UNIVERSITY OF TWENTE.

WHAT DO STAKEHOLDERS HAVE TO SAY ABOUT SAND NOURISHMENTS?

THE USE OF UNCERTAINTIES TO COPE WITH GAPS IN WATER GOVERNANCE IN THE CONTEXT OF DUTCH ADAPTATION TO CLIMATE CHANGE

Student Rafael Guerreiro Imada

Student ID s1653741

Date 28/08/2017

Course name CEM Master Thesis Water

Course ID 195419999

WHAT DO STAKEHOLDERS HAVE TO SAY ABOUT SAND NOURISHMENTS?

THE USE OF UNCERTAINTIES TO COPE WITH GAPS IN WATER GOVERNANCE IN THE CONTEXT OF DUTCH ADAPTATION TO CLIMATE CHANGE

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN CIVIL ENGINEERING AND MANAGEMENT

Specialization in Water Engineering and Management

Faculty of Engineering Technology

University of Twente

28-08-2017

AUTHOR

R. (Rafael) Imada BSc

Student WEM, s1653741

r.guerreiroimada@student.utwente.nl

SUPERVISORS

dr. K.M. (Kathelijne) Wijnberg

Water Engineering and Management
Faculty of Engineering Technology
University of Twente

dr. M.F. (Marcela) Brugnach

Water Engineering and Management
Faculty of Engineering Technology
University of Twente

EXTERNAL SUPERVISOR

dr. J.P.M. (Jan) Mulder

Consultant and guest lecturer
Water Engineering and Management
Faculty of Engineering Technology
University of Twente

PREFACE

Throughout the years, the protection of coasts around the world has been done by means of hard flood defense structures such as dikes and storm surge barriers. This type of structure would guarantee a high level of control over the environment. However, one major disadvantage of hard structures is their fixed dimensions, capable to withstand a certain maximum level. This drawback is particularly significant nowadays due to the increasingly rise in sea level caused by climate change.

Climate change has brought a new mindset to the development and application of policies concerning the protection of the coast. In one front, it calls for the development of more sustainable and climate durable practices and mitigation strategies. While in the other, requires adaptation. In the Netherlands, the policy handling the adaptation to climate change is called Delta Programme. Within this policy, there are specific strategies and measures for the protection of the coast against floods.

The Dutch coast, with almost 350 km of extension, is mainly sandy. Annually, the coast suffers from sand loss, requiring additional input of sand to maintain the basic coastline. Considering the natural characteristics of the Dutch coast and the need for more flexible and adaptable strategies for coastal flood protection, sand nourishments have been introduced as the main strategy in recent years.

The use of sand nourishments is still a new development in many aspects, surrounded by many uncertainties on its effects on the functions of the coast. Given the dynamic and broad qualities of the coast, there are many different stakeholders directly or indirectly involved or affected by the implementation of these nourishments. Different views and interpretations of these actors are not always accounted for in the policy level, which could represent a lost opportunity for policymakers to strengthen the adaptive quality of the policy and increase its acceptability. Furthermore, during the implementation phase of nourishments, the existence of unaccounted for uncertainties can represent setbacks in project costs, effectiveness and also acceptability.

In this thesis, I investigate how the different perspectives regarding sand nourishments from different actors directly or indirectly involved or affected in the process can benefit both policymakers (in the context of the Delta Programme) and practitioners in the implementation of nourishments projects. To this end, the relevant stakeholders are identified and interviewed to obtain their interpretations of sand nourishment as an adaptive strategy and this data is used to describe the system and its complexities in the form of uncertainties.

The uncertainties obtained from the interviews, are then characterized and related to describe specific situations referring to sand nourishments. In the sequence these uncertainties are contextualized in the Delta Programme, and gaps between the identified uncertainties and the policy are identified. Next, a discussion of possible coping strategies to deal with the identified uncertainties is provided. Finally, the conclusions and recommendations are presented.

Although the accuracy of this analysis may be limited, due to the lack of involvement of certain stakeholders, a short validation process and time constraints, the results of this study may provide insights to coastal managers to improve their adaptive policies.

CHAPTER 1: **INTRODUCTION**

1.1 BACKGROUND

Climate change has introduced a new set of uncertainties for policy-making. The fact that the globe is warming is known, as well as its consequence: significant changes in average weather. Similarly, there will be more extreme weather events. However, the nature of the impacts and their precise extent remain impossible to predict. Climate change as an issue has evolved from a narrow interest base in the meteorological sciences to a broad social recognition in which both impacts and policy responses will have great implications for human development (IISD & TERI, 2006).

On its own way, climate change has brought new and unexpected challenges to our current lifestyle. On the one hand, it is fundamental to develop more sustainable and climate durable practices by applying mitigation strategies into our daily activities. Meaning that citizens, companies, and governments have to create more sustainable practices, procedures and investments (van Buuren et al., 2013). On the other hand, mitigation alone is not sufficient to deal with the threats associated with climate change. There is a necessity to adapt our societies to the (potential) impacts of climate change that cannot be prevented.

Adaptation, as defined by the IPCC is "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." (IPCC, 2007). Termeer et al. (2011) state that adaptation focuses on anticipating climate impacts in three distinct ways: minimizing potential damage, coping with the possible consequences of impacts, and taking advantage of opportunities.

The manifestations of climate change in the physical environment includes change in temperature or precipitation, sea level rise, changes in the frequency and duration of extreme weather events, resulting in changes in hydrologic conditions (IISD & TERI, 2006). There is uncertainty about the characteristics and extent of these changes, on the one hand because the implications are extremely complex and our understanding of them are incomplete and, on the other, because of different interpretations of the different people involved. Brugnach et al. (2008) defines uncertainty as to the situation in which there is not a unique and complete understanding of the system to be managed. In the conceptualized model proposed by these authors, uncertainty can originate from incomplete knowledge, unpredictability or ambiguity. Several authors argue that, although much has been written about embracing uncertainties from incomplete knowledge and unpredictability, there is also a need to embrace ambiguities in certain situations (e.g. Dewulf et al. (2005); Brugnach et al. (2008); Brugnach et al. (2009) and Fleming and Howden (2016)).

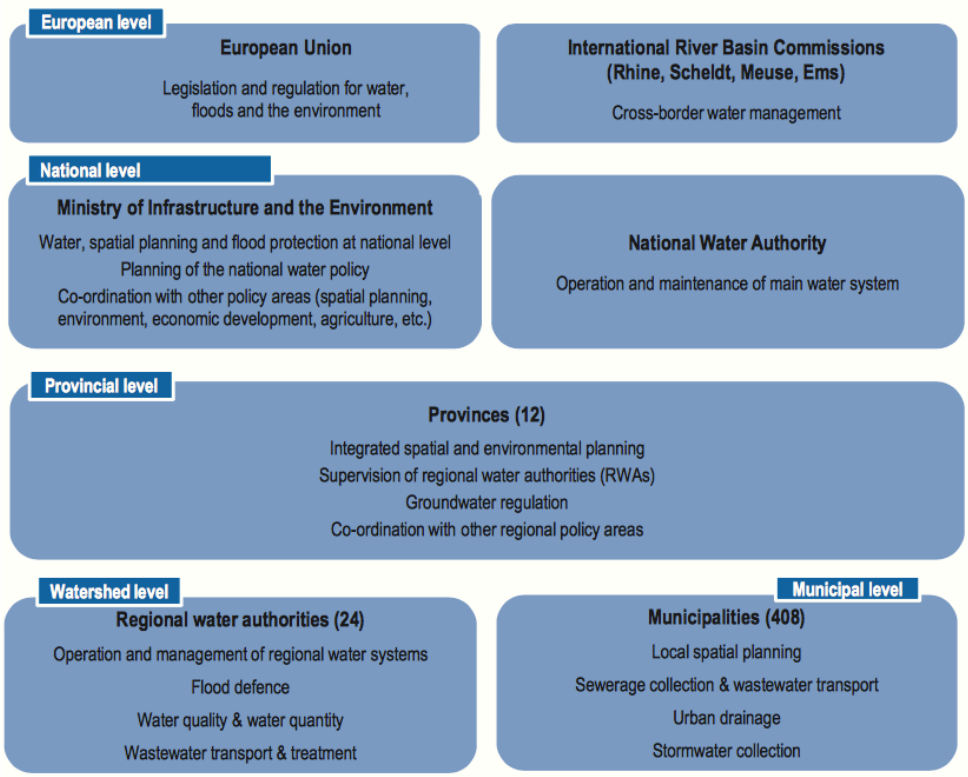
1.2 WATER MANAGEMENT IN THE NETHERLANDS

1.2.1 WATER GOVERNANCE

In 2009 the Water Act updated the roles and responsibilities for water management in The Netherlands, designating, in combination with secondary legislation, the authorities responsible for the management of water systems as well as the authorities at the international and national level with whom the cooperate (OECD, 2014).

The water governance in The Netherlands can be differentiated between the three levels of government (national, regional and local). The national level is represented by the Ministry of Infrastructure and the Environment and Rijkswaterstaat. At the regional level there are both the provinces and Water Boards (on a water basin level), and locally the municipalities. Internationally, the governance involves the European Union and International River Basin Commissions. Figure 1 illustrates the water governance in The Netherlands.

FIGURE 1: WATER GOVERNANCE IN THE NETHERLANDS.



Adapted from OECD(2014)

The national government, provinces, regional water authorities and municipalities all have specific tasks and responsibilities when it comes to water management. In addition, the country also integrates legislation from the European Union into the national system (OECD, 2014). According to OECD (2014) the following authorities are also responsible for the indicated water management activities:

- The central government (represented by the Ministry of Infrastructure and the Environment) is responsible for national water policy and the compliance with other policy areas (such as spatial planning, environment, nature conservation, economic development, agriculture and horticulture).
- Rijkswaterstaat, the executing agency of the ministry, is responsible for operation and maintenance of the main water system (North Sea, Wadden Sea, Lake IJsselmeer and the major rivers and channels).
- The 24 regional water authorities (also called Water Boards) are responsible for the management of regional water systems in order to maintain water levels, water quality and treat wastewater. They are decentralized public authorities equipped with specific legal and

financial resources, each operation in areas delimitated by their physical drainage characteristics.

- The 12 provinces are responsible for the integration of spatial and environmental planning (within administrative boundaries that do not coincide with hydrographically determined boundaries), supervision of regional water boards, development of groundwater plans and regulations, as well as agreements with other regional policy areas.
- The 408 municipalities are in charge of spatial planning at the local scale, dealing with sewerage collection system, urban drainage and storm water collection in urban areas.

1.2.2 GAPS IN THE WATER GOVERNANCE

In 2014 the OECD conducted a study on water governance that provides policy makers with a range of tools and indicators to diagnose and overcome major governance gaps in water policy design and implementation. This report states that, generally, the Dutch water governance is aligned with generic principles of good governance. However, they highlight a number of multi-level governance gaps, with the potential to hinder water policies in place today and in the future.

A detailed panorama of the gaps in the Dutch water governance can be found in the report from OECD (2014). In this document, only a brief summary of the most relevant gaps to the main topic of the research are presented:

- The lack of clarity on who is responsible for executing and financing joint measures;
- The increase in regional disparities can represent a significant equity challenge for the near future: necessity of assessing the distributional effects of the cost recovery system; affordability to the lowest percentage of the population; mismatch between the ones generating costs for water protection and those footing the bill;
- Lack of a systemic monitoring of the efforts towards cost-savings and efficiency gains in water management as well as identification of remaining opportunities to be seized;
- Institutional and territorial fragmentation of water policy across multiple actors;
- The need to address potential gaps in knowledge, human capital, technology and other capabilities to design and implement sustainable, efficient and effective water policies;
- How to engage stakeholders via fostering accountability mechanisms and protect consumers through transparent and inclusive decision making;
- The development of physical, socio-economic, financial and institutional water information systems for the support of decision makers, giving particular emphasis to their coherence, consistency, reliability and public disclosure as well as to cost-benefits.
- The alignment of objectives, diverging interests and priorities paying attention to existing trade-offs for policy coherence;
- How to conciliate administrative and hydrological boundaries to manage water resources at the relevant scale.

1.3 COASTAL MANAGEMENT

The Dutch coastline is about 350 km long and commonly divided into three distinct regions: the Delta coast in the south, the Holland coast in the center and the Wadden coast in the North (Taal

et al., 2006). From this total, 290 km is comprised of dunes and beach flats with the remaining 60 km being protect by dikes, dams and storm surge barriers (de Ruig, 1998).

The management of the Dutch coastal zone involves a large group of public and private-sector groups. The water boards, under the supervision of the provinces are responsible to manage the coastal defenses protecting the main land from sea floods. However, on the Wadden island this task is carried out by Rijkswaterstaat, who is also responsible for the maintenance of the coastline and the management of the North Sea (Taal et al., 2006).

Taal et al. (2006), states that the coastal policy in the Netherlands normally concerned safety from floods, especially after the storm surge disaster of 1953 when it was decided to set all sea defenses to a predefined safety level, this levels have been defined in the Flood Defense Act. In the sequence, the Dutch government started to take precautions to stop any further structural recession of the coastline, and in 1990 implemented the national policy of ***Dynamic Preservation*** in which is defined the safety levels and sustainable preservation of the values of the dune area (de Ruig, 1998 and Taal et al., 2006). This policy meant that the coastline would be maintained as, at least, it was in 1990 with all erosion counteracted (de Ruig, 1998) making use of sand nourishments whenever possible (Taal et al., 2006).

In recent year, the government has made the decision to shift flood safety policy towards risk assessment (Delta Programme | Coast, 2013), based on three objectives: the probability of flooding of 10^{-5}; the possibility of extra protection in the event of great social impact; and the possibility of additional protection for essential infrastructure.

According to the Delta Programme (2014) – DP 2014 – a risk based approach provides flood management in the Netherlands with a more robust foundation in which both the likelihood and possible consequences of a flood determine the level of safety. The DP 2014 distinguishes three types of measures, also called multilayers of safety, to be implemented in order to achieve the goals for risk management:

Layer 1: Preventive measures to limit the probability of a flood;

Layer 2: Spatial organization of an area to limit the consequences of a flood;

Layer 3: Disaster management to limit the consequences of a flood in terms of casualties.

When this principle is applied to the coastal area, a flood event could have the potential in parts of the area to claim large number of victims and severe economic consequences, as point out by the DP 2014. Prevention, as the first level of the multilayer safety, is the principle on which the safety of the coast and hinterland is based and if, nevertheless, an emergency occurs, evacuation to higher grounds is the only option (Delta Programme, 2014).

Safety is the main priority of the Dutch coastal management. The Delta Programme | Coast (2013) states that proper management and maintenance and, where necessary, reinforcement of the flood defenses, coastline and coastal foundation minimize the risk of flooding, losses and damages.

This vision for the water management for the Dutch coast was created in collaboration with municipalities, water boards, provinces and the Dutch government and inputs from civil society organizations, research institutes and the business community (Delta Programme | Coast, 2013). Given the large number of parties involved, decisions on coastal zone policy and management

require platforms for multi-stakeholder discussion and consultative committees (such as the provincial consultative committees on coastal affairs) (Taal et al., 2006).

1.4 EFFECTS OF CLIMATE CHANGE ON THE DUTCH COAST

The Netherlands is particularly vulnerable to climate change mostly since it's a low-lying country situated on the delta of the rivers Rhine, IJssel and Meuse, with about 24% of its lands below mean sea level, which means that, without water defenses, 60% of the country is susceptible to flooding from both sea and rivers (OECD, 2014).

From the 2014 OECD report the following statements can be identified concerning how the Dutch water management accounts for the potential implications of climate change:

- The policies are based on climate scenarios developed by the Royal Netherlands Meteorological Institute (here after referred to as KNMI), which are periodically updated and combined with socio-economic scenarios to base the Delta scenarios that are used in the Delta Programme.
- In the 2006 KNMI report, two scenarios were developed for mean temperature change, for +1°C and +2°C.
- A more extreme scenario of mean temperature (+6°C) was used as an underlying assumption to estimate the upper range of possible sea-level rise in 2100.

According Delta Programme | Coast (2013), the Dutch coast must be prepared to face a future which combines sea level rising more quickly, the possibility of wave climate changing, and the subsidence of the land. Nonetheless, current studies cannot precise when this acceleration will happen and how significant it will be, and yet, the research done indicates that the consequences will most likely appear in the medium and long terms (until 2100).

1.4.1 SEA LEVEL RISE

According to the Intergovernmental Panel on Climate Change (IPCC), global warming is expected to accelerate the rise in sea-level. The KNMI climate scenarios for the Netherlands (2014) predict that, by 2050 the sea-level may be up by 15-40 cm and by 2100 the difference may increase up to 100 cm.

When it comes to flood safety, the coastal protection is generally expected to be enough over the course of this century, if properly managed and maintained. Furthermore, forecasts and new insights indicate that the consequences of relative sea-level rise are likely to occur in the medium and long term, meaning that optimum management and maintenance should be carried on over the next decades (Delta Programme | Coast, 2013). Nonetheless, this scenario could change if new insights into the impact of relative sea-level rise on flood defenses or new assessments of the consequences of flooding come to light.

1.4.2 ADAPTATION TO CLIMATE CHANGE IN THE NETHERLANDS

In The Netherlands the policy concentrating the works on coping with the effects of climate change is the so called ***Delta Programme***.

The Delta Programme, started in 2010 but has its roots as a set of measures introduced by the Dutch government in response to the disastrous floods of 1953 aiming on heightening the coastal dikes. Fifty years later the aim of the Delta Programme is to protect the Netherlands against floods, now and in the future, while ensuring sufficient freshwater supply, and taking into account a combination of higher temperatures, ground subsidence and sea level rise. It comprises a joint agreement between national government, provinces, water boards, and municipalities working in close cooperation with social organizations and business (OECD, 2014).

The Delta Act on Flood Risk Management and Freshwater Supplies from 2012 as an amendment to the Water Act provides the required support to the Delta Programme. It establishes the Delta Commissioner as the head of the Delta Programme, appointed by the central government. One of the main responsibilities of the Delta Commissioner is to submit a yearly report containing the overview of all measures, facilities, studies and ambitions of the program to the Cabinet (OECD, 2014).

The Delta Programme can work towards bridging the gaps in the water governance, previously mentioned, from different fronts (OECD, 2014):

- Accountability gap: multi-stakeholder dialogues in decision making process where different groups are consulted and involved, engaging several actors and their interests, contributes to better transparency and public participation.
- Awareness gap (information gap): The Delta Commissioner is responsible to ensure that all sectors involved (ministries, provinces, water boards, municipalities, social organizations, businesses and citizens) are informed and aware of the political decisions and projects, as well as have access to data, studies and climate-change scenarios, raising the awareness on Dutch water institutions, risks and functions.
- Knowledge gap (capacity gap): the projects designed and implemented are based on scientific and technical expertise, where university and other knowledge institutes and implementation agencies are involved to help identify gaps. Furthermore, they participate in the development of agendas and strategies, cooperating with the responsible governments, targeting specific qualification needs, working on the capacity gap.
- Policy gap: since the creation of the program involved all levels of the Dutch water governance, its coordination helps towards preventing segmented working methods and scattered responsibilities between different levels of government, creating meaningful convergence for decision making.
- Objective gap: by having the objectives of the Delta Programme collectively agreed-upon, with consultation of advocacy groups, academics, and the business community, as well as the secure allocation of specific financial resources guaranteed by the Delta Fund. Helping in the alignment of policy areas and political agendas to ensure the continuity of public policy at the provincial and municipal levels.

