Eco-dynamic Development and Design tested for coastal management.

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Unlimited Opportunities

Working in coastal planning is nearly always innovative, since no two coasts are the same. Even if they appear to be physically similar, local conditions and governance settings are usually different, thus requiring a different approach. Each project is unique, which makes coastal projects exciting and diverse.

This diversity opens perspectives to a variety of ways to develop a coast, supported by a wide range of guidelines, books and articles on coastal zone management and coastal planning. In general, important factors influencing any given project are:

- functionality (flood protection, recreation & nature, possibly sand or gravel mining),
- physical characteristics (metocean, materials, bathymetry, etc),
- ecosystem characteristics (dune forms and habitat, foreshore and surf zone biota),
- economics (costs and benefits, exploitation, return on investment),
- governance issues, including permitting and politics,
- public opinion.

In most innovative projects the consequences of the interventions are not exactly known, usually less so than in projects taking a traditional approach. This may constitute an obstacle to the implementation of such projects, where a combination of existing 'traditional' designs, measures and materials is often considered a safer choice. This paper claims that this practice should better be changed and demonstrates the feasibility of a more innovative approach.

After an introduction of the philosophies and principles behind 'Building with Nature' and on the steps to be taken within 'Eco-dynamic Design and Development' process, two pilot

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projects are described in which Building with Nature has been tested, both technically and procedurally.

Building with Nature Innovation Programme

The Building with Nature (BwN) innovation programme addresses this issue by bringing together ecologists, engineers and governance experts in a new cooperative setting, enabling them to explore integral solutions, instead of looking for mitigating measures and compensation for environmental impacts after the principal design choices have been made: combining ecology, engineering, economy and decision making to maximise total project value. A unique feature of the programme is that the resulting ideas are then tested in real-life pilot projects in different aquatic environments. BwN is involved in four such projects, one of which, on the Holland coast, is highlighted in this paper (other pilot projects focus on bank- and shore stabilisation using natural materials in a way that both. structural stability and ecological development are enhanced). Furthermore, the programme includes 3 generic studies and 19 PhD- studies connected to the pilot projects

Building with Nature is a five-year innovation and research programme (2008-2012) carried out by the Foundation EcoShape **(**www.ecoshape.nl **)**. This 30 million Euro program is initiated by the Dutch dredging industry, while partners represent academia, research institutes, consultancies and public entities.
This approach is created around five program objectives:

1. Develop ecosystem knowledge enabling Building with Nature
2. Develop scientifically sound design rules and norms
3. Develop expertise to apply the BwN concept
4. Make the concept tangible using practical BwN-examples
5. Establish how to bring the BwN-concept forward in society and make it happen

Throughout the program the interaction between disciplines is promoted, involving ecologists, engineers and social scientists.
The work comes together in a work package called ‘eco-dynamic development and design’, which aims to draft a document with guidelines for eco-dynamic design of hydraulic (mainly coastal) engineering infrastructure. Results will become publicly available in the course of the program, with completion of the design guideline envisaged for December 2012.
Explorations are being made for an extension of the program after 2012, including the extension of international cooperation.

The project teams, which include policy makers, contractors, consultants and scientists, ultimately aim at up-to-date, factual and down-to-earth guidelines for those who wish to implement these ideas in their practice.

The BwN-programme aims at exploiting the potential of this cooperation, looking for ways to combine ‘wet’ infrastructural engineering with the help of nature, at the same time creating new opportunities for nature. Examples highlighted in this paper, are:

i. Along the coast: re-establishing natural solutions to century-old challenges.
   Examples of ongoing pilot projects are the use of shellfish reefs and other eco-engineers for estuarine shoal stabilisation, ecologically-engineered nourishments, mega nourishments using natural dynamics for their redistribution (‘Sand Engine’), etc. The projects are supported by PhD research on key relationships between hydrodynamics, sediment, morphology and ecology, as well as on governance issues. Indicators are sought that show the state of the ecosystem in the vicinity of such projects.
ii. In coastal shelf seas: second life for sand borrowsites:
   Two borrowsites for the extension of Rotterdam harbour are left behind with a sand ridge (>2Mm^3) to investigate the potential added value for nature, recreation and fisheries, including the ecological recovery time after sand extraction. The new physical lay-out

provides a wider range of water depths, a wider variety of flow conditions and more variation in bed composition, thus probably providing habitat to more species.

iii. In society: governance:
The role of actors and stakeholders in decision making on building-with-nature projects and the effective way to introduce building-with-nature concepts in early stages of the project are investigated and translated into practical guidelines.

