Deltares

KPP: Deltaprogramma Wadden

Quick Scan 6:
Sediment budget and channel dynamics
(including a set-up of a project proposal)

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1204229-000

Deltares

Titel
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Opdrachtgever	Project	Kenmerk	Pagina's
RWS-Waterdienst & Ministerie Economische Zaken, Landbouw en Innovatie	1204229		33

Trefwoorden
Tidal systems, tidal inlet and tidal flat dynamics, sediment budget, effects of climate change, safety, international cooperation, study proposal.

Samenvatting
Meer kennis en ervaring uit het Waddengebied nodig voor de toekomst

De hoofdconclusie van de quickscan sedimenthuishouding is dat met de huidige kennis vragen over de toekomst van het Waddengebied niet te beantwoorden zijn.

Deltares adviseert sedimentonderzoek voor het Waddengebied op te zetten dat de komende jaren de kennis op het juiste niveau brengt. Het kennisniveau van de sedimenthuishouding van de Waddenzee, de voordelta en het kustfundament moet verder ontwikkeld worden. Deze kennis is noodzakelijk, zodat processen rond de eventuele verdrinking van de Waddenzee beter begrepen kunnen worden, effecten van klimaatverandering in beeld gebracht kunnen worden en mogelijke maatregelen voor veiligheid zo goed mogelijk in een natuurlijk waddengebied in te passen zijn.

Het project sedimenthuishouding van de Waddenzee richt zich op de volgende beleidsvragen:

1 Wat is de relatie tussen de sedimentatiehuishouding van de Waddenzee en de langs de Waddenzee gelegen primaire waterkeringen?
2 In welke mate is er sprake van verdrinken van wadplaten als gevolg van de zeespiegelstijging?
3 Wat is de betekenis van het mogelijkerwijs verdrinken van de wadplaten voor de primaire waterkeringen?
4 In welke mate vormt geulerose lokaal een bedreiging voor de primaire keringen?
5 Welke korte en lange termijn maatregelen kunnen genomen worden om het verdrinken van wadplaten tegen te gaan?

Om een antwoord te krijgen op deze beleidsvragen adviseert Deltares om het beantwoorden van de volgende kennisvragen centraal te stellen in het project sedimenthuishouding:

1 Hoe werkt het sediment-transport en erosie/depositiesysteem in de trilaterale Waddenzee (op verschillende ruimteschalen zoals : op kombergingniveau, op niveau van plaat-geuluitwisseling)?
2 Hoe en waar kunnen we de eerste tekenen van verdrinking waarnemen?
3 Welke sediment-toevoer strategien rekening houdend met de eigen aard (morfologisch en ecologisch) van het natuurlijke systeem kunnen ontwikkeld worden om verdrinking van de Waddenzee bij te houden?

In het advies geeft Deltares aan dat de basiskennis over de sedimentstromen en de geuldynamiek vergroot moet worden binnen 5-10 jaar. Deltares adviseert bestaande modellen te verbeteren. Naast het opzetten van modelonderzoek en monitoring adviseert

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Deltares om zoveel mogelijk te leren van korte termijn beheersingrepen rond baggeren, zandsuppleties en bescherming tegen geulen om daarmee kennis en ervaring op te doen voor eventuele maatregelen bij negatieve effecten van de klimaatverandering. Vanuit dit project gaat het dan om het gericht volgen van de zandverplaatsing, waterbeweging en golven in het Wadden-monitoringprogramma. Ook adviseert Deltares om zo mogelijk met praktijkproeven aan te sluiten bij huidige vraagstukken rond kustveiligheid en bevaarbaarheid in het Waddengebied.

Binnen het Deltaprogramma Wadden is samenwerking en afstemming ingepland met het project Integraal kust en eilandbeheer en het project golfreductie Eemsdollard en het project monitoring. Samenwerking met de trilaterale Waddenpartners Duitsland en Denemarken is ook van groot belang voor het onderzoek. In het trilaterale overleg heeft Duitsland in februari 2011 aangegeven erg geïnteresseerd te zijn in het project. In de onderzoeksplanning is in de analysefase ruimte opgenomen voor trilaterale afstemming en opzet van de samenwerking.

In het onderzoeksplan is onderscheiden in 3 fasen met daar tussen go-no go beslissingen. Het onderzoeksplan is een getrapt, toegepast programma, waarin de trilaterale partners intensief samenwerking om de einddoelstellingen te bereiken. Een eerste fase bestaat uit een relatief beperkte inventarisatie en een haalbaarheidsonderzoek. De tweede fase bestaat uit een intensief data-verwerkingsdeel, wat de afbakening en inhoud van het derde deel gaat opstellen. Tijdens de uitvoering vindt regelmatig terugkoppeling plaats met andere uitvoeringsplannen binnen DP wadden, en andere aanpalende programma's die in de (NL) Wadden tegelijkertijd lopen.

Referenties
KPP BOA Gebieden

Versie	Datum	Auteur	Paraaf	Review	Paraaf	Goedkeuring	Paraaf
1	28 feb. 2011	L. van der Valk		Z.B. Wang		T. Schilperoort	
		A. Oost		A.J.F. van der Spek			

Status
concept

Content

1 Policy issues

1.1 Policy issues and second thoughts

The central policy issue is:

"*in what way will the Wadden system be able to function as a so-called climate buffer while maintaining its natural functions and its safety level* ?"

The question is composed of several elements, which will be shortly discussed below:
"the Wadden system", is not a very well defined entity. Here we might use the broad definition, which is based on our knowledge of how the Wadden area functions and on coastal policy documents. The Wadden system is then defined as the whole area from the -20m MSL line in the North Sea, up to and including the dikes at the mainland and including the whole of the barrier islands. In this way the strong effect of dampening of waves of the barrier islands and ebb-tidal deltas is included in the question. However, from informal discussions we know that the original idea behind this question was mainly addressing the Wadden Sea sensu stricto, that is the backbarrier part of the Wadden system, the sub-, inter- and supratidal shoals and the tidal channels.
"function as so-called climate buffer" is here taken to mean: the fact that the tidal shoals and channels can keep up with sea-level rise by means of extra sedimentation, up to a certain critical point, above which the shoals start to drown.
"maintaining its natural functions" is here taken to mean primarily its functions as a habitat for invertebrates and as a feeding ground for fish, birds and seals and to some extent also its natural functioning, i.e. the hydro- and morphodynamics of channels and shoals.
"its safety level" is here taken to mean the safety which the shoals and winding channel systems offer to the inhabited places.

It will be clear from the above definitions that the shoals are expected to drown at some moment in time if the rate of sea-level rise accelerates above a critical maximum. When this point is reached is still unclear. The starting point for this issue is thus that available knowledge will not be directly suitable to answer this long-term question, and can be summarized as follows: . "Which knowledge must be available at what moment?" At the same time: what knowledge will be available from other programmes that must also be used to answer this question?

The starting point for this issue is that available knowledge will not be directly be suitable to answer this long-term question. Which knowledge must be available at what moment ? At the same time: what knowledge will be available from other programmes that must also be used in answering this question?