According to the Delta Programme (2015) – DP 2015 – climate change may impact the Dutch coast as a result from sea level rise (with associated change in wave heights and patterns). The report states that if sufficient effort is made into managing and maintaining the basic coastline, the coastal foundation zone, and the flood defense systems, significant interventions will not be required until 2050. However, such statement is heavily dependent on the rate at which the sea level rises.

From the Delta Programme emerged the Delta Programme Coast, which aims at combining efforts to improve flood safety with retaining and exploring the possibilities for sustaining a good,

attractive, and pleasant working and living environment in the Dutch coast (Delta Programme | Coast, 2013). Which is translated into the following adaptive management terms:

- Account and make allowance for the possibility of responding effectively, making use of innovative methods, to uncertain changes on climate, socio-economic trends, new insights and changing public opinion (e.g. on flood safety).
- Take responsibility instead of shifting the burden to different parties, generations or other levels of government.
- Use measures to improve the quality of the everyday environment and of ecosystems.

The Delta Program is then based on three fundamental values: flexibility, solidarity, and sustainability, which were used to develop the following five principles of the National Costal Framework, for the integrated coastal development, based on the motto "soft where possible, hard where necessary" as defined in the Delta Programme | Coast (2013):

- Adaptive principle: both flood defenses and the functions of the coast must be adaptable to sea-level rise and climate change as well as maintain the best possible cost-benefit ratio.
- Principle of basic security: in order to be maintained and attractive for investments, the function in the coast must have a basic security.
- Principle of natural dynamics: working for and with natural processes, the dynamic of the natural system should be seen as an objective and as a resource for coastal development.
- Principle of spatial quality: focus on specifying and monitoring core qualities, while fitting in safety measures as efficiently as possible, developing new future-proof qualities.
- Financing principle: different parties should contribute to the cost of public goals other than safety in proportion to the benefit each party derives.

From the values and the development principles the National Coastal Strategy sets as goals a safe, attractive, and economically viable coast, which are translated into the practical aims depicted in Table 1.

The Dutch government believes that the adaptive strategies and flexible measures set into motion enables them to account for new knowledge and insights as, for example, regarding accelerated sea-level rise (Delta Programme Commissioner, 2017). They state that once every six years an assessment is conducted to verify the need to adjust the course and/or the implementation of measures. For example, increasing the frequency or volume of the sand nourishments if the rising in the sea-level requires it.

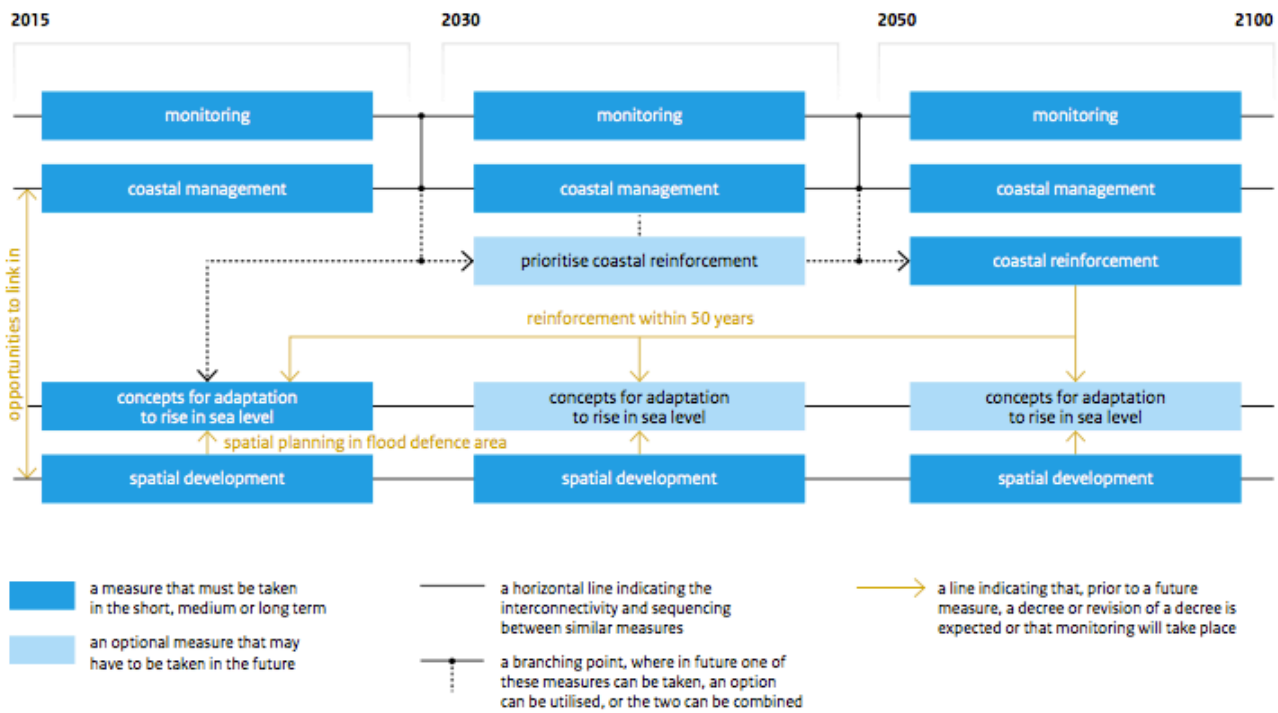
TABLE 1: SUMMARY OF FUNDAMENTAL VALUES, DEVELOPMENT PRINCIPLES AND THE AIMS OF THE DELTA PROGRAMME COAST IN PRACTICE.

Values	Development principles	Aims	Aims in practice
Flexibility Solidarity Sustainability	Adaptation Basic security Natural dynamics Spatial quality Financing	Safe	→ Sustainable balance between coastal foundation and relative sea-level rise → Keeping the coastline in place → The basic safety level of 10^{-5} for the risk of death by flood is a good legal basis for standardising the flood defences that protect the coast → Foreland: land retention actually guarantees a very low risk level
		Attractive	→ Maintaining/improving (spatial) quality and facilities → Preserving/developing identity of the coast and cultural heritage → Dynamic and interconnected nature reserves
		Economically viable	→ Maintaining basic security → Pleasant business climate → Good access

Adapted from Delta Programme | Coast (2013)

When it comes to the implementation of the measures for the short, medium, and long term agenda of the Delta Plan on flood risk management for the coast, the main measure consists of sand replenishments (management and maintenance) (Delta Programme, 2015). Figure 2 presents the adaptive path for flood risk management taking into consideration the spatial development ambitions.

FIGURE 2: COAST ADAPTATION PATH FOR FLOOD RISK MANAGEMENT



Adapted from Delta Programme (2015)

1.4.3 SAND NOURISHMENTS ON THE DUTCH COAST

The Dutch coast is sandy and constantly requires additional sand to maintain the coastline at the desired place, given the natural negative balance of the Dutch coast (due to the relative rise in sea levels, reduced supply from rivers, human interventions, and wind and tide induced erosion) (Delta Programme | Coast, 2013).

As previously defined, the national government implemented the policy of Dynamic Preservation stating that the coastline would be maintained as, at least, it was in 1990 with all erosion counteracted (de Ruig, 1998) making use of sand nourishments whenever possible (Taal et al., 2006). According to the Delta Programme | Coast (2013), some of the rationale behind using sand are: (1) the Netherlands has a good supply of sand on its own and (2) transport distances are relatively short; (3) sand is a natural and flexible way of strengthening and maintaining the coast; (4) it is consistent with the collective image of the identity of the Dutch coast.

From past experiences, the Netherlands identifies beach nourishments as an effective and flexible method to maintain the coastline. They have been able to halt the structural decline of the coast and learned that it is possible to expand the shallow part of the coast and allow the dunes to grow seaward, which would increase safety (Delta Programme | Coast, 2013). In the current policy, nourishments are believed to compensate for the consequences of the relative sea level rise and the structural erosion of the coast, promoting enabling condition to preserve and develop the physical space for different function of the coastal zone. It is in their view that a continuous management and maintenance of the coast can increase its attractiveness and boost its economy. Moreover, beach nourishments can also benefit the coastal ecology by exploiting the coastal dynamics, making it possible to maintain corridors between different habitats.

The current practice when it comes to sandy mitigation strategies using beach and shore face nourishments are carried out frequently every 3 to 10 years as a solution for several populated sandy coasts with structural coastal recession (Cooke et al., 2012; Hamm et al., 2002). In areas with large annual sand deficit large quantities of sand need to be supplied or frequent re-nourishments are required (de Schipper et al., 2016). A proposed alternative is to place a large volume of sand in a single location, which is intended to feed a larger alongshore stretch of coast over time, by means of alongshore diffusion. In this approach, the combined natural forces of wind, waves and tides are expected to redistribute the sediments in, along and cross-shore directions and enhance the safety of a longer area of coast. A mega-nourishment has been implemented in the Netherlands in 2011 in the form of a large hook with approximately 17 Mm^3 of sand, covering an area of 2.5 km by 1 km (de Schipper et al., 2016).

Implementing sand nourishments as a flood defense approach, making use of natural dynamics, leads to solutions that are more adaptable in relation to uncertain changing, natural or socio-economic conditions (Schasfoort and Janssen, 2013). The presence of a diverse group of stakeholders in such projects can easily result in a situation of ambiguity, in which is no longer clear what the problem or its solution is (van den Hoek, 2014).

Projects of sand nourishments may fall under the scope of the so called Building with nature (BwN) approach in the Netherlands. The BwN is referred to as an innovative flood defense approach incorporating both flexibility and sustainability. It makes use of natural materials associated with dynamic processes to develop flood defense projects focusing both on human and natural goals,

such as providing flood defense and creating new recreational space combined with opportunities for ecosystem development (van den Hoek, 2014).

In the Netherlands, about 1600 coastal profiles are yearly surveyed since the 1960s. Since the middle of the 19th century already, the position of the low water line, high water line and dune foot has been monitored. Nowadays, efficient survey systems combined with data-based management allows for a quick process-time (Heuvel, 2011). According to the author, these results are used each year for:

- Identifying the erosion hotspots;
- Indicating the sand nourishment locations;
- Estimating the average life-time of a sand nourishment for a particular coastal stretch;
- Analyzing the economic cost and benefit for each stretch;
- Evaluating the effectiveness of the national sand nourishment scheme and used for the five-year reporting to the Parliament.

1.5 UNCERTAINTIES

1.5.1 DEFINITION OF UNCERTAINTY

As Walker et al. (2003) states, when it comes to understanding the existing economic, natural and social systems there are many uncertainties to be dealt with. In the policymaking process the amount of uncertainties surrounding the development and choice of courses of action is evident, and assistance comes from scientific decision support. However, little attention is given to the many different dimensions of uncertainty.

The definition of uncertainty tends to vary between different domains and disciplines (Brugnach et al., 2008). Many authors agree in the distinction between the ontological and epistemic natures of uncertainty (see Walker et al. (2003), Brown (2004), Refsgaard et al. (2007), and van der Keur et al. (2008)). Brugnach et al. (2008) introduces ambiguity as a third nature of uncertainty. The three natures of uncertainty can be described as follows:

- Ontological uncertainty: uncertainty due to inherent variability of the system, and concerning social, economic, and technological developments (Walker et al. (2003) and van der Keur et al. (2008)).
- Epistemic uncertainty: uncertainty due to imperfect knowledge of the system (Walker et al. (2003) and van der Keur et al. (2008)).
- Ambiguity: multiple knowledge frames or different but (equally) sensible interpretations of the same phenomenon, problem or situation (Brugnach et al., 2008).

Epistemic uncertainty can in principle be reduced by more research and empirical efforts, ontological cannot. Nonetheless, van der Keur et al. (2008) points out that although epistemic uncertainty could be reducible the addition of data and analysis does not imply in their automatic reduction, which is specially the case for when the epistemic uncertainty refers to different views and perspectives of the numerous stakeholders.

Weick (1995) has defined ambiguity as the presence of too many possible interpretations of a situation instead of simply a lack of information. According to Brugnach et al. (2008), ambiguity results from the presence of simultaneos different valid, and at times conflicting, ways of framing a

problem. The authors define framing as an interective process in which the actors are engaged in the development of an understanding of problems and alternative solutions.

These uncertainties can be found under different contexts in IWRM, namely: natural, technical, and social (Walker et al., 2003) as presented in table 2. The natural context (or system) incorporates climate impacts along with its aspects, water quality and quantity, and ecosystem. The technical system consists of the elements/artefacts employed to modify the natural system, both with infrastructure and technologies. Lastly, the social context comprehends economic, cultural, legal, administrative, and organizational aspects (Brugnach et al., 2008).

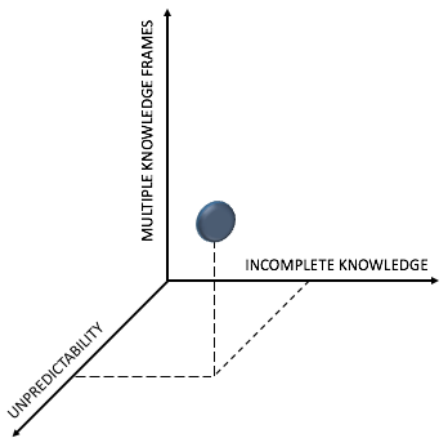
TABLE 2: CONTEXT OF UNCERTAINTIES

CONTEXT	NATURE OF UNCERTAINTY		
	EPISTEMIC	ONTOLOGICAL	AMBIGUITY
Natural context	Limitation in data and models, and limited understanding of processes in a broad sense. e.g. How will climate change affect weather extremes?	Inherent randomness of nature, the non-linear, chaotic and unpredictable nature of natural processes. e.g. What are reliable measurements of water levels?	Multiple knowledge frames about the natural system. e.g. Is the main problem in this basin the water quantity or ecosystem status?
Technical context	Limited knowledge of the technical components of the system. e.g. What will be the side- effects of technology X?	Includes technological surprises or unexpected consequences. e.g., To what water level will this dike resist?	Multiple knowledge frames about the technical system. e.g. Should dikes be built or flood plains created?
Social context	Limited knowledge on the social and economic components of the system. e.g. How strong will stakeholders' reactions be at the next flood?	Value and belief diversity, human behavior, social, economic, cultural and political dynamics (societal variability). e.g. What are the economic impacts of a flood for the different stakeholders?	Multiple knowledge frames about the social system. e.g. Should water markets be introduced to deal with water scarcity or negotiation platforms?

Adapted from van der Keur et al. (2008) and Brugnach et al. (2008)

When combining the three natures of uncertainty to characterize a water management problem one can use the representation shown in Figure 3. In most water management situations all of these three forms of uncertainties (unpredictability, incomplete knowledge, and multiple knowledge frames) are present, and a decision-maker needs to devise an appropriate strategy of action (Brugnach et al., 2009). However, given the interrelated nature of uncertainties, acting on one of its forms will impact the others. On the one hand such occurrence may be unwanted since it will demand an in-depth reanalysis of the problem to evaluate the actual benefit of the proposed solution.

FIGURE 3: CHARACTERIZATION OF THE UNCERTAINTIES OF A WATER MANAGEMENT PROBLEM



Adapted from Brugnach et al. (2009)

On the other hand, it may have the opposite effect where, by acting on one uncertainty, the impact on the other forms are positive, implying that the efforts made towards address one problem may solve multiple issues related to the situation at hand.

In water management processes van der Keur et al. (2008) classifies the sources of uncertainty into four different groups: (1) data uncertainty, which is the most common source of uncertainty considered; (2) model or conceptual uncertainty, meaning the uncertainty in understanding and describing the system and its functions; (3) multiple frames as a source of uncertainty, due to different perceptions of the various stakeholders on what the problems are, the stakes, the goals, likelihood of success, etc.; (4) boundary conditions of the water management system as a source of uncertainty, due to future regulatory conditions and other external factors (such as the impacts of future economic, environmental, political, social and technological developments).

The definition of the types of uncertainties were extracted from van der Keur et al. (2008), in which is stated the following:

> "Walker et al. (2003) distinguished between various levels of uncertainty: determinism, statistical uncertainty, scenario uncertainty, recognized ignorance and total (unrecognized) ignorance. Regard et al. (2007) added qualitative uncertainty from Brown (2004) and adopted the name 'types' instead of 'levels'."

The types of uncertainty used for epistemic and ontological uncertainties ranging from determinism and statistical uncertainty to indeterminacy and total ignorance. The pertinent dimension for ambiguity is not the one from complete knowledge to complete ignorance, as used to distinguish the types of the two other natures of uncertainty. Instead, something ranging from complete clarity to total confusion due to too many people expressing different but still pertinent interpretations (Brugnach et al. (2008) and Dewulf et al. (2005)).

1.5.2 UNCERTAINTIES IN CLIMATE CHANGE ADAPTATION POLICIES

As stated by Walker et al. (2003) although policymakers are known for expecting scientists to provide certainties, thus disliking uncertainty in the scientific knowledge base, uncertainty is a fact of life. By better understanding their different dimensions and implications for policy choices one could expect an increase in the trustworthiness of scientists in providing decision support, ultimately resulting in better policies (Walker et al., 2003).

Addressing the many problems concerning policymaking for climate change adaptation requires support of multiple views and options, going past the traditional reductionist approach to science, communication and decision-making, not only acknowledging the existence of uncertainties (both from incomplete knowledge, unpredictability or ambiguity) as well as embracing ambiguities in some situations (Fleming and Howden, 2016).

Ambiguity is frequently viewed as a weakness in the context of climate change science, which leads to confusion and misinterpretation, partially driven by the fact that the traditional scientific method is built on eliminating uncertainty (including ambiguity) and because embracing ambiguity would require a shift towards greater recognition of social construction of facts (Fleming and Howden, 2016). Brugnach and Ingram (2012) affirms that the knowledge production processes are mostly

dictated by the natural and economic sciences, not taking into consideration the insights of different disciplines such as politics, anthropology, sociology, and other social sciences. The authors argue that the assumptions underlying this processes are flawed and particularly inappropriate (see Brugnach and Ingram (2012) for further explanation), going against the ideas of inclusiveness and integration embedded in the matter of managing climate change.

In this sense, Fleming and Howden (2016) argue that dealing with climate change requires new methods and new approaches and, in this regard, ambiguity could play an important role in a new approach to science that is more conscious of its social construction, where a range of ways of thinking are included as well as diversity of values promoting multiple pathways forward. The authors suggest climate adaptation researchers to embrace ambiguity, allowing for a more practical focus towards facilitating cooperation and action, enabling multiple actors to work alongside each other in different ways. In this way, promoting the achievement of impact through integration and multiplication of ideas rather than imposing particular ideas (with their embedded values) over others (Fleming and Howden, 2016).

van den Hoek et al. (2014) states that the paradigm in water management is slowly shifting from command-and-control approaches, with hard engineering emphasizing on reducing uncertainties, towards more nature-inclusive approaches. In doing so, ambiguity could be seen as a strength, providing support to the investigation of different solutions as a response to the resulting challenges of a changing climate, that would be in alliance with a broader set of values (Fleming and Howden, 2016).

It is clear that responding to climate change challenges by harnessing ambiguity requires the use of stakeholder engagement and knowledge sharing approaches that move past traditional knowledge-deficit models of science communication (Fleming and Howden, 2016).