The Building with Nature Philosophy: a paradigm shift

As a result of the ongoing demographic concentration in coastal, deltaic and riverine areas, the increasing demand for safety, prosperity and sustainability and the need for action bound to arise from climate change and accelerated sea level rise, there is a persistent demand for large infrastructural projects (Ehrlich and Ehrlich, 1997). Coasts need to be protected from sea level rise, rivers need space to safely accommodate extreme floods (see http://en.wikipedia.org/wiki/Room_for_the_River_(Netherlands)) , capacity of harbours and navigation channels needs to be increased, quality of water bodies and subsoils needs to be maintained or restored, natural resources need to be utilised in a sustainable way, etc.

The past decades have shown that the realisation of infrastructural works can be characterised by the following trends:

– we want more (multifunctional designs, including environmental aspects),
– we know more (knowledge of natural systems has increased enormously), and
– we can do more (increased technological capabilities enable new approaches),

whereas at the same time:

– we have to operate more carefully (care for the environment has increased),
– we have more difficulty getting things done (complexity of society and decision making has increased), and
– we have to meet increasingly complex functional requirements (modern society has high demands).

These developments present hydraulic engineering and environmental protection with challenges as well as opportunities. The only possibility to sustainably reconcile the needs of the environment with the growing demand for infrastructure development and use is to ensure that infrastructure works with nature, rather than against it. This requires a change in thinking, acting and interacting, a paradigm shift in all aspects of project development.

In the past, infrastructural works used to be designed and constructed without paying much attention to the potential environmental impact. Since the 1970's, interest and legislation for the environmental protection have developed and has led to more attention for minimising the environmental impacts caused by infrastructural works: building **in** nature.

Since the 1990's, European environmental legislation adopts the principle of prevention, mitigation and compensation of residual effects. The compensation of any residual environmental loss triggers building **of** nature. Legislation emphasizes conservation of existing nature and puts a lot of emphasis on the precautionary principle. As a consequence, projects are still dominated by impact minimisation, extended with mitigation and compensation measures.

Good engineering complies with nature and makes optimum use of natural forces. In the 80’s and 90’s (coastal) projects have been implemented that successfully made use of those forces:

building **by** nature. One example is shore nourishment to maintain sandy coasts (http://en.wikipedia.org/wiki/Beach_nourishment; Van Duim et al., 2004).

The next step in the development of hydraulic engineering is to attribute a more active role to natural processes, by utilising these natural forces and at the same time creating opportunities for development of new nature. This concept in now termed building **with** nature (see Figure 1). The credo is no longer ‘doing less harm’, it now becomes ‘doing more good’.