Intermezzo related programmes
Somewhat similar issues are investigated in some coastal management programmes. It is explicitly needed for the current QS subject to interact with these programmes, for instance:

- *Naar een Rijke Waddenzee (for 'bioarchitect' ecology)*
- *Inception report 'mud in the Wadden Sea'*
- *Deltaprogramme Kust (future of the entire Netherlands' coast)*

- *Kustlijnzorg; Kustlijnzorg-eco (running coastal maintenance programme using predominantly nourishments)*
- *SBW (civil engineering programme dealing with coastal resilience)*
- *Waddenfonds-based projects and the likes*
- *Etc.*

1.2 Policy issue analysis

1

Q: What measures can be envisaged and weighed up front ?

A: These could be nourishing outer rims of tidal delta's, sediment buffers in front of dikes, cyclic excavation of high tidal marshes, decommissioning of polders etc.

2

Q: What measures could invoke that the balance between drowning and keeping up with SLR is reached?

A: Only study the trilateral data available for the time being, and keep on the alert. Depending on the outcome of studies: use and, if lacking, install appropriate monitoring techniques to know what is going on. There will be plenty time to react, since intertidal shoal drowning is a very slow process, measured in centuries rather than decennia.

3

Q: Do these "soft measures" eventually improve safety levels of mainland and/or island dikes?

A: Use "morphological dredging" to increase the height of sandy tidal flats at crucial locations, maintain ecology and improve when possible.

4

Q: What issues will not be on the list of this QS ?

A: Short-term management issues such as maintenance dredging in navigational channels that have nothing to do with safety.

5

Q: What stakeholders will be involved? Any differences in their approach?

A: There are substantial differences between the various groups of stakeholders. The local public managers and the local public prefer to put the short-term issues on the agenda of the Deltaprogramme. This seems not so sensible to do. However, if parties are prepared to shift the paradigm and are prepared to enter into a constructive dialogue along with Joint Fact Finding, tests may be organized, for instance using clever dredging methods

1.3 Relation to Delta programme

The relation to the Deltaprogramme Wadden is clear, as safety comes first, and then nature and socioeconomics. The relation to Deltaprogramma Kust is equally obvious, as the coastal system as a whole is subject of study, although the DP Kust is currently more a spatial planning issue than anything else. DP Kust, however, will have to absorb nature and economy as its second-rank after safety, equal to DP Wadden. There are good opportunities for both programmes to learn from one another. On the other hand it might be argued that, if no worth is given to the intertidal character of the Wadden Sea area, one might choose to formulate answers in terms of improved dike design: end-of-pipe so to say.

1.4 Focus

The central issue is the eventual drowning of the Wadden Sea and the consequences this has for safety. In this QS it is very special indeed that the boundaries of the study area are extended out into the North Sea down to the -20m depth contour, which includes the entire ebb-tidal delta's. Equally special is the call for international cooperation within the trilateral Wadden Sea Committee.

The following subjects must be taken into account at the level of the Wadden and adjacent North Sea natural system:

- the eventual process of drowning of the Wadden Sea and the speed with which is likely to occur;
- locations, directions and magnitudes of sediment fluxes (sand & mud);
- channel dynamics (to a limited extent);
- net transport of sand and mud into the Wadden Sea
- effects of 'bioarchitects' in terms of sediment dynamics (to be absorbing from various ongoing projects in that particular field of study)
- measures needed (and when?), to prevent flooding of the Wadden Sea tidal flats?
- How and when will prediction capacity improve significantly?

Since the data of the Wadden Sea depth soundings are rather crucial to the improvement of the critical limit up to which sea-level rise can be followed are of relatively poor quality, it is necessary to study as many basins as are available, perhaps after selection of data which seem reliable enough. This would include the whole of the Wadden Sea and as much time slices as are available.

The Wadden Sea, as it is now, still has a surprising degree of natural dynamics despite human action to improve safety (e.g., fixing the position of the islands, strengthening of the primary sea defenses along the mainland). In general, the system is experiencing all-over sedimentation as it has had over the many thousands of years it already exists, with only local erosion which is prevailing along the North Sea coast of the islands, in the main channels and at the front of the ebb-tidal delta's. The Wadden Sea moves according to its forcing from the North Sea. It is therefore likely that the system will continue to act as it has done. It has coped with periods of a high rate of SLR before, surviving it as a system. It will then be able to act as a "climate buffer" to the changes forced upon it as we perceive it now.
For the execution of the DP Wadden it will be important to acknowledge that within the triangle Safety-Nature-Accessibility, safety is first, and next is nature with local presence of accessibility

Because the process of drowning will take place gradually no immediate actions are required. There is sufficient time to think before acting. And if measures will be taken these would likely be of a long-term nature. However, there is no reason to sit back. Methods must be designed and investigated up front, monitoring of certain features and processes must start within a few years. The correct and best way of dealing with these long-term issues needs to be designed and tested, and evaluated, and implemented at the right moment in time. The development of these methods needs to be in close contact with the regular coastal maintenance programmes. There is also a strong need to keep in close contact with other QS studies, as no doubt there numerous cross-over opportunities will be available.

The ambition of the QS

The ambition of the future research that is mapped out in this QS is to acquire the necessary insights in terms of sediment fluxes in and out of the Wadden Sea, and what mechanism prevail in the Wadden Sea itself. It will be equally necessary to incorporate the North Sea coastal zone. The various landscapes of salt marshes, tidal flats, channels, ebb-tidal delta's and the adjoining coastal zone. Sediment includes mud. Mostly (temporarily-) wet parts of the Wadden Sea are involved, but also the island dunes are part of the system. Main emphasis will be on the wet part of the Wadden Sea , however. From this it may easily be understood that the northern part of North Holland is incorporated into the study area. Deltaprogramme Kust and – Wadden have equal tasks here.

During the joint sessions some stakeholders voiced the opinion that the wider Wadden Sea sediment budget (as defined above) is a typical task of the national government and that the scientific institutions have a clear task to guide the scientific approach. It can be concluded that the provincial and municipal governments do not see themselves as a principal actor. This certainly reflects on the mission and the ambition of this QS.

Studying a number of tidal sub-basins will probably give best opportunities to gian insight into system development, in an international setting combining forces with D and DK experiences.

2 Knowledge: needed

The central knowledge needs focus on the question if eventual drowning of the Wadden Sea tidal flats has consequences for safety. For this subject the boundaries of the study area have been stretched into the shallow North Sea to a depth of -20m, which includes the ebb-tidal delta's. The following system knowledge is needed:
1. the process of drowning and the possible speed with which this will take place; a first step is to better understand the channel-tidal flat interactions. This step is also needed to grasp the mechanism of tidal flat accretion critical build-up maximum.
2. the sediment fluxes (sand and mud) in threatened parts of the system
3. channel dynamics in relation to safety
4. what are suitable measures and what will be the effects of these measures?

Intermezzo: modeling

Two types of modeling will be needed, or may be used depending upon the availability of data and the type of problem that needs to be studied. LT modeling is generally not performed by using a process-based model (such as D3D), but by using an empirical model(such as ASMITA). The issues under this QS could be studied by either model. Site, period to be studied, and available data indicate the choice of the model. If ASMITA will be used, it needs a round of updating and focusing on the study issues. For sediment transport studies, process based models are a likely choice.