Fleming and Howden (2016) argue that embracing ambiguity could reduce the scientific tendency of spending efforts searching for definitions that satisfy all and fit across disciplines, allowing the focus to shift towards supporting and understanding appropriate action. However, they point out the existing trade-off between accepting enough ambiguity to promote multiple interpretations, diversity of action and common ground to support collaboration, while not allowing a scenario where "anything goes" or even one where nothing changes. Moreover, an inherent risk that can arise from ambiguity is the potential for persuasive behaviors by individuals and groups that form alliances to exploit emotions and ideological beliefs and biases of different actors (Cairney, Oliver and Wellstead, 2016).

1.6 PURPOSE OF THE STUDY

Delta Programme and gaps in water governance

In 2014 the OECD conducted a study on water governance that provides policy makers with a range of tools and indicators to diagnose and overcome major governance gaps in water policy design and implementation. In this report is stated that, although the Dutch water governance is aligned with generic principles of good governance, there are a number of multi-level governance gaps, that may potentially hinder water policies in place today and in the future. Nonetheless, the same report points out to the possibility of the Delta Programme in bridging them. The gaps in water governance presented in item 1.2.2 and the potential of the Delta Programme in bridging these gaps, showed in item 1.4.2 are both summarized in Table 3.

TABLE 3: GAPS IN WATER GOVERNANCE AND THE POTENTIAL OF THE DELTA PROGRAMME IN BRIDGING GAPS.

GAPS IN WATER GOVERNANCE		BRIDGING THE GAPS
Accountability gap	Difficulty ensuring the transparency of practices across the different constituencies, mainly due to insufficient users' commitment' lack of concern, awareness and participation.	Multi-stakeholder dialogues in decision making process where different groups are consulted and involved, engaging several actors and their interests.
Information gap	Asymmetries of information (quantity, quality, type) between different stakeholders involved in water policy, either voluntary or not.	The Delta Commissioner is responsible to ensure that all sectors involved are informed and aware of the political decisions and projects, as well as have access to data, studies and climate-change scenarios, raising the awareness on Dutch water institutions, risks and functions.
Capacity gap	Insufficient scientific, technical, infrastructural capacity of local actors to design and implement water policies (size and quality of infrastructure, etc.) as well as relevant strategies.	The projects designed and implemented are based on scientific and technical expertise, where university and other knowledge institutes and implementation agencies are involved to help identify gaps, develop agendas and strategies, targeting specific qualification needs, working on the capacity gap.
Policy gap	Sectoral fragmentation of water-related tasks across ministries and agencies.	Since the creation of the program involved all levels of the Dutch water governance, its coordination helps towards preventing segmented working methods and scattered responsibilities between different levels of government, creating meaningful convergence for decision making.
Objective gap	Different rationales creating obstacles for adopting convergent targets, especially in case of motivational gap (referring to the problems reducing the political will to engage substantially in organizing the water sector).	By having the objectives of the Delta Programme collectively agreed-upon, with consultation of advocacy groups, academics, and the business community, as well as the secure allocation of specific financial resources guaranteed by the Delta Fund. Helping in the alignment of policy areas and political agendas to ensure the continuity of public policy at the provincial and municipal levels.

Delta Programme and the coast

The Delta Programme Coast emerged from the Delta Programme, and aims at combining efforts to improve flood safety with retaining and exploring the possibilities for sustaining a good, attractive, and pleasant working and living environment in the Dutch coast (Delta Programme | Coast, 2013). According to the Delta Programme (2015) – DP 2015 – climate change may impact the Dutch coast as a result from sea level rise (with associated change in wave heights and patterns).

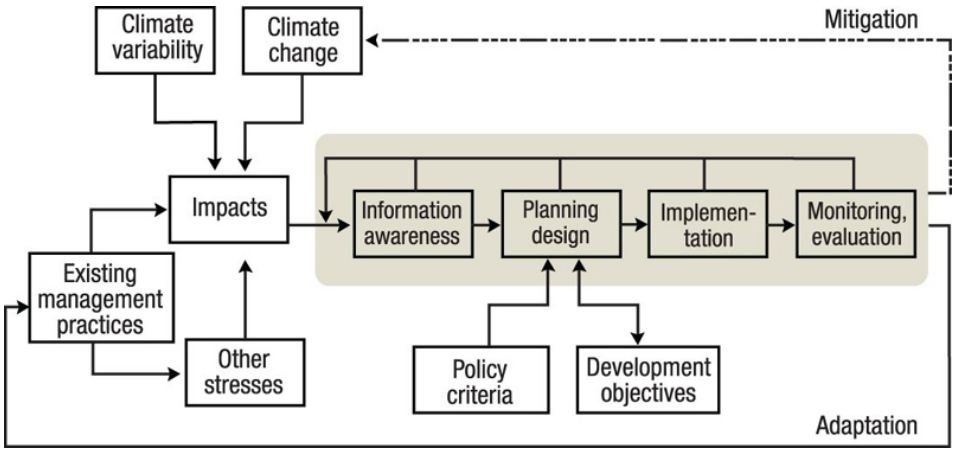
The adaptive approach that constitute the Delta Programme, is based on the principle of "learning while working". The Delta Programme reports annually on whether the elaboration and implementation of the Delta Decisions, preferential strategies and Delta Plans are on schedule. The current "*Delta Decision on Sand*" is to maintain the sand balance along the coast and to ensure that the coastal base remains in line with the rise of sea level, where the preferential strategy is to implement sand nourishments along the coast. Every year, it will also review whether any new developments call for fine-tuning or adjustment of the preferential strategies and the associated Delta Plans. In addition to this annual cycle of adaptive delta management, once every six years it

takes a more fundamental look at the question of whether it has managed to keep up the pace and adjust its course on time (Delta Programme, 2017).

Delta Programme as an adaptive policy and its relation to uncertainties

The conceptual framework developed by Klein, Nicholls and Mimura (1999) on the process of planned adaptations, aimed at changing existing management practices in coastal zones, considers adaptation as a continuous and iterative cycle, composed of several steps: information collection and awareness raising, planning and design (where policy criteria and development objectives are incorporated), implementation, monitoring and evaluation, as shown in Figure 4. This model can be used to illustrate the adaptive policy cycle of the Delta Programme.

FIGURE 4: CONCEPTUAL FRAMEWORK SHOWING IN THE SHADED AREA THE ITERATIVE STEPS INVOLVED IN COASTAL ADAPTATION TO CLIMATE VARIABILITY AND CHANGE



Adapted from Klein, Nicholls and Mimura (1999)

Within the policy design cycle under this adaptive concept, plans have to be continuously monitored and updated to take into account new information. From a PBL (Dutch environmental assessment agency) study, the Delta Programme aims at promoting adaptive management, given the uncertainties involved ahead in water governance systems, and seeks to ensure that a diversified group of stakeholders participate in a process that is sufficiently open and integrated (PBL, 2016). According to Brugnach et al. (2009), uncertainties can manifest themselves at different stages in the decision-making process and active stakeholder involvement is the fundamental key to provide feedback on any stage in this process, which could result in adjustments and in parts of the policy cycle being repeated.

Linking the Delta Programme, uncertainties and gaps in water governance

This research aims at identifying uncertainties based on the interpretation of different stakeholders directly or indirectly involved in the Delta Programme or it impacted by its decisions. These uncertainties will then be characterized and contextualized with the policy. Furthermore, this research is interested in providing coping strategies for the identified uncertainties and relate them with the water governance gaps described in the 2014 OECD report. The working assumption is that managing the identified uncertainties can be used as a tool to bridge the existing gaps in water governance. Policies such as the Delta Programme, developed under the adaptive principle, relies on the participation and involvement of different stakeholders throughout the process. Understanding how the stakeholders interpret the use of sand

nourishments, regarding their perceived impressions, their views, beliefs, experiences and frames not only promotes the goal of the adaptive management, but also provides policy-makers with important information on possible improvements. This information from different stakeholder can be translated into uncertainties based on their interpretations of the use of sand nourishments, and these uncertainties can be related to the gaps in water governance. Therefore, providing coping strategies for these uncertainties goes in the direction of bridging the gaps in water governance.

The follow research objective was formulated to elucidate the core of the proposed research:

RESEARCH OBJECTIVE	To identify possible uncertainties based on the interpretation of different stakeholders regarding the use of sand nourishments in the context of Dutch coastal adaptation to climate change, to relate them with the gaps in water governance and propose coping strategies in order to bridge the existing gaps.

Now, with the purpose of the study identified it is possible to formulate the research questions. Research questions are important to achieve the desired objective, providing guidance and centering the research. The main research questions (in bold) and sub-questions that help underpin and solve the main questions are presented in the next box.

RESEARCH QUESTIONS	**1. What are the characteristics of the stakeholders interviewed?** 1.1. Which stakeholders will be considered for this research? 1.2. What are their power and interests? 1.3. What are their frames on the use of sand nourishments in this context? **2. What are the characteristics of the identified uncertainties?** 2.1. What are the main uncertainties according to the stakeholders? (obtained directly or indirectly from the interviews) 2.2. How are these uncertainties interrelated? 2.3. How do the interrelated uncertainties appear in the context of the Delta Programme? **3. How can the identified uncertainties improve the ability of the Delta Programme in bridging gaps in water governance?** 3.1. What is the relation between the identified uncertainties and the gaps in water governance according to the OECD framework? 3.2. What is the relation between the coping strategies for the identified uncertainties and the potential of the Delta Programme in bridging the existing gaps in water governance?

This thesis consists of 6 chapters. After this introductory chapter the thesis continues with a chapter to present the methodology used. In the following three chapters each one of the specific research questions is addressed. Chapter 3 covers the characterization of the stakeholders considered for this research, with their power and interests, as well as their frames. In chapter 4, the characteristics of the identified uncertainties are presented, with their relationship both between uncertainties and with the Delta Programme. Chapter 5 deals with connecting the interrelated uncertainties with coping strategies, as well as relating them to gaps in water governance and to the potential in bridging these gaps. In chapter 6, the main conclusions of this thesis are presented with a summary of the answer to the three research questions. Furthermore, recommendations for further research are provided.

CHAPTER 2: **METHODOLOGY**

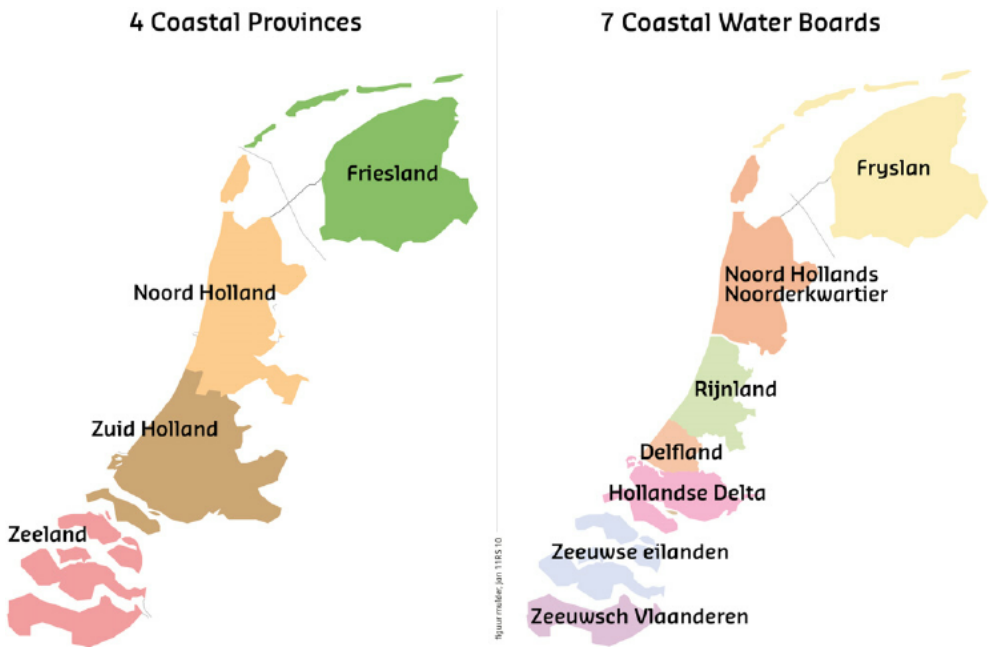
2.1 IDENTIFYING AND SELECTING STAKEHOLDERS

2.1.1 POTENTIAL STAKEHOLDERS

Crane and Rue bottom (2011) affirm that there are several definitions of stakeholders, all of which share their basis with the definition proposed by Freeman (1984): "Any group or individual who can affect or is effected by the achievement of the organization's objectives." This research considers the definition proposed by Clarkson (1994), which includes risk in the definition of stakeholder as follows: "a stakeholder bear some form of risk as a result of having invested some form of capital, human, or financial, something of value, in a firm" or "are placed at risk as a result of a firm's activities." In this sense, the research is not addressing an organization or firm but rather the issue of sand nourishment as a strategy for climate change adaptation on the Dutch coast.

The first step made here is to identify potential stakeholders in the process of using sand nourishments as a preferred strategy to adapt the coast to the impacts of climate change. As previously stated, the management of the Dutch coastal zone involves a large group of public and private-sector groups. The public sector at the national level is represented by the Ministry of Infrastructure and the Environment and Rijkswaterstaat, at the regional level there are both the provinces and Water Boards (on a water basin level) shown in Figure 5, and locally by the municipalities. According to the Delta Programme | Coast (2013), within the coast-specific sectors, most businesses are to be found in the retail and tourist services sector (53%) and the hotel, restaurant and leisure sector (21%). Other business activities include: fishing and fish processing, ports and shipping, agriculture, and water and energy. Further private sector groups include local communities, tourists and NGOs.

FIGURE 5: COASTAL PROVINCES (LEFT) AND COASTAL WATER BOARDS (RIGHT).



Adapted from Mulder, Hommes and Horstman (2011)

The participation process is highly dependent on the scale of the nourishment. Small scale nourishments are usually seen as technical issues, and do not involve stakeholders other than the coastal engineering community. On the other hand, larger projects, such as the creation of the Sand Engine, given its significant impact on coastal environment, tourism and recreation, as well as land use, require the involvement of a larger community of stakeholders. The following table shows some of the general stakeholders involved in this process.

TABLE 4: POTENTIAL STAKEHOLDERS.

STAKEHOLDERS	PARTICIPATION
Ministry of Infrastructure and Environment (Delta Programme)	Responsible for the strategic policy
Rijkswaterstaat	Overall supervision of the coastline management, in charge of counteracting long-term erosion
Water boards	Daily management of the flood protection structures and dunes
Provinces	Responsible for supervising the water boards, coordinating and integrating the regional policies
Municipality	Under the supervision of the provinces and national government, have influence on area development
Consultants/Experts	Provide advices for the management of the coast
Local communities	Concerned with their living environments
Commercial businesses	Provide services to local communities and tourists
Visitors/tourists	Concerned with recreation, aesthetics and accessibility of the coast
NGOs	Concerned with the natural environment of the coastline

2.1.2 STAKEHOLDER CLASSIFICATION

According to Mitchell, Agle and Wood (1997), stakeholders can be classified based on whether they have, or perceive to have, one, two, or all three of these attributes: ***power*** to influence; ***legitimacy*** of their claim; and ***urgency*** of their claim. In this sense, the power of a stakeholder group refers to its ability to make something happen that would not have otherwise been done. Legitimacy concerns the desirability or appropriateness of the claims and actions of a stakeholder in reference to the accepted norms. Urgency is characterized both by the severity or how critical a claim is and/or when abstaining or delaying a response to it is unacceptable.

The authors consider stakeholders with ***power*** to be able to influence or disrupt a certain process and, therefore, are important. Nonetheless, stakeholders with no or little power can still be influential if their claims are ***legitimate*** and so considered in the process. Stakeholders holding both power and legitimacy may still not have influence over the process if their claim, although recognized, lacks ***urgency***.

Still according to Mitchell, Agle and Wood (1997), the different combinations of power, legitimacy, and urgency, referred to as stakeholder salience, provides the structure for the typology of stakeholders, as presented in the next table. Stakeholders can shift from one category to another since their salience could increase/decrease by changes in one or more of their attributes.

TABLE 5: STAKEHOLDER TYPOLOGY

STAKEHOLDER CATEGORY	STAKEHOLDER SALIENCE	ATTRIBUTES	STAKEHOLDER SUBCATEGORY
Latent stakeholders with only one of the three attributes	Low	legitimacy	Discretionary stakeholders
		power	Dormant stakeholders
		urgency	Demanding stakeholders
Expectant stakeholders with two of the three attributes	moderate	power and legitimacy	Dominant stakeholders
		legitimacy and urgency	Dependent stakeholders
		power and urgency	Dangerous stakeholders
Definitive stakeholders with all the three attributes	high	power, legitimacy and urgency	

Adapted from Mitchell, Agle and Wood (1997)

2.1.2.1 Stakeholder framing

In a decision-making process, such as in the case of the Delta Programme, where multiple actors are involved, the frames may present divergences from one another. When incompatible frames are present, they can result in the occurrence of ambiguities, indicating the present of different possible and yet equally sensible interpretations of a certain problem (Brugnach et al. (2008) and (Brugnach et al. (2011)).

van den Hoek (2014) consideres six main elements or attributes as playing an important role in the process of framing and in the formation of individual stakholder frames: interests, values, beliefs, background, passed experiences, and societal position. ***Interests*** refer to the main ambitions or goals of a specific stakeholder group. The ***values*** are related to the moral principles deemed important by an actor regarding the topic. The ***beliefs*** of an actor are the propositions or premises regarding the topic they judge to be true. Each stakeholder group may have a specific set of expertise, education or knowledge in reference to the topic, which comprehend their ***background***. The actors may also use ***past experiences*** or previous situations to interpret the topic. The ***position*** of the stakeholder in the society may also influence their frame of the topic. Table 6 presents an model of the table used to characterize the frames of different stakeholders.

TABLE 6: EXAMPLE OF THE TABLE USED CHARACTERIZE STAKEHOLDER'S FRAMES

STAKEHOLDER FRAMING		
	Frame	Interpretation of the situation according to the stakeholder
Attributes	Interests	ambitions or goals of a specific stakeholder group
	Values	the moral principles deemed important by an actor regarding the topic
	Beliefs	the propositions or premises regarding the topic they judge to be true
	Backgrounds	specific set of expertise, education or knowledge in reference to the topic
	Experiences	previous situations or past experiences used to interpret the topic
	Actor position	Position of the stakeholder in the society

Adapted from van den Hoek (2014)

2.2 CHARACTERIZING UNCERTAINTIES

2.2.1 UNCERTAINTY CLASSIFICATION MATRIX

As previously presented, we understand uncertainty as a situation where people don't know something about the system (e.g. coast), due to many factors such as error in measurements, missing data or information, and lack of understanding of how the system behaves. This type of uncertainty can, in theory, be reduced with more research or with more and better data collection. In problems related to water management, not only uncertainty from what is not known about the system can appear, but also from how people see and interpret the problem. The way people relate to a situation is influenced by their experiences, beliefs, values, know-how, interests, and position in the society. More often than not, people share different perceptions and conflicting views about a situation. This type of uncertainty is not necessarily solved with more information, which could lead to more confusion, but rather promoting the recognition that more than one way of seeing a situation can be equally valid (Brugnach et al. (2008), van den Hoek (2014), (van den Hoek et al. (2014)).

In this sense, we can distinguish between three different forms of uncertainty (Brugnach et al., 2008):

- **Unpredictability:** uncertainty due to unpredictable or chaotic behavior of e.g. natural processes, human beings or social processes;
- **Incomplete knowledge:** uncertainty due to the imperfection of our knowledge, e.g. due to lack of specific knowledge, data imprecision or approximations;
- **Ambiguity:** uncertainty due to the presence of multiple but equally sensible ways how people see, interpret and relate to the same phenomenon, problem or situation.