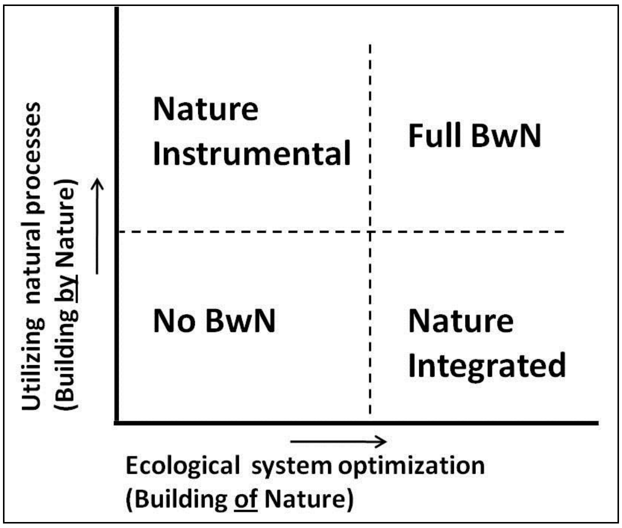

Figure 1: The building-with-nature philosophy in project development

Where the usual approach to large hydraulic projects basically follows the steps:
1. Plan a project or activity, starting from the functionality it has to provide for,
2. describe the effects on the ecosystem,
3. optimize the design to minimize or mitigate detrimental effects,
4. compensate by building of nature, and
5. execute the project in strict adherence to fixed norms and regulations.

the alternative, ecosystem-based approach boils down to:
1. Understand system functioning ('read' the ecosystem, the socio-economic system and the governance system),
2. plan a project or activity taking the system's present and envisaged functions into account (combining functional and ecological specifications),
3. determine how natural processes can be used and stimulated to achieve the project goals and others (using the power of nature),
4. determine how governance processes can be used and stimulated to achieve the project goals (using the power structures in place),
5. monitor the environment during execution, analyse the results, make risk-assessments, if necessary adapt the monitoring program and/or the project execution (monitoring and adaptive management), and
6. monitor the environment after completion, as to assess the project's performance and to learn for the future (knowledge development).

This alternative approach reflects the notion that from an overall project performance point of view, the best choices are not necessarily the ones that fit best to the individual project phases (project initiation, planning & design, construction, operation & maintenance). Rather we should balance long-term costs and benefits, in monetary and non-monetary terms. The term

Eco-dynamic Development and Design (EDD) is used to refer to this alternative ecosystem-based design approach.

EDD principles

The paradigm shift from Building in Nature, via Building of Nature to Building with Nature, drives the need for an alternative eco-system based design approach: Eco-dynamic Development and Design. In order to achieve this paradigm shift, a different attitude is required, from individuals as well as from social groups. Individuals may need to think, act and interact in another way than they were used to. EDD can only be applied successfully if changes can be achieved in the basic aspects of human behaviour (Edwards, 2009; Kira and Van Eijnatten, 2008):

- ***think and behave differently***: adopt a BwN philosophy, based on a thorough understanding of how the system you are working in functions, and strive for balanced win-win situations;
- ***act differently***: take the entire complex of system functions into account and optimize on the entire project, integrating and evaluating all development phases; cope with the uncertainty that is inherent to nature.
- ***interact differently***: make sure that all parties with a stake in the development can bring in their views and are heard, while being aware that existing societal boundaries might impose limitations to what is feasible; cope with the complexity of multi-party and multi-interest decision making.

EDD steps

A project lifecycle usually has 4 phases: ‘initiation’, ‘planning & design’, ‘construction’ and ‘operation & maintenance’, with at the end possibly a fifth phase: ‘demolition & removal’. Depending on project management and contracting formats, two or more phases may be merged into one. Although each phase offers opportunities for integration of EDD solutions, maximum flexibility and BwN-potential exist in the earliest stages of development. To optimally seize these opportunities, it is recommendable to take a life-time approach and consider the potential in later phases as early as possible (see Figure 2).

