Building with Nature: Mega nourishments and ecological landscaping of extraction areas

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Abstract

Coastal management in the Netherlands is based on sand nourishment. Large scale nourishments as a new strategy is currently discussed. The focus of coastal development and protection, including sand extraction is on technical designs and are mainly assessed for ecological threats.
The Dutch programme Building with Nature is an innovative research program aimed at developing new design concepts for the layout and sustainable exploitation of river, coastal and delta areas. It is coordinated by EcoShape, an initiative of Dutch dredging industry. Opportunities to use natural processes are identified and integrated into the planning and designs balancing natural ecosystems and human intervention and tested in four real-world projects initiatives.

A mega nourishment plan called Sand Engine is initiated by the Province of South-Holland. The Building with Nature project will use this initiative as a pilot developing knowledge regarding the essential processes and their consequences for ecological development. The opportunities for landscaping extraction areas will be studied in a second pilot project.

Introduction

The sandy coast of the Netherlands with a length of 432 km forms a natural protection against flooding by the sea. Due to erosion of certain parts of the coast approximately half of the Netherlands, however, would be flooded without coastal protection measurements on a regular base. Soft-engineering measures such as beach and shoreface nourishments are the preferred techniques to combat erosion and to protect the Dutch coast (Klein, 2005).
Climate change and its consequences like sea level rise and increasing storm frequencies will increase the demand for marine and coastal protection measurements and to maintain the coastline position.

The coastal management in the Netherlands is heavily based on sand nourishment of eroding areas on a 4 to 5 year interval with between one and several million m^3 sand. Starting in the 90's, beach nourishment was the most important way of replenishing the coast with sand. Lately, the emphasis shifted to foreshore nourishment making use of natural processes to bring sand towards the beach.. In recent years very large nourishments as a new strategy for coastal management have come into discussion. Strategic use of mega nourishment may lead to a more cost-effective management. With sea level rise it is expected that smart and strategic nourishment become vital.
The assessment of the all-embracing impact of coastal development and coastal protection, including extraction and nourishment activities, on the regional marine and coastal environment is as such of growing interest.

The coastal and offshore environment is protected by (inter)national legislation and regulations such as the Water Framework Directive, Natura 2000, EU Bird and Habitat Directive. The European Commission has adopted in 2006 the Marine Strategy Directive to protect the marine environment and as a result of this management of the coast should be based on an ecosystem approach.

As the ecological implications of dredging and nourishments become more and more important these must be taken into account in the policy making process, confronting the dredging industry and applicants of large extraction licenses nowadays with national and international obligations in order to obtain licensing. In the Netherlands the national policy on extraction is documented in the Dutch Regional Extraction Plan (Ministerie van Verkeer en Waterstaat 2004).

Delta Committee

In 2007 the Dutch government installed after more than 4 decades a 2nd Delta Committee. This in order to advice on protecting the coast and the entire low lying part of the Netherlands against the consequences of climate change. The results of the Delta Committee were presented in September 2008. A summary of the Advice can be found on http://www.deltacommissie.com/ . The committee's recommendations lay emphasis on development along with climate change and other ecological processes. Their implementation will allow the Netherlands to better adapt to the effects of climate change and create new opportunities. To prepare the Netherlands to become climate proof, the Delta Committee drafted a Delta Program.
The Committee issued a number of research questions at specialist institutes. Such a consulted institute predicted a regional sea level rise between 0.65 to 1.3 meters by 2100, whereas so far 0.65 m following the average sea level rise scenario was used. A worse case scenario of 2 to 4 meters was predicted by 2200.. Based on these predictions, recommendations were made to take sustainable measurements. The level of flood protection must become at least a factor 10 higher than the present level. In the view of the Committee, the best way to protect the coast from sea flooding is by replenishing the entire coastline, from Zeeland to Den Helder and along the Wadden Sea Islands. The advise includes the use of marine sand for large scale nourishments to protect the Dutch coast, resulting in a seaward growth of the coastline providing great added value to society. In doing so it is recommended to make greater use of natural processes in sea defences; "Build with nature".