These uncertainties can be found under different parts of the system to be managed, namely natural, technical, and social systems. These three systems can be defined as follows (Brugnach et al., 2008):

- **Natural system:** incorporates climate impacts along with its aspects, water quality and quantity, and ecosystem;
- **Technical system:** consists of the elements/artefacts employed to modify the natural system, both with infrastructure and technologies;
- **Social system:** comprehends economic, cultural, legal, administrative, and organizational aspects.

The uncertainty classification matrix proposed by Brugnach et al. (2008) combines the different forms of uncertainty with the different parts of the system, which is used in this research to classify the uncertainties identified from the interviews with the different stakeholders.

The identified uncertainties can be combined in different groups based on their relationship. These groups of uncertainties can be used to describe certain situations concerning the topic of sand nourishment (within the context of this thesis).

TABLE 7: MODEL OF THE UNCERTAINTY CLASSIFICATION MATRIX.

	UNPREDICTABILITY	INCOMPLETE KNOWLEDGE	AMBIGUITY
NATURAL CONTEXT	Nature has a non-linear, chaotic and unpredictable behavior.	We have a limited understanding of natural processes, which translates into models that do not represent the full complexity of the natural system as well as limited data.	People relate and interpret situations concerning nature in different ways.
TECHNICAL CONTEXT	Includes technological surprises or unexpected consequences.	Limited knowledge of the technical components of the system.	People may have different opinions on which infrastructures and/or technologies should be used to modify the natural system.
SOCIAL CONTEXT	Value and belief diversity, human behavior, social, economic, cultural and political dynamics (societal variability).	Limited knowledge on the social and economic components of the system.	People relate and interpret situations comprehends economic, cultural, legal, administrative, and organizational aspects differently.

Adapted from Brugnach et al. (2008)

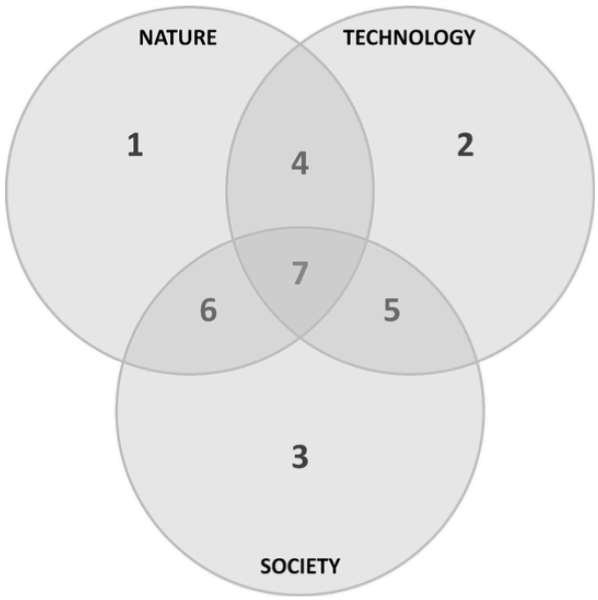
2.2.2 CASCADE OF INTERRELATED UNCERTAINTIES

van den Hoek et al. (2014) explains the term cascade of uncertainty or uncertainty explosion in climate change studies as the process of uncertainty propagation, downscaling global climate change forecasts into regional scenarios and subsequent impact assessments.

The authors then go on to exemplify how a cascade of uncertainty works using climate predictions, which have a significant level of uncertainty given our limited knowledge of the climate system while describing an expected set of temperature increase and sea level rise in a specific timeframe. They argue that, even though these predictions could be used as an input for a model, the model itself will have an accumulated level of uncertainty, since it is a simplified representation of the reality. Therefore, the uncertainties in the outcome of the model is most likely larger than the one from the input data. This example serves as an illustration of how the unpredictability in the input data of the model is increasingly amplified throughout the cascade of uncertainties. As a result, when decision-makers use the outcomes of the model for the creation of adaptive measure they will most likely add a safety margin larger than what the original climate input data would have required.

To explain the cascade of interrelated uncertainties, van den Hoek et al. (2014) combines the theory on cascade of uncertainty from climate change literature with the relational approach to uncertainty of Brugnach et al. (2008). This relational approach to uncertainty distinguishes between three different parts of the system to be managed: natural, technical and social. Uncertainties can be found in each of these systems and, although it is useful to make the distinction between them as it provides support for structuring the knowledge in the decision-making process, it is just as important to recognize that these systems are all closely interrelated and interdependent (van den Hoek, 2014).

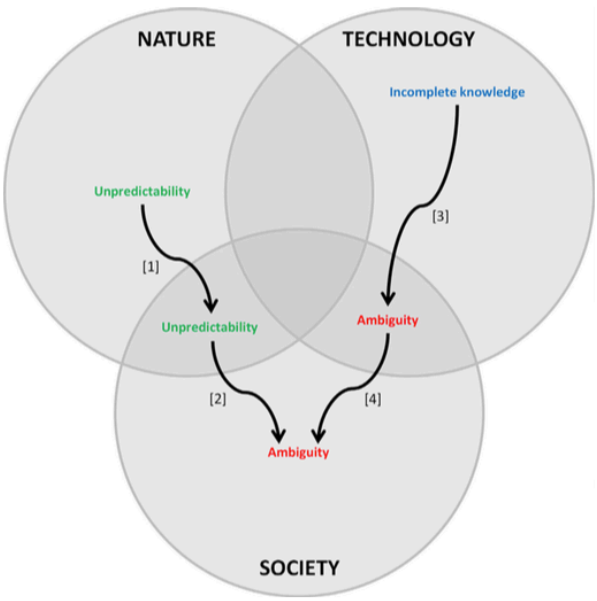
FIGURE 6: SCHEMATIZATION OF THE SYSTEM TO BE MANAGED COMPOSED OF ITS THREE PARTS.



Adapted from van den Hoek (2014)

Given the interrelated aspect of the system as presented in Figure 6, van den Hoek (2014) argues that uncertainties can involve more than just one of the three subsystems. Uncertainties found in areas 1, 2 and 3 mainly concern only one subsystem. However, an uncertainty can also concern both the natural and technical systems (area 4), the technical and social systems (area 5) or the natural and social systems (area 6). Furthermore, some uncertainties may involve all subsystems (area 7). To express the relationship between different uncertainties, the auhtors use the structure of Figure 7 to illustrate the uncertainty cascade and how they can relate to different parts of the social-technology-nature system. Uncertainties in blue are from incomplete knowledge nature, while the ones in green are from unpredictability and in red, ambiguities.

FIGURE 7: CASCADE OF INTERRELATED UNCERTAINTIES



Adapted from van den Hoek et al. (2014)

Given the interrelated characteristic of uncertainties, to successfully cope with a particular uncertainty of the cascade could result in an influence over other uncertainties related to it and, by doing so, maybe reduce the necessity to manage each uncertainty found in a project (van den Hoek et al., 2014). The potential of the cascades to support adaptive management of uncertainties comes in handy, for example, if a given strategy fails or if the conditions of the system change, pointing out to new directions for coping with the uncertainties found (van den Hoek et al., 2014).

2.3 UNCERTAINTIES IN THE CONTEXT OF THE DELTA PROGRAMME

After the identified uncertainties are characterized, it is important to related them to the Delta Programme. In order to do so, the following questions are used to contextualize the different groups of uncertainties (hereafter referred to as situations) in relation to the policy:

- What are the main stakeholders involved?
- How is the situation defined in the policy?
- How was the situation defined by the stakeholders?
- What are the differences between the two definitions?

Answering these questions provides a good description of the extent to which the groups of uncertainties identified by the stakeholder are already considered in the Delta Programme, as well as showing how they are defined. There are multiple possibilities of how the uncertainties and the Delta Programme are related:

a. The situation is not mentioned in the Delta Programme
b. The situation is mentioned in the Delta Programme but the uncertainties identified by the stakeholders are not addressed
c. The situation is mentioned in the Delta Programme and the uncertainties identified by the stakeholders are addressed
d. The situation is not mentioned in the Delta Programme and the uncertainties identified by the stakeholders are addressed

Knowing to what extent the Delta Programme considers these uncertainties provides the foundation to the next step, which is to suggest strategies to cope with uncertainties. If the uncertainties are already being considered in the policy, instead of coping strategies, there is a need to make the stakeholders aware of the existence of these mechanisms.

2.4 STRATEGIES TO COPE WITH UNCERTAINTY

Brunch et al. (2009) defines the general approach for dealing with uncertainty as a creation of capacity, through learning and adaptation, for responding flexibly and effectively to changing and unknown conditions. Furthermore, the authors recognize the following aspects of the process of coping with uncertainties:

- Humans are an essential part of the system to be managed, responsible for making decisions about a system of which they are a part of.
- Environmental and socio-economic developments can result in changes on the system to be managed.
- Defining operational targets for the different management goals to be achieved may originate ambiguity.
- The occurrence of conflicts of interests may be inevitable, and will require participatory goal setting to create inclusive and adaptive solutions.
- It is not feasible to accurately represent the human-technology-environment systems.
- Reducing or totally eliminating uncertainty may not be possible. Learning to leave with uncertainty is fundamental and knowledge gaps can be reduced by insights gained during implementation.

Table 8 presents the strategies for coping with uncertainties based on their usefulness to handle unpredictability, incomplete knowledge or multiple knowledge frames. The basic rationale behind it is that the type of uncertainty mainly determines the strategies needed. In general lines, coping with unpredictability requires "accepting not knowing"; dealing with incomplete knowledge means "improving factual knowledge" and handling multiple frames entails "learning how to deal with differences" (Brugnach et al., 2009).

TABLE 8: STRATEGIES FOR DEALING WITH UNCERTAINTIES

UNPREDICTABILITY	Accepting not knowing (better)	• Develop solutions robust to multiple possible futures • Damage control • Diversification of solutions • Combine multiple strategies • Apply temporary adaptation strategies • Improvise
INCOMPLETE KNOWLEDGE	Work on improving knowledge	• Range estimation (confidence intervals) • More data gathering and scientific research to complete or improve factual knowledge base • Use simulation models to evaluate implications of imperfect knowledge • Uncertainty propagation in models • Use expert opinions • Improve communication between scientist and decision makers
MULTIPLE KNOWLEDGE FRAMES	Learning to deal with differences	• Cognitive problem solving • Persuasive communication • Dialogical learning • Negotiation approach • Oppositional mode of action • Making present/co-presenting

Adapted from (Brugnach et al., 2009)

2.5 DATA COLLECTION AND ANALYSIS

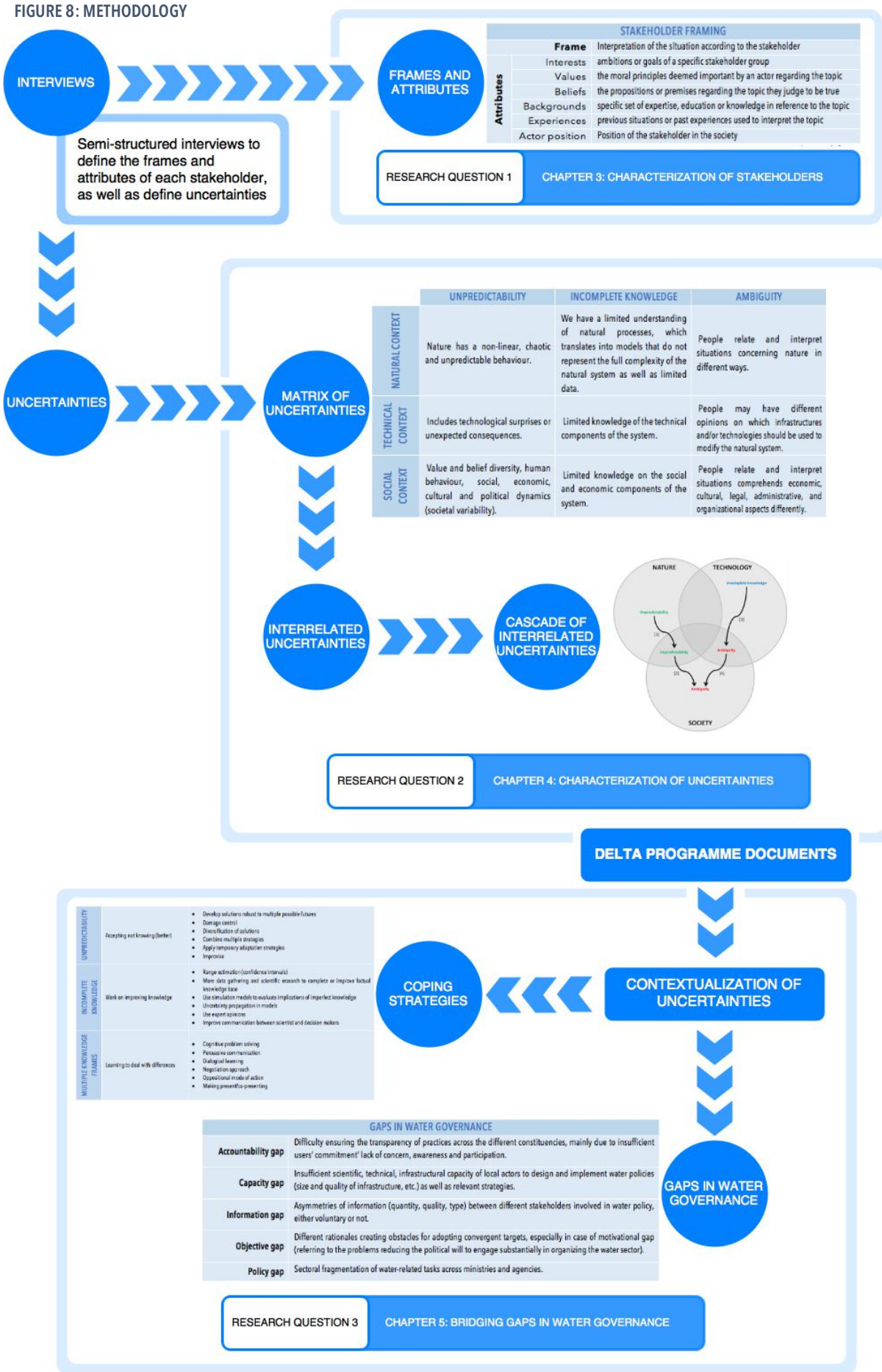
For this research, semi-structured interviews were conducted, comprised of 14 open-ended main questions and several follow-up questions (Appendix A). These questions helped defining the frames and attributes of each stakeholder's group. Beforehand, a brief description of uncertainties was given to the interviewees as well as a blank matrix of uncertainties where they could already fill in their own identified uncertainties concerning sand nourishments (Appendix B). Thereafter, the interview continued with an iterative process of identifying and relating uncertainties. At this point the research also focused on asking how the identified uncertainties were managed or coped with, according to the groups of stakeholders directly involved with the Delta Programme policy. The following step was to analyze the data collected to determine the stakeholder's frames and attributes (as presented in item 2.1.2.1), which is used to answer the first research question.

Sequentially, the matrix of uncertainties (as in item 2.2.1) was filled, considering the uncertainties directly pointed out by the stakeholders as well as indirectly from the interpretation of the researcher. Throughout this process the relationship between uncertainties was also defined, and the interrelated uncertainties were coupled in what was here referred to as "situations" to describe the relationship of the uncertainties, also making use of the cascade of interrelated uncertainties (as in item 2.2.2). Once the identified uncertainties were properly characterized and the relationships were defined, the research focused on associating the uncertainties to the Delta Programme. This process consisted of verifying, in a selection of documents from the Delta Programme (mentioned in item 4.2), which uncertainties are mentioned and how they are being managed and coped with in the program, followed by a comparison with the information obtained in the interviews. All this information was then used to answer the second research question.

Next, the research connected the previously identified uncertainties to the gaps in water governance (presented in item 1.2.2 and Table 3). The process of relating the uncertainties and gaps in water governance involved only the interpretation of the researcher over the data available, and so can be considered subjective. Finally, coping strategies (showed in item 2.4) were associated with the different uncertainties from each situation aiming at bridging the identified gaps. The abovementioned material was used to answer the third research question.

Figure 8 illustrates the methodology described above, linking the steps of data collection and analysis with each of the research questions.

FIGURE 8: METHODOLOGY



CHAPTER 3: **CHARACTERIZATION OF THE STAKEHOLDERS**

The previous methodology was applied for the following stakeholder groups and produced the results presented in this chapter. In section 2.1 in Table 4, 10 possible stakeholder were presented, which included the 6 groups interviewed and 4 groups that, due to time limitations could not be included in this analysis. However, the groups interviewed already present a significant part of the stakeholders involved directly or indirectly in sand nourishments.

Stakeholder groups interviewed:

- Ministry of Infrastructure and Environment
- Rijkswaterstaat
- Water board
- Province
- NGO
- Board of Tourism

3.1 STAKEHOLDER CLASSIFICATION

In any situation not all stakeholders are considered equally important, and one tool to rank the stakeholders in order to narrow the range within a specific setting is to define the ones with high salience. In this case, we use the attributes: power, legitimacy and urgency to characterize the diverse groups of stakeholders as shown in Table 9.

TABLE 9: CLASSIFICATION OF STAKEHOLDERS ACCORDING TO THEIR ATTRIBUTES.

STAKEHOLDER		ATTRIBUTES			STAKEHOLDER SALIENCE	
		POWER	LEGITIMACY	URGENCY		
1	Ministry of Infrastructure and Environment	x	x	x	High	Definite stakeholder
2	Rijkswaterstaat	x	x	x	High	Definite stakeholder
3	Water Board	x	x	x	High	Definite stakeholder
4	Province	x	x		Moderate	Dominant stakeholder
5	Nature groups		x	x	Moderate	Dependent stakeholder
6	Board of tourism		x		Low	Discretionary stakeholder

This attributes help define the salience of each stakeholder based on the perceptions of the different groups interviewed. The Ministry of Infrastructure and Environment and Rijkswaterstaat (representing the national government) and the water boards are classified as ***definite stakeholders*** when it comes to sand nourishments along the Dutch coast due to the responsibilities attributed to them by force of law, with a primarily focus on safety: of the coastline for the Ministry of Infrastructure and Environment and Rijkswaterstaat, and safeguard the primary function of flood protection of the dunes for the water board. They are all considered stakeholders with high salience given their ability and responsibility to develop and revise policies as well as enforcing them, providing them with ***power*** and ***legitimacy*** attributes, and at the same time, they also have an ***urgent claim*** in the management and implementation of sand nourishments along the coast.

Next, the provinces are classified as ***dominant stakeholders*** with an indirect relation to the management of the coast. Slightly less salient when compared to the definite stakeholders, the coastal provinces

are the link between the national government and the local authorities and other private groups along the coast, which gives them ***legitimacy*** as well as ***power*** to influence decisions both regionally and at the national level. However, they do not have any critical claims both in decision making and implementation process, translating in a lack of urgency.

Another moderate stakeholder are the nature groups, considered ***dependent stakeholders***. Their main limitation is power, since they are not directly included in the decision making process, other than during consultation phases, and thus depending on others for the power to protect their interests. In this sense, if they have the capability of mobilizing enough people towards their claims, the combined voice could influence the decision of more powerful groups involved in the decision making process.

The board of tourism represents the interests of visitors and local businesses affected by changes on the Dutch coast. They legitimacy is guaranteed by the economic aspect associated with their relation to the coast. However, the little influence in decision processes and relevantly little sense of urgency makes them ***discretionary stakeholders***, with low salience.

