A knowledge intervention to explore stakeholders' understanding of a dynamic coastal nature reserve

Floortje d'Hont[1], Jill Slinger[1] and Petra Goessen[2]

[1]Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, 2628 BX Delft, The Netherlands (j.h.slinger@tudelft.nl)

[2]Hoogheemraadschap Hollands Noorderkwartier, Bevelandseweg 1, Heerhugowaard, The Netherlands

Abstract
As quantitative modelling can be used to build stakeholder understanding for management decisions, and can help build consensus (Stave, 2003), a system dynamics modelling study of the abiotic dynamics of an archetypical small estuary, the Slufter in the Netherlands is formulated. The model is used in combination with an analysis of stakeholders' values, their perceptions and the multi-functional utility of the Slufter in the design and application of a participatory approach aimed at enhancing the (collaborative) long-term decision-making on the inherently dynamic, coastal nature reserve. In particular, the information derived both from the model and the interviews with stakeholders provides an indication that a shared understanding of the ecological and social functions of the Slufter estuary can be enhanced by integrating a stakeholder approach and problem modelling. Although stakeholders' opinions changed less than expected, we believe that such an integrated approach can contribute to increasing the effectiveness of problem modelling in multi-actor systems.

Key words: coastal management; environmental management; estuary; Slufter; stakeholder consultation; participation; policy; hydrodynamic model; knowledge intervention.

1. Introduction

The *Slufter* is a unique nature reserve on Texel, an island in the Wadden Sea area of the Netherlands. The Slufter is an estuary located in the island's North Sea dunes, and comprises a channel through the dunes, a salt-marsh and an intertidal zone landwards of the coastal dunes. The channel at the mouth allows North Sea water to flow in and out with the tides. The Slufter is a small system, with seasonal freshwater inflow of unknown total volume. The intertidal zone is enclosed by a sand dike. The inherently dynamic nature of the Slufter gives rise to species richness in the vegetation (Pedroli & Hoekstra, 1992). The entire Slufter area, including the sand dike, forms a component of the primary flood defence of Texel, and protects the hinterland from flooding from the North Sea.

The district water board *Hollands Noorderkwartier* (HHNK) is formally responsible for maintaining the sandy coast of Texel so that it adheres to the legally prescribed safety standards for flood defence. HHNK currently intervenes in De Slufter by straightening the channel near the opening every four to six years to maintain the integrity of the dune front, and to reduce the storm wave intensity near the sand dike (Figure 2). Simulations from new storm wave models (Rooijen & van Thiel de Vries, 2013) provide reason to review the current practice of channel straightening. Accordingly, HHNK is considering intervening less in the system and letting nature take its course in the Slufter in the future, as this is likely to have only limited effects on flooding safety.

However, flooding safety is not the only issue at stake. The Slufter also forms a tourist attraction on the island of Texel, attracting nature lovers, particularly bird watchers, as well as hikers and cyclists, and generating economic value to medium and small business enterprises. The Slufter is a nature protection area and part of several nature networks established under national and European legislation.

Figure 1 and Figure 2: The Slufter is situated along the North Sea coast of Texel, the Netherlands (Picture: Flying Focus)

Clearly other actors besides HHNK have an interest in, some responsibility for, or are affected by decisions regarding the Slufter. These actors include governmental authorities, environmental organizations, nature managers and citizens of the island. The value of such a system is perceived differently among different actors (Costanza et al., 1997; Farber et al., 2002), each of whom may hold different opinions . The multi-actor environment and the formal and informal responsibilities of Hollands Noorderkwartier result in a playing field in which HHNK wants to enhance (collaborative) long-term decision-making about the Slufter. For HHNK this means maintaining safety standards efficiently and effectively, while minimizing the negative effects on the ecosystem and maintaining good relations with stakeholders.

As quantitative modelling can be used to build stakeholder understanding for management decisions, and can help build consensus (Beall et al., 2011; Stave, 2003, 2010), a system dynamics modelling study of the abiotic dynamics of archetypical small estuary systems such as the Slufter was proposed in combination with an analysis of stakeholders' values, their perceptions and the multi-functional utility of the Slufter. This paper describes the design and application of a model and stakeholder-based approach to enhance the quality of long term decision making on an inherently dynamic, coastal nature reserve. In particular, the utility of combining the information derived from the model and the interviews with stakeholders for enhancing system understanding is explored. This paper therefore presents a unique, integrated approach to combining stakeholder analysis and problem modelling. Such an integrated approach can contribute to increasing the effectiveness of problem modelling in multi-actor systems.

The paper is structured as follows. First the design of the approach is described in section 2. Thereafter, the details of the methods used in each stage of the approach are provided in section 3. This is followed by the formulation of the system dynamics model of water and sediment movement of archetypical small Slufter-like estuaries in section 4. The results from the model and the stakeholder analysis are then described, followed by the outcomes of a knowledge intervention workshop (section 5). Finally, conclusions are drawn regarding the efficacy of the knowledge intervention in generating more system understanding and influencing policy in the long term in section 6.

2. Designing the Approach

In this paper, the Slufter is viewed as a social-ecological system (SES), where system knowledge among stakeholders is important. A social-ecological system is defined as a coherent system of both biophysical and social factors that regularly interact in a resilient, sustained manner. Social-ecological systems are defined at several temporal, spatial and organizational levels, and show dynamic, complex behaviour with continuous adaptation (Redman et al., 2004). The social system comprises social institutions, temporal patterns of human activity and cultural patterns for organizing interactions among people and groups (Redman et al., 2004). Stakeholders are denoted as any individual or group who is affected by or can affect the "achievement of an organization's purpose" in this paper (Freeman, 2010, p. 46).

The variety and conflicting interests of the stakeholders involved with the Slufter and the lack of clarity on the long-term effects of policy interventions in the past and in the future results in discussion among stakeholders (Ir. P. Goessen, pers. comm.). However, Ostrom (2009) argues that increased system understanding can lead to better long-term management supported by local stakeholders: "When users share common knowledge of relevant SES attributes, how their actions affect each other, and rules used in other SESs, they will perceive lower costs of organizing" (Ostrom, 2009, p. 421). Our underlying motivation for developing and applying our selected approach lies in our conceptualization of the nature reserve as a social-ecological system where system knowledge among stakeholders is important. Accordingly, we choose to focus on increasing the system understanding of local stakeholders using a three stage analysis process.

First, a stakeholder analysis was performed – so as to be able to assess values, interests and functions and to assess system understanding and perspectives. The study of the biotic and social subsystems demands rich data, which may be found within the mental models of experts and local actors, using a qualitative approach. Semi-structured interviews based on open ended questions were conducted in addition to desk research.
The desk research revealed that the ecosystem of the Slufter responds to morphological changes over time scales ranging from minutes or hours to centuries and over spatial scales ranging from small habitats to the entire Slufter. However, impacts on the social subsystem reach beyond the Slufter, to the island of Texel and further. The multiple scales relevant to the functioning of the Slufter as social-ecological system meant that in the interviews stakeholders were encouraged to explain their view of the system, revealing their own scale perspectives and preferences, and supplying information-rich insights and answers (Vreugdenhil et al., 2010). The specific system knowledge of the stakeholders led to an appreciation of the range and diversity in each individual's system understanding regarding the normal, exceptional, desirable and undesirable situations with regard to the extent, frequency and duration of inundation and exposure i.e. their understanding of water and sediment dynamics.

Second, a system dynamics modelling approach was adopted to illustrate how the abiotic processes that occur within archetypical estuaries such as the Slufter, influence the biotic environment. The abiotic processes are the main driver for the dynamic behaviour of the

Slufter, particularly the Slufter mouth, as sediment disposition and erosion shape the landscape, enhancing freshwater-seawater gradients and contributing to the highly valued biodiversity (i.e. diversity in vegetation, invertebrates and birds). The system dynamics method which was developed for modelling situations in socio-technical systems (Lane, 2000), is regularly used in environmental modelling (Kwakkel & Slinger, 2011; J. H. Slinger & Breen, 1995; Stave, 2003) and can be used for engaging stakeholders in discussions (D'Hont et al., 2013; Stave, 2003). Indeed, "Even when stakeholders are not involved in the model development process, a completed model can be an effective public outreach tool" (Stave, 2003, p. 309). An additional advantage of system dynamics for this situation is that accurate, detailed data are not a prerequisite for modelling. Although the Slufter is a well-studied nature reserve relevant, usable data on the interconnections between freshwater inflow, bathymetry and tidal water levels within the Slufter are not readily available.