Since 2004 the volume of annual marine sand extraction reaches approximately 26 Mm^3, of which 13 Mm^3 are annually used for nourishments. This volume of sand for nourishments might increase up to a volume of 40 Mm^3 that is yearly needed. This may result in one new gully each year of 10 m depth, 200 m wide over a length of 20 km, or several separate dredging areas which in total will exceed these dimensions. For economic reasons, the sand extraction areas most probably will be located somewhere between the 20 m depth contour and the 12-mile zone contour line. Such large scale extractions could result in a new morphology in the coastal zone. Therefore the geomorphological and especially the ecological implications at sea and in the coastal area, the benefits, economic requirements as well as the governance aspects associated with the nourishment of such large volumes should be investigated.

Building with Nature

The Dutch national program 'Building with Nature' started in 2008 and is an innovative, long-term research program aimed at developing new design concepts for the layout and sustainable exploitation of river, coastal and delta areas (Van Raalte *et al.*, 2008). It is dedicated to research on the role of natural processes in design and management of (coastal) projects. Opportunities to use natural processes or to positively support natural ecosystems are identified and integrated into the planning and designs balancing natural ecosystems and human intervention. The program is focused on infrastructure development in marine, coastal and estuarine environments, although inland construction works in fresh water systems are included as well.
For the implementation of the recommendations of the Delta Committee towards the management of the coastline a research program as Building with Nature will be essential in order to arrive at a sustainable and integrated coastal zone management, that is science based, realistically feasible and socially- and politically-acceptable.

Building with Nature is an initiative of main Dutch dredging contractors Boskalis and Van Oord. It is a multi-disciplinary program in which ecologists, scientists and technical specialists will work, design and create together, with nature as the starting point in the design process, to gain new knowledge on effectively developing and using ecosystems.
This special feature is known as 'ecodynamic design': the synergy and cooperation that will allow natural ecosystems and human intervention to reinforce each other. This approach lays emphasis on the opportunities natural processes offer in the design and management of (coastal) projects, yet obviously without ignoring infrastructural and economic conditions. Building with Nature aims to provide objective, scientific knowledge and tools, technical and managerial, to help designers, builders and leaders develop areas in such a way that the economic and living environment evolves safely, prosperously and harmoniously in the long term.

Important part of the program is the identification of the Building with Nature core qualities. These are those aspects that can be used in a design process to enhance the natural value of the design and its result, whilst reaching a cost- and time efficient solution. Building with Nature core qualities can be linked to stakeholders and their demands and wishes, enhancing also the possibility of achievement of societal goals and increasing social acceptance of infrastructure development projects. The core qualities can be determined based on functions (nature, fisheries, recreation, tourism, spatial development, etc) and on the design process. Core qualities will facilitate the Building with Nature approach into coastal management by supporting a more transparent decision-making process having different alternatives, creating a sense of ownership of the major infrastructural projects and better and more broadly informed discussions between decision makers, NGOs and the public.

The program focuses on:
- Identifying, understanding and quantifying natural processes
- Integration of these processes in the design, planning and management processes
- Identification of the way in which they can be addressed in the decision process.

The program has several well-defined work packages each aimed at specific issues. The main work packages are:
- Ecologically Meaningful Criteria
- Natural Dynamics & Cumulative Impacts
- Predictive Modelling and Effective Practice
- Landscaping for Ecological Enhancement

These issues are being investigated and tested in relation to four realistic cases which all represent real-world projects in the early stage of development.
This to guarantee the practical focus and applicability of the research.

The Program is coordinated by EcoShape, a foundation consisting of public and private parties that coordinates the various themes and related projects. More information can be found on www.ecoshape.nl and in Van Raalte *et al.* (2008).