The time scales involved vary from 'some years' for smaller morphological units(channels, tidal flats)up to 'decades to centuries' to study processes dealing with tidal (sub-) basins. Very likely both study scales will be needed, sometimes switching form one to the other and vice versa.

2.1 Primairy knowledge needs

The following questions are to be answered:
1. How will the Wadden system be able to function as a climate buffer while maintaining safety and keeping up (or even improving) the quality of its nature? Issues as sedimentation and erosion, biology, Natura2000, WFD and POP play distinctive and interfering roles.
2. The starting point is that knowledge currently available is not sufficient to answer to answer or solve these long-term issues. Which knowledge must be available? When has it to be ready? When do we need to develop what? What knowledge developed in other programmes will be able to provide (parts of) this new knowledge?
3. Which tidal sub-basins will be offering the best opportunities to develop system knowledge that is needed? In view of the large uncertainties that we register in the quality of bathymetry data it is recommended to first view all tidal sub-basins of the entire Wadden Sea over an as long as possible period. Later a focus on a limited number of areas that are rated to give the most relevant information.
4. Which of the likely measures that already now can be eyed (nourishments on the outer rim of ebb-tidal delta's, coasts, 'clever' dredging pilots, cyclic excavation of 'old' salt marshes, decommissioning of polders, etc..)
5. Would these soft measures be improving safety levels for increased safety levels of mainland- and island dikes (primary sea defenses)?

Intermezzo: Morphological modeling of indirect effects
Using morphological modeling on a system shows how a system reacts on the long-term to measures. For instance, reduction of current speeds will likely reduce the transport capacity, and hence, generate sedimentation. It could also be the cause for a different sedimentary regime on the tidal flats adjacent to the channel. The effect could be self-enhancing.
Studying these effects requires morphological modeling of sand and mud transport. Simulation of bathymetry changes is has its limitations especially when dealing with cohesive sediment. Tidal asymmetries need to be studied to simulate (changes in) sediment transport.
Foci for study are the following:
Morphological predictions over large time-scales (decades-centuries)
Interaction of non-cohesive (sand) transport and transport of cohesive materials
The effect of tidal asymmetries on sediment transport

2.2 Secundairy knowlegde needs

While discussing the directions for solutions secondary knowledge needs surfaced. These are listed here, but need not necessarily be solved or attended to while drafting the proposal.

Boundary conditions: change and/or margin of uncertainty

Especially for sea-level rise, the boundary conditions may change in future. For the time being we propose to use the last-century (relative) SLR, which is in the order of 20 cm/century.

Also, in terms of wave climate and strength and magnitude of storms, boundary conditions may change over the coming 1-2 centuries, the period over which the Deltaprogramme will be active.

More lengthily observation periods during which relevant statistics will be collected, are essential. Here is a clear link to be established with the North & Wadden Sea monitoring programme.

Climate models may improve over the coming 100 years, as will be morphodynamic and other models simulating hydraulic processes and their morphological responses.

Comparison of safety levels in NL, D and Dk: if the study will be spread out over the three countries this will be needed.

3 Knowlegde: available and gaps

3.1 Available knowlegde

Hydrodynamic modeling requires depth-averaged (2Dh) models. Model schematizations are partly available (RWS, Deltares, Arcadis-Alkyon). Schematization is required for morphological calibration and simulation modeling. The resolution of the grid is very important and may be enlarged in order to model e.g. channel development.

Morphological simulations can be carried out using D3D: this software package has functionalities to compute sediment transport and bathymetry changes. Lesser et al. (2004) have described the model with various validation cases applied to different water system in- and outside the Netherlands.

Within the programme Kustlijnzorg, much expertise is available in tackling the complicated sediment exchange processes between the Dutch coast, the North Sea and the Wadden Sea. There is an opportunity here to create synergy.

3.2 Knowlegde gaps

Intermezzo
The German Wadden Sea experiences an increase in tidal amplitude while NL Wadden area tidal amplitudes remain the same: how come?
(pm)

For the Wadden Sea as a whole, there is too little knowledge available to grasp the sediment fluxes in and out of the tidal inlets and onto and from the sandy tidal flats and onto the salt marsh. Up to now there is not one (combined) management authority that has recently asked the question of integrated sediment management. Nor has the question been asked how this ties up with the boundary conditions that are enforced by the North Sea onto the Wadden System. The novelty of this QS indeed is looking into integration of available knowledge while listing the knowledge needs dealing with the sediment budget over the larger Wadden Sea area, including the islands and the North Sea border. Here is a unique opportunity to acquire large scale system knowledge. Without this knowledge, large scale measures cannot be executed.

Intermezzo
How much sand is needed to elevate the bathymetry of the Wadden Sea by one cm?
(pm)

There is very little knowledge on the Short-Term dynamics and historical sediment composition of sandy tidal flats and the possible reaction of these flats to SLR, let alone of the reaction on the long-term. Only around the natural gas extraction site of Ameland where soil subsidence is monitored consequential to an EIA procedure, sufficient data are available to

monitor sandflat behavior behind the island. The impression is that the flats can easily follow SLR. The island itself, however is slowly drowning, at least its eastern spit. Furthermore, generally tidal are flats during the winter are “more sandy” than during summer. No doubt this has to do with winter storms stirring up the mud fraction and temporarily removing it. To where we may ask, and does the mud return in summer? Does this mechanism work all over the Wadden Sea?

> ***Intermezzo***
> *What are **sandy tidal flats**? Wide-stretched predominantly mainly intertidal and shallow subtidal sand ridges and flats, adjacent to shallow and not so shallow tidal channels. The ridges and flats are drained and flooded twice daily under normal tides. At spring or storm tides they may remain flooded through the tidal cycle. The ridges and flats contain a certain percentage of mud, and are therefore attractive to benthos and epibenthos, which makes these areas prime feeding grounds for wading birds and the like.*

From the SBW programme insight is being gained into the influence of wave energy imposed from the North Sea in relation to the waves generated in the Wadden Sea itself. From this position estimates can be made form the contribution of the Wadden Sea to the safety levels along the mainland dikes. Effects of storm surge set-up are also known from this study.

Directly contributing programmes

Various programmes that are running already are of direct importance to the subject of this QS.

- Feasibility study into “Mud in the Wadden Sea” carried out for the Waddenacademie by Deltares and others (results expected by 1 april 2011).
- ‘Biobouwer’ programmes
- Bilateral NL-D call for Georisk and Biorisk research proposals (at NWO) has seen several submissions. It is expected that the winning proposal will be of direct relevance to this QS’s programme (see Burchard, 2011). Focused as both the DP and the submitted Georisk proposal are on the effects of climate change, active collaboration with be needed, in this specific case.
- The Kustlijnzorg-ecology programme is (ecologically) monitoring the large nourishment that has been placed in the central and eastern part of Ameland. Although this programme does not have the funds to monitor the pathways of the nourishment sand, it is may be able, together with the monitoring of the Ameland gas extraction site, to generate hints of these pathways.
- EIA effects of dike construction Ameland (Deltares).
- Similar programmes in D and DK.

4 Developments elsewhere

4.1 At the national level

Over the last years, a large amount of integrated work has been carried out in the Westerschelde area. Lessons learned there can easily be imported into the Wadden area. The existence of an international (B-NL) technical secretariat has been utterly beneficial to the integrated programme. A lot of experience in dealing with the large morphological changes that occur in estuarine and tidal areas was gained, notably in relation to safety and ecology.