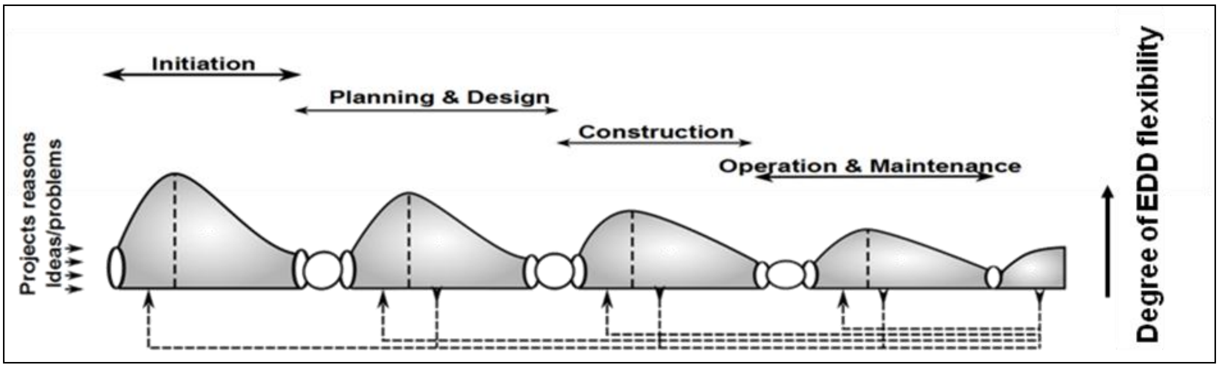

Figure 2: Project phases and flexibility to introduce EDD-principles.

Analysis of practical cases revealed a number of steps that are invariably taken when developing creative Eco-dynamic Designs. Although the process is cyclic, the steps outline a basic creative process that can be followed in any project development phase (Figure 3).

The steps are:

1. ***Gather system understanding.*** Every phase will give the opportunity to amass new information giving more insight into the functioning and the functions of the system one is working in. One shall be clear about primary objectives and realise that finding win-

win solutions creates room for flexibility in catering for secondary objectives. Looking at primary objectives only may lead to a limited definition of the system to consider. Adding secondary objectives entails consideration of other system characteristics: other parameters, other time and spatial scales etc.

2. ***Identify alternatives and options*** that have the potential to meet the project requirements. These alternatives may build upon the options selected in the previous phase, but can also open up for new points of view. This step requires people who can think creatively, beyond the borders of their own profession and expertise.

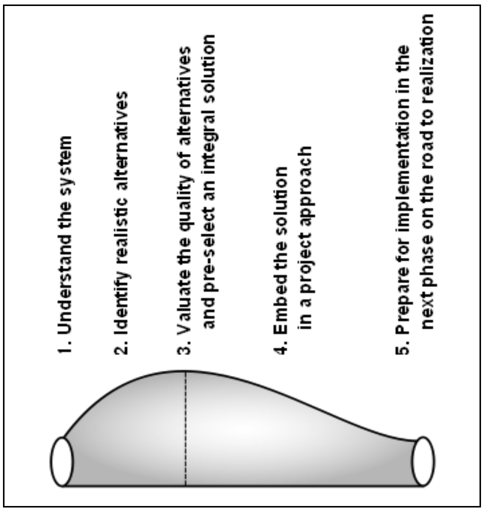

Figure 3: EDD steps in a project phase

3. ***Assess the inherent qualities*** of the alternatives on the basis of a decision framework that includes the BwN sustainability criteria. This may involve an environmental-societal cost benefit analysis and also formal screening against existing rules and regulations, e.g. for nature conservation. Models for estimating ecological values against social and economic values play an important role in this assessment.
4. ***Embed these alternatives*** in the socio-ecological context, notably the allocation of costs, benefits, environmental values, risks and related management.
5. ***Optimise these alternatives*** taking into account multiple goals, costs, dynamics and risks, based on the assessment made. The next project phase will then build upon these optimised alternatives.

The BwN Program is drafting an Eco-dynamic Development and Design Guideline based on the above principles and steps.

Pilot Projects

Sand Engine: Mega nourishments and the "art of letting go"; coastal defence in the hands of nature and natural processes.

A large part of the Dutch coast is sandy, with beaches and dunes forming the first line of sea defence. Part of this coastline is in a state of dynamic equilibrium and hardly requires attention. Other sections, however, require regular maintenance and strengthening, on average 12 million m³ per year of sand nourishment. This implies that certain parts of the coast are disturbed and reworked every so many years, with consequences for the local ecosystem and beach use. Moreover, consistently nourishing the beach and the upper part of the shoreface leads to over-steepening of the lower shoreface (Stive and De Vriend, 1993). These are generally accepted consequences, they can reasonably well be managed, but nevertheless it is of interest to reduce such effects. As a consequence of climate change and sea level rise larger nourishment quantities and/or more frequent campaigns must be expected. This further triggers the interest to explore more sustainable approaches (e.g. http://www.deltacommissie.com/doc/deltareport_full.pdf).