Third and finally, the results from the first two analytical stages are synthesized and reported back to selected stakeholders, forming the knowledge intervention. The knowledge intervention was designed with the aim to increase shared understanding and to enhance individual system understanding in a stakeholder setting. In a previous paper we described a case in which a system dynamics model was used to identify areas of contention between stakeholders, which opened up "spaces for, and support[ed] (...) interactions between stakeholders" (D'Hont et al., 2013, p. 11). In that case, a system dynamics model was used to structure the key issues within a technical water supply system in rural South Africa, and this information was used to start strategic conversations between opposing stakeholders. In the current paper, we describe the design and application of a knowledge intervention within a *potentially* contentious situation, owing to the existing degree of discussion among stakeholders and the extent and variety of the values associated with the nature reserve, the Slufter. Clearly, the long term influence of the knowledge intervention cannot be understood fully immediately after the workshop, nor can it be understood in isolation of other knowledge acquisition opportunities or events. Instead, the analysis in this paper focuses on identifying the efficacy of the type of knowledge in altering the existing viewpoints of local stakeholders. For long term effectiveness, regular interactions between local stakeholders, knowledge providers and policy makers are needed.

3. Method

a. Model

After first conceptualizing the Slufter as a social-ecological system and identifying the knowledge gaps among the stakeholders, we chose to model the abiotic processes (e.g. water flows and sediment erosion and deposition) in archetypical estuary systems under normal weather conditions. This means that the focus did not lie on flooding per se, but on the characteristic abiotic dynamics.
Information on estuary system behaviour and the Slufter was derived from the following sources:

- A study on modelling the physical dynamics of estuary systems in South Africa (J. Slinger, 1996);
- Studies on sediment transport in open channels (Ackers & White, 1993, 1973);
- Results of studies on morphodynamics in the Slufter (Durieux, 2004; Van der Vegt & Hoekstra, 2012);

- Information from reports of the district water board Hollands Noorderkwartier and preceding Slufter managers.

The estuary system behaviour for archetypical estuary systems is specified as a system dynamics model in VenSim DSS for Macintosh Version 5.9ex10 (beta release).

b. Stakeholder analysis

Stakeholder analysis approach is rooted in strategic management literature and focuses on “stakeholder environment to maximize cooperative potential and minimize threat of obstruction” (Enserink et al., 2010, p. 82). Accordingly, after first identifying stakeholders by a study of written material a series of interviews was conducted with selected stakeholders.

The interviews were centred on (1) the interviewee’s experience and (local) knowledge of the Slufter (including, but not limited to natural dynamics, biophysical linkages, policy interventions and their effects); (2) indication of the functions and values associated with the Slufter; (3) analysis of perceptions, spheres of influence and interests of other stakeholders.

13 people were interviewed. A diverse group of interviewees was selected to gain different perspectives. Interviewees include:

- People living on Texel (primary contact); or regular visitors of the area;
- People with jobs related to management and maintenance of De Slufter (primary or secondary contact);
- And/or experts with a scientific perspective on De Slufter and comparable (social-ecological) systems (secondary contact).

Interviewees are selected in two ways. First, participants (local stakeholders) were selected by self-application within the steering committee *Nationaal Park Duinen van Texel*. Second, experts were identified with the ‘reputation-method’. Already identified actors are interviewed and asked to identify other experts (Thissen & Walker, 2013, p. 85). A first analysis of publicly available documents and conversations with HHNK employees served as a starting point. Interviews typically took 60 – 90 minutes. The interviews were conducted in person, recorded on tape and notes were taken. Visual materials to support the conversation included an aerial photo of Texel with topographic information and a detailed aerial photo of De Slufter. Written minutes, based on audio recordings and notes, were submitted for approval with the interviewees. A checklist for the structure of the interviews is included in Appendix B.

c. *Knowledge Intervention Design and choice: Combining Model Results And Social Values.*

The knowledge intervention took place in a plenary workshop setting with 12 participants. All interviewees were invited to participate. If they were unable to attend, interviewees were encouraged to send someone else (i.e. a colleague, a friend) who they personally deemed fit to participate. The pool was supplemented with researchers who performed a hydrodynamic study with regard to the water safety function of the Slufter. The knowledge intervention comprised a pre-workshop questionnaire, then two presentations including discussions, followed by a post-workshop questionnaire. The first presentation contained insights from the system dynamics model study about the characteristic behaviour of Slufter-type systems. The second presentation provided a synthesis of the findings regarding social functions and the perceived system behaviour derived from the individual interviews. The presentations served as input for discussions between participants, who were encouraged to question the information and to exchange ideas, thus exposing their individual perceptions to (potential) change. An *ex ante* voting form was used to assess the individual participant's system understanding and values. Identical voting options were presented on wall posters *ex post,* following the knowledge intervention in order to assess whether the information provided had caused participants to modify their opinions and whether learning had occurred (Appendix D).

Finally, inferences regarding the utility of the information derived from the model and the interviews in enhancing the system understanding of local stakeholders are drawn.

3. Formulating a model of water and sediment flows in the mouth of an estuary

The estuary is conceived as a basin with a specific water volume to water level relationship, connected to the sea by a channel of fixed width, but variable sill height. Thus changes in the form of the basin are not treated in the model, while the dynamics of the mouth channel are central to the model.

Two primary sub-sectors are distinguished in the model, namely the water sector and the sediment sector. The primary variable of interest in the water sector is the water flow through the estuary mouth as the magnitude and direction of this flow determines whether erosion of deposition of sediment occurs in the mouth, influencing the sill height (Figure 3).

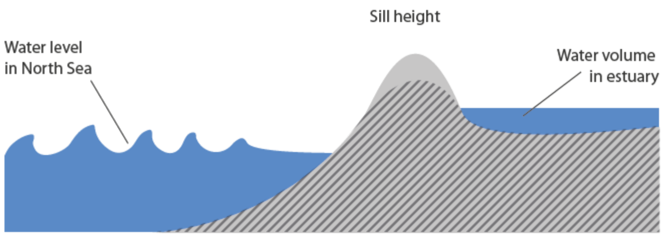


Figure 3: Position of estuary and sill

In the water volume sector, the exogenous factors of rainfall on the estuary and riverine inflow to the estuary contribute to an increase in water volume whereas the endogenous evaporation from the surface of the estuary decreases the water volume (Appendix E). However, it is the tidal flux through the estuary mouth that primarily determines the water volume within the estuary. When the water level in the sea (the tidal water level) exceeds the sill height in the mouth, water can flow through the mouth. The direction of flow depends on whether the tidal water level is greater or less than the water level in the estuary itself. When the water level within the estuary exceeds the tidal water level in the sea (and the sill height), water flows from the estuary into the sea forming the ebb tide. Similarly, when the tidal water level exceeds the water level within the estuary (and the sill height), sea water flows into the estuary, forming the flood tide (Figure 4). The flood and ebb flow rates are directly proportional to the head difference, that is the difference between the tidal water level and the water level in the estuary, acting over the characteristic length of the estuary. However, the volume of water flowing through the mouth is further influenced by velocity asymmetry between the flood and the ebb flows. Such asymmetry is a characteristic feature of estuaries. For small, temporarily closed estuaries, the highest current velocities through the mouth occur during the shorter, more intense flood component of the tidal cycle. The current velocities during ebb tend to be lower, but persist for longer over the longer ebb component of the tidal cycle. This non-linearity in water flow through the mouth is incorporated in the model via the velocity asymmetry function, a sigmoidal graphical function (Appendix E).

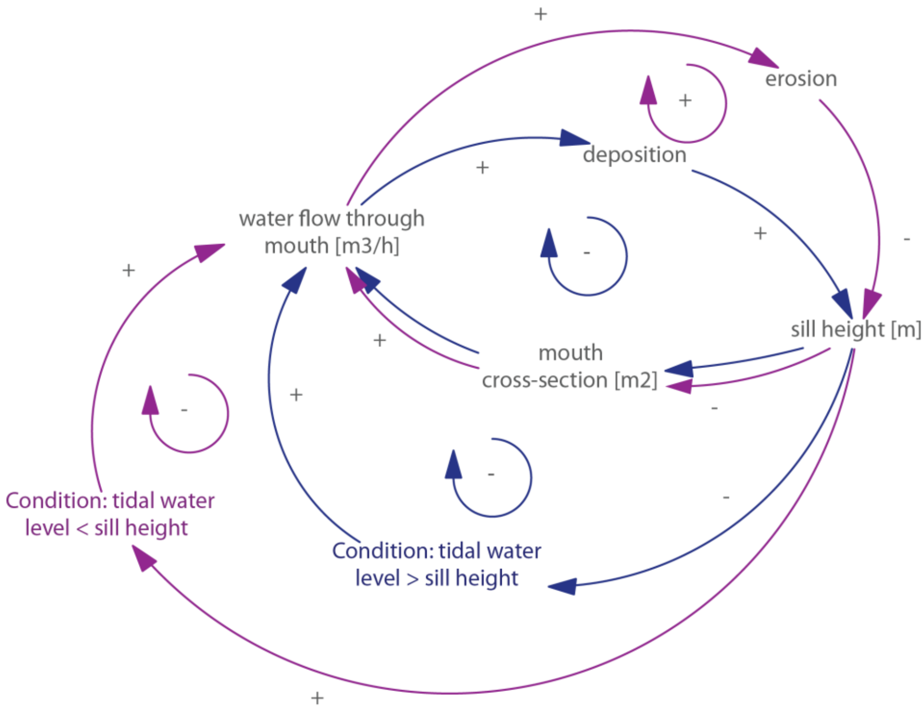


Figure 4: Aggregate causal relations diagram ***indicating the constraining effect of the sill height and associated mouth cross-section on the inflow and outflow of water through the mouth of the estuary (balancing loops on the lower left). As water flows through the mouth to the sea, sediment is eroded from the mouth channel and the sill height decreases. This causes the mouth cross-section to increase and enhances the flow through the mouth, forming the reinforcing erosion feedback loop depicted by the purple arrows at the top right. In contrast, when sediment laden seawater enters the estuary, sand is deposited in the mouth channel, the sill height increases, the mouth cross-section decreases constraining the flow through the mouth. This is represented by the blue balancing feedback loop at the top right.***

Further, as explained in detail in Slinger (1996), the theory of Armi and Farmer (1986) and Farmer and Armi (1986), on maximal two-layer flow over a sill or through a constriction is applied to the flood and ebb flows through the mouth of the estuary. The flow is two layer because there are strong density differences between the estuary water exiting through the mouth and the sea water entering from the sea (Largier & Slinger, 1991). This implies that a maximum volume flux can be associated with a given head difference, and this acts to constrain the volume of water entering or leaving the estuary under the influence of the tide.