First and foremost is the establishment of a similar type of organization for the Netherlands Wadden area. Only then the ownership of the area is clear making it possible that integrated management can be following.

4.2 At the international level

As mentioned elsewhere in this report, The Netherlands is currently leading in the application of climate-adaptation to safety levels, which is the national Delta programme, divided over three generic applied research streams and six study areas. The Tri-partite Commission is actively interested in the outcome of the current QS. Contributors to the Tri-partite Commission are keen to participate.

5 Governance

The following “governance” issues are listed; it is expected that more will surface in preparing a full proposal:

a. Cooperation with the active support of the trilateral commission, with Germany and Denmark

From the side of the Trilateral commission there is a strong interest in the potential of the Deltaprogramme Wadden for the all three countries involved. The Netherlands is running ahead in the implementation of climate effects programmes. The Bundesland Schleswig-Holstein has indicated a strong interest to the extent of active participation. In any case the Trilateral commission has proposed to take an active part in the preparation even in this QS stage of development.

b. Current coastal management plans

The regular management plan of the coast of the Netherlands is carried out by providing nourishments to the coast in various forms (underwater-, beach and more rarely dune nourishments to the average extent of some 5-6 Mm3/yr). The ecological effects of such nourishments are currently subject to evaluation. Lessons learned in these projects have to be incorporated into this particular part (but also other parts) of the DP Wadden. A pilot project dealing with muddy sediment dynamics will also provide suggestions.

c. Natura2000

Natura2000 being part of the governance issue, it must become clear what kind of measures will be acceptable from the point of view of the regional nature management plans.

6 Organisation

In summary, the short term proposal is this QS document being the first stage, while the long-term proposal is the full applied research proposal to be prepared during the second stage. The full study follows.
In more detail:
1. Short-term QS proposal: worked out in this QS report (Chapter 8).
2. Writing up of the full proposal (second half year 2011): choice of methodology; differentiating the project vs. other similar projects and delineating cooperation with other affiliated projects;
3. Long-term full study (probably 5-10 years).

Towards a long-term full study (presumably decades)

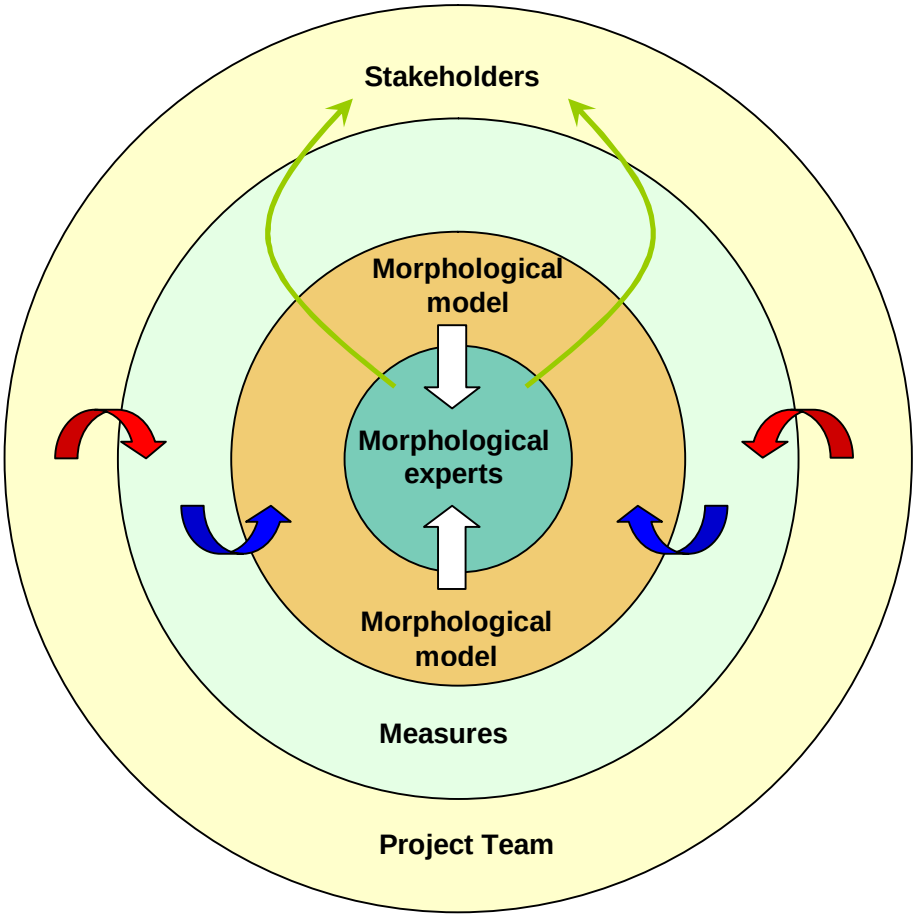
- Likely further developments of morphological models (process based (D3D) & ASMITA types of models with processes incorporated and with increased resolution)
- Detailed modeling actions: for instance tidal flat-channel interactions (seasonal; long term decadal scale; mud-sand interactions)
- Incorporate Natura2000 targets
- Test most suitable measures (if possible)
- Organize a scientific support programme incorporating PhD. students.

7 Societal participation and communication

7.1 Societal participation

The execution of the project is depicted in the figure (below). Four layers are present:

- The financer, the stakeholders and the project team
- The agreed packedge of measures
- The modelling system
- The morphological experts



The drawing above indicates the following:

- Stakeholders and project team (if needed supplemented by experts) together propose measures for study) (red arrows);
- The measures will be proposed to the morphological models (blue arrows);
- The results will be provided for discussion to the morphological experts (white arrows);
- Finally, feed back is provided to the stakeholders (green arrows).

7.2 Communication and dissemination of results

National (NL and potentially D and DK) international communication and dissemination of results (internally and externally) is an integrated part of the project from the onset. While compiling the project proposal specific attention must be paid to these aspects.
Recently, various initiatives in this regard have been developed from which methods and tools can be copied. Below, some of these examples are copied from another of the QS's, in this case the QS "Effects of climate change on storm surge levels in the Eems-Dollard estuary". Visualization is an extremely important medium for communication and dissemination.