The last decades experiments have been made with beach nourishments following the principle of Building by Nature: rather than placing dredged sand directly on the beach, at the toe of the dunes, sand was placed on the foreshore. There it was left to natural forces, waves, currents, tides and wind, to distribute the material along the coast and within the profile up to the dry beach (for instance, http://www.nottingham.ac.uk/efm/research/shoreface.php). The experiences with these foreshore nourishments are positive: although in total larger volumes may have to be handled, the effectiveness is found to be good, total costs are less and the area is significantly less disturbed. Yet, the overall outcome of each individual nourishment operation is less certain, as one relies on nature doing part of the work.

A next step in this process, expanding from regular small-scale shoreface nourishments, is to place a very large quantity in one operation, at one well selected location (not all along the coast), sufficient to feed a stretch of coastline for 15-20 years, with nature doing the majority of the work. Based on this idea a mega-nourishment, a so-called 'sand engine', was launched. A large volume of sand is put onto the shoreface and left to be re-distributed alongshore and into the dunes, through the continuous action of waves, tides and wind. Besides gradually inducing juvenile dune formation along a larger stretch of coastline over a period of one or more decades, thus contributing to safety against flooding over a longer period of time, the surplus sand volume, before being fully distributed over the coastal system, temporarily creates added value for nature and recreation; amongst others by providing shoals and beach lagoons as rest areas for sea mammals and birds, wide beaches for daily tourism and challenging surf conditions for the local surf community.

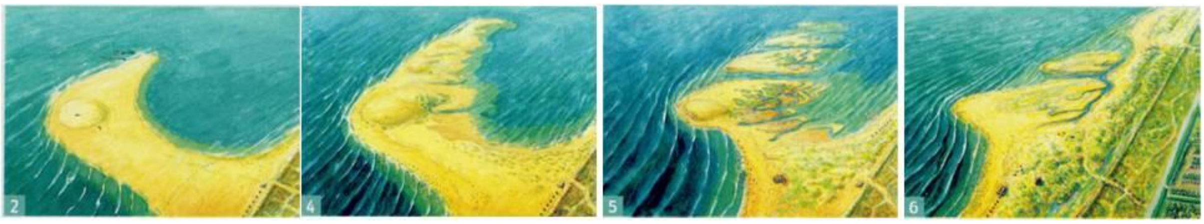

Figure 4: Artist impression of the Sand Engine development on Delfland coast.

This concept has now been adopted for the coast of Delfland, one of the weaker parts of the Holland coast, through an intensive design, governance and communication process with many stakeholders involved.(Aarninkhof et al, 2010; Mulder et al, 2006). In 2011, a volume of more than 20 million m³ of sand will be placed in this Delfland Sand Engine (Figure 4), in the shape of a sandy hook connected to the beach. Under the BwN program the whole process will be followed intensively through frequent monitoring, both during construction and during the years thereafter. Monitoring covers amongst others climatic conditions, beach- and dune profiles, beach material and water quality, beach and dune vegetation, benthos, fish, sea birds and sea mammals, recreation and swimmers' safety. Monitoring results will enable a concept validation and supports adaptive management actions during the period of natural development. If needed smaller auxiliary (foreshore) nourishments can be considered, should unsafe situations develop.

Results of the Sand Engine pilot are to be reported through the BwN channels and in the open literature when they become available.

Ecological Sand Extraction site: natural hotspots in the sea?

Borrow- or extraction sites, for the purpose of beach nourishment or land reclamation, were traditionally determined in terms of size, shape and location on the basis of geographical, geological, and physical aspects. These conditions were subsequently laid down in permits allowing for little variation. Ecology, with the exception of the expected rehabilitation period, was usually not a main issues. Later on, especially for larger extraction sites, choices / requirements in the permits were based on an EIA. These assessments generally classify extraction sites as having a negative impact on the local environment (De Groot, 1979). The general idea was that during the construction of the site, the top layer of sand and its inhabitants (benthos) were removed, leaving a deeper area with potentially different sediment characteristics. The EIA evaluation usually considered this to require a rehabilitation period of 3-4 years (De Groot, 1979).

