general+frame+of+reference+page+-+BwN+programme+at+large)

Strategic Objective	**Operational Objective**	**Quantitative State Concept (QSC)**	**Bench-marking Desired State**	**Bench-marking Current State**	**Intervention Procedure**	**Evaluation Procedure**
To have the BwN-concept and way of working broadly accepted and applied	Making the BwN-program into such a success, that continuation after 2012 is guaranteed	Percentage of key partner categories committed to continuation after 2012 / Level of committed budget for continuation	All key partners committed to continuation / budget level equal to or greater than 30 MEuro	Commitment unclear for all partner categories, for continuation in principle as well as for the funding level	Create sense of success and perspective on successful application of the BwN-concept for all parties involved by showing intermediate results of the projects and how they feed into the BwN-tools (manual, tools, portfolio, valuation methods, etc.).*	Is the basic attitude towards continuation positive among all key partners' categories and funding agencies?

* we must also go for feedback from practical BwN-type projects, also outside our immediate vicinity

4.2 Applying the frame of reference to the case study Maasvlakte 2

In this paragraph the frame of reference has been applied to the case study MV2. Note that the scope of this case study is limited to the construction phase of the MV2 and only considers the monitoring related to sand extraction. The Monitoring Plan of van Zanten et al. (2008) is used as a source of information. The MV2 frame of reference is shown in Table 4 . Not all information as provided in the table is explicitly noted in the Monitoring Plan. Some are induced based on available information.

As can be seen in Table 4, the main 'white spot' (see Chapter 4.1) is the lack of an intervention procedure within the MEP of MV2. According to the frame of reference, the MV2 MEP could improve when at least significant manipulation of the system's 'current' state is facilitated, towards its desired state identified in the previous step. The quantitative state concept should be used as one of its primary building blocks.

Table 4 Frame of reference applied to the monitoring plan of sand extraction for the MV2

Strategic Objective	**Operational Objectives**	**Quantitative State Concept (QSC)**	**Benchmarking Desired State**	**Benchmarking Current State**	**Intervention Procedure**	**Evaluation Procedure**
Verification of the expected scenario's and filling gaps in knowledge of: Nature; Fish stocks; and Morphology	The operational objectives are determined for each relevant theme:	The QSC is determined for each relevant theme:	In general: state as determined by the baseline monitoring or predicted state	Not available (n.a.)	Not included in Monitoring Plan	Are effects observed?/ Is a stable situation achieved?
	Data sand extraction					
	To obtain insight in the amounts and the properties of the extracted material and to follow the development of the sand extraction site(s)	- Bathymetry - Amount and volume-weight of extracted material and location and time of extraction - Properties of extracted material	Bathymetry: stable situation	n.a.	n.a.	
	Seafloor properties					
	To determine the seafloor properties within and surrounding the extraction site	Change in seafloor properties (granulometric analysis) within and surrounding extraction site	No observed changes in seafloor properties	n.a.	n.a.	
	TSM concentration					
	To determine the mud distribution and the start of the spring bloom	- Satellite images, modelling results, measurement TSM concentration 2009 and possible additional in-situ measurements - Satellite images of phytoplankton	Predicted scenario	n.a.	- Selecting extraction sites with relative low mud content in the sediment will limit the TSM concentrations. - Season-dependent extraction. Note that stopping the extraction in spring will not lower the TSM concentration because of the 'naijleffecten' of the TSM already in the water column. (Vertegaal et al. 2007)	

Strategic Objective	Operational Objectives	Quantitative State Concept (QSC)	Benchmarking Desired State	Benchmarking Current State	Intervention Procedure	Evaluation Procedure
	To determine whether the observed plume (TSM concentrations and -distribution) follows the predicted pattern	As above	Predicted scenario	n.a.	n.a.	
	To determine if a change in spring bloom occurs and if this could be related to increased mud	As above	Predicted scenario	n.a.	n.a.	
	To determine to which degree the accessibility of food for visual predators is affected by possible changes in visibility and if this leads to population effects	As above	No observed effect	n.a.	Extraction further from the coast will limit the impact on the protected coastal area "Voordelta". However, more fuel is needed further from the coast which will increase emissions to air (Vertegaal et al. 2007)	
	To determine whether the benthos in areas with increased mud concentrations deviates from reference areas and, if so, what the possible consequences are for the marine ecosystem	Sediment samples of different locations	No observed effect	n.a.	n.a.	