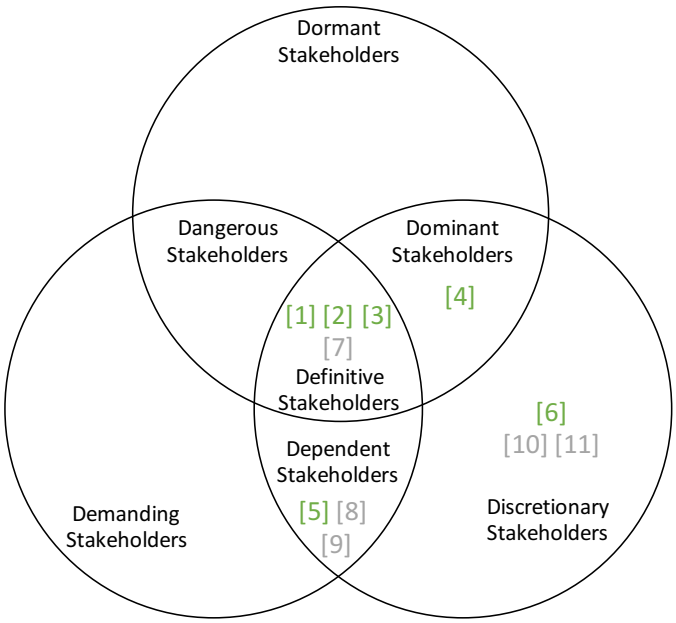
Other stakeholder groups that were mentioned but not interviewed are shown in the Table 10.

TABLE 10: POSSIBLE CLASSIFICATION OF STAKEHOLDER GROUPS NOT INTERVIEWED.

STAKEHOLDER		ATTRIBUTES			STAKEHOLDER SALIENCE	
		POWER	LEGITIMACY	URGENCY		
7	Municipality	x	x	x	High	Definite stakeholder
8	Dredging companies		x	x	Moderate	Dependent stakeholder
9	Beach Hut Associations		x	x	Moderate	Dependent stakeholder
10	Restaurant Associations		x		Low	Discretionary stakeholder
11	Local residents		x		Low	Discretionary stakeholder

Figure 9 illustrates the overall classification of the different stakeholder groups according to their attributes. It is noticeable the absence of stakeholders without legitimacy to the issue of sand nourishments on the coast in the perception of the groups interviewed. In terms, this means that each group has some responsibility in the process of decision-making or implementation of sand nourishments or are affected by decision made about it. Main authorities hold the power to directly influence the decision-making process, whereas nature groups and local associations depend of the capacity of mobilizing enough numbers to influence the decision of more powerful actors in order to have their interests taken into account.

FIGURE 9: CLASSIFICATION OF STAKEHOLDERS ACCORDING TO THEIR ATTRIBUTES



The remaining actors, namely the discretionary stakeholders, also rely on the power of other groups to have their interests represented, however their somewhat lower urgency makes them, in general, less participative than the dependent stakeholders.

From the interviews with the different groups it was possible to define the frames of each stakeholder group based on a specific set of attributes: interests, values, beliefs, background, past experiences, and societal position. All this information is presented in the next section.

3.2 FRAMES

The frames of each distinct group of stakeholders provides a clear description of how each group perceives the topic of sand nourishment, contextualizing their participation in the process, their perceptions, wishes, understandings and knowledge. All this information is fundamental to better understand the uncertainties identified. Each table presents the frames and attributes of the different groups interviewed.

3.2.1 MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT

The Ministry of Infrastructure and the Environment is part of the central government of the Netherlands. It is committed to improve quality of life, access and mobility in a clean, safe and sustainable environment. It is responsible for the creation of an efficient network of roads, railways, waterways and airways, effective water management to protect the Netherlands against flooding, and improve air and water quality.

The ministry's interest on the coast can be summarized as safety. They are interested in protecting the inland from the sea as well as prevent the structural recession of the coastline. To do so, the ministry invests in yearly measurements of the coast and its status. In terms of organization and transparency, the ministry states that the majority of information can be easily found in one of the many documents digitalized and available online.

Considering the maintenance of the basic coastline and the overall safety from the sea, sand is considered the best alternative at the moment. Not only having a better cost-benefit then conventional hard structures, but also allowing for more flexibility of the system: The long period contractors have to implement the nourishments make it a very competitive strategy in terms of costs; it is easy to adjust to new conditions of the system, with estimates made for future scenarios, having to adjust only the amount of sand added to the system.

Given the fact that their main concern is safety, the ministry only invests in sand nourishments for protection reasons, and the other benefits are secondary. In their view, the use of sand nourishments raises a new set of questions: who is responsible? Where does the money come from? Is there enough sand for all uses? In this sense, one point that is relevant is the fact that not always the nourishments are made on the beach, which would increase the area for other uses but requires more sand. These, sometimes is not perceived as good from other stakeholder that, first, don't see any changes and don't get the impression of effectiveness and protection provided by the nourishments and, second, don't see any benefits for the multiple uses of the beach.

Especially since recent years, there has been a growing concern towards the impact of measures on the natural environment. The government is interest in combining the protective measures with strategies capable of either benefiting the environment or at least not impacting it negatively. In general, there has also been a claim for more participation in the decision-making process, allowing for more discussion of the strategies and pathways since their inception, with the governmental bodies more open to new inputs from the population and other interested groups.

Technically, the strategy of using sand nourishments has, in the view of the ministry, been beneficial, and allowing for more exploration of possibilities. Initially, the idea was to supply the coast with 12 million cubic meters of sand per year. New estimations show that only 7 million cam ne used and the effects on the coast can be monitored and evaluated. This flexibility is also based on feasibility analysis, which in terms are dependent on the natural conditions of the system. If the conditions change due to climate change, for example, the feasibility of sand nourishments will have to be re-evaluated. However, the flexibility of the measure allows policymakers more room to make changes when necessary. The turning point of the policy would be a situation in which the volume of sand necessary would be too high to be supplied in an economically attractive way.

Another point interest concerning safety regards the presence of munition on the seabed. Sand extraction works become costlier when they encounter munitions, and it also represents a risk for the workers themselves. They are aware of a need for more surveys of the seabed.

The frames and attributes of the Ministry of Infrastructure and the Environment is presented on the next table.

TABLE 11: FRAMES AND ATTRIBUTES OF THE MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT

MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT		
	Frame	• Sand nourishments are an efficient way to protect the coast against floods in face of changes posed by climate change
Attributes	**Interests**	• Maintenance of the basic coastline • Protection against floods • Cost efficient solutions
	Values	• Safety of the Dutch people • Sustainable use of the coast • Improve quality of life
	Beliefs	• It is important to have as much information as possible available for consultation as well as integration between different organization to increase knowledge and better solutions • Sand has a good cost-benefit ratio and allows room for flexible implementation • Nourishments with the purposes other than safety are not the responsibility of the ministry and financing them should come from other sources • The location of the nourishments may not satisfy all stakeholders, with some groups preferring beach nourishments in order to benefit other activities such as tourism and recreation • It is important to consider the effects over nature • The flexibility of sand nourishments allows for the exploration of different volumes added to the system to study the effect on the coast • Monitoring and simulating the conditions due to climate change is fundamental to define the feasibility of the nourishments • Munition can be a real risk for sand nourishments

MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT		
		• More participation from the population and nature groups have to be encouraged
	Backgrounds	• Part of the central government of the Netherlands responsible for the national policies concerning water management and climate change adaptation • Cooperation with other government bodies (with Rijkswaterstaat as the operational body of the ministry for the implementation of measures)
	Experiences	• Population and nature groups can oppose to projects depending on the specific characteristics of the location • Sand extraction works can be compromised by the presence of munition for WWII, which results in safety issues for the dredging companies and increases in the project costs
	Actor position	• Powerful actor, with national influence and direct contact with all levels of government, capable of influencing decision making processes

3.2.2 RIJKSWATERSTAAT

Rijkswaterstaat is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. This includes the main road network, the main waterway network and water systems.

They are responsible for the maintenance of the coast (maintaining the Dutch coastline at 1990 level, the basic coastline). In order to do so, the main strategy is to use sand nourishments along the coast, both on the beach and underwater, with an average of 12 million m^3 added per year. The idea behind the use of sand is to balance the sea level rise and the natural loss of the system.

It is in their understanding that the coast incorporates many functions, so the protection against flood has to be aligned with the protection of nature and the dune systems, recreational functions, spatial planning and fresh water extraction. In this sense, instead of compartmentalize the multiple functions of the coast, it is beneficial to look at the coast as a whole system, especially in the long-term scale.

Regarding mega scale nourishments, they make an important distinction between volume and area. Large scale nourishments have already been implemented throughout the Netherlands, especially in shoreface nourishments, with large volumes of sand. However, pilot projects such as the Sand Motor, which besides using a large volume of sand are spread in a large area on the beach are still being studied. From an economic point of view, there is a large investment beforehand on sand, long before the sand is actually needed. This extra investment needs to be balanced out with additional benefits, such as ecological or recreational benefits. Furthermore, there is a need for further investigations of its applicability, which is mainly restricted to the Holland coast (excluding the Delta Coast in the south and the Wadden coast in the north) due to the morphological dynamic.

When it comes to the sand used for the nourishments, there is an intent in utilizing sand with similar grain size of the one naturally occurring in the area of implementation. Therefore, the extraction sites chosen have comparable grain size range of the natural sand. On the one hand, they recognize there could be impacts to the ecosystem. But on the other hand, this impact is only occurring on the short term, since the system is capable of rebalancing itself, resulting in no long-

term impacts to the ecology. They point out the occurrence of conflict with different stakeholders about the type of sand depending on their interests. For example, beach hut and pavilion owners prefer coarser grains, since they are less blown by the wind, causing less nuisance.

The process of selection of the excavation site includes an environmental impact assessment and, one of the elements addressed is the existence of known munition on the sea bed. In this sense, areas with known and possible munition are avoided to ensure the safety of the workers and infrastructure of the dredging ships. One possible alternative for the future is to devise what is the acceptable risk (to society, workers and structures) related to munition, since working with risk zero would mean the impossibility of implementing nourishments. The current practice allows the excavation of the first two meters of sand which is considered the mobile bed, with the sand presenting the same morphological features. However, some sites do have special permits to extract deeper sand.

The availability of sand is also a source of concern. The use of sand for multiple purposes is discussed within the context of the marine spatial planning, which limits the possible extraction sites. Other uses include wind farms and sand for construction works. As a commodity, the extraction of sand is also limited by its economic feasibility. Another limitation is the coastal foundation.

Until 2012, the contracts for the implementation of the nourishments were done on an annual base, with implementations occurring during spring and autumn usually. Such practice was cause for increased competition within different regions of the Netherlands for the nourishments. Since 2012, the contract shifted to multiannual. In a period of 4 years, contractors would have a window of 2 years to implement the nourishment. The nourishments would be able to compensate for the erosion within this time frame. Such change resulted in a significant reduction in costs for the implementation of the nourishments.

When it concerns the use of nourishment for other purposes, Rijkswaterstaat recognize that other functions are important for the coast. However, monetarizing them is not so straightforward. Their goal is to maintain the basic coastline. In this sense, sand nourishments are a good strategy, even considering climate change. The calculation for the amount of sand takes into account the actual measured sea level rise, thus not relying on predictions only. Therefore, this strategy is valid on the long term since it considers the incremental contribution of climate change instead of an estimated value for a point in the future.

Over recent years, Rijkswaterstaat, in alliance with other governmental bodies, has increased the connection with nature groups. There is a tendency to create a relation of partnership as opposed to each competing for their own individual interests, translated into the combination of flood protection and sustainability when possible. At this point, there is the awareness that the incorporation of the complexity of environmental interaction is oversimplified in the modelling process.

Regarding the policy structure, Rijkswaterstaat understand that communication is important and the policy should not be unilateral. The participation of different stakeholders has benefits for the overall process; however, it is important to define the moment of when this participation occurs as well as how it should occur.

The frame and attributes of Rijkswaterstaat are presented in the next table.

TABLE 12: FRAMES AND ATTRIBUTES OF RIJKSWATERSTAAT

RIJKSWATERSTAAT		
	Frame	• Sand nourishments are an efficient way to protect the coast against floods in face of changes posed by climate change
Attributes	**Interests**	• Maintenance of the basic coastline • Protection against floods • Integration of multifunction of the coast
	Values	• Safety of the Dutch people • Sustainable use of the coast • Improve quality of life
	Beliefs	• Sand nourishments balance the effect of sea level rise over the Dutch coast • The coast is a multifunctional system • Additional benefits are needed to justify the large investments in mega nourishments • The type of sand used should be taken into account, however, no long term impacts are expected over the ecosystem • The Environmental Impact Assessment should help rule out locations for the excavation of sand that are prone for the existence of munition • It is important to define what is the acceptable risk for society, workers, and investor regarding munition • Sand is a multipurpose commodity and its availability is limited to other uses. However, enough sand is available for the implementation of nourishments over the future years • The flexibility in the contracts for the implementation of nourishments represents a large reduction in cost for the government, increasing the feasibility of sand as an adaptive measure • The calculation for the amount of sand takes into account the actual measured sea level rise, thus not relying on predictions only • The incorporation of the complexity of environmental interaction is oversimplified in the modelling process
	Backgrounds	• Part of the central government of the Netherlands responsible for the implementation of national policies concerning water management and climate change adaptation • Cooperation with other government bodies
	Experiences	• Yearly contracts for the implementation of nourishments resulted in high competition within different regions of the Netherlands • The participation of different stakeholders has benefits for the overall process, however it is important to define the moment of when this participation occurs as well as how it should occur
	Actor position	• Powerful actor, with national influence and direct contact with all levels of government, capable of influencing decision making processes

3.2.3 WATER BOARD: HOLLANDS NOORDERKWARTIER

The water board Hollands Noorderkwartier is responsible for the water management of the northern quarter of the Dutch province of Noord-Holland, the area above the North Sea and

including the island of Texel. The water board is responsible for the dikes and dunes, waterways, water levels, water quality and sewage treatment.

When it comes to the coast, the primary responsibility of water boards is safety. They are responsible for the management and maintenance of the dune and dike systems, therefore their main interest with sand nourishments is to contribute to the quality of the dunes. Rijkswaterstaat is responsible for the whole process of sand nourishments, however, the water boards usually work in close cooperation with them, so the nourishments can be used to reinforce the dunes as well as maintain the coastline at the desired place. At this point one question that remains unanswered concern the occurrence and intensity of storms, if they increase in the future, there is uncertainty about the capacity of Rijkswaterstaat in covering the demand from all different water boards, which could result in a reduction of the cooperation and good relations.

In the past, the water boards were used to making use of hard structures to protect the inland from the water. In recent years, this view has slowly shifted to accommodate new paradigms, opting for more flexible and adaptable solutions, which is the case of sand dunes. However, in their experience, it can be tricky to stimulate and implement such changes in certain locations due to resistance of local communities. People have a preference for no alterations to their surroundings, and so people used to dikes and other hard structures were not, initially, satisfied with the idea of shifting towards sand. Nonetheless, given the massive incentive from the national government, eventually even those strongly opposing to sand started to change their opinion, requiring 10 years of negotiations. In this sense, people have realized the potential of sand nourishments to benefit recreational activities and boost tourism, which contributes not only for people and organizations related to tourism but also improves the quality of life of all inhabitants due to increase in investments.

There are two distinct situations when it comes to the sand from nourishments and its relation to the dunes for the water board. In the first, when there are buildings close by, the water board is interested in maintaining the sand closer to the dunes, working with it. When the area is not inhabited, they allow the natural processes to run its course. Alternatively, there are particular cases where it becomes unclear how the distribution of responsibilities has to occur. These situations arise when certain structures are located outside of the specified safety levels. For example, a pavilion build on the dunes, which creates a conflict of responsibility between municipal level (responsible for permits), Rijkswaterstaat (responsible for nourishments) and water board (responsible for dunes).

One situation that brings concerns to the water board regarding the nourishments is the danger associated with the presence of munition dumped in the sea during world war II. Rijkswaterstaat is responsible for providing the dredging companies with permits for sand extraction, and for defining the location of the dredging works. In their experience, sometimes the dredging works have to be interrupted due to munition being found on site, representing a safety risk for the ships and crew. Only after the artefacts are properly removed can work be resumed, resulting in time delays and cost escalations for the project.

Another interesting point brought up by the water board is the power of the media, including social media, in mobilizing people either in favor or against a certain project. The fast pace of transfer of information nowadays provides people with a powerful tool in voicing their interests and concerns about anything. When it comes to water management projects, and sand nourishments, it is no different. Groups with specific interests in a given location where a project

will take place can mobilize a larger audience to their claims very fast and, therefore, could contribute positively or negatively for the realization of the project. In this regard, the stakeholders interested in moving the project forward have to be able to account for the power and influence of the media in the social acceptance of the project.

The frame and attributes of the water board Hollands Noorderwatier are presented in the next table.

TABLE 13: FRAMES AND ATTRIBUTES OF THE WATER BOARD HOLLANDS NOORDERKWARTIER

WATER BOARD: HOLLANDS NOORDERKWARTIER		
	Frames	• Sand nourishments are an important measure for the safety of the coast
Attributes	**Interests**	• Meeting safety standards for the protection of people • Sand nourishments can be used to feed the dune system in order to protect the coast and the inland • Good communication and transparency between different governing bodies to improve the management of the coast
	Values	• Safety is the number one priority by means of the dune and dike systems • Align measures with better nature when possible
	Beliefs	• It is difficult to get people to accept changes, the process of shifting from hard structures (dikes) to sand (dunes) required a long time and studies • There is also a need in changing the attitude towards the coast and consider the characteristics of a dynamic system into the mindset of people with any form of interest on the coast • There should be caution and recognition regarding the power of the media, especially social media, in mobilizing people in favor or against specific projects • Use of sand is the alternative with best cost benefits for the Dutch coast and allows the possibility of exploring multiple uses of the coast • Sand nourishments are a more flexible alternative than hard structures and can be associated with building with nature projects • Beach nourishments have the capacity of creating more areas for recreation • It is important to monitor and assess the coast regularly to review policies and measures implemented in order to verify their feasibility and effectiveness • There is uncertainty regarding the effectiveness of sand nourishments if the number and intensity of storms increase due to climate change • It is important to study the effects of climate change on technical parameters in the models • Sand nourishments could be used to increase the economic value of the coast and attract more tourists • In case nourishments are used for other purposes (recreation or economic activities) there is uncertainty related to who should finance these projects • It is important to study large scale nourishments such as the Sand Motor, to verify its applicability (cost-benefit analysis) in other locations of the Dutch coast • The elements presented in the Delta Programme are vague and usually their translation to the actual system does not work as expected. There is a need for more integration between policymakers and the authorities responsible for the implementation of policies
	Background	• Good cooperation with other governmental bodies such as Rijkswaterstaat (responsible for the management of the coastline) • Strong technical background in problems related to water; still needs to improve communication skills with general public

WATER BOARD: HOLLANDS NOORDERKWARTIER		
	Experiences	• Water boards are responsible for the management, maintenance and integrity of the dune system • Population and nature groups can oppose to projects depending on the specific characteristics of the location • Sand extraction works can be compromised by the presence of munition for WWII, which results in safety issues for the dredging companies and increases in the project costs
	Actor position	• Powerful actor, with regional influence and direct contact with all levels of government, capable of influencing decision making processes

3.2.4 PROVINCE OF ZEELAND

The province of Zeeland, located on the south-western most portion of the Netherlands is comprised of a number of islands and peninsulas as well as a strip bordering Belgium. With its name translating to "Sealand" the province has large areas below sea level, and its where the disastrous flood of 1953 took place.