Future development in coastal protection: Mega nourishments

Nourishments in the foreshore make use of natural processes to redistribute sand along the coast. With mega nourishments these processes will effect the coastal environment on a larger time and special scale (Baptist *et al.* 2008, Klein 2005, Holzhauer 2009). One of the potential locations for such a mega nourishment is the coast of Delfland in the Province of South Holland. This stretch of the South Holland coast is generally speaking an eroding coast for which frequent nourishment is needed to maintain the present shoreline.
The Province of South-Holland initiated a plan for a mega nourishment under the name "Sand Engine". This project can be seen as the next step in coastal management, seeking an alternative for the present frequent nourishment of small-scale coastal stretches.

The Sand Engine project consists of nourishing a large volume of sand in the order of 20 Mm^3 (figure 1). It is set-up with a three-fold objective, viz. (i) sustainable guarantee of coastal safety, (ii) create space for nature development and recreation and (iii) explore opportunities for innovations. Potentially, the choice for a large volume of sand will be cost-effective because of economy of scale and because a mega supply can be timed to a dip in market prices. The idea is that natural processes (water and wind) will redistribute the sand along the coast towards the beach and thereby support natural formation of the shallow coastal region and the dune area. The mega nourishment at Delfland, in combination with wider beaches, will instigate active dune formation in the coming decades. This dune formation is expected to be swift enough to follow sea level rise, so a structural solution is

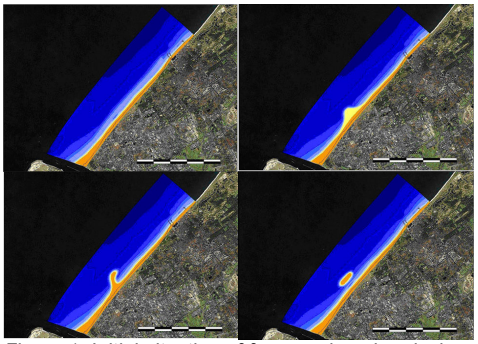

Figure 1. Initial situation of four sand engine designs: shoreface nourishment (top left), peninsula (top right), hook-shape (bottom left) and island (bottom right). With courtesy of Grontmij (2009).

offered that will ensure the safety standards of the sea defence in spite of climatic change.

The Building with Nature program has adopted the Sand Engine initiative as a practical test as part of the over-arching Holland Coast case. The Holland Coast case aims at increasing knowledge regarding the essential processes for sustainable protection and their consequences for ecological development. Besides the Sand Engine, a second experimental study is defined: Landscaping for ecological enhancement. Both experiments introduce the key elements of the Building with Nature approach into the real-world design process and are examples of ´learning by doing´.

The Sand Engine pilot investigates the concept of mega-nourishments as an environmentally friendly and flexible pro-active method for coastal maintenance facing accelerated sea level rise, at the same time boosting nature and recreation. The pilot Landscaping for ecological enhancement investigates the opportunities for beneficial use of extraction areas by creating relevant new habitats.

The Sand Engine pilot project aims at gaining a better understanding of the morphological development of a mega nourishment, the growth of beach and dunes due to landward transport of sediment, (temporary) nature development as a result of the interaction between morphology and ecology, and the identification and utilisation of ecological potential in the design. The development of system knowledge and testing of new models and techniques is linked with an extensive monitoring program of a dune compensation measure in Delfland. The project will also provide concrete information for the policy discussion about the effects of a sand engine on several user functions of the coastal areas and of the sand extraction sites.
Currently proposals for applying the Sand Engine concept at other regions along the Dutch coast are in preparation.

Landscaping for ecological enhancement

The Building with Natures project 'Landscaping for ecological enhancement' will investigate the promotion of an ecosystem approach in marine projects through an ecological design and realization turning threats into sustainable opportunities. As a practical example the possibilities for landscaping a dredging site will be investigated. Whereas present extraction policies still aim at quick recovery and restoration of the original habitat the activities in this project will explore the possibilities in time and space to enhance both nature and economy by desk and experimental studies in actual dredging areas.