The tide is in turn determined as an exogenous influence, using data and or functions provided by the hydrological service (e.g. Rijkswaterstaat, 2014). In some instances, this involves using a complex multi-parameter harmonic series; in others a simple cosine/sine function is sufficient to emulate the oscillatory behaviour of this exogenous variable.

Once the water flowing through the mouth is determined, it remains to determine the sediment flux associated with it and whether erosion or deposition is occurring. This is undertaken in the sediment sub-sector. As mentioned earlier, the estuary is viewed as a basin with a specific water volume to water level relationship (the storage capacity function) connected to the sea by a channel of fixed width, but variable sill height. The sill height increases when sediment is deposited in the mouth channel and decreases when erosion occurs in the mouth channel. The sediment is transported by the water flowing through the mouth on the ebb and flood flows. The maximum sediment transport capacity of the water flowing through the mouth is calculated according to the modified formula of Ackers and White (Ackers & White, 1993). This formula is utilized widely for estimating the total load of sedimentary bed material transported when there is a mobile bed over the full width of the flow, as in the channel at the mouth of the estuary. During the ebb flow, the volume of sediment eroded from the mouth channel and transported out to sea is given by the product of the ebb flow volume and the total sediment load transported per unit volume of flow. This erosion causes the sill height to decrease (Table 1). During the flood flow, the action of waves in the breaker zone means that the capacity of the seawater to transport sediment is enhanced by a wave stirring factor above that of the equivalent volume of water flowing steadily and uniformly as given by the modified Ackers and White formula. As the water enters the mouth channel the flow calms, becoming more uniform. It is no longer able to transport all the sediment that it is carrying in suspension. The volume of sediment deposited in the mouth channel is determined by the product of the flood flow volume and the difference between the enhanced total sediment load and the total sediment load transported per unit volume of steady, uniform flow. The excess sediment deposited in the mouth channel during the flood tide causes the sill height to increase and the mouth cross-section to decease (Table 1). It is this mechanism which can cause the mouth to close and the tidal influence on the estuary to be cut off within a tidal cycle, an effect simulated by this System Dynamics model and no other hydrodynamic model.

The potential for communities and authorities to intervene in such a situation by breaching the mouth is included in the model in the form of an exogenous breaching function.

4. Preliminary results and discussion

In this section a synthesis of the results of the model, followed by the stakeholder analysis and knowledge intervention is presented.

a. Model

The Slufter is located in an area which exhibits semidiurnal and spring-neap tidal variations, which are associated with high-low variations in water level on a 12 hour 40 minute and 28 day time scale respectively. Three archetypical behaviour patterns, represented by characteristic variations in water level within the estuary, could be associated with specific ranges of parameter settings and are described below.

In type 1 (Figure 5), which represents a long, relatively deep basin for a shallow estuary, with a deep mouth channel (lower sill height relative to Mean Sea Level), the water level variation within the estuary exhibits some tidal variation at all stages of the neap-spring cycle. As with types 2 and 3 (A and B), there is evidence of enhanced average water levels during spring tides compared with neap tide. This is ascribed to the additional water that enters the estuary on every progressive high tide, as the tidal cycle moves towards spring and that cannot escape fully on the subsequent ebb tide.

In type 2 (Figure 6), which has a smaller, shallower basin form with a higher sill height relative to Mean Sea Level, there is reduced semidiurnal tidal influence throughout the spring-neap cycle, but enhanced average water levels during spring tides. This is indicative of the constraining effect of the smaller mouth cross-sectional area.

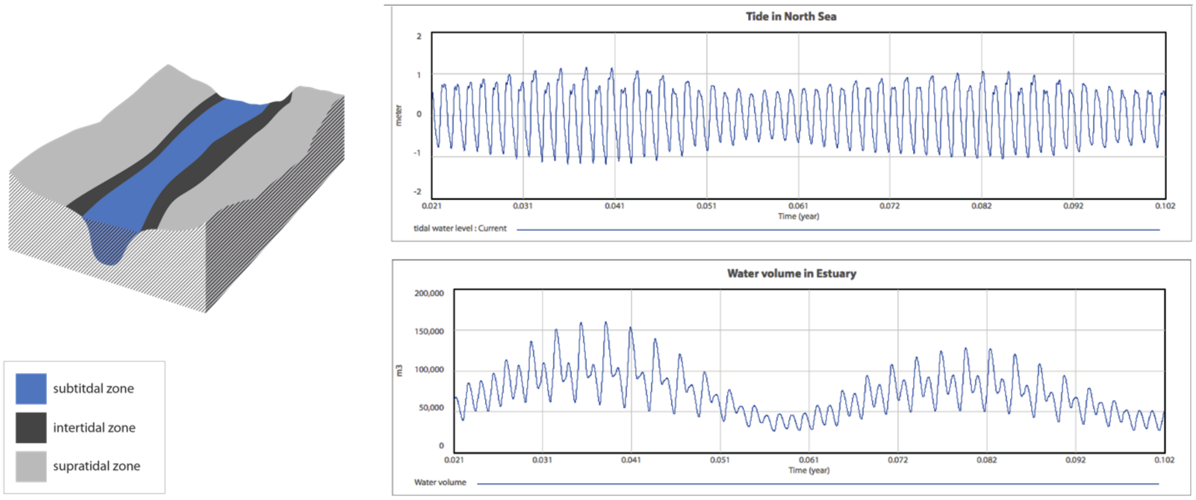


Figure 5: Water level variations in a long, deep estuary (Type 1)

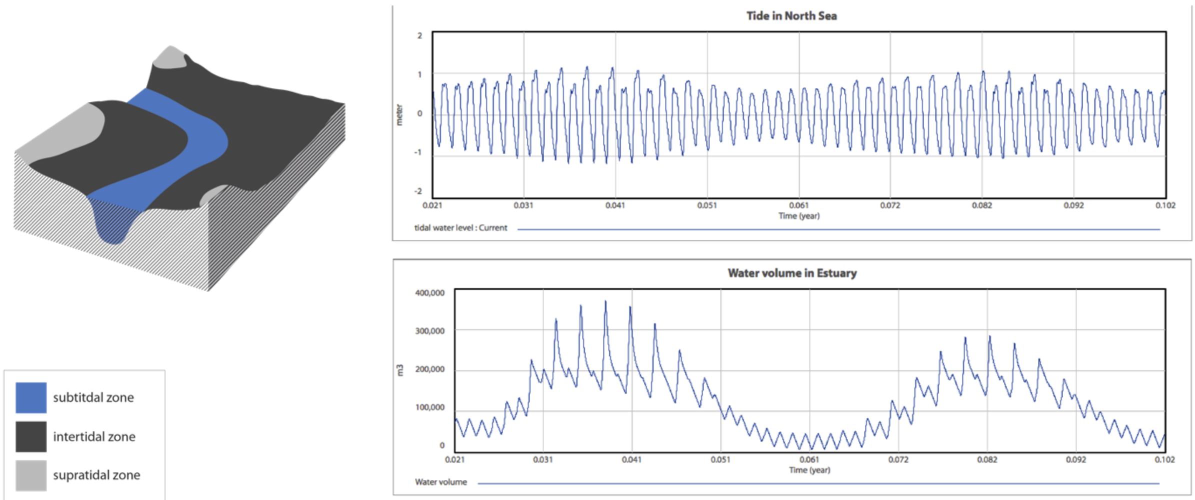


Figure 6: Water level variations (Type 2)