The coast is very important for the proper functioning of the province. Apart from its primarily function of protection against floods, the coast also has an important economic function for the province. Tourism is an important economic activity, in summer many of its beaches are popular destinations for tourists. In some areas the population doubles or even quadruples during the high summer season. For that reason, the main concern of the province towards the coast is to improve its economic value.

When it comes to the application of sand nourishments, the province focuses more on the socio-economic aspects, rather than on the environmental and technical ones, claiming to have a lack of expertise to do so. As previously stated, the coast largely determines the revenue from tourism in the province, where most recreational companies, commerce and other businesses are located. According to the province, a considerable number of important recreational beaches are located in areas prone to structural erosion. Therefore, it's in the best interest of the province to have these areas regularly supplemented with sand to preserve their economic function, or to avoid economic losses.

One aspect of the nourishments that raises concerns for the province refers to the schedule of the nourishments. With the procurement policy applied by Rijkswaterstaat, contractors have a large period frame to implement the nourishment, which in practice provides a significant cost reduction with contractor having more flexibility to adjust their schedules to the demands of the market.

The larger flexibility given to the contractors in choosing when to implement the nourishments reduces the ability of the province to plan and prepare for the implementation. In their view, the province and local authorities are only informed shortly before the beginning of works. The coastal municipalities are responsible for informing beach operators and beach property owners of the time of implementation so they can adjust their schedules around it. When the municipalities are only informed shortly before work starts, they are unable to inform all interested parties on time.

Another consequence of the long contract period is the occurrence of erosion in more sensitive areas, resulting in losses for administrators, due to damage to dune crossings and roadwork, for

example, and losses for beach operators as a result of insufficient dry beach. In their experience, the contractors tend to schedule the implementation of the nourishments towards the end of the contract. One desire from the province is to improve the communication between different organizations about the implementation of the nourishments.

Still considering the procurement policy of Rijkswaterstaat for the nourishments, the province would like the possibility of customizing the agreement with contractors, including a provision allowing the implementation period to be shortened in case of real risk of damage to structures on the beach or economic damages to beach activities. However, they are aware that such practice could result in increased costs for the responsible authorities.

Nowadays, the nourishments are used with the primarily focus of safety and other benefits are considered only secondary effects. The province is interested in exploring the potential of sand nourishments in maximizing the economic value of the coast. Nonetheless they are aware that this use of nourishments lays outside of the budget set for safety and, therefore, would require negotiations to define where the financing would have to come from.

Concerning climate change, the province has prioritized other impacts such as heat, droughts and river floods as more apprehensive than sea level rise, to which they believe the measures set in place to protect the coast are effective. Furthermore, they see the sea level rise is a long term problem, while the other impacts can be already felted.

The frame and attributes of the province of Zeeland are presented in the next table.

TABLE 14: FRAME AND ATTRIBUTES OF THE PROVINCE OF ZEELAND

PROVINCE OF ZEELAND		
	Frames	• Sand nourishments are an important measure to maintain the economic and recreational functions of the coast • Knowing when the implementation of sand nourishments is going to occur, specially beach replenishments, is considered very important
Attributes	**Interests**	• To improve the economic value of the coast • To avoid economic losses due to structural erosion (include clause so contracts can have a shortened duration in particular cases) • To improve the communication between different levels of government about the schedule of sand nourishments
	Values	• Economic use of the coast • Safety

PROVINCE OF ZEELAND		
	Beliefs	• The beach is of great economic importance: main responsible for tourism in the province, where most recreational companies are located, and source of income to many entrepreneurs • The erosion of the coast is responsible for damages to dune crossings and road works, resulting in extra costs for the administrators • The erosion also has negative effects for beach entrepreneurs, since insufficient dry beach prevents the construction of cabins or beach pavilions • Several important recreational beaches are located in areas susceptible to structural erosion • According to the procurement rules promoted by ROWS, contractors have a two-year period to carry out the nourishment, which gives them a significant price advantage based on when the market is most favorable • With this rule it is more difficult to predict when the nourishments will occur • The province of Zeeland is only informed shortly before the implementation, which is practice is at the end of the two-year period • When nourishments are only implemented at the end of the maximum period some beaches have already suffered from advance erosion processes • The province of Zeeland believes changes in the procurement documents of RWS are needed in case of real risks of damage to facilities or economic damages, when the period of implementation should be shortened • Producing new rules for procurement documents could have a negative impact on regional governments and entrepreneurs
	Background	• The province lacks expertise to dive into the technical background of the sand nourishment program and its effects on the ecosystem and coastal foundation • Focus on the social-economic aspects of sand nourishment • Close relation with other governmental bodies: annual meeting with municipalities and Rijkswaterstaat about the coast; regular meetings with policymakers about the coast
	Experiences	• In the past, delays from RWS in informing coastal municipalities about the schedule of implementation of sand nourishments prevented the municipalities of being able to inform local coastal businesses for planning purposes • Length of contracts have resulted in erosion at sensitive areas causing damages to the existing infrastructure and losses to administrators and private sector
	Actor position	• Powerful actor, with regional influence and direct contact with all levels of government, capable of influencing decision making processes

3.2.5 NATURE GROUP: NATUURMONUMENTEN

Natuurmonumenten is a society for the preservation of nature in the Netherlands founded in 1905, which buys and manages nature areas within the country, and has a total of 735.000 members as of 2013. Their main objective is to promote the conservation and restoration of nature and landscapes; advocate for better quality of water, soil and air as well as protect silence; and to promote the notion that humans are responsible for nature. Their main interest towards the coast is to its uniqueness and invaluable natural environment.

When it comes to sand nourishments, Natuurmonumenten does not leans towards being pro or against exclusively, it varies according to each situation. One of the main treats to the nature of the Dutch coast is the increase in projects for villas, apartments, beach houses and other establishments boosted by the profound interest of Dutch, German and Belgian tourists to the potential for recreation of the coast. In this regard, nourishments could contribute to increase even

more the pressure on the coast for the exploitation for tourism, which could result in a reduction of the quality of nature. In this regard it is important to define which areas are suitable for further economic/recreational uses, and which ones should be set aside for nature, allowing for a sustainable multiple use of the coast. It is important to plan the land use and natural functions for the future and consider the effects of climate change and sea level rise on the coast and its functions as well.

Furthermore, one big concern about the nourishments refers to the quality of the sand. In their view, not all sands are the same and it is important to identify what is the specific type of sand that exists in the natural condition, so the nourishments also should have a similar composition. Still related to sand, but regarding the location of the dredging works, they are concerned about the lack of interest in protecting the existing ecosystem of the seabed. According to them, most protection is done in areas where people can see what exists, and there is no awareness of the diversity of the seabed, resulting in less protection. Furthermore, the deposition of sand for the nourishments also have an impact on what will lay underneath it, and could impact specific elements of the local biota.

Another point brought by them is that, in their view, sand is not needed everywhere. In some areas the natural processes should be improved or stimulated and monitored. They believe the measures set in place are capable of guaranteeing the safety of the coast until the end of the century, however, more efforts should be made towards raising awareness and protecting the existing nature on the coast in face of climate change and sea level rise. In this regard, they believe people are growing more concerned with protection of nature, and this desire is already more prominent for the land environments but still incipient for what lays under water. This concern is also present within the government, which is now taking into account the value of nature in its projects when possible. One treat to safety of nature and people is the uncertainty about munition, and the possibility of the nourishments in facilitating the artifacts to wash up on the beach.

Finally, they are aware that the nourishments could also be used to benefit the natural quality of the coastal ecosystem. Nowadays, sand nourishments are only used for the maintenance of the basic coastline and dunes, and any benefits to nature are secondary results. In the future, they would like more information on the use of nourishments with the primary function of benefiting the ecosystem and natural processes. This new use would require a lot of negotiation regarding investments, feasibility, responsibilities and partnerships.

The frame and attributes of the nature group Natuurmonumenten are presented in the next table.

TABLE 15: FRAMES AND ATTRIBUTES OF NATUURMONUMENTEN

NATURE GROUP: NATUURMONUMENTEN		
	Frame	• Sand nourishments should not reduce the quality of the existing nature
Attributes	**Interests**	• Protection of the coastal ecosystem and natural processes • Raise awareness of people towards the importance of nature • Use of sand nourishments to benefit natural processes
	Values	• The coastal environment is unique and invaluable • Nature should be protected for future generations

	Beliefs	• It is important to consider the quality of the sand and the properties of the location of the nourishments so the new material is similar to the one in the natural situation • There is a need for more attention and protection to the ecological value of the seabed • Increased tourism and economic activities throughout the whole year on the coast could have negative impacts on the quality of the natural ecosystem • Sand nourishments that have as secondary effects benefits to these activities may also contribute to reducing the quality of nature • There is a need to clearly define which areas should be protected due to their ecological value and where it is more suitable for other uses on the coast • Natural processes should be encouraged in areas with lower occupation, having no impact on the overall safety of the population but benefiting the ecosystem • Munition represent a treat to nature and safety of people
	Backgrounds	• Strong works done towards acquiring land and managing nature areas throughout the Netherlands\ • Capable of mobilizing people
	Experiences	• Recently the government has included nature groups in the decision making process in order to account for the quality of nature in their projects and policies • Economic interests are still more important than ecological interests
	Actor position	• The power of natuurmonumenten is directly related to their capacity to mobilize their members and other people towards their interests in order to influence the decision of more powerful actors.

3.2.6 BOARD OF TOURISM

The Netherlands Board of Tourism – NBT – is an organization responsible for the promotion of the Netherlands nationally and internationally. Their goal is to promote the country as an attractive destination for holidays, business meetings and conventions. They are funded by the Ministry of Economic Affairs and also cooperate closely with partners within the tourism industry. They are responsible for the marketing of the Netherlands as a destination, with good expertise in the marketing, communication and research fields, resulting in effective campaigns and publicity that attract more visitors to the Netherlands.

The coast is of high importance for the tourism of the Netherlands, attracting not only the domestic tourists but also international ones, especially from Belgium and Germany. The NBT is interested in promoting the tourism in the Netherlands in a spread out way, so each area can accommodate the tourists in a more sustainable way. In order to do so, they work with storylines. One of the storylines they work with is water.

They are aware of the potential impacts of climate change in the quality of life as well as the impact of tourism. They also have programs to raise awareness towards this subject. Since they work closely with partners at risk in the coast this is also a relevant topic for them, however they do not have any direct action towards it. The same goes for sand nourishments, some of their partners may have direct interest in the nourishments, but they do not actively take part in any discussions, being only responsible for marketing and communication campaign. However, they recognize the need for making the coast safe and that some groups within the tourism industry can benefit from them.

The frame and attributes of the NBT are presented in the next table.

TABLE 16: FRAMES AND ATTRIBUTES OF THE BOARD OF TOURISM

BOARD OF TOURISM		
	Frame	• Sand nourishments can be beneficial for coastal tourism
Attributes	**Interests**	• To promote the country as an attractive destination for holidays, business meetings and conventions
	Values	• Sustainable tourism spread out across the country
	Beliefs	• Sand nourishments can be beneficial to some groups within the tourism industry • Climate change can affect tourism
	Backgrounds	• Lot of expertise in the marketing, communication and research fields • Effective campaigns and publicity that attract more visitors to the Netherlands
	Experiences	• They do have participate in the process of sand nourishments
	Actor position	• The power of the board of tourism is directly related to their capacity to mobilize their members and other people towards their interests in order to influence the decision of more powerful actors.

CHAPTER 4: **CHARACTERIZATION OF UNCERTAINTIES**

The characterization of the stakeholders, with their frames and attributes, enables us to identify a series of uncertainties related to the perceptions of these distinct groups to the topic of sand nourishment as a strategy to manage the safety of the Dutch coast in face of climate change. The following table provides the uncertainties identified in this research. A number has been attributed to each uncertainty to facilitate their identification in later sections of the report.

Table 17 presents the summary of uncertainties from the various stakeholders interviewed for this research, classified according to their kind and the part of the system in which they are present. All uncertainties were either explicitly or implicitly mentioned during the interviews by one or more stakeholders. The direct uncertainties are presented in bold and represent 45% of the total. Figure 10 shows the distribution of the identified uncertainties in relation to where in the system they appear (natural, technical or social system), their nature (unpredictability, incomplete knowledge or ambiguity) and if they were obtained directly from the stakeholders interviewed or if they were indirectly identified by the researcher from the different frames.

Considering the nature of the uncertainties identified, the ones from Incomplete Knowledge represent 49% of the total (12% direct / 37% indirect), whereas ambiguity comprises 36% (21% direct / 15% indirect), and unpredictability 15% (12% direct / 3% indirect). When it concerns the location in the system, 55% of the uncertainties appear in the social part and 24% in the natural part and 21% in the technical.

Combining the three aspects (Direct/indirect, nature and location in the system), the largest number of uncertainties identified are from the indirect incomplete knowledge in the social system, with 5 uncertainties (or 15% of the total).

FIGURE 10: DISTRIBUTION OF THE IDENTIFIED UNCERTAINTIES

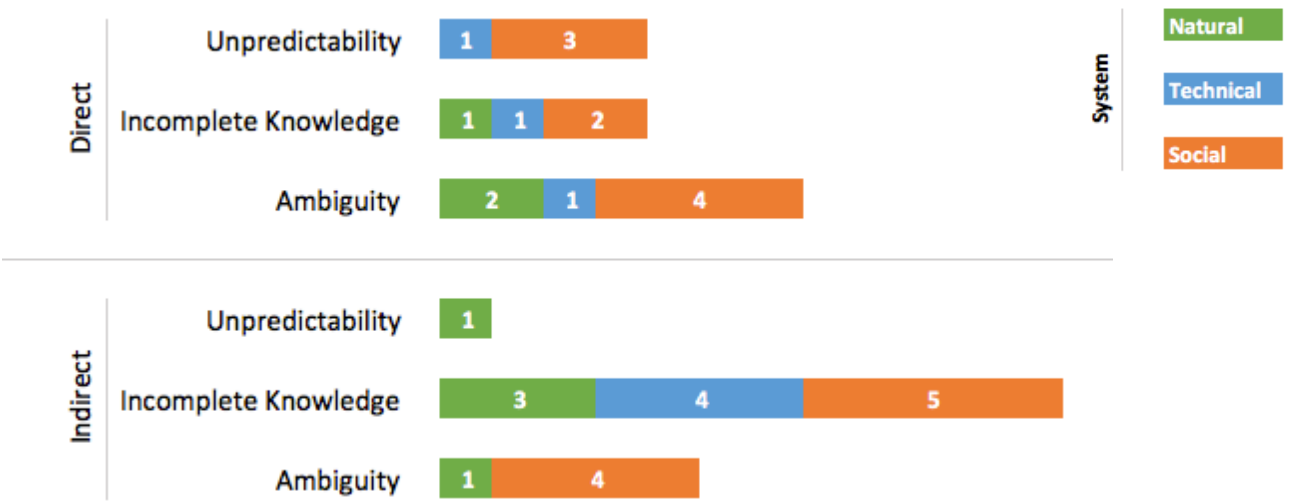


TABLE 17: UNCERTAINTIES FROM THE INTERVIEW WITH DIFFERENT STAKEHOLDERS

	UNPREDICTABILITY	INCOMPLETE KNOWLEDGE	AMBIGUITY
NATURAL SYSTEM	[1] What is the impact of climate change on the occurrence and intensity of storms on the Dutch coast?	**[2] How much sand is available?** [3] What is the impact of climate change on sea levels and wind? [4] What is the impact of large scale sand nourishments on the environment? **[5] Where are the munition of the WWII located?**	**[6] Is there climate change?** **[7] How much is the sea level rising?** [8] What is the impact of sand nourishments on nature?
TECHNICAL SYSTEM	**[9] What is the impact of more storms on the coastal protection system?**	[10] How to avoid accidents with munition from WII? [11] In which cases should sand nourishments be implemented? [12] What is the impact of climate change on the feasibility of sand nourishments? [13] What is the effectiveness of large scale sand nourishments for protection of the coast? **[14] What should be the time scale of the nourishments?**	**[15] Which models are reliable and should be used?**
SOCIAL SYSTEM	**[16] When will the sand nourishments be implemented?** **[17] How will beachgoers behave?** [18] How will the media, especially social media behave?	**[19] What is the impact of lack of information to local businesses?** **[20] How much are people willing to change?** [21] Where should the nourishments be implemented? [22] What are the risks of munition to people and structures? [23] What is the impact of sand nourishments for recreation? [24] What is the effect of more participation on the policymaking process? [25] How to integrate policy and implementation strategies?	[26] When should RWS inform the Province/municipalities of the implementations of SN? [27] How long should the period the contractors have to implement the SN be? [28] Should there be a provision in the contracts allowing for shorter timeframe for implementation in case of safety/economic risks? **[29] What are other possible purposes for sand nourishments?** **[30] Who should finance sand nourishment for these other purposes?** **[31] Who should be responsible for dealing with munitions found on the coast?** **[32] How can sand nourishments benefits other attributes/uses of the coast?** [33] Is sand nourishment a good adaptive strategy?

4.1 INTERRELATED UNCERTAINTIES

Although the uncertainty matrix does not explicitly show the relations between different uncertainties, it is still possible to verify that some of them share connections to describe a number of situations. The following situations present the identified uncertainties according to their relation, where each uncertainty is discussed for the specific situation.

In this section of the thesis, the uncertainties identified are interrelated using the cascade of interrelated uncertainties (item 2.2.2). Uncertainties presented in blue are of incomplete knowledge nature, the ones in green are from unpredictability and in red ambiguity.

SITUATION 1: UNCERTAINTIES RELATED TO THE EFFECTIVENESS OF SAND NOURISHMENTS

Sand nourishments are relatively a new strategy, being studied for the Dutch coast for the past two decades. Much is already known about their effectiveness in small and local nourishments. However, larger scaled nourishments are still novelty and are currently the source of many studies.

The following uncertainties are associated with this particular situation:

[4] What is the impact of large scale sand nourishments on the environment?

Mega-nourishments have everything amplified, starting from the volume of sand, which could have serious implications for the area of the excavation. However, there is little information about the seabed. Similarly, there may be impacts from the type of sand used and the quality, to the existing environment at the location of the implementation.

[11] In which cases should sand nourishments be implemented?

Not necessarily the nourishments will be the best option to be implemented at a specific location. In general lines, the main factor is the cost-benefit of the project. However, other factors, such as the environmental impact also should influence this decision. There are groups advocating that, in areas with low occupation, the natural processes are allowed to follow their course without human intervention, since this would not result in a reduction of safety.

[13] What is the effectiveness of large scale sand nourishments for protection of the coast?

Since mega nourishments largely depend on the natural processes to transport the sediments across a large stretch to the coast, there is uncertainty about its effectiveness on the safety. More insights are still needed to make this evaluation.

[15] Which models are reliable and should be used?

There are many scenarios built on the latest predictions of temperature rise, each of them using a different set of input data. Given this variety of scenarios, groups with different frames may be inclined to the outputs of different models/scenarios, which generates ambiguity.

[21] Where should the nourishments be implemented?