Strategic Objective	Operational Objectives	Quantitative State Concept (QSC)	Benchmarking Desired State	Benchmarking Current State	Intervention Procedure	Evaluation Procedure
	Benthos					
	To provide insight in the effect of the additional mud on the benthos surrounding the extraction sites and to determine the recolonisation at the extraction sites	Sediment samples of different locations	No observed effect	n.a.	n.a.	
	Underwater noise					
	To study possible consequences of noise production and to generate general knowledge and experience on disturbance of sea mammals by underwater noise	Source strength of dredging vessel during different activities	n.a.	n.a.	n.a.	
	Disturbance (Voordelta)					
	To determine whether the disturbed area by shipping movements corresponds to the predicted surface	Maps with trackplots of transport vessels during a certain period	Predicted scenario	n.a.	n.a.	
	Terns (Voordelta)					
	To determine the increased area with high turbidity along the coast considering effects on terns	- Satellite images, modelling results, measurement TSM concentration 2009 and possible additional in-situ measurements - Satellite images of phytoplankton	No observed effect	n.a.	Extraction further from the coast will limit the impact on the protected coastal area “Voordelta”. However, more fuel is needed further from the coast which will increase emissions to air (Vertegaal et al. 2007)	

5 Conclusions

Evaluation of the Maasvlakte 2 monitoring program showed that:

- Through sufficient motivation, the constructor was allowed by the authorities to deviate from the permit requirements in the monitoring program of MV2.
- Main deviations are lower monitoring frequencies.
- The extensive monitoring program of MV2 already includes several adaptive strategies. The adaptations are, however, related to the monitoring itself, rather than the execution of extraction work.
- Permit conditions allow adaptations of the monitoring plan only when approved by the authorities.
- There are two types of adaptive monitoring strategies that can be distinguished:
    1. Structural evaluation of the complete monitoring plan.
       The monitoring plans are evaluated every five years and, if needed, plans will be adjusted.
    2. Periodically evaluation of results within themes.
       Evaluations of monitoring results are performed after each monitoring study and new insights are used to adjust the next monitoring study.
- A separate working group for conducting the monitoring program has been established which makes it possible to maintain an adequate information exchange between the authorities and the constructor. It is preferred to have periodically meetings to discuss progress, results and, if necessary, adaptation of the monitoring.

Applying the Frame of Reference (a tool in support of decision making as well as a target for specialist improvement) to the Maasvlakte 2 monitoring program showed that:

- Almost all elements of the 'basic' frame of reference can be found in the monitoring program of MV2, leading to a successful and coherent approach.
- The main ‘white spot’ is the lack of an intervention procedure.
- The monitoring program could improve when at least significant manipulation of the system's 'current' state is facilitated, towards its identified desired state.
- The quantitative state concept should be used as a primary building block in the development of an intervention procedure.

References

Boyd SE, Limpenny DS, Rees HL, Cooper KM. 2005. The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). ICES Journal of Marine Science 62(2):145.

Boyd SE, Limpenny DS, Rees HL, Cooper KM, Campbell S. 2003. Preliminary observations of the effects of dredging intensity on the re-colonisation of dredged sediments off the southeast coast of England (Area 222). Estuarine, Coastal and Shelf Science 57:209-223.

Dankers PJT. 2002. The behaviour of fines released due to dredging; a literature review. . Delft: Hydraulic Engineering Section, Faculty of Civil Engineering and Geosciences, Delft University of Technology. 67 p p.

Erftemeijer PLA, Lewis RRR. 2006. Environmental impacts of dredging on seagrasses: A review. Marine Pollution Bulletin 52:1553-1572.

Langenberg VT, Troost T. 2008. Overview of indicators for Good Environmental Status: National evaluation of the Netherlands. . Deltares publications Z4771. 58pp. p.

Ministerie van LNV. 2008. Vergunning Nb-wet 1998 Maasvlakte 2.

Ministerie van Verkeer en Waterstaat. 2008. Ontgrondingenwet; Vergunning voor het winnen van zand in de Noordzee tbv de aanleg van Maasvlakte 2.

Phua C, Van den Akker S, Baretta M, Van Dalfsen J. 2004. Ecological Effects of Sand Extraction in the North Sea. Utrecht: Stichting De Noordzee. 22 p p.

Projectorganisatie Maasvlakte 2. 2009. Maasvlakte2.com Havenbedrijf Rotterdam N.V., Projectorganisatie Maasvlakte 2.

Van Dalfsen JA, Essink K, Madsen HT, Birklund J, Romero J, Manzanera M. 2000. Differential response of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. ICES Journal of Marine Science 57:1439-1445.

Van Koningsveld M. 2003. Matching Specialist Knowledge with End User Needs. Bridging the gap between coastal science and coastal management.: Universiteit Twente.

van Zanten M, Hordijk D, van Veen P. 2008. Monitoringsplan Aanleg Maasvlakte 2. Projectorganisatie Maasvlakte 2 / Royal Haskoning.

Vertegaal CTM, Heinis F, Goderie CRJ. 2007. Milieueffectrapport Aanleg Maasvlakte 2, Bijlage Natuur. Havenbedrijf Rotterdam N.V.Projectorganisatie Maasvlakte 2 & Royal Haskoning.

6 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

7 Justification

Report	C062/11
Project Number:	430.61110.62

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved:	Dr. R.H. Jongbloed Research scientist
Signature:	
Date:	May 27, 2011

Approved:	F.C. Groenendijk, MSc. Head of Department
Signature:	
Date:	May 27, 2011

EcoShape is een consortium bestaande uit