The inevitable growth in nourishment activities and large scale infrastructural development projects will lead to an increased demand for marine aggregates in the Netherlands. The volumes of material involved will substantially impact the sea bed at the extraction sites. The environmental effects can be either temporary or permanent and may be either negative or positive. Environmental laws and regulations usually attempt to prohibit, mitigate or compensate undesirable effects by imposing norms and standards.

At present the (inter)national legislation, policy and public awareness focus on infrastructural activities lies primarily on the economic value, whereas environmental impacts are seen as inevitable and should be minimized to acceptable standards, which are often defined without much scientific justification. When negative effects can not be avoided, these should be minimized in time and space or even compensated in other areas.
Current legislation and policy, however, does not foresee in the exchange of one habitat in to another habitat. For the marine and coastal waters of the EU areas are described and classified in order to indicate areas of special interest to meet the Natura 2000 call. Within EIA procedures potential areas are compared to select the one in which the impact of an intended activity is expected to be minimal, next to a description of a most environmental friendly alternative for the total activity. Classifying the alternatives on their post-dredging potential value is, however, rarely part of an EIA. As such the opportunities that could improve or add to the overall sustainability of the dredging project are not considered and therefore missed. Management of the sand extraction process in such a way that the end-result of the dredging operation is an area ecologically more valuable than before, is a new concept which needs a mind shift in the method of approach and will influence the design and construction procedures for a dredging project.

Ecological engineering has already been introduced and promoted in terrestrial infrastructure projects to incorporate the interests of nature and environment in sustainable development (Van Bohemen, 2005). In the case of land based sand & gravel extraction operations, ecological designing (eco-engineering) has become an increasingly important part of licensing procedures in order to increase public support. Developing a similar approach in the marine environment may facilitate social and political acceptance of the future large scale dredging operations accelerating licensing procedures.
The development of artificially created sea bed habitats (landscaping) at dredging sites may provide habitats for target organisms, such as endangered or commercial species, in areas which, at present, do not provide biodiversity and biomass. The development of reef ecosystems on ship-wrecks and man-made reefs throughout the world has clearly demonstrated the opportunities of constructions in protection, restoration and expansion of ecological functions of local systems as well as increasing economic values (Jensen *et al*, 2000).

Under water landscaping of dredging sites may even offer the opportunity for increasing the economic potential of areas. Created landscapes for instance could be attractive for fisheries by enhancing biomass production of economically valuable target species as shellfish, lobsters, certain fish species or provide nursery grounds. Landscaping as an integral part of aggregate extraction operations may even offset the negative impacts of other types of human activities by creating refugia sheltering endangered species. Even tourism could benefit.

The amount of material needed for mega nourishments and large scale infrastructural works is of such dimension that shallow dredging up to a maximum of 2 meters below the seabed as it is currently practiced in the Netherlands will affect vast areas and is therefore not the most optimal dredging strategy. For the second Rotterdam harbour extension Maasvlakte-2, approximately 365 Mm^3 sand is needed. Mitigating the scale effects has resulted in the permission of deeper dredging within the Extraction Law. For the Maasvlakte-2 project dredging is foreseen with a maximum depth of 20 m below the original seabed, with an average depth of about 16 m below the original seabed. As the depth and scale of the project exceeds all current experience for the Dutch situation, a large scientific environmental monitoring program is set up by the Port of Rotterdam which has already delivered an important amount of data. This and the foreseen monitoring program will increase the knowledge on its consequences and also on its possibilities.

The expected growth of marine sand needed in the future and its consequences for the scale of extraction activities such as needed for the Rotterdam harbour extension will create an opportunity to experiment with landscaping the seabed. Extracting sand in such a way that differences in depth, seabed morphology and sediment types are modified to a certain extent, may enhance valuable habitats at places where these naturally would not or only on long term occur.