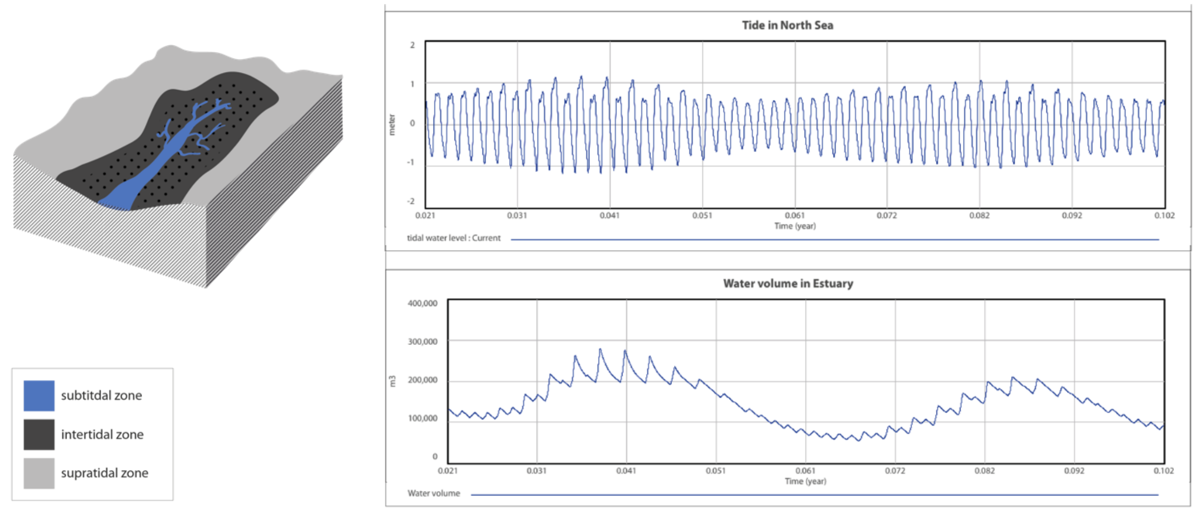


Figure 7: Water level variations (Type 3)

In type 3 (Figure 7), which has a perched, shallow form, more representative of a mudflat with a high sill height relative to Mean Sea Level, semidiurnal tidal influence may be distinguished, but the influence of the spring-neap cycle is constrained relative to type 2.

This is indicative of both the effect of a smaller mouth cross-sectional area, and a smaller retention volume within the estuary, and so reduced erosive effects during ebb tide.

The synthesis of the model results is represented by the three types of archetypical estuary characteristics. Each of the characteristic variations in water level is in turn associated with typical exposure and inundation frequencies, and extents, of subtidal, intratidal and supratidal zones within the estuary (Figure 8). That is, the abiotic driving forces are associated with typical biotic habitats.

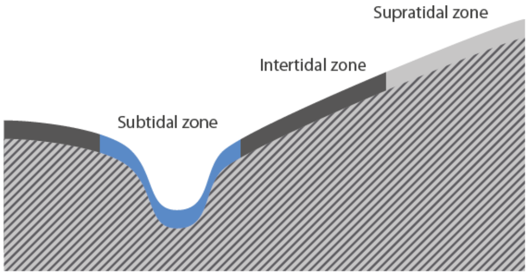


Figure 8: Subtidal, intertidal and supratidal zones within estuaries

b. *Stakeholder analysis*

As the Slufter is a nature protection area and part of several nature networks established under European and national legislation, there are several public authorities that carry a degree of responsibility for the Slufter. These include the Dutch Ministry of Infrastructure and the Environment, *Rijkswaterstaat* (civil government service for waterways and public works), the district water board *Hollands Noorderkwartier* (flood defence), the municipality of Texel, and the nature management authority (*Staatsbosbeheer*). These governmental authorities form a complex multi-actor network together with environmental organizations, inhabitants of Texel, entrepreneurs from the tourist sector and recreationists. The values and functions of the Slufter are perceived differently among different stakeholders, influencing policy perceptions, decisions and outcomes. Information on the differences in perceptions and understanding of the Slufter were obtained from 13 interviews conducted (Table 1) with interviewees selected because of their familiarity with the Slufter either professionally or personally.

Table 1: Backgrounds and affiliation of interviewees

Number	Background	Affiliation	Interviewee's perspective
1	Jurist, expert on Natura 2000-related legislation	HHNK	Institutions and policy
2	Researcher of sediment dynamics	Independent	Abiotics
3	Nature manager Texel, vegetation and monitoring	Nature manager	Ecology
4	Cyclist, regular recreationist on Texel	n/a	Recreation
5	Ecologist, expert on sediment suppletion programmes in the North Sea	Civil government service for waterways and public works	Ecology (foreshore)
6	Inhabitant Texel, regular tourist guide in nature reserves on Texel	National Park Dunes of Texel	Ecology
7	Manager regarding sandy coasts of North Holland	HHNK	Water safety and policy
8	Formerly operational flood defence management on Texel	HHNK	Water safety
9	Operational management flood defence management of Texel Member of crisis management team Texel	HHNK	Water safety
10	Bird watcher and nature photographer	Bird watchers club	Ecology (birds and landscape)
11	Ecologist within district water board	HHNK	Ecology
12	Researcher morphodynamics	Deltares	Abiotics

13	Ecologist within district water board, implementation of Natura 2000 regulation, bird watcher	HHNK	Ecology and policy

When interviewees were asked to describe how people (including themselves) use the Slufter, they described use functions that included (i) a component of the primary flood defence, (ii) a nature reserve with vegetation and birds, (iii) a location of sediment flows in the North Sea, (iv) recreational area, (v) part of a recreational route, (vi) a tourist attraction, (Vii) a bird habitat for foraging, resting and breeding, and (viii) part of a migration route for birds. The set of conducted interviews revealed a diversity of scale perspectives on the Slufter on a spatial level. Whereas some viewed the Slufter as a stand-alone, small scale nature reserve, others view it as an embedded part of Texel's landscape or, on a larger scale, as part of the Natura 2000 European network, or as an essential link in bird migration routes from Siberia to Africa. On a smaller scale, interviewee perspectives focused on specific areas within the Slufter, such as bird habitats or dune front areas susceptible to erosion. However, during the conversation, most interviewees exhibited flexibility in re-adjusting their scope and viewing the Slufter in a different scale perspective. Perspectives on the Slufter and its values were consistent with the background interests or training of the interviewees.

An additional demonstration of diverse perspectives among the interviewees was demonstrated by the use of the word 'dynamics'. Although most (but not all) interviewees agreed that 'dynamics' play a determining role in the nature area, use of the term 'dynamics' varied greatly. Some interviewees regarded human interventions such as dredging the mouth channel and fixing sand as dynamic over time, whereas others viewed the natural processes such as water flows associated with tidal dynamics, the effects of storm surges and diversity in species as typically dynamic. A third group saw the dynamic nature of the Slufter in the diversity of the landscape; both on Texel and within the Slufter itself. Six out of 13 interviewees stated that "the Slufter is different every time I visit it".

Nine out of 13 interviewees stated that "the current Slufter is how the Slufter ought to be", for reasons such as uniqueness and the recreational value of the area, high biodiversity, 'dynamics', wild nature and an empty horizon, all achieved while maintaining the safety standards. Again, although the perspectives of interviewees varied, the interviewees agreed on the overall importance and value of the nature area under the present circumstances.

c. The knowledge intervention workshop

A synthesized understanding from the system dynamics model outcomes and stakeholder analysis was presented to a selection of participants in a workshop setting in the form of two presentations. The participants group was a mixture of researchers familiar with modelling techniques and local actors from the island (Appendix C), all with individually different point of views and substantial, ready knowledge of the Slufter. An ex ante measure on preferences and values was conducted by asking the participants to fill out a voting form (Table 2, Table 3 and Appendix D). Thereafter, a first 15-minute presentation on the three archetypical estuary characteristics and estuary behaviour occurred, followed by a half hour discussion on estuary dynamics in relation to the Slufter. Participants were encouraged to consider the situation of normal weather conditions and ordinary tidal dynamics, as opposed to other meetings and workshops on the Slufter that commonly emphasized flood defence and consequently the situation of exceptional storm weather conditions. The aim in this regard was to increase dynamic system understanding of the participants by discussing known dynamic behaviour and system boundaries that related to the individual real-world experiences of the participants. As expected, the discussion quickly diverted from water safety, and participants were able to communicate regarding the potential consequences of dynamic estuary behaviour on vegetation and birds, based on the information supplied on the abiotic dynamics.

Next, information on stakeholder perceptions and values derived from the interviews was provided in a second 15-minute presentation, and discussed in the hour that followed. Contrary to expectations that the discussion would focus on differences in the perceptions of stakeholders and what they could learn from each other, participants repeatedly came back to discussing the importance of wild nature versus human interference. They agreed that finding a balance between human interventions and wild nature remains difficult. Participants did communicate their individual values and exchanged some knowledge on the system thereby creating some common knowledge. For example the unknown volume and seasonal variability of the freshwater inflow to the Slufter estuary was discussed and whether the freshwater inflow should be considered significant was debated. An additional discussion was started regarding the values of a participant who emphasized the function of the Slufter as a bird habitat and a link in global migration routes. After a coffee break and a stroll outside during which the discussion and sharing continued, the participants voted again by sticking dots on the posters hanging in the room, which provided the same options as the *ex-ante* measure (Appendix D).