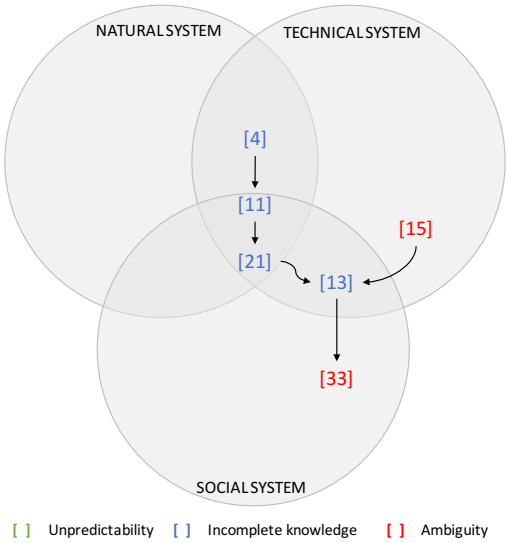
The specific location for the implementation of the nourishment can also be considered an uncertainty of incomplete knowledge nature. The simple definition would be to combine the factors from nature and technology to dictate the location of the implementation. However, its implications on the social part of the system is the cause for the uncertainty. There is a need to identify the repercussions of the implementation for the economy and nature before defining the most appropriate location.

[33] Is sand nourishment a good adaptive strategy?

Considering the amount of uncertainties referring to the impact of climate change on sand nourishment, some groups may start to disagree on the benefits of sand nourishments as the main adaptive strategy for the safety of the Dutch coast.

Regarding the feasibility of sand nourishments, and more specifically mega nourishments, the first thing that is noticeable is the lack of uncertainties due to unpredictability according to the interviewed stakeholders as seen in Figure 11. First, there is incomplete knowledge about the impact of mega nourishment on the environment ([4]), which is directly related to the question of in which cases should sand nourishments be implemented ([11]). Next, there is also incomplete knowledge about the location for the implementation of the nourishment ([21]), and the effectiveness of the large nourishments for the protection of the coast ([13]). Associated with that is the ambiguity about which models are reliable and should be used ([15]), which largely depend on the interests of different stakeholders. Last, there is ambiguity on whether or not sand nourishments are a good adaptive strategy for the safety of the coast ([33]), which is also dependent on the view of different stakeholders.

FIGURE 11: CASCADE OF UNCERTAINTY RELATED TO THE FEASIBILITY OF SAND NOURISHMENTS



SITUATION 2: UNCERTAINTIES RELATED TO CONTRACTS FOR THE IMPLEMENTATION OF SAND NOURISHMENTS

There are uncertainties concerning to the contracts for the implementation of sand nourishments in the Dutch coast. The current strategy Rijkswaterstaat uses to procure contractors for the implementation of the nourishments has some benefits for the government. The high cost-benefit of the sand is related to this degree of flexibility provided to the contractors. Most of the companies responsible for dredging/sand extraction works are acting also on the international market, which is very competitive, especially given the high interest of middle-eastern investors in sand works. Therefore, stricter contracts would result in higher investment costs, since the companies use the

demand of the market to define their prices, which wouldn't allow them to work on the sand nourishments during low international demand times.

On the other hand, the large flexibility given to contractors has an impact on the planning at a regional and local level. The issue here refers to the moment local and regional governments are informed about the schedule of the implementation. According to the Province of Zeeland, this communication is only made shortly before the beginning of works. Coastal municipalities are responsible for informing beach operators and property owners of the programed implementation of sand nourishments, and they are unable to do so if this communication is not done in advance.

Furthermore, the province is also worried about the occurrence of damages due to erosion on the existing infrastructure (dune crossings and roadworks) and to beach operators/owners due to insufficient dry beach.

The following uncertainties are associated with this particular situation:

[14] What should be the time scale of the nourishments?

This uncertainty refers to the expected lifespan of the nourishment or, in other words, how long will take for the extra sand to be completely eroded, requiring a new nourishment. This is intrinsically related to the conditions of the location where the nourishment was implemented.

[16] When will the sand nourishments be implemented?

The large window provided by the current contracts to when the nourishments can be implemented reduces the predictability of when the work will in fact be carried out. Factor such as the demand of the international market largely influence the schedule of the implementation of the nourishments aiming on reducing the costs for the investors.

[19] What is the impact of lack of information to local businesses?

When the information from the schedule of implementation of the sand nourishments does not reach the groups directly affected (such as beach operators and owners), there could be an impact to their businesses or properties. The extension of this impact remains uncertain since there hasn't been studies to investigate this problem.

[26] When should RWS inform the Province/municipalities of the implementations of SN?

This ambiguity refers to the different views from the province/municipality and RWS/contractors. In the view of the province, they should be informed at least one month prior to the beginning of the implementation.

[27] How long should the period the contractors have to implement the SN be?

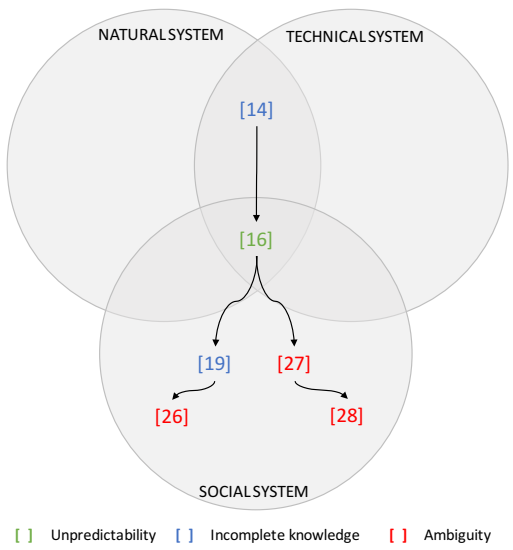
The current length of the contracts for the implementation of the sand nourishments can generate conflicts between stakeholders with different frames. One the one hand, stakeholders responsible for the investment and management of the sand nourishments (Ministry of Infrastructure & Environment/Rijkswaterstaat) are interested in providing the contractors with more flexibility in order to reduce the costs of implementation of the nourishments. On the other hand, stakeholders such as provinces and municipalities may be concerned with the occurrence of damages caused by structural erosion in some specific

areas, resulting in economic losses, if the contractors choose to implement the nourishments only towards the end of their contracts.

[28] Should there be a provision in the contracts allowing for shorter timeframe for implementation in case of safety/economic risks?

This ambiguity is largely related to the previous one ([27]), involving the same set of stakeholders with different interests concerning this detail of the implementation process.

FIGURE 12: CASCADE OF UNCERTAINTIES REGARDING THE CONTRACTS FOR THE IMPLEMENTATION OF SAND NOURISHMENTS



Regarding the contracts for the implementation of the sand nourishments, as illustrated in Figure 12, there is incomplete knowledge about the precise timescale of the nourishments ([14]), which is largely influenced by local natural conditions controlling how often there will be a need for a supplement of sand in a specific area. Although the need for nourishments is determined by the action of the natural environment of the coast, the actual implementation of the nourishment ([16]) is also affected by conditions of different parts of the system. The contractors need permits to start extracting sand, which is related to technical aspects, and also will depend on the demand of the international market, which regulates the price for the work. The uncertainty about when within the timeframe of the contract the nourishments will actually be implemented can negatively affect some stakeholders. The existing incomplete knowledge about the impact of the lack` of timely information of the implementation to beach operators and property owners ([17]) is one of the points of concern of the province of Zeeland about the whole process. There is an ambiguity associated to the previous concern, referring to when should the regional and local authorities be communicated of the schedule of implementation in order to inform in advance the interested parties at location where the nourishment will take place ([26]). Furthermore, the degree of flexibility for the implementation is also related to an ambiguity involving the length of the contracts ([27]). While for some stakeholders, the current situation is very favorable, there are situations in which some groups may suffer losses due to structural damages. This leads to another ambiguity dealing with the possibility of altering the length of the contracts in order to avoid the occurrence of such damages ([28]).

SITUATION 3: UNCERTAINTIES DUE TO MUNITION FROM WW I&II

After World Wars I and II, large amounts of munitions were dumped in the North Sea. These dumped munitions included conventional munitions such as bombs, grenades, torpedoes and mines as well as phosphorus incendiary devices and chemical munitions containing, for example

mustard gases. Historical records on the quantities of munitions dumped and their exact location are limited and with dubious accuracy (OSPAR Commission, 2010).

During the interviews, some stakeholders expressed their concerns with dumped munitions and the issue associated with their disturbance by seabed activities. One of the risks identified during the interviews concerned the safety of the sand extraction works. Not only the ships and its workers are at risk when they encounter these artefacts during their operation, it also represents an aggravation for the project costs (since work can only be resumed after the safety and integrity of workers and machinery is once again restored). From the environmental point of view, some of the chemical munitions are also hazardous due to their potential for bioaccumulation.

In the view of some stakeholders it is very important that the locations of all munitions dumpsites and areas where clusters of encounters are detected on the seabed are identified. Furthermore, some concern was mentioned about the safety of beachgoers and nature due to the possible wash-up of munitions after the implementation of the nourishments.

The following uncertainties are associated with this particular situation:

[5] Where are the munition of the WWI&II located?

As previously mentioned the location of the dumpsites are not well known due to unreliable information from the historical records and lack of spread out surveys of the seabed. Therefore, there is uncertainty regarding the location of the dumped munitions. Given the passage of time, natural conditions may also have an impact on the current situation of these munitions.

[10] How to avoid accidents with munition from WWI&II?

The best coping mechanism to deal with the munition and avoid accidents is directly related to the type of munition and their location. The absence of surveys results in uncertainty about how to prevent accidents caused by the encounter with munition to happen.

[15] Which models are reliable and should be used?

Here the word model is used to describe the methodology to survey the seabed. The uncertainty is associated to the type of survey, its extent, and reliability. In this case, different people with different interests may disagree on the methodology to be used in order to benefit their purposes.

[17] How will beachgoers behave?

People's behavior is not always trivial to predict. It is not different when it concerns people going to the beach. In this sense, there is uncertainty of how people would react if they are aware of the danger of munition appearing on the beach due to the nourishments.

[18] How will the media, especially social media behave?

Similarly to the previous uncertainty ([19]), it is difficult to predict the behavior of the media. In the case of a project where the news of encounters with munition were published, depending on the nature of the news, it could have an impact on the acceptability of the project.

[22] What are the risks of munition to people and structures?

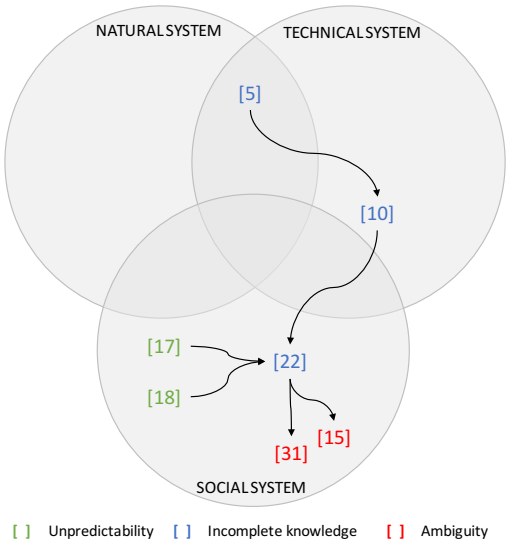
The type of munitions and their location is fundamental to define their risk to both people and structures (like ships and fishing boats). Not knowing more about the dumped munitions reduces the capacity to be prepared to avoid human and economic losses.

[31] Who should be responsible for dealing with munitions found on the coast?

This ambiguity is involving the policy, management, and implementation aspect of the issue posed by dumped munition.

Regarding munition from WWI&II (as shown in Figure 13), there is incomplete knowledge on the location of the dumping sites ([5]) which is aggravated by the action of natural processes over time. Historical records are not always reliable and many dumping sites are unaccounted for. This lack of information results in the subsequent uncertainty also from incomplete knowledge, which strategy to use in order to prevent accidents with munitions ([10]). Furthermore, the real risk posed by dumped munition ([22]) is also unknown, since it is deeply related to the type of artefacts dumped. Another aggravator of this issue is the unpredictable behavior of people, especially beachgoers ([17]) and the media ([18]). The first ones could be exposing themselves to risks by nourishments with potential munition and, thus, be against the implementation of nourishments. The second can influence the view of the general public about the nourishments. There is also ambiguity about which models are more suited for surveys of the seabed ([15]). Finally, there is uncertainty about the delegation of responsibilities ([31]) concerning the issue of dumped munition within the process of sand nourishments.

FIGURE 13: CASCADE OF UNCERTAINTIES REGARDING THE ISSUE OF MUNITION FROM WWI&II



SITUATION 4: UNCERTAINTIES DUE TO THE IMPACT OF CLIMATE CHANGE ON SAND NOURISHMENTS

Climate change is one of the main sources of discussions in the international political and scientific scenarios. One of the purposes of adaptive policies is to take into consideration the effect of the change in temperatures and sea level due to the excessive emission of greenhouse gases into the atmosphere during the current and past centuries.

Much has been discussed over the extent of these changes and their effects on the human activities and environment. When it comes to the Netherlands, a low lying country, there is a high interest in unravelling the potential impacts climate change may cause to coastal management practices.

All the stakeholders interviewed are aware that climate change can play an important role in the process of sand nourishments on the Dutch coast. However, there is still differences concerning

the extent of the impacts cause by it. Similarly, some stakeholders are more concerned with the different impacts of climate change such as droughts, heat waves and river floods.

The following uncertainties are associated with this particular situation:

[1] What is the impact of climate change on the occurrence and intensity of storms on the Dutch coast?

One of the uncertainties associated with climate change is its effect on the manifestation and severity of extreme weather events along the coast. Weather forecasts use complicated models with a lot of built-in uncertainties for the prediction of weather events in the short term. On medium and long term, this type of estimation is not feasible, making this uncertainty unpredictable.

[2] How much sand is available?

The availability of sand for the nourishments can be considered incomplete knowledge since it results from limitation in data and models as well as on the understanding of the natural process. Furthermore, it depends on the use for other purposes, such as offshore windfarms. In this case, although the sand is available for exploration, it cannot be used for the nourishments since it is needed for the foundations of the wind turbines. Similarly, areas with dumped munition are also not good locations for the extraction of sand.

[3] What is the impact of climate change on sea levels and wind?

The main drive of climate change is the rise in mean temperatures due to the emission of greenhouse gases. However, the rate the temperatures are increasing varies according to different groups and models. From the expected temperature change, modelers also try to estimate the rise in sea levels and change in wind patterns. Given that much is still unknown about this temperature increase, there is uncertainty in the expected sea level rise and wind variations due to incomplete knowledge about climate change.

[6] Is there climate change?

In face of the many scientific evidence of the existence and effects of climate change, there are still those who, for personal or political-economic reasons, do not believe climate change is happening. This ambiguity opposes those who believe climate change poses a threat for humanity and those who believe the observed changes in temperature are part of the natural cycle of warming up and cooling off of the planet.

[7] How much is the sea level rising?

This ambiguity refers to the different predictions of sea level rise. Depending on the data used, modelers reach different results and new insights on climate change are always being used to reevaluate their prediction. However, different groups have distinct views on when the change in sea level will occur, especially being a prediction for the medium and long term.

[9] What is the impact of more storms on the coastal protection system?

If there are more storms hits the coast of the Netherlands in future years, more sand will be removed from the protection structures. As a result, there will be an increase in the need for more nourishments, resulting in more costs and demanding a re-evaluation of the feasibility of nourishments as strategy.

[12] What is the impact of climate change on the feasibility of sand nourishments?

As previously mentioned, climate change will have impacts on several elements that have an influence on the process of sand nourishment. There is still incomplete knowledge of the technical feasibility of the sand nourishments due to the effects of climate change.

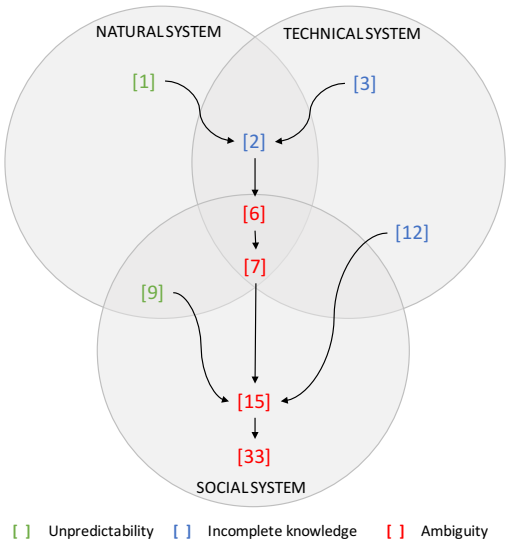
[15] Which models are reliable and should be used?

There are many scenarios built on the latest predictions of temperature rise, each of them using a different set of input data. Given this variety of scenarios, groups with different frames may be inclined to the outputs of different models/scenarios, which generates ambiguity.

[33] Is sand nourishment a good adaptive strategy?

Considering the amount of uncertainties referring to the impact of climate change on sand nourishment, some groups may start to disagree on the benefits of sand nourishments as the main adaptive strategy for the safety of the Dutch coast.

FIGURE 14: CASCADE OF UNCERTAINTIES REGARDING THE EFFECTS OF CLIMATE CHANGE ON SAND NOURISHMENTS



The implications of climate change for sand nourishment start with uncertainties acting up on the natural and technical parts of the system, as described in Figure 14. The unpredictability of natural process results in uncertainty about the impact of climate change on the intensity and occurrence of storms ([2]). There is incomplete knowledge on how much climate change is resulting in sea level rise and changes in wind patterns ([3]). Both of these uncertainties contribute to the unpredictability of the availability of sand for the nourishments ([1]), associated also with the possibility of use for different purposes (e.g. windfarms). In a broader spectrum, there is still ambiguity about the existence of climate change ([6]) in the first place, with groups disputing the vast scientific evidence of its impacts over the past years.

There is also ambiguity about the rate of sea level rise ([7]), with different groups advocating to different scenarios and predictions in order to benefit their interests. The uncertainty about the effects of climate change is also translated into the unpredictability of its impact on the protection system ([9]) which is associated with the previous ambiguity and with the incomplete knowledge of the impact of climate change on the technical feasibility of nourishments ([12]) in the form of ambiguity about the models to be used ([15]). In this sense, there will be groups claiming for the use of specific scenarios/models in order to achieve their goals. Lastly, the relation of all the uncertainties associated with the effect of climate change on sand nourishments can result in people starting to question the concept of the nourishments as a suitable adaptive strategy ([33]) for the Dutch coast.

SITUATION 5: UNCERTAINTIES RELATED TO THE USE OF SAND NOURISHMENT FOR DIFFERENT PURPOSES

At this moment, sand nourishments are only implemented as a strategy to maintain the Dutch coast safe. However, safety is not the only reason for which a san nourishment could be implemented. Some stakeholders pointed out to the economic benefits sand nourishments could have for the coast. Others to the environmental service that the nourishments could provide.

The main difficulty regarding multiple uses of the nourishments apart from safety is the source of investment. According to the ministry of Infrastructure and Environment and Rijkswaterstaat, they would not finance nourishments that are not meant to maintain or improve the safety of the coastline.

Another problem with implementing nourishments for other purposes is related to the attribution of responsibilities and management. Furthermore, there would be a need to manage conflict of interest of the different parties involved.

The following uncertainties are associated with this particular situation:

[2] How much sand is available?

The availability of sand for the nourishments can be considered incomplete knowledge since it results from limitation in data and models as well as on the understanding of the natural process. Furthermore, it depends on the use for other purposes, such as offshore windfarms. In this case, although the sand is available for exploration, it cannot be used for the nourishments since it is needed for the foundations of the wind turbines. Similarly, areas with dumped munition are also not good locations for the extraction of sand.