The most common mitigation measure was to limit the depth of the extraction to 2m depth, so that re-colonisation could take place under similar hydraulic and morphological conditions as before. However, due to the scale increase in required sand volumes, maintaining a maximum of 2m extraction depth would lead to very large surface areas for the sites. After research had shown that deeper extraction is possible, this was allowed at certain sites.

Building with Nature expands on the modern philosophy of searching for opportunities to realise additional quality in a project without compromising its main function. In fact BwN tries to go one step further: in addition to looking for opportunities to enhance the natural value of the project, it seeks ways to utilise nature in the construction and later on operation of the project.

The large-volume sand borrowing sites in the North Sea for Maasvlakte2, the extension of Rotterdam harbour, offered the opportunity for a pilot project. Within the boundaries of the available mining permits and procedures an opportunity was found to create a few sand ridges by leaving an elongated strip of the original bottom untouched (Fig. 5). Two orientations were chosen, one similar to that of the large natural sand waves in the area and the other one similar to that of the tidal ridges in this part of the North Sea. According to ecological models and field observations, the gradients in hydrodynamic and morphological conditions created by this ‘ecological landscaping’ should lead to a greater biodiversity, a larger biomass production, a faster ecosystem recovery and finally a richer ecology than originally present (Van Dalfsen and Aarninkhof, 2008).. This could be achieved without a significant increase of the overall costs of the sand mining project, thus avoiding the question whether project owners would be prepared to pay more for sustainable sand extraction.

The hands-on pilot project also offered all actors and stakeholders, from project initiators and owners to design engineers, permit authorities and contractors, the opportunity to investigate the pros and cons of integrating the ecological function (landscaping) in an existing infrastructure project.

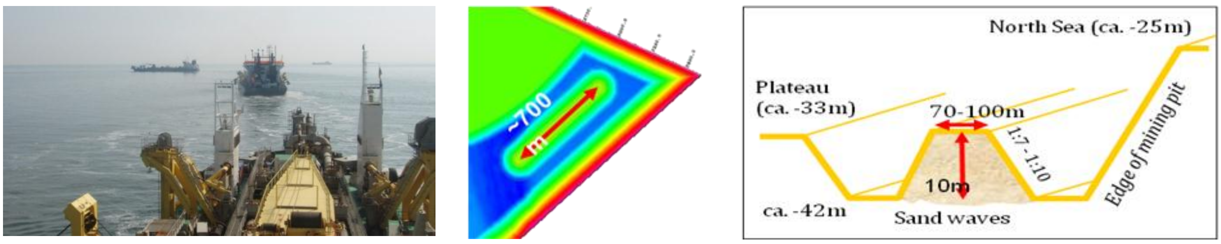

Figure 5: Trailing Suction Hopper Dredgers creating an ‘eco-landscape’



Figure 6: Benthos monitoring around ecological sandpit.

Shortly after the sand mining operation, the first monitoring results showed that there is already a significant amount of benthic organisms around the ridges, also compared with an undisturbed reference area (Fig. 6). This is considered a first indication of a positive ecological development. In general, the results of the bathymetric- , benthos- and fish surveys will be published when they become available.

Experiences with stakeholder involvement in these projects

Embarking on Building with Nature integrated projects has provided quite some new insight into the governance aspects of such projects. Two 'lessons learned' are highlighted here.

The decision making processes leading to the Sand Engine and the Ecological Mining Pit both included a significant degree of stakeholder involvement. Engaging stakeholders in project planning is nothing new (Hommes, 2008), but here stakeholders were involved all the way from the beginning, and not with the focus on how to address their concerns, but on involving them on how to get the most out of the project. The leading principle in these processes was to be honest, transparent and open, at all levels. Sharing of all information and knowledge sometimes proved to be difficult, but as long as common interests can be defined people and organisations are willing to really cooperate. To avoid deception or frustration later on in the process, it is essential to document all agreements and covenants in a rather detailed, if not contractual format. Nonetheless, the principal lesson learned is that by taking an open, transparent and truly integrated approach win-win situations can really be achieved.