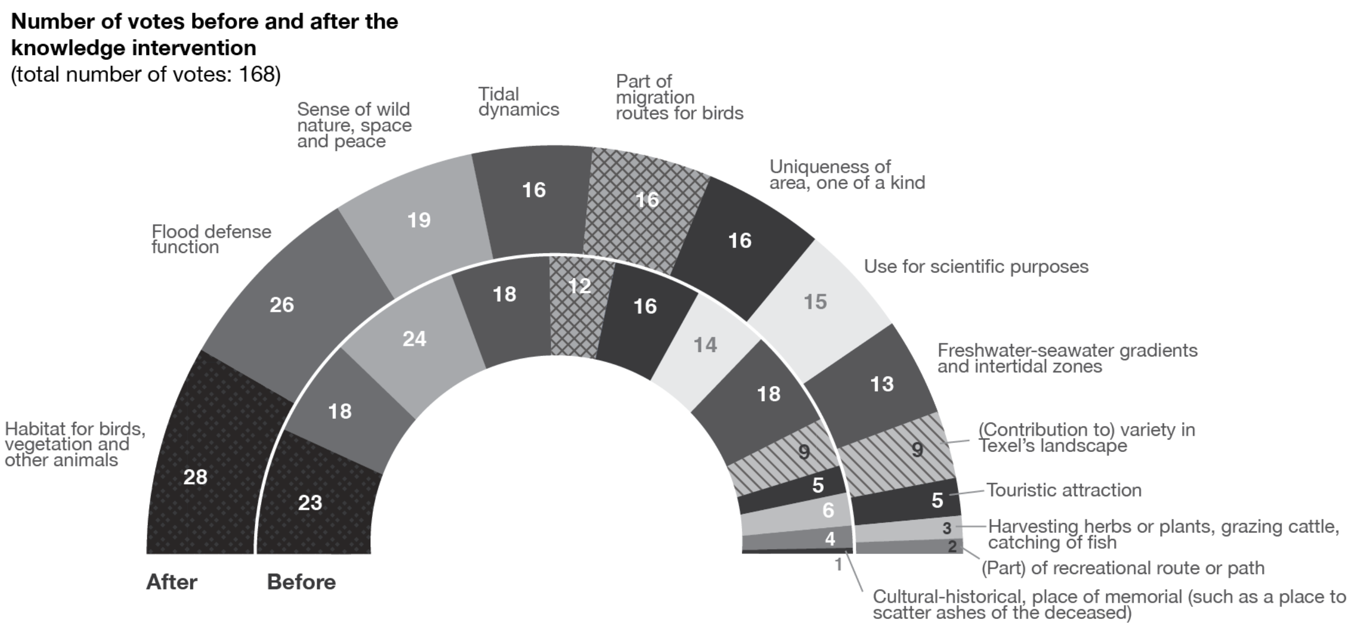


Figure 9: Participants each had 12 votes to rank the qualities of the Slufter before and after the knowledge intervention.

As depicted in Figure 9, the greatest change in the participants' perceptions lay in the increased recognition of the nature reserve's function as a habitat and migration route for birds, vegetation and other animals, as well for the flood defence function of the Slufter. This change can be explained by the topics discussed during the session. In reacting to proposed policies, the participants agreed almost unanimously that the Slufter mouth should not be closed (Figure 10). Figure 9 and Figure 10 reveal that participants' opinions did not change radically, although the quality of the Slufter as a bird habitat or migration route was more valued than before the event. The limited change in stakeholders' opinions can be ascribed to the composition of the stakeholder group attending the workshop, which was less diverse than we had anticipated and exhibited a tendency to seek consensus. However, the knowledge intervention undertaken provides an indication that a shared understanding of the ecological and social functions of the Slufter estuary can be enhanced by an integration of a stakeholder approach and problem modelling.

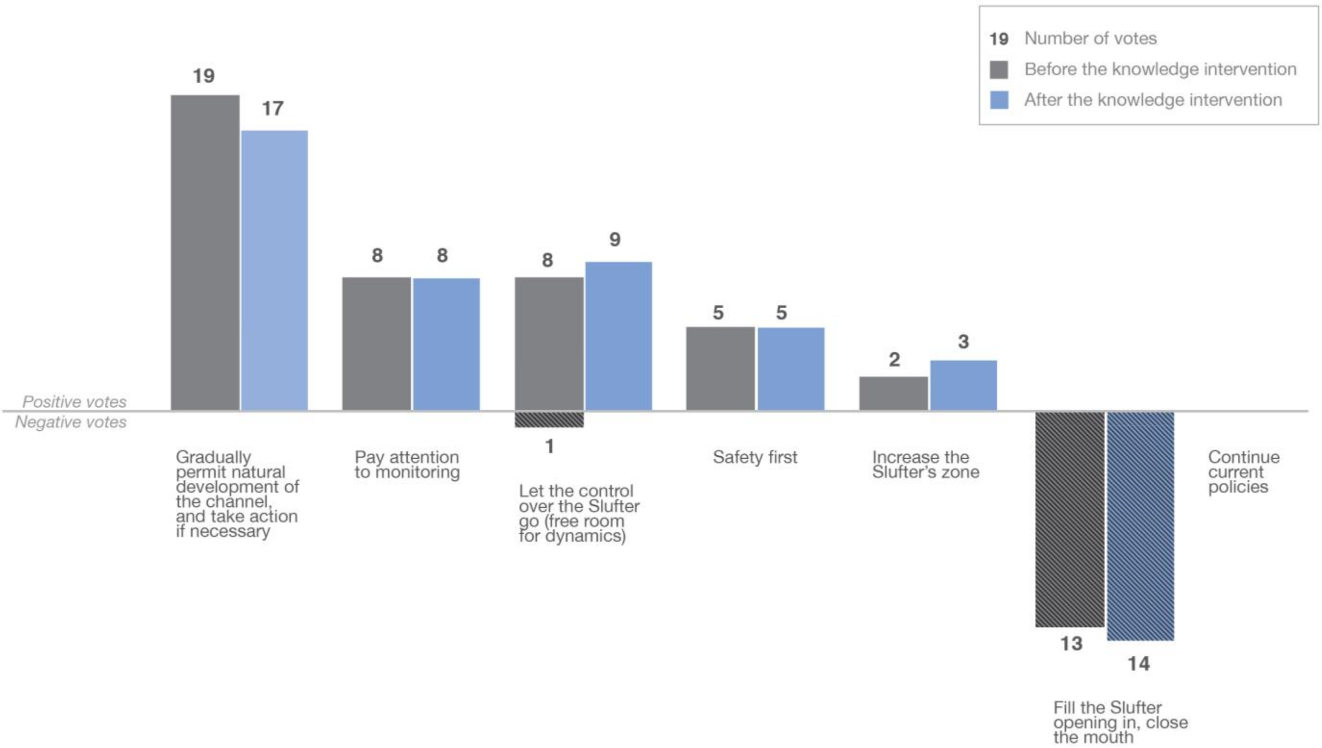


Figure 10: Participants each had 3 positives votes and 1 negative vote to express how their preferences were to be translated to (hypothetical) policy options.

6. Concluding remarks

This paper has presented a three stage approach to the design and application of a knowledge intervention that aimed to improve system understanding and influence policy in the long term. The approach is characterized by a combination of a stakeholder analysis and problem modelling, and requires the adoption of a dynamic, multi-actor, social-ecological systems conceptual lens. In developing and testing the approach, we chose to focus on a small estuary with familiar biophysical dynamics, known social characteristics and accessible local stakeholders. We distilled archetypical behaviour patterns for small estuary systems, using outcomes of a system dynamics model. Stakeholders were able to use this synthesized understanding of the dynamic system, as well as information from the stakeholder analysis, as a starting point for discussions in the knowledge intervention. But, the knowledge intervention caused less change in stakeholders' opinions than expected. Indeed, the knowledge intervention was possibly not as effective as it could have been. Different participants, small or one-on-one groups might be more effective conditions for knowledge interventions to improve system understanding and enhance policy influence over the long term. In addition, it might be profitable in the future to not only undertake stakeholder analyses, but also to model stakeholder interactions and outcomes of interest to them. In the current paper, we modelled the abiotic processes that form the main drivers of the dynamic behaviour of the Slufter estuary and showed that synthesized information from a system dynamics models is useful in a multi-stakeholder setting. In future research, the focus of the modelling might change to include both ecological indicators and multi-actor behavioural responses to these and other biophysical estuary dynamics.

Further, the effects of improved system understanding on the part of stakeholders from isolated knowledge interventions are unknown. Deepening understanding of this aspect will require repeated interactions with the multi-stakeholder environment over a long time, as well as the integration of collective learning concepts into the existing combined stakeholder analysis and problem modelling approach. Testing of the approach on other social-ecological systems is also advocated.