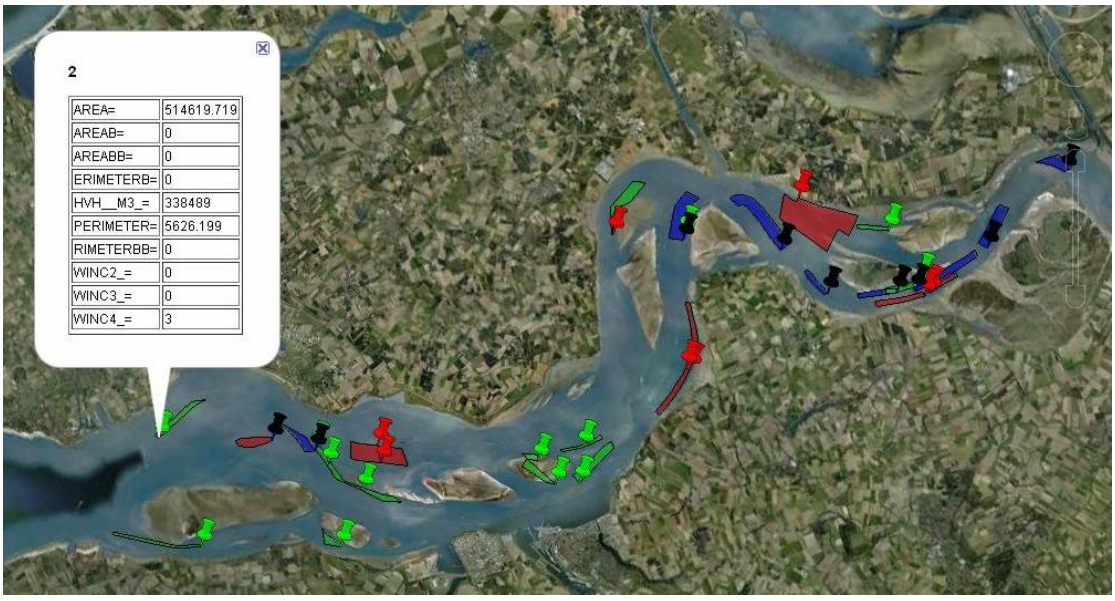


Fig. 7.1: Measures: dredging (blue), dumping (red) en sand extraction (green).

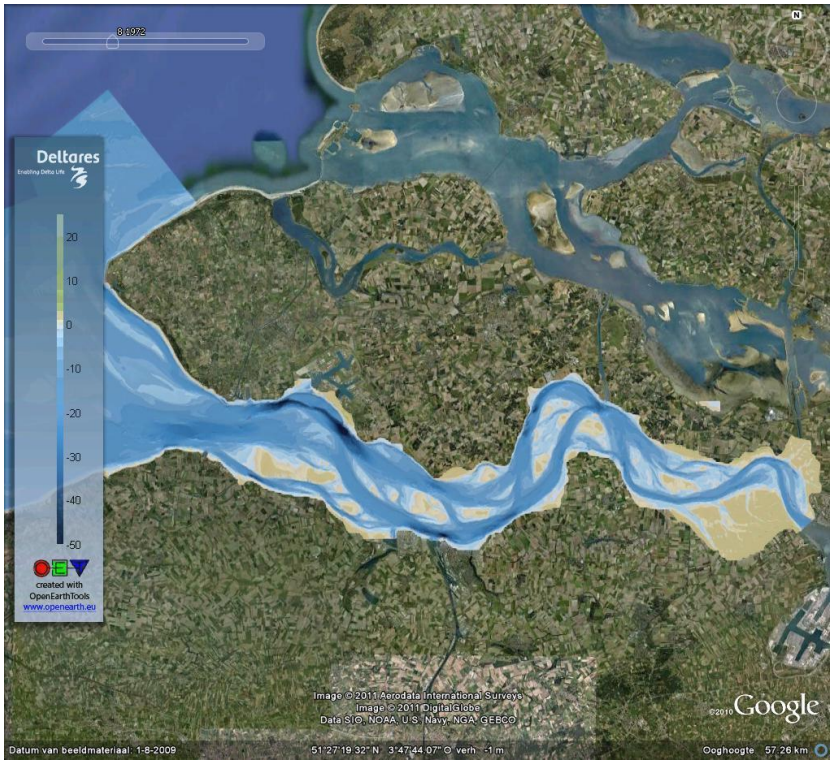


Fig. 7.2: Bathymetry.

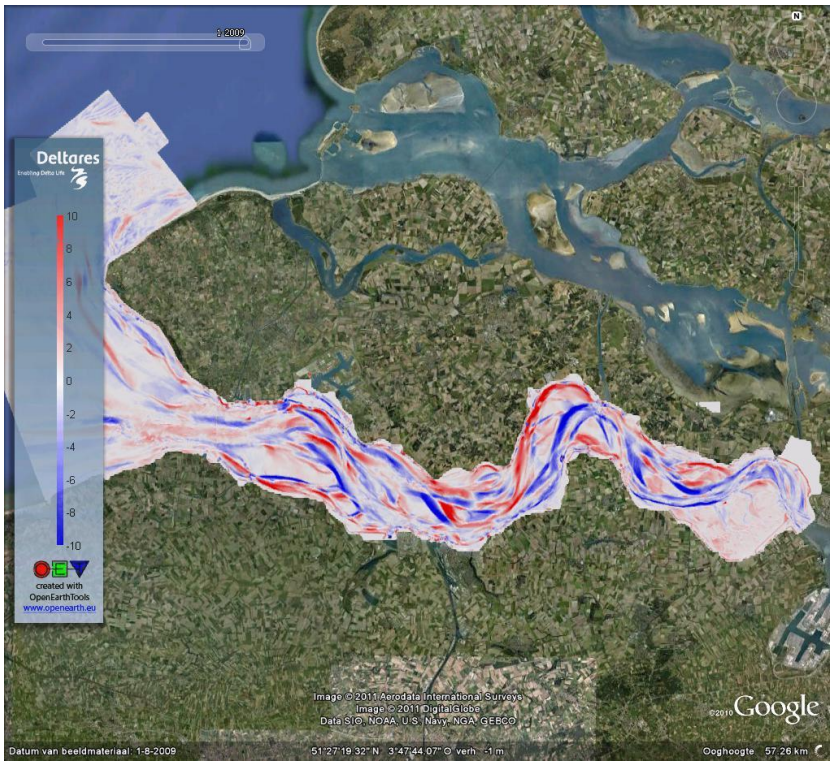


Fig. 7.3: Maps showing the differences between two consecutive bathymetries: erosion = blue, red = sedimentation.

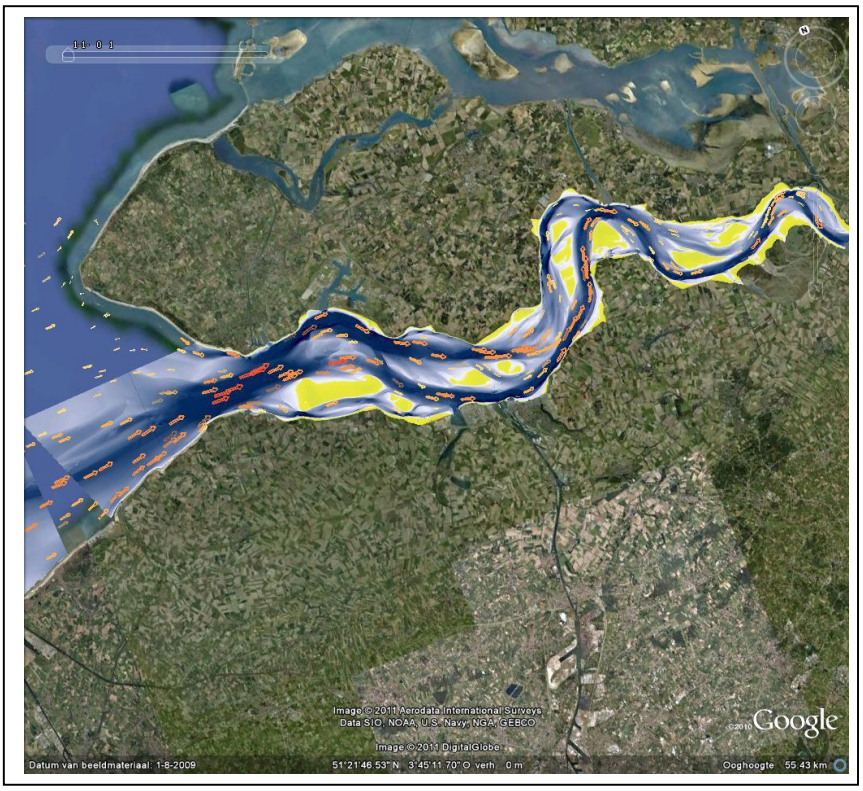


Fig.7.4: Calculated speedvectors and bathymetry.