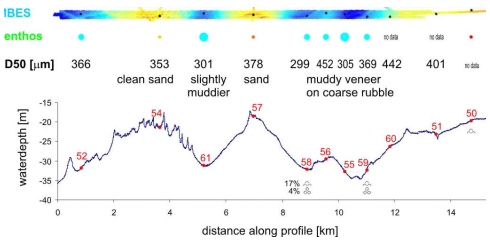

Figure 2. Seabed profile, surface sediment description and benthos community type and density as found over a transect of tidal ridges in the North Sea. With courtesy of Van Dijk et al. (2007).

The distribution of marine organisms and communities is strongly related to hydrodynamic, morphological and sediment parameters (Hawkins *et al.*, 1998; McLusky & Elliott, 2004).
Recent studies have increased the knowledge on the macrofauna distribution in the North Sea (Degraer 2008, Pesch 2008), but also have given a start at gaining insight in the small scale distribution and (seasonal) variability in relation to the geomorphology of the seabed (Baptist *et al.* 2006). Results show that tidal ridges accommodate different benthic habitats, which are important to both benthic and pelagic organisms (Figure 2). In general a zonation exists over larger geomorphological features such as tidal ridges in which the crests accommodate poor benthic communities and the adjacent slopes and troughs are characterized by communities of higher density and diversity (Figure 3). Local and even small meso-scale bedforms influence the distribution of (marine) organisms (Baptist *et al.* 2006). Although several studies were conducted on the recovery of dredging sites (Boyd 2005, ICES, 2001, Desprez 2000, Kubicki *et al.* 2007, Van Dalfsen & Essink 2000, Van Dalfsen *et al.* 2001) the process of recolonisation/restoration of the benthic communities is yet not fully understood an needs more study.

Extraction of aggregates has a direct impact on the sea bed as its top layer is removed, affecting the depth, the morphology and the sediment composition resulting in a different habitat, with possible radiating effects. Depending on the scale, the design and the construction method, extractions can cause changes in the hydrodynamic patterns leading to effects on transport of fines, salinity and oxygen gradients. These, in turn can affect habitat quality in a wider area, the transport of fish larvae and the abundance of food for fish, birds and mammals. So physical changes in the sea bed will lead to a response in the composition of its natural benthic assemblages and their predators such as fish.

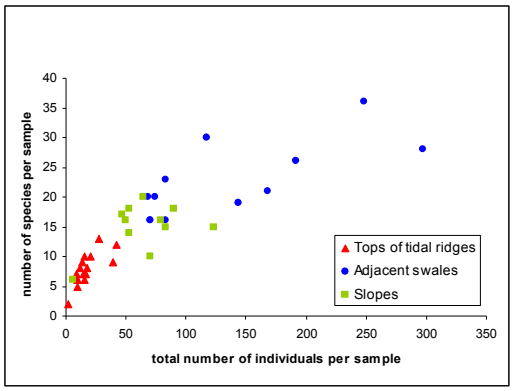

Figure 3. Density and diversity per morphological unit as found over two of tidal ridges (both banks) in the North Sea. With courtesy of Van Dijk et al.(2007).

Through landscaping of an extraction area according to a predefined design of its dimensions (shape and contours) the characteristics of the seabed within the extraction area will be arranged or modified, even with possible effects on the surrounding area. The understanding of the interactions and feedbacks between the physical and biological processes can therefore be deployed to alter the environment in such a way that ecologically valuable habitats can develop, attracting benthos, fish and birds giving opportunities for enhancing the ecological and economic potential of the post-dredging situation.
Understanding ecosystem principles and basic morphodynamics are the key factors to produce effective designs for sustainable landscaping projects. At present such detailed knowledge is lacking. Scientific research is needed to assessment of the opportunities and to evaluate the effectiveness and sustainability of landscaping in terms of supporting marine life, as well as its social and economic value. This research will be conducted within the Building with Nature case study Holland Coast pilot project 'Landscaping for ecological enhancement' and executed as part of a PhD project. The opportunities and obstacles for landscaping extraction areas will be identified and insight in the design process as well as the constrains in the policy and juridical framework related to extractions will be increased.