Appendices:

- **Appendix A: System dynamics model structure**
- **Appendix B: Checklist for semi-structured interviews**
- **Appendix C: Participants for knowledge intervention**
- **Appendix D: Voting form for knowledge intervention**
- **Appendix E: List of model variables**

Bibliography

Ackers, P., & White, W. (1993). Sediment Transport In Open Channels: Ackers and White Update. Technical Note. *Proceedings of the ICE-Water Maritime and Energy*, *101*(4), 247–249.

Ackers, P., & White, W. R. (1973). Sediment transport: new approach and analysis. *Journal of the Hydraulics Division*, *99*(hy11).

Armi, L., & Farmer, D. M. (1986). Maximal two-layer exchange through a contraction with barotropic net flow. *Journal of Fluid Mechanics*, *164*, 27–51.

Beall, A., Fiedler, F., Boll, J., & Cosens, B. (2011). Sustainable water resource management and participatory system dynamics. Case study: Developing the Palouse basin participatory model. *Sustainability*, *3*(5), 720–742.

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., … Paruelo, J. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260.

D'Hont, F., Clifford-Holmes, J., & Slinger, J. (2013). Addressing stakeholder conflicts in rural South Africa using a water supply model. In *31st International Conference of the System Dynamics Society*. Cambridge, Massachusetts: System Dynamics Society. Retrieved from http://www.systemdynamics.org/conferences/2013/proceed/papers/P1235.pdf

Durieux, M. (2004). *De stabiliteit van de Slufter op Texel*. Delft University of Technology. Retrieved from http://repository.tudelft.nl/view/ir/uuid%3Aac0b9379-169e-42b3-90f8-b1f111ca27d4/

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., Groenewegen, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems*. The Hague: Lemma. Retrieved from http://ocw.tudelft.nl/courses/engineering-and-policy-analysis/policy-analysis-of-multi-actor-systems/readings/

Farber, S. C., Costanza, R., & Wilson, M. A. (2002). Economic and ecological concepts for valuing ecosystem services. *Ecological Economics*, *41*(3), 375–392. doi:10.1016/S0921-8009(02)00088-5

Farmer, D. M., & Armi, L. (1986). Maximal two-layer exchange over a sill and through the combination of a sill and contraction with barotropic flow. *Journal of Fluid Mechanics*, *164*, 53–76.

Freeman, R. E. (2010). *Strategic management: A stakeholder approach*. Cambridge University Press.

Kwakkel, J., & Slinger, J. (2011). A system dynamics model-based exploratory analysis of salt water intrusion in coastal aquifers. In *Proceedings of the 29th International Conference of the System Dynamics Society*.

Lane, D. C. (2000). Should system dynamics be described as a "hard" or "deterministic" systems approach? *System Research and Behavioral Science*, *17*, 3–22.

Largier, J. L., & Slinger, J. H. (1991). Circulation in highly stratified Southern African estuaries. *Southern African Journal of Aquatic Science*, *17*(1-2), 103–115.

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science*, *325*(419). doi:10.1126/science.1172133

Pedroli, A. I. J., & Hoekstra, G. B. M. (1992). *Sluftervorming en natuurontwikkeling*. Delft. doi:TPG190123

Redman, C. L., Grove, J. M., & Kuby, L. H. (2004). Integrating social science into the long-term ecological research (LTER) network: social dimensions of ecological change and ecological dimensions of social change. *Ecosystems*, *7*(2), 161–171.

Rijkswaterstaat. (2014). Astronomical tides. Retrieved January 20, 2014, from live.getij.nl

Rooijen, A. A. van, & van Thiel de Vries, J. S. M. (2013). *Stormgedreven morfodynamiek van De Slufter, Texel. Modelstudie naar het effect van de monding op de kustveiligheid en morfodynamiek* (No. 1207993-000-ZKS-0010). Delft.

Slinger, J. (1996). *Modelling the physical dynamics of estuaries for management purposes*. University of Natal.

Slinger, J. H., & Breen, C. M. (1995). Integrated research into estuarine management. *Water Science and Technology*, *32*(5), 79–86.

Stave, K. (2003). A system dynamics model to facilitate public understanding of water management options in Las Vegas, Nevada. *Journal of Environmental Management*, *67*(4), 303–313. doi:http://dx.doi.org/10.1016/S0301-4797(02)00205-0

Stave, K. (2010). Participatory system dynamics modeling for sustainable environmental management: Observations from four cases. *Sustainability*, *2*(9), 2762–2784.

Thissen, W. A. H., & Walker, W. E. (2013). *Public Policy Analysis - New Developments*. New York: Springer. doi:10.1007/978-1-4614-4602-6

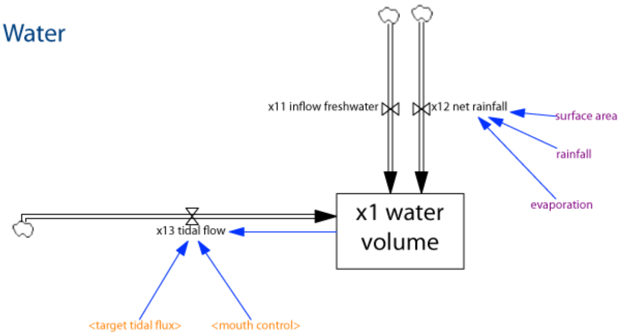
Van der Vegt, M., & Hoekstra, P. (2012). Morphodynamics of a storm-dominated, shallow tidal inlet: The Slufter, the Netherlands. *Netherlands Journal of Geosciences-Geologie En Mijnbouw*, *91*(3), 325.

Vreugdenhil, H., Slinger, J., Kater, E., & Thissen, W. (2010). The Influence of Scale Preferences on the Design of a Water Innovation: A Case in Dutch River Management. *Environmental Management*, *46*(1), 29–43. doi:10.1007/s00267-010-9524-0

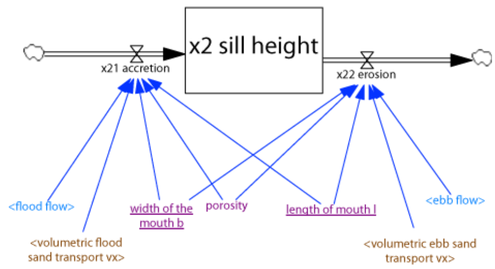
Appendix A: System dynamics model structure

Stock variables & rates

Water

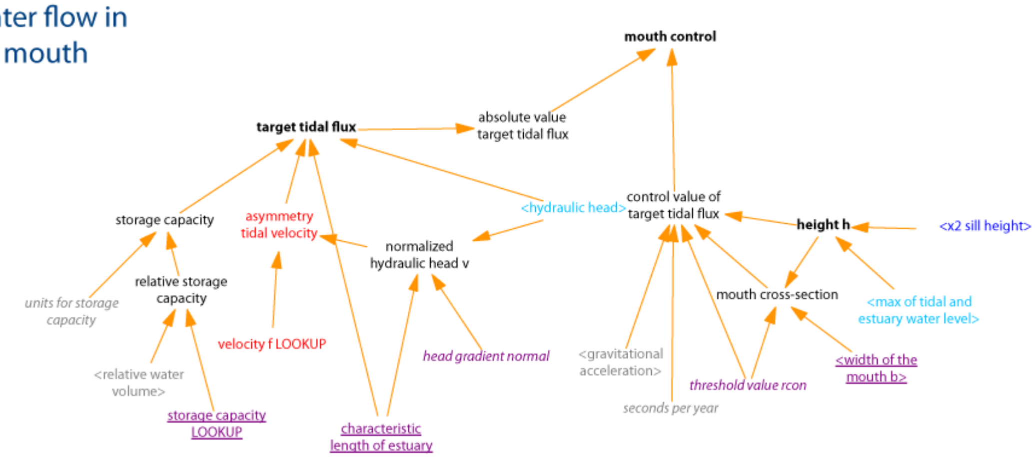


Sediment

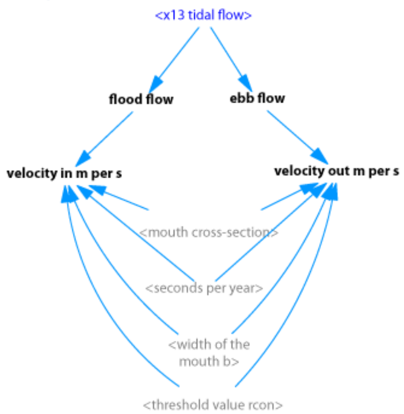


Section: water

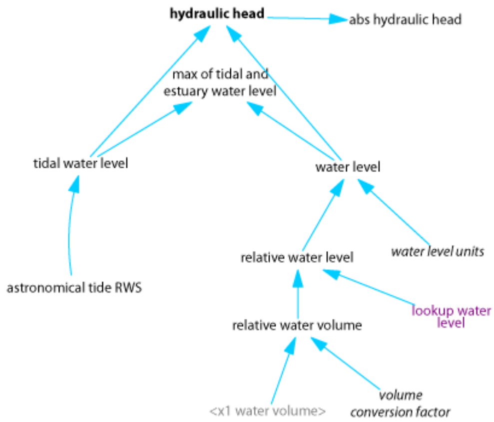
Water flow in mouth



Flood and ebb flow velocity (derived from rate x13)