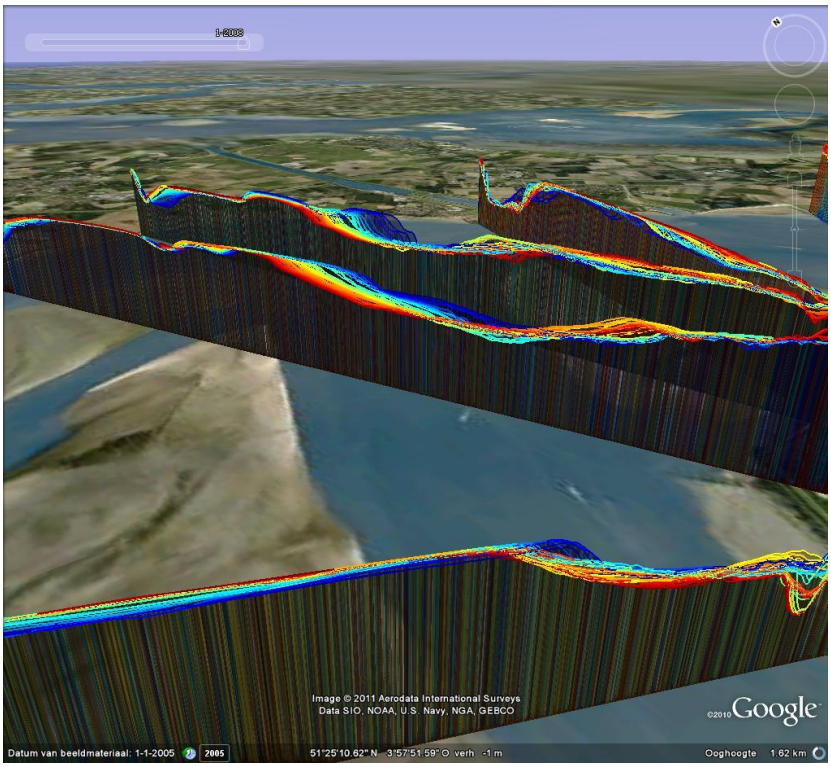


Fig. 7.5: Cross sections of consecutive years (different colours).

8 Possible solutions

Regarding the effects of measures that could be taken in the and around the Wadden Sea some of the following promising measures could be implemented, initially for fact-finding;

- nourish the ebb-tidal delta's: these areas are highly dynamic and carry less benthic fauna compared to any other part of the coastal system.
- channel –side nourishments and restoration of channel patterns
- "clever dredging" tests: use maintenance dredging spoils for system tests (and for testing the morphological and environmental impacts of such dredging): select the proper season to do the dredging & deposition of spoils
- test bio-fixation of nourishment and/or "clever dredging" materials (sea grass, Japanese oysters,…)
- test effects of limited filling in of deeply scoured channels

It may be necessary to combine some of these test proposals into a major test operation to limit potential impacts geographically as well as to restrict the monitoring activities in area and better/more economically combine monitoring activities.

These issues must be clear at the start of stage 2. Stakeholder involvement is necessary. Monitoring and evaluation at the proper level is necessary in any case.

9 Draft proposal

Introduction
The essential knowledge issues deal with the absorption capacity of the Wadden Sea in keeping up with relative SLR, and what can we do to determine this capacity, including the issue of possibly raising it. Question on the side are: what are the signs of (incipient) drowning and how can we register and even better measure them?

To answer these research questions, initiatives must be taken during the first years of the Deltaprogramme. Although the LT process suggests that the urgency is low, it is an important issue to start to articulate the research questions and start answering these questions. The question are sometimes hard to answer. A lot of relevant issues are still underdeveloped (such as (automated) measurements in the field, monitoring required, and the nature of some effects).

The monitoring infrastructure must be initiated that in due course will (probably) answer the issues dealing with sediment budgets sans as well as mud. For mud, Deltares (and others) are now designing a separate programme that runs along the same time lines as the current QS. Therefore it seems natural that the current QS study focuses on 'sand'. Information on how to deal with the Wadden Sea 'mud' will be provided by the mud study.

Fundamental to a proper analysis of the sediment budget is the availability of a well-working hydrodynamic model. Some of these are available, but non of these covers the entire Wadden Sea, nor are specific parameters for sedimentation and erosion modeled. A further version of D3D is being set up where drying and flooding is worked out in detail, so that realistic sedimentation and erosional processes can be simulated.

An important issue for the QS subject is monitoring. It a clear that for the Wadden Sea as a whole new 'cheap' monitoring methods need to be designed for better system analysis and system management.

According to opinions expressed by the regional stakeholders during the meetings is the general understanding among them that the dynamics of the larger Wadden Sea area are very much specific for the area, as they determine the attractiveness of the area for tourists and hence, the economy of the area. The understanding is also that the level of dynamics should not change. This is a quite different notion as compared to DP Kust stakeholders.

We therefore focus on the extension of system understanding in relation to sand budgets. First we list what is currently known about the system, and what could be improvements of our understanding. We work on different scales, i.e. the scale of entire tidal basins, and the scale of tidal flats with adjacent channels.

Understanding the system

Tidal basins

It is widely accepted that import of sediment into the Wadden Sea has played a constant role in the past, which includes the recent past. The imported sediment has to be provided by the North Sea coast and the ebb-tidal delta's. We know the latter are being reduced in size, although we do not know yet if there exception to the rule-there are indication that the might be (Texel Inlet for instance). The coastline is eroding that we (partly) supplement by sand nourishments. There are estimates that the volume of nourished sand is not equal to the volume lost, i.e. the coast must be losing sand in the end. Waves and currents transport ca. 95 % or more of the sand-in-motion, while wind takes care of a few percent. Blown sand equals the position of mud in terms of volume: also a few percent.

> *Intermezzo: relation to other programmes*
> *For the reason mentioned above it is adamant that DP Wadden and in particular this QS subject strikes partnership with DP Kust. This programme is quickly developing into targets dealing with spatial planning and safety, and much less with nature. Research institutes have only a minor role in it-yet. Within the KPP project Kustlijnzorg it is concluded that there are many relations between coastal management and nature, hence it can be expected that these also will play a role in DP Kust, lager than currently the case. System view is further developed in DP Wadden. Here is ground for mutual exchange.*

How much sediment can be deposited maximally per year is determined by the volume that will be transported gross and the volume that is effectively deposited in a tidal basin. The volume deposited is depending on the local settling process and subsequence degree of disturbance. SLR and human actions are predominantly responsible for disturbances. Prior research has shown that there is a practical limit to volume of sand that can be transported from coast into the Wadden Sea. This is the very reason why a large measure such as the closing of the Zuiderzee takes centuries to be balanced in terms of sediment dynamics. A similar conclusion may be drawn from the speed with which the central parts of the Wadden Islands coast move landward: this may a measure for the sand volume extracted from the coast and shifted into the Wadden Sea.