An extensive database will be set-up that includes data on North Sea abiotic and biotic parameters (hydrography, sedimentology and morphology) as well as spatial data on benthos, fish, bird and mammal distribution and other relevant parameters. Based on this generic knowledge of habitat factors in the North Sea, key parameters and boundary conditions for habitat development in extraction areas will be identified. A next step is the development of an assessment methodology for describing the physical and biological interactions and ecosystem effects of (deep) dredging. This methodology will be made operational in a model system in which various designs of a extraction areas will have to be evaluated on their habitat suitability for benthos, fish, mammals and birds. Variables in the

design include the depth, width and length, the direction with respect to residual flow, the direction with respect to waves, the steepness of the slopes, the internal morphology and other factors. The resulting set of models will be used to identify the most effective sand extraction site designs for creating valuable North Sea habitats, which can be used to make a projection for a desired lay-out of sea bed morphology for the next decades in relation to future large scale dredging operations and marine infrastructure development.

The 'Landscaping for ecological enhancement' pilot project will improve the prediction of ecological consequences in time and space, and develop concepts and methods to create ecologically valuable habitats through under water landscaping.

Conclusion

The predicted sea level rise resulting from climate change will lead to an increased demand for marine and coastal construction schemes to protect the Netherlands from being flooded.
The Dutch Delta Committee has advised the use of large scale nourishments to protect the coast and the entire low lying part of the Netherlands against the consequences of climate change. Where applicable natural processes should be used. Large nourishments as a new strategy for coastal management implies an increase of sand extraction activities in the Dutch part of the North Sea.

The environmental consequences of this scale increase in dredging and nourishments activities for the marine environment of the North Sea and the coastal zone needs serious consideration. The overall effect on the environment will be time and space dependent and related to the ecological functions of the affected areas, but also on the design and execution of these works.
The use of ecosystem principles in the design and implementation of marine infrastructural projects, including extracting materials, will offer the opportunity to incorporate environmental protection or even enhancement with economical and social benefits in such projects. Research is therefore needed to better understand the dynamics and the relationships in the chain-of-effects between the project, the construction techniques and ecosystem development so that decision-making can be based on both economic and ecological benefits and costs.

The "Building with Nature" research program aims at a knowledge base on improved designs and construction techniques for infrastructure development in marine, coastal and estuarine environments that will minimize ecological impacts, stimulate ecological development or recovery, and create new areas of natural beauty and cultural significance.
The Sand Engine pilot project will increase the understanding of the morphological and ecological functioning of the sandy coast system, with a focus on beach-dune interactions. With that knowledge it may become possible to combine the protection of the land and the protection of the marine environment into 'coastal protection' in the true sense of the word. An important step forward can thus be made in the attempt to an 'integrated coastal zone management', in which human activities, large scale extraction and nourishment are based on an ecosystem approach.

The 'Landscaping for ecological enhancement' pilot project will improve the prediction of ecological consequences in time and space, and develop concepts and methods to create ecologically valuable habitats over a prolonged period of time through under water landscaping. In order to develop predictive models for the design and deployment of landscape projects, research will be conducted to increase the understanding of the interactions and feedbacks between the physical and biological processes.

The "Building with Nature" program will help to increase the knowledge that currently pose restrictions on "Building with Nature" and aims to realize a paradigm shift in our appreciation of marine, coastal and inland water construction works. The knowledge developed will be based on practical experience and ready to be translated and adapted to the other environments and situations as well as of use to international policy frameworks.

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