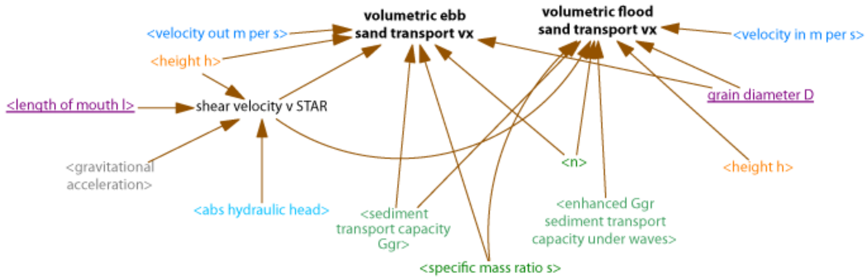


Tides

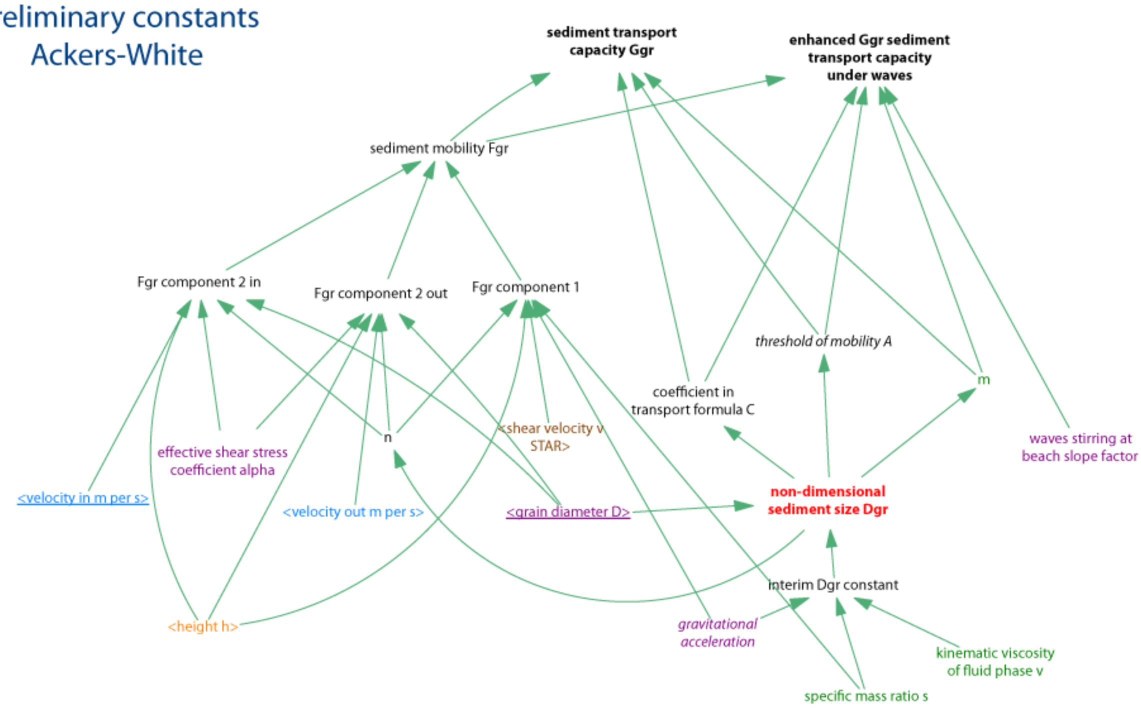


Section: sediment

Sediment transport



Sediment transport preliminary constants Ackers-White



Legend

De Slufter-specific parameters

Parameters

Ackers-White parameters

<shadow variables> appear somewhere else in the model as well (any color)

key variables (any color)

SI parameters

Stocks and rates

Tides submodel

flood and ebb flow velocity submodel

Water flow in mouth submodel

sediment transport submodel

Appendix B: Checklist for semi-structured interviews (translated from Dutch)

Introduction

- Who am I?
- Why this project?
- Current status of project
- Interview objectives: grasping different perspectives of people, mostly on use and importance of the Slufter.
- Approach: semi-structured interview, open conversation.

Today's topics

0. General
1. Nature reserve the Slufter
2. Functions of and values for the Slufter
3. Actors, their roles and connections
4. Specific extra questions, if desired

0. General

0.1. Profession, role, background
0.2. How are you familiar with theSluftere

1. Nature reserve the Slufter

1.1. What can you tell me about dynamics?
  1.1.1. If desired: are you aware of the policy of periodically re-digging the mouth channel? (In: '73, '78. '83, '87, 91, '98, '05, '09, '13)
    1.1.1.1. Why do you think this happens?
    1.1.1.2. Main consequences?
    1.1.1.3. What would you do differently?
1.2. What do people not know about the Slufter?

2. Functions and values the Slufter

2.1. How do you use the system?
2.2. Any foreseeable problems for the Slufter? What are the main ones?
2.3. What entails a desired/healthy/good Slufter?
  2.3.1. What are indicators for the functioning of the Slufter?
2.4. How is the Slufter used by others?
2.5. What if: current policies change? What should be done differently, according to you? Which changes could affect others?

3. Actors and connections

3.1. To whom would you go if you see a problem (currently or in the future?)
  3.1.1. And why? What are their resources?
  3.1.2. To whom wouldn't you go?
  3.1.3 How do they make decision happen?
3.2. Who would you interview on this topic?

4. If desired: specific extra questions

5. Closing

5.1. Thank you.
5.2. I will make a concise summary of this interview and send it to you for approval.

Appendix C: Participants for knowledge intervention

Table 2: List of partipants

Number	Background	Affiliation	Participant's perspective
1	Nature manager Texel, vegetation and monitoring	Nature manager	Ecology
2	Ecologist within district water board, implementation of Natura 2000 regulation, bird watcher	HHNK	Ecology and policy
3	Researcher, ecologist	Deltares	Ecology
4	Researcher, ecologist	Deltares	Ecology
5	Researcher on morphodynamics in the Slufter	Deltares	Abiotics
6	Student	VU	Abiotics
7	Student	VU	Biotics
8	Researcher on flood defence policy	HHNK	Water safety and policy
9	Manager regarding sandy coasts of North Holland	HHNK	Water safety and policy
10	Formerly operational flood defense management on Texel	HHNK	Water safety
11	Inhabitant Texel, regular tourist guide in nature reserves on Texel	National Park Dunes of Texel	Ecology
12	Researcher on morphodynamics	Deltares	Abiotics
13	Operational management flood defense management of Texel Member of crisis management team Texel	HHNK	Water safety
14	Bird watcher and nature photographer	Bird watchers club	Ecology (birds and landscape)

Appendix D: Voting form for knowledge intervention(translated from Dutch)

A. Which qualities of the Slufter are the most important to you?
Distribute the 12 numbered, ***yellow*** *stickers among the qualities below. Each sticker represents one vote. You can vote for each quality more than once. Please use the entire set of votes.*

	Tidal dynamics
	Freshwater-seawater gradients and intertidal zones
	Habitat for birds, vegetation and other animals
	Part of bird migration routes within and beyond Europe
	Uniqueness of area, one of a kind
	Sense of wild nature, space and peace
	Flood defence function
	Harvesting herbs or plants, grazing cattle, catching of fish or eel, and other uses by Texel inhabitants
	Touristic attraction
	(Part of) recreational route or path
	(Contribution to) variety in Texel's landscape
	Use for scientific or research purposes
	Cultural-historical, place of memorial (such as a place to scatter ashes of the deceased)
	Else, namely:..

B. How would you like to see this translated to policies for the Slufter? In other words: which hypothetical policy options would you prefer?
Distribute the 3 numbered, ***green*** *stickers and the single, red sticker among the policy options below. Each green sticker represents a positive vote; each red sticker represents a negative vote. You may vote for each policy option more than once. Please use the entire set of votes.*

	Let the control over the Slufter go (free room for dynamics)
	Safety first
	Continue current policies
	Gradually permit natural development of the channel, and take action if necessary
	Pay attention to monitoring
	Fill the Slufter opening up
	Increase the Slufter's zone
	Else, namely …

--- Thank you for completing ---

Appendix E: List of model variables

Table 3: List of variables, units, mathematical definition and their corresponding (sub-) section