Earlier research showed that at locally larger disturbances the minimum estimate of suspended sediment through a channel more or less equaled the deposited volume of sediment in the tidal basin behind it (Eysink in Oost et al., 1995). In some smaller tidal basins observations have been recorded that indicate sand loss over a period of about half a 18.6 year tidal cycle while the larger tidal basins showed sedimentation gains higher than the supposedly long-term maxima in projected sedimentation volumes would indicate in these tidal basins (Hoeksema et al., 2004).

It is recommended to expand these import-net sedimentation relation over the trilaterale Wadden Sea with as many as possible data. In doing so, the understanding about the sediment-import and sediment-storage capacity of tidal basins could quickly be much improved.

The interaction of tidal flats and tidal channels

The tidal flats reaction potential as one anticipated effect of SLR will be highly determining for a number of functions of the Wadden Sea system (natural dynamics, safety). Anticipated (positive) bathymetry changes will likely be counteracted by continued or new extraction of oil & gas, or minerals. The maximum potential for compensation is not known. This puts boundaries to the extraction of these.

On a larger scale the exchange between North Sea and Wadden Sea is a determinant. In spite of earlier studies (Oost et al., 1995; Hoeksema et al., 2004; Wang, div.refs) the state of affairs is not

well known especially with regard to meso-scale tidal flat-tidal channel interaction (Waddenacademie, 2008).

For instance it is not well known which changes are responsible for the increase in tidal flat height, whether these are tidal levels, storm surges or atmospheric pressure in general, or highest current velocities or normal ones, wave action in channels etc. System knowledge is not sufficient at the moment hence future developments cannot be given. Of interest are recent observation made (Esselink et al., 2011). In relatively sheltered embayment such as Balgzand and Dollard strong correlation exists between tidal flat elevation and Mean High Tide levels some 1,5 years preceding the measurement of the level. The tidal flat level seems to follow MHT level. When longer periods are measured correlation becomes weaker. This indicates that the response of tidal flats is rapid. It is as of yet, unclear what causes this mechanism and how exactly the relations are. Possible explanations are:

- through more/less sediment advection through more/less tidal volume over the tidal flats vs. less/more effective wave refraction at MHT rise/drop;
- Through set-up of the tide (by northerly winds) during periods with higher MHT;
- Through discharge from the channels at larger tidal volume (which discharge enters onto the tidal flats;
- Through barometric pressure changes through which a higher MHT coincides with quiet weather periods and sedimentation.

Equally crucial for the sedimentary system analysis is the availability of a well-balanced hydrodynamic and morphological model. Some of these are available, but none of these models cover the entire Wadden Sea, nor are specifically important parameters for sedimentation and erosion modeled. Currently a version of D3D is worked on that includes the 'drying' of tidal flats: in this way it becomes possible to realistically simulate sedimentary and erosional processes.

As already mentioned the relations between tidal flats and tidal channels are a knowledge gap (Waddenacademie, 2008). Only if this gap is sufficiently filled, models can be improved. Predicting the future of the Wadden Sea morphology will become easier, by finding indications of locations where first signs of drowning by accelerated SLR will be visible.

Another important element is the monitoring that will be needed. We do not know what we should monitor more for the analysis at the system level. Modeling will help us determine possible additional monitoring actions as models can handle extreme situations that will show the gaps in the current monitoring.

Summarizing
Fundamental is a optimal understanding of the sedimentary (budget) system as is currently active in the Wadden Sea. The central policy issue is: *in what way will the Wadden system be able to function as a so-called climate buffer while maintaining its natural functions and its safety level ?*"

In short this would involve:

1. the sedimentary dynamics of entire tidal basin areas; how does the sediment enter the Wadden Sea and at what pace does this occur ?
2. How the sand is transported from channels onto tidal flats?

Centrally the following issues need to be studied:

1) At what pace is it possible to import sediment into the tidal basins?
2) At what pace is it possible to increase the elevation of the tidal flats (as averaged over some decennia under conditions of (accelerated) SLR)?
3) At what pace do tidal flats react to relative SLR?
4) If possible: study the processes that steer these relations;
5) Which indicators of early drowning must be studied (and monitored)?

What is the benefit to DP Wadden if the proposed programme will indeed take place?

- Overview of (sandy) sediment fluxes, in as many tidal sub-basins as possible. Within a certain band width total sediment fluxes can be determined (policy issues 1, 2)
- Overview of the resilience of tidal basins and tidal flats under conditions of accelerated SLR (policy issue 2,3).
- Overview of places where the first signs appear of effects likely due to accelerated SLR, i.e. where critical boundaries are crossed after which safety will be at stake (policy issue 3).
- As and when pilots will be executed that will be monitored at essential parameters, al lot of experience may be gained (policy issue 1,2, 3).
- On this basis, after some years, a Wadden Sea sediment-management plan may be drafted with a mid- to long-term perspective, as is now taking place for the regular sand nourishment programme along the entire NL coast and in some places like the Eastern Scheldt (policy issue 1).
- Involve local stakeholders (policy issue 5)

What is specifically needed?

As mentioned flat-channel interactions are a gap in our knowledge, as are the sediment import processes into tidal basins. The sediment exchange data are needed on these various scales as to provide inputs into the models under development. Observations in the system and initial modeling results may then improve the efficiency of the monitoring programme. Zooming in & out between the scales in imperative as an iterative action all through the project.

The proposal in more detail

Title:
Towards the International Wadden Sea future sediment dynamics and –budgets

Phase 1

Drafting the project plan

A small committee drafts the project plan during joint work in a central locality having data available to test hypotheses. The set-up of the project and delineations with other (active) projects is discussed and agreed upon. International cooperation needs proper funding. A phased project budget needs to be set up. Once agreed, funding agencies need to have budget ready for spending. Allowing gaps in the programme to occur (at go-no go decision moments) must be discussed and decided up front.

Kick-off meeting

A KO meeting is held bringing together scientists and managers from NL, D and DK. At this meeting presentations are given demonstrating the potential feasibility of the methods, availability of data, determination of hot spots, etc. leading to results as outlined in the draft project plan. At the end of the meeting a joint conclusion on feasibility of the project is made, and recommendations are listed. Local relevance must be clear at this stage.

What follows is a go-no go moment.

A decision needs to betaken for the following phase (1-2 years), not for the main project work (5-10 years).

Phase 2
This phase starts with working out the project plan. The same group as in Phase 1 helped by the trilateral working group, works out the results from the KO meeting into an inception report for the entire project.

Phase 2 consists of two major parts. Actually, the part “monitoring maintenance works” can already start earlier as and when suitable opportunities arise. Problem is that for this kind of wider than usual monitoring at these “simple” monitoring works require a larger-than-normal budget. There has to be willingness at management authorities to undertake and invest into such monitoring.