Nature is, by definition, not fully predictable, and the same goes for processes in society. Both are nonlinear dynamic systems driven by partly stochastic inputs (e.g. weather, economy). Working with such systems, like in Building with Nature projects, leads to a higher level of uncertainty in the predicted process outcome and the project effects as compared to a more traditional approach. Willingness, capability and room (also in legislation and regulations) to deal with such uncertainties are crucial to BwN-projects. Uncertainties can for instance be handled by adaptive management procedures (as in the Sand Engine project), or by contingency provisions in the project plan. Obviously, we shall be careful, if not precautionary, when addressing possible negative effects, but potentially positive variations shall be given 'the benefit of the doubt'.

Conclusions

This paper describes the outcome of recent research on 'Building with Nature'. It demonstrates that with proper integration of ecology, economy and societal needs substantial gain can be achieved in development of sustainable hydraulic engineering projects.

Two coastal pilot projects in the Netherlands that have (partly) been developed according to the BwN-philosophy are analysed. The results show that each coastal planning project has its own specific conditions and requirements, so needs a tailor-made solution in order to optimally effective. Where possible, the forces of nature may be used in design, construction and operation in order reduce construction and maintenance costs and to enhance functionality and value.

The analysis of the decision making processes shows that many stakeholders are open to a constructive cooperation, as long as their interests are understood and transparently taken into account as much as realistically possible. Crucial to a successful BwN development is not so much new technology, but much more so a change in attitude: from 'minimising negative impacts' to 'maximising positive development'.

Acknowledgements

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References

Aarninkhof, S.G.J., van Dalfsen, J.A., Mulder, J.P.M., and Rijks, D.C. (2010). Sustainable Development of Nourished Shorelines Innovations in project design and realization. In Proc. Of PIANC MMX Congress (2010), Liverpool (UK)

De Groot, S.J. (1979). An assessment of the potential environmental impact of large-scale sand-dredging for the building of artificial islands in the North Sea. *Ocean Management* 5(3): 211-232.

Edwards, M. (2009). Through AQAL eyes, part 4: A new theory of holons. http://www.integralworld.net/index.html?edwards8.html

Ehrlich, P.R. and A.H. Ehrlich, (1997). The population explosion: why we should care and what we should do about it. _Environmental Law_, *Winter*, 1997

Hommes, S. (2008). *Conquering complexity*, PhD thesis, University of Twente, 182 pp., ISBN 978-90-365-2742-2

Kira, M. & Eijnatten, F.M. van (2008). Socially sustainability work organizations: A chaordic systems approach. System Research and Behavioral Science, 25 (6), 743-756.

Mulder, J.P.M., Nederbragt, G., Steetzel, H.J., Van Koningsveld, M. and Wang, Z.B. (2006). Different implementation scenarios for the large scale coastal policy of the Netherlands. In: Proc. of Int. Conf. on Coastal Engineering (2006), San Diego (USA)

Stive, M.J.F. and De Vriend, H.J. (1993). Shoreface profile evolution on the time scale of sea level rise. In: J.H. List (Editor), *Large-Scale Coastal Behaviour '93*, USGS Open file Rept. 93-381, p. 189-192.

Van Dalfsen, J.A. and Aarninkhof, S.G.J. (2008). Building with Nature: Mega nourishments and ecological landscaping of extraction areas. In: Proc. of EMSAGG Conference (2009), Rome (Italy).

Van Duim, M.J.P. Wiersma, N.R., Walstra, D,J.R., Van Rijn, L.C. and Stive, M.J.F. (2004). Nourishing the shoreface: observations and hindcasting of the Egmond case, The Netherlands. Coastal Engineering 51(8-9): 813-837.