Section and subsection	Variable	Units	Formula / mathematical definition	Comments
Water: tides	Lookup water level	1	[(-10000,-1)-(3e+07,10)],(-10000,-1),(0,0),(1,-1),(5,-0.2),(15000,0),(33000,0.2),(92200,0.4),(245300,0.8),(454000,1.2),(706200,1.6),(1.0058e+06,2),(1.3545e+06,2.4),(3e+07,4))	lookup calculates water level given the water volume
Water: tides	max of tidal and estuary water level	meter	MAX (tidal water level,water level)	
Water: tides	abs hydraulic head	meter	ABS(hydraulic head)	
Water: Tides	Astronomical tide RWS	meter	GET XLS DATA	(Rijkswaterstaat, 2014)
Water: Tides	Tidal water level	meter	= Astronomical tide RWS	
Water: Tides	water level	meter	water level units*relative water level	
Water: flood and ebb flow velocity	ebb flow	meter* meter* meter/ year	MAX(0, -1*x13 tidal flow)	absolute value for ebb flow
Water: flood and ebb flow velocity	flood flow	meter* meter* meter/ year	MAX (0, x13 tidal flow)	
Water: flood and ebb flow velocity	velocity in m per s	meter/ second	IF THEN ELSE ("mouth cross-section" < (threshold value rcon * width of the mouth b), 0 , (flood flow / ("mouth cross-section" * seconds per year)))	
Water: Water flow in mouth	absolute value target tidal flux	Meter* meter* meter/ year	ABS(target tidal flux)	
Water: Water flow in mouth	asymmetry tidal velocity	1	velocity f LOOKUP(normalized hydraulic head v)	
Water: Water flow in mouth	characteristic length of estuary	meter	250	
Water: Water flow in mouth	control value of target tidal flux	m^3/year	IF THEN ELSE (height h <= threshold value rcon, 0 , seconds per year * "mouth cross-section" *SQRT(gravitational acceleration * height h))	
Water: Water flow in mouth	Height h	meter	MAX (0.1, max of tidal and estuary water level-x2 mouth threshold)	
Water: Water flow in mouth	head gradient normal	1	0.0002	meter / meter normalizing factor for the head gradient difference
Water: Water	target tidal	meter*	(hydraulic head / characteristic	for how much hydraulic

Section and subsection	Variable	Units	Formula / mathematical definition	Comments
flow in mouth	flux	meter* meter/ year	length of estuary)*storage capacity*asymmetry tidal velocity	head, for each slice of the estuary, how much storage is there (above the norm)?
Water: Water flow in mouth	threshold value rcon	meter	0.02	rcon = h 0.035 or rrcon - if the water level is lower than this value, there is no inflow or outflow
Water: Water flow in mouth	Hydraulic head	meter	tidal water level - water level	
Water: Water flow in mouth	mouth cross-section	meter* meter	IF THEN ELSE (height h <= threshold value rcon, 0, width of the mouth b * height h)	if negative, the mouth cross section is effectively zero.
Water: Water flow in mouth	mouth control	1	IF THEN ELSE (control value of target tidal flux > absolute value target tidal flux, 1, control value of target tidal flux / absolute value target tidal flux)	
Water: Water flow in mouth	water level units	meter	1	
Water: Water flow in mouth	normalized hydraulic head v	1	hydraulic head / (characteristic length of estuary*head gradient normal)	
Water: Water flow in mouth	relative storage capacity	1	storage capacity LOOKUP(relative water volume)	bathymetry
Water: Water flow in mouth	relative water level	1	lookup water level(relative water volume)	
Water: Water flow in mouth	relative water volume	1	volume conversion factor*x1 water volume	
Water: Water flow in mouth	seconds per year	second /year	24*3600*365	
Water: Water flow in mouth	storage capacity	meter* meter* meter/ year	relative storage capacity*units for storage capacity	
Water: Water flow in mouth	storage capacity LOOKUP	1	([(-2.14748e+09,-1)-(1e+08,10),(-100000,0),(0,0),(1,4e-05),(5,0.529),(15000,0.582),(33000,1.361),(92200,2.393),(245300,3.188),(454000,4.062),(706200,4.863),(1.006e+06,5.713),(1.354e+06,5.713),(1e+08,5.713)],(-1e+10,2e-05),(0,3e-05),(1,4e-05),(5,0.529),(15000,0.582),(33000,1.361),(92200,2.393),(245300,3.188),(454000,4.062),(706200,4.863),(1.006e+06 ,5.713),(1.354e+06,5.713),(1e+08,5.713))	
Water: Water flow in mouth	velocity f LOOKUP(	1	[(-2000,0)-(10000,10)],(-2000,1.05),(-2,1.05),(-1,1),(0,0.9),(1,1),(1.33793,1.90476),(1.55862,3),(1.69655,3.47619),(1.88966,3.71429),(2.02759,3.95238),(	

Section and subsection	Variable	Units	Formula / mathematical definition	Comments
			2.33103,4.09524),(4,4.1),(10000,4.1))	
Sediment: Sediment transport	Volumetric ebb sand transport vx	1	sediment transport capacity Ggr*((specific mass ratio s*grain diameter D) / height h) * POWER (velocity out m per s/ shear velocity v STAR , n)	sand transport cube sand per cube water
Sediment: Sediment transport	shear velocity v STAR	meter/ second	SQRT(gravitational acceleration * height h * (abs hydraulic head / length of mouth l))	used as calibration coefficient, velocity near the bottom
Sediment: Sediment transport	waves stirring at beach slope factor=	1	1	effect of sediment availability due to beach slopes.
Sediment: sediment transport	Length of mouth l	Meter	10	
Sediment: sediment transport	porosity	1	0.4	
Sediment: Sediment transport preliminary constants Ackers-White	sediment transport capacity Ggr=	1	IF THEN ELSE (sediment mobility Fgr <= threshold of mobility A , 0 , coefficient in transport formula C * POWER (((sediment mobility Fgr - threshold of mobility A)/threshold of mobility A) , m))	
Sediment: Sediment transport preliminary constants Ackers-White	Fgr component 1	1	POWER(shear velocity v STAR, n) / (SQRT (gravitational acceleration * (specific mass ratio s - 1) * height h))	
Sediment: Sediment transport preliminary constants Ackers-White	Fgr component 2 in	1	POWER (velocity in m per s / (SQRT (32* LOG ((effective shear stress coefficient alpha * height h)/ grain diameter D ,10))) , (1- n))	
Sediment: Sediment transport preliminary constants Ackers-White	Fgr component 2 out	1	POWER (velocity out m per s / (SQRT (32* LOG ((effective shear stress coefficient alpha * height h)/ grain diameter D ,10))) , (1- n))	
Sediment: Sediment transport preliminary constants Ackers-White	interim Dgr constant	1	gravitational acceleration * (specific mass ratio s - 1) / ((kinematic viscosity of fluid phase v)^2)	
Sediment: Sediment transport preliminary constants Ackers-White	non-dimensional sediment size Dgr	1	grain diameter D * POWER(interim Dgr constant , 0.333333)	
Sediment: Sediment	kinematic viscosity of	(meter *meter	1e-06	

Section and subsection	Variable	Units	Formula / mathematical definition	Comments
transport preliminary constants Ackers-White	fluid phase v	)/second		
Sediment: Sediment transport	volumetric flood sand transport vx	1	(enhanced Ggr sediment transport capacity under waves-sediment transport capacity Ggr)*((specific mass ratio s*grain diameter D) / height h) * POWER (velocity in m per s/ shear velocity v STAR, n)	Flood and ebb sand transport flows are have separate
Sediment: Sediment transport preliminary constants Ackers-White	enhanced Ggr sediment transport capacity under waves	1	IF THEN ELSE (sediment mobility Fgr * waves stirring at beach slope factor <= threshold of mobility A , 0 ,coefficient in transport formula C * POWER (((sediment mobility Fgr * waves stirring at beach slope factor - threshold of mobility A)/threshold of mobility A) , m))	
Sediment: Sediment transport preliminary constants Ackers-White	Effective shear stress coefficient alpha	1	10	
Sediment: Sediment transport preliminary constants Ackers-White	specific mass ratio s	1	2.65	
Sediment: Sediment transport preliminary constants Ackers-White	velocity out m per s	meter/ second	IF THEN ELSE ("mouth cross-section" < (threshold value rcon * width of the mouth b), 0 , (ebb flow / ("mouth cross-section" * seconds per year)))	
Sediment: Sediment transport preliminary constants Ackers-White	coefficient in transport formula C	1	POWER(10 , (-3.53 + 2.86 * LOG("non-dimensional sediment size Dgr", 10) - (LOG("non-dimensional sediment size Dgr" , 10)^2)))	Ackers- White 1973 paper differs here from 1994 2.85 = 2.79 -1 = -0.98 -3.53 = -3.46
Sediment: Sediment transport preliminary constants Ackers-White	threshold of mobility A	1	0.14 + (0.23 / SQRT("non-dimensional sediment size Dgr"))	
Sediment: Sediment transport preliminary constants Ackers-White	n	1	1 - (0.56 * LOG ("non-dimensional sediment size Dgr" , 10))	
Sediment: Sediment	grain diameter D	meter	0.00035	Slufter: between 0.00025 and 0.00035

Section and subsection	Variable	Units	Formula / mathematical definition	Comments
transport preliminary constants Ackers-White				
Sediment: Sediment transport preliminary constants Ackers-White	gravitational acceleration	meter/(second*second)	9.8	
Sediment: preliminary constants Ackers-White	m	1	1.67 + 6.83 / "non-dimensional sediment size Dgr"	
Ackers White	sediment mobility Fgr	1	(Fgr component 1 * Fgr component 2 in) + (Fgr component 1 *Fgr component 2 out)	