Desk study
At first, an analysis of the supposed drivers behind tidal flat sedimentation and sedimentation in tidal basins is made using relatively simple existing elevation data as well as and tidal data:
The tidal flats
To collect as much as possible elevation data of small- to medium sized tidal basins (10 to 100 km2) and analyze these data in conjunction with other data:

- MLW, MSL, MHW and SHW levels of **the year** preceding the timing of the analysis;
- MLW, MSL, MHW and SHW levels of **two years** preceding the timing of the analysis;
- MLW, MSL, MHW and SHW levels of **three years** preceding the timing of the analysis;
- Storm surge history of the years (or years) preceding the timing of the analysis
- Barometric history of the years (or years) preceding the timing of the analysis
- Prepare a cumulative sediment transport scheme (cf Kohsiek et al., 1988).

It is recommendable to do a comparable analysis for the channels in these areas, to trace channel-flat exchange as well as trace possible imports/exports from the areas. From this analysis it would be possible to get a good impression which indicators are important to register early response to relative SLR and which indicators must be present in the models, in order to improve capabilities of the models.

> Intermezzo
> **Potentially hazardous channel dynamics and possible solutions**
> One must distinguish between regular maintenance dredging in channels (that has to do with accessibility) and lateral channel shifts that may undercut primary sea defenses. The latter category is clearly subject of this QS, while the former isn’t.
> Yet the first category may offer opportunities for “exercise” for the second category. For instance the perpetual shallowing southern part of the Holwerd channel may offer a test site for “Building with Nature”-type of approach. Now every time and again the same mud is dredged (some 1 Mm3/yr) and deposited further west. Further east might just be a better solution.

The tidal basins
The same methods are used to study the tidal basins. A selection of appropriate tidal basins is taking place, in the tripartite countries. Tripartite meetings are held to investigate the feasibility of the project set-up.

Suggestions and 'recipes' for monitoring and modeling need to be listed in the slip stream of the desk study and fed back into the overall monitoring stream. At the same time, the project needs to be in touch with other QS studies and take from these/bring to these new insights.
At the end of this desk study another go-no go moment arises. The decision needs to be taken for the implementation of the full project work (5-10 years).

Phase 3
Modeling
Newly gained insights need to be worked into the most important available models (a.o. Estmorf, ASMITA en Delft3D 'new version'). Weaknesses in the current monitoring must be exposed and indications must be generated where and when the first signs of effect of (accelerated) SLR will be visible, and what indicators must be followed. Models may also generate insights into potential test locations for measures that will help the Wadden Sea in keeping up with SLR.
Start with a limited number of test locations and expand when successful. Iterative modeling actions needed when data collected under the project justify such.

Monitoring
Based on iterative model research and field tests monitoring have to be 'revised' in order to increase the quality of our system views on sedimentation and erosion in the Wadden Sea. Depending on the degree of additional monitoring and the results of this, another improvement may be made in predicting the future of the Wadden Sea.

Designing methods of nourishing the Wadden Sea where and when
Based on the project work, while incorporating influx of views from directly relevant projects, methods are designed to help the Wadden Sea keeping its shape and safety levels, with respect for ecology.

All through the project
Stakeholder involvement
In view of its importance it is recommended that an independent committee of scientists and local management authorities, as well as a representative of the NGO's will be established (in NL, i.e. Waddenacademie, Deltaprogramma Waddengebied & Rijke Waddenzee, Waddenvereniging) for establishment of the necessary provision of information to stakeholders and incorporation of local views where possible.
Feed back loops
It will be very important to keep up feed-back loops with other QS's under execution (in NL) and other projects in D and Dk, and with regular maintenance works for dual purpose: to learn from these works (from extended monitoring as explained above) and to introduce newly gained insights into regular works and into general monitoring programmes (Walter & DP Wadden). Flexible management and allocation of resources to the project is a must. Yearly reviews are needed in order to re-allocate budget.

Planning
First 1-2 years
Desk Study: Data analysis of "all data" available in the trilateral Wadden Sea.
Pilotstudies tidal channel management Dollard, Balgzand, Pinkegat and Zoutkamperlaag.

Next year (depending on outcomes of the first years)

Model studies on the effects and at locations where effects are registered to improve the monitoring tract.

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A Remarks and suggestions during the workshop sessions & replies

A.1 Remarks and suggestions during the second workshop 9 Februari 2011

remark/suggestion	reply
Monitoring sediment pathways thru RS	in the QS
Morphological consequences of nourishing for Wadden Sea (WZ) (height, sediment characteristics)	in the QS
What is contribution of WZ system to general safety	jointly to undertake with other QSs
Connect to DP kust/use system view (wet & dry)	Incorporated into the design of QS
Is the WZ similar to the Kust system ?	no, although some parts/themes are alike
Channel mobility and sediment budget in relation to fixation of islands/non-fixation of islands	unique to the Wadden and Zeeland open channels systems around non-fixed boundaries
What is our target for the WZ?	it is not sensible to choose a target from the past: the WZ IS a dynamic coast. Neither is it sensible to choose some target in the future for the same reason
Need to know more about channel mobility?	to be incorporated into monitoring
Channels threaten current primary sea defenses	local feature; careful monitoring: learn form it
measuring= knowledge; modeling=learning	always true, but hardly feasible to roll out over the entire Wadden Sea
Define tidal sand flats	done; to be worked out further
Define sediment budget	all sediment that is contained into the Wadden Sea and beyond
Marking of individual sand grains ?	not recommended while un-doable and expensive
How to deal with the LT aspects that are predominant in this QS subject?	Decision to be made that monitoring the LT aspects is crucial to survival of the Wadden Sea. Not an issue in this QS
What role for the research institutes?	Provide them with budget; they will be more than happy responding to complicated system issues. Not an issue in this QS
What role for data collection/analysis?	Prominent role; to be incorporated in the second stage
How to deal with low urgency of measures (as it seems now)?	Political decision. Not an issue in this QS.

A.2 Remarks and suggestions during the first workshop 5 Januari 2011

remark/suggestion	reply
sediment pathways largely unknown, including those from nourishments	into LT monitoring programmes
improve band widths by studying multiple sub-basins	into proposal
better understanding of channel dynamics	into proposal
ASMITA study to refine/enhance LT predictive capacity (100-200 years)	into proposal
Influence of wave heights on sedimentation/erosion regime	learn from SBW project
tidal amplitude increases in the German Wadden Sea: why not in NL?	into proposal
Relation to ongoing monitoring programmes along the NL coast	learn from KLZ (now) and DP Kust (in due course)
Harbour siltation incorporated?	not a part of this QS
How do intertidal flats 'work' in relation to channels? >> this is part of the wider issue of sediment dynamics, as many other questions brought forward	sediment (sand + mud) dynamics (coast, ebb-tidal delta's, channels, shoals, flats) prominently to be taken into proposal
Stakeholders: who?	into proposal
Which locations to be used for nourishments?	a follow-up of sediment dynamics study
Accessibility islands 24/7 under all conditions	not an issue of this QS>> different discussion
Effects of historical measures	into LT approach in proposal
How best to influence lateral channel migration?	is a regular maintenance issue at most times>> not an issue of this QS, only when safety levels of dikes are at stake: part of proposal
feasibility of measures such as nourishments (if large scale, LT, repeated)?	if MER/EIA will be obligatory, then these issues will be studied in EIA context.