[8] What is the impact of sand nourishments on nature?

There is uncertainty about the effects sand nourishment can have over nature. The ambiguity here concerns how people with different interests may perceive these effects, which are largely dependent on the specific conditions of the location the nourishments are going to be implemented.

[11] In which cases should sand nourishments be implemented?

Not necessarily the nourishments will be the best option to be implemented at a specific location. In general lines, the main factor is the cost-benefit of the project. However, other factors, such as the environmental impact also should influence this decision. There are groups advocating that, in areas with low occupation, the natural processes are allowed to follow their course without human intervention, since this would not result in a reduction of safety.

[17] How will beachgoers behave?

People's behavior is not always trivial to predict. It is not different when it concerns people going to the beach. The use of the nourishment for economic reasons is directly related to the demand of people going to the beach.

[18] How will the media, especially social media behave?

Similarly to the previous uncertainty ([19]), it is difficult to predict the behavior of the media. The public acceptance of projects can be highly influenced by how the media present the information to their followers.

[19] How much are people willing to change?

In many cases, people are used to a situation, either the scenery, a measure or a purpose. When there are changes proposed to what people are used to, there could be resistance or unacceptance. In order to understand how people will react to a specific change, either in how things are done or to their environment, there is a need to more knowledge on how people behave and what is important for them, which are always specific to a particular group and situation.

[21] Where should the nourishments be implemented?

The specific location for the implementation of the nourishment can also be considered an uncertainty of incomplete knowledge nature. The simple definition would be to combine the factors from nature and technology to dictate the location of the implementation. However, its implications on the social part of the system is the cause for the uncertainty. There is a need to identify the repercussions of the implementation for the economy and nature before defining the most appropriate location.

[23] What is the impact of sand nourishments for recreation?

This uncertainty concerns the effects sand nourishments may have on recreation. More insights are needed to define if there is a significant gain in terms of recreation potential in areas where beach nourishments were implemented.

[29] What are other possible purposes for sand nourishments?

Although Rijkswaterstaat only explores the use of sand nourishments to ensure the safety of the Dutch coast, it could also be used for other functions. A discussion about its uses could be a source of conflict or disagreements between different stakeholders, since they may have different interests: some economic, some social and others nature.

[30] Who should finance sand nourishment for these other purposes?

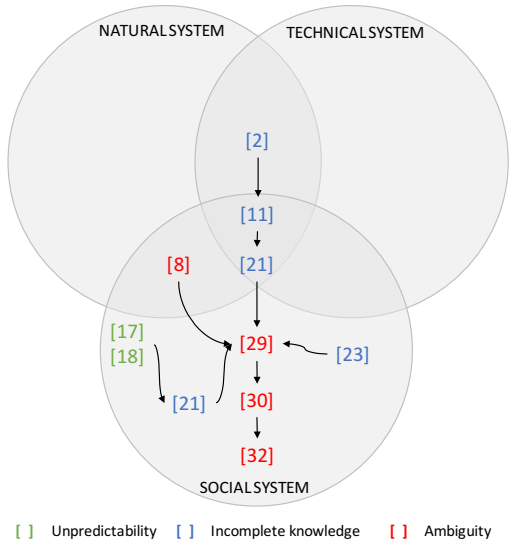
One of the main sources of ambiguities in this particular situation concerns the source of investments in the event of implementing sand nourishments with different purposes. Although many stakeholders may be interested in the benefits of the nourishments, it requires a large investment, which makes it impossible for local and small groups to be able to finance it without any assistance from bigger groups, such as the government. On the other hand, the government is already concerned about multiple investments and needs to manage carefully the taxpayers' money.

[32] How can sand nourishments benefits other attributes/uses of the coast?

It is clear that sand nourishments could benefit functions other than safety. However, there is still disagreements to the extent and applicability of the nourishment for other purposes (such as to increase recreation, boost tourism and increase the environmental value of an area).

When it comes to the use of sand nourishment for different purposes, the cascade of uncertainties (Figure 15) starts with the question about the availability of sand ([2]), which has to be distributed between multiple uses leading to the inquiry of in which cases should the nourishments be implemented ([11]), due to their impact on all three parts of the system. Knowing where to implement them ([21]) is also a matter that could affect all three parts of the system, and also requires more insights. This leads to the ambiguity of what are the other purposes for sand nourishments ([29]) which is also influenced by the following uncertainties: there is ambiguity about the impact of the nourishments of nature ([8]), which could influence the view of some stakeholder on the applicability of nourishments for different purposes; there is incomplete knowledge on the impact of sand nourishments for recreation ([23]); people and the media have unpredictable behaviors ([17] and [18]) which can influence the public perception about nourishments as well as how much people are willing to change to accept the implementation of nourishments ([20]). After that, there is ambiguity about who should be responsible for financing these new types of nourishments ([30]) and about how the nourishments could benefit other functions of the coast ([32]).

FIGURE 15: CASCADE OF UNCERTAINTIES RELATED TO THE USE OF SAND NOURISHMENT FOR DIFFERENT PURPOSES



SITUATION 6: UNCERTAINTIES RELATED TO PARTICIPATION IN THE POLICYMAKING PROCESS

The strategy of using sand nourishments for the maintenance of the safety on the Dutch coastline is part of a larger policy, the Delta Programme. One of the main trend for the policymaking process nowadays is to promote more participation throughout the development, evaluation and implementation of policies.

According to the ministry of Infrastructure and Environment, the Dutch government has been more attentive to the involvement of different groups with the purpose of developing better solutions. This view has also been corroborated by other stakeholders, such as the water board, the province and natuurmonumenten. According to them, there is a good line of discussion to the main government.

However, one point brought up during the interviews, is the lack of specific and concrete elements in the policy to assist practitioners in the implementation of the measures. Furthermore, involving more people in the discussion process may not result in better solutions or developments. When there are more representatives of different groups involved, more contrasting and diverging ideas could be expressed. In this case, to achieve good outcomes, it is important that there are mechanisms set in place to cope with these differences.

The following uncertainties are associated with this particular situation:

[11] In which cases should sand nourishments be implemented?

Not necessarily the nourishments will be the best option to be implemented at a specific location. In general lines, the main factor is the cost-benefit of the project. However, other factors, such as the environmental impact also should influence this decision. There are groups advocating that, in areas with low occupation, the natural processes are allowed to follow their course without human intervention, since this would not result in a reduction of safety.

[18] How will the media, especially social media behave?

It is difficult to predict the behavior of the media. The public acceptance of projects can be highly influenced by how the media present the information to their followers.

[20] How much are people willing to change?

In many cases, people are used to a situation, either the scenery, a measure or a purpose. When there are changes proposed to what people are used to, there could be resistance or unacceptance. In order to understand how people will react to a specific change, either in how things are done or to their environment, there is a need to more knowledge on how people behave and what is important for them, which are always specific to a particular group and situation.

[21] Where should the nourishments be implemented?

The specific location for the implementation of the nourishment can also be considered an uncertainty of incomplete knowledge nature. The simple definition would be to combine the factors from nature and technology to dictate the location of the implementation. However, its implications on the social part of the system is the cause for the uncertainty. There is a need to identify the repercussions of the implementation for the economy and nature before defining the most appropriate location.

[22] What is the effect of more participation on the policymaking process?

In the adaptive policymaking process there is a call for participation. Increasing participation, however, does not mean better solutions and policies necessarily. There is uncertainty about the effects of increased participation, especially of groups with opposed interests, and a need for tools to promote the discussion and dialogue between these groups.

[25] How to integrate policy and implementation strategies?

This uncertainty comes from the disconnection that sometimes exists between policymakers, scientist and practitioners responsible for the implementation of policies. On the one hand, more technical groups tend to think the policies are too vague. On the other, it tries to make room for different interpretations to avoid conflicts. There is a need for more in-depth knowledge on how this relationship should be managed.

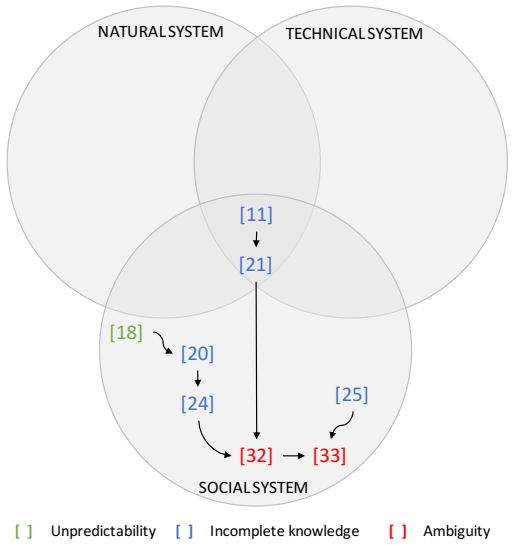
[32] How can sand nourishments benefits other attributes/uses of the coast?

It is clear that sand nourishments could benefit functions other than safety. However, there is still disagreements to the extent and applicability of the nourishment for other purposes (such as to increase recreation, boost tourism and increase the environmental value of an area).

[33] Is sand nourishment a good adaptive strategy?

Considering the amount of uncertainties referring to the impact of climate change on sand nourishment, some groups may start to disagree on the benefits of sand nourishments as the main adaptive strategy for the safety of the Dutch coast.

FIGURE 16: CASCADE OF UNCERTAINTIES REGARDING THE PARTICIPATION IN THE POLICYMAKING PROCESS



When it comes to the participation in the policymaking process, the first noticeable aspect is the lack of uncertainties exclusively from the natural and technical system, as shown in Figure 16. There is uncertainty about the situation which sand nourishments should be implemented ([11]), since they have an impact on all three parts of the system. Which leads to the question of where they should be implemented ([21]) due to the impact it has on the social system. There is an influence of the media on how the general public sees the use of nourishments ([18]) which can be related to how much people are willing to change ([20]). Meaning that there is a need to gather insights on what people find important and how to make sure they either understand the importance of the project or see that their interests are represented ([24]). Both uncertainties converge to the ambiguity of how the nourishments can benefit other functions of the coast ([32]), which is dependent on the frames being considered. It ultimately leads to the question of either or not nourishments are a good adaptive strategy ([33]), which is also influenced by the uncertainty of how to better integrate policy strategies and their implementation, demanding the mutual understanding between policymakers and technical practitioners responsible for the implementation of the measures described in the policies ([25]).

4.2 UNCERTAINTIES IN THE CONTEXT OF THE DELTA PROGRAMME

This section focus on contextualizing the identified uncertainties in regard to the Delta Programme. To do so, the following documents were consulted. This documents were selected for being the latest available documents from the Delta Programme with information about the coast and, more specifically on sand nourishments. Furthermore, the official website of the Delta Programme was also consulted for extra information that might not be contained in the selected documents.

- Delta Programme 2015: Working on the Delta
- Delta Programme 2017: Work on the Delta
- Delta Programme | Coast 2013: National Coastal Strategy
- https://english.deltacommissaris.nl/search

SITUATION 1: UNCERTAINTIES RELATED TO THE EFFECTIVENESS OF SAND NOURISHMENTS

What are the main stakeholders involved?

- Rijkswaterstaat
- Ministry of Infrastructure and Environment
- Province
- Municipality
- Nature groups

How is the situation defined in the policy?

- Using sand instead of hard flood defenses ("softening") when possible, desirable and cost-effective because using sand for our coast is the most adaptive and natural method of reinforcing and maintaining the coast. (Delta Programme | Coast, 2013, p.11)
- In order to keep sufficient sand available at all times, sand extraction inside the 12-mile zone has been given priority in the National Water Plan and RWS has developed a sand extraction strategy. The sand extraction strategy focuses on safeguarding sufficient affordable sand for both coastal defense and use on land (e.g. infrastructure and construction). After all, it is more cost-effective to extract sand close to nourishment sites or transshipment ports. At the same time, the aim is to facilitate other uses at sea and allow options to be carefully considered. (Delta Programme | Coast, 2013, p.60)
- Flood defenses benefit from sand nourishments because they reduce the wave attack. Research also shows that a large amount of (nourishment) sand drifts towards the dunes and, in particular, that the fore- dunes have increased in height in many places since 1990. (Delta Programme | Coast, 2013, p.121)
- The report *"Zandsuppleties in de 21e eeuw"* [Sand nourishments in the 21st century] presents eight different nourishment variants in which the quantity of sand, the timing of nourishment, the type of nourishment, the distribution of nourishment sand and the frequency of nourishment vary. For each variant, the effect on the functions (safety on the foreland and on the land side of the dykes, drinking water supply, recreation and nature) in the coastal area is quantified using a specially developed model. This makes it possible to compare the eight variants. Of course, numerous other variants are possible and great uncertainty surrounds the description of the quantities, costs and effects. (Delta Programme | Coast, 2013 p.123)
- The Delta Progamme is developing an adaptive pathway with emphasis on an approach of "learning and innovating by experimenting" because there are still uncertainties surrounding the way that the sandy system operates and the impact of choices in that system. (Delta Programme | Coast, 2013 p.99)
- To be able to anticipate future developments, expertise is being developed concerning the operation of the sandy system as a whole and of the individual sub-regions, for now and in the future. (Delta Programme, 2015 p.41)
- […] focusing research and monitoring on the effects of sand replenishments on the dynamics in dunes and the interactions between shore face, beach, outer dunes and rear dunes. (Delta Programme, 2015 p.133)

How was the situation defined by the stakeholders?

There is uncertainty about the effectiveness of large scale nourishments and the need for more studies. In this sense there are questions concerning: (1) the availability of sand; (2) the impact on nature; (3) the protection achieved; (4) when and where to implement; (5) the nourishments as a strategy.

What are the differences between the two definitions?

The Delta Programme considers sand nourishments the best strategy for the Dutch coast. However, they are aware of the existence of uncertainties, thus opting for an adaptive pathway, allowing for them to learn throughout the process. Many studies have been commissioned and are aimed at studying the effects of mega nourishment.

The stakeholders also believe the sand nourishment strategy to be appropriate for the Dutch coast, however, they still have concerns that are not completely clear, as presented by the uncertainties mentioned above.

SITUATION 2: UNCERTAINTIES RELATED TO CONTRACTS FOR THE IMPLEMENTATION OF SAND NOURISHMENTS

What are the main stakeholders involved?

- Rijkswaterstaat
- Ministry of Infrastructure and Environment
- Province
- Municipality
- Contractors

How is the situation defined in the policy?

No direct mention to contracts or to specific terms of the implementation of sand nourishments were found in documents of the policy.

How was the situation defined by the stakeholders?

Concerning the contracts for the implementation of sand nourishments, the main points of brought up by the stakeholders are: (1) the lack of knowledge on the timescale of the nourishments; (2) the reduced predictability of when they will be implemented; (3) the impact of lack of timely information for local businesses; (3) the different frames about the length of the contract period and when should different parties be informed; (4) the possibility of shortening the contracts in special cases.

What are the differences between the two definitions?

Not defined.

SITUATION 3: UNCERTAINTIES DUE TO MUNITION FROM WWI&II

What are the main stakeholders involved?

- Rijkswaterstaat
- Ministry of Infrastructure and Environment
- Municipality
- Contractors
- Tourists/Beachgoers
- Nature groups

How is the situation defined in the policy?

No direct mention to munition were found in documents of the policy.

How was the situation defined by the stakeholders?

Munition from WWI&II represent a risk both for people and structures during the implementation phase of sand nourishments and afterwards. The uncertainties refer to: (1) lack of detailed information on the location of dumping sites; (2) risk for sand extraction; (3) risk of munition washing up to the beach? (4) responsibility for the munitions.

What are the differences between the two definitions?

Not defined.

SITUATION 4: UNCERTAINTIES DUE TO THE IMPACT OF CLIMATE CHANGE ON SAND NOURISHMENTS

What are the main stakeholders involved?

- Rijkswaterstaat
- Ministry of Infrastructure and Environment
- Water board
- Province
- Municipality
- Nature groups

How is the situation defined in the policy?

- The Delta Programme has a clearer picture of what the consequences of relative sea-level rise are likely to be in the medium and long term. As far as flood safety is concerned, the protection provided by the coast is generally expected to remain sufficient over the coming century if it is properly managed and maintained. (Delta Programme | Coast, 2013 p.10)
- This picture could change in the light of new insights into the impact of relative sea-level rise on flood defenses or new assessments of the consequences of flooding. (Delta Programme | Coast, 2013 p.10)

- These forecasts are based on the delta scenarios. The delta scenarios consist of four possible scenarios. The delta scenarios are based on the climate scenarios of the Royal Netherlands Meteorological Institute [KNMI] and the socio-economic WLO [Welfare, Prosperity and Quality of the Living Environment] scenarios produced by the collaborating planning offices. (Delta Programme | Coast, 2013 p.36)
- The flood defenses and the functions must be able to adapt to sea-level rise and climate change while maintaining the best possible cost-benefit ratio. (Delta Programme | Coast, 2013 p.79)
- The structural safety of the coast and hinterland (now, in essence, under control) requires the sandy coastal system to be kept permanently in balance with the relative rise in sea level by continuously compensating for ongoing erosion and by adapting so and hard sea defenses. (Delta Programme | Coast, 2013 p.8)
- To ensure that the coastal foundation remains in balance with the relative sea- level rise, the coastline can be maintained and the sand balance in the overall sandy coastal system remains in good order, we are using an adaptive pathway in which the volume of sand to be nourished is gradually increased. (Delta Programme | Coast, 2013 p.11)
- Research conducted by RWS shows that more than enough sand is available to satisfy the demand described in scenarios depicting rapid sea-level rise, provided that attention is paid to managing stocks. (Delta Programme | Coast, 2013 p.60)
- According to the delta scenarios, more and fiercer storms will occur as a result of climate change. The greatest uncertainty is the speed at which developments will take place. (Delta Programme | Coast, 2013 p.119)
- If this concerns the consequences of climate change, the delta scenarios will assume an acceleration in the current rate of sea level rise, i.e. a possible rise in sea level along the Dutch coast of between 15 and 35 centimeters by 2050 and between 35 and 85 centimeters by 2100. The greatest uncertainty is the speed at which this development will take place. (Delta Programme | Coast, 2013 p.36)
- As a consequence of rising sea levels, current sand replenishments may not be sufficient to preserve the coastline. With the Decision on Sand, the sandy system will be permanently kept in balance with the rise in sea levels, by gradually adapting the sand replenishments in the coastal foundation zone to the rise in sea levels. (Delta Programme, 2015 p.41)
- There is enough sand in the North Sea to keep the coast safe, also in the very long term (the coming centuries). Good sand extraction sites that are located relatively close to the coast are essential to keep sand replenishments affordable. That is why sand extraction in the zone between the twelve-mile limit and continuous isobaths at NAP (Amsterdam Ordnance Datum)-20 meters is a priority. It has been decided to extract a layer of sand of 10 meters where possible (instead of the previous layer of 2 meters). This will ensure that the area has enough sand to meet the demand for sand in the coming century, even if the demand for sand increases rapidly as a consequence of policy choices and an accelerated rise in sea levels. Effective management of the sand

supply, taking other uses and nature into account, is essential, however. (Delta Programme, 2015 p.43)

How was the situation defined by the stakeholders?

The stakeholders are aware climate change may have a significant influence over sand nourishments. In their view the following aspects are important: (1) the availability of sand; (2) the impact on the occurrence and intensity of storms; (3) sea level rise; (4) impact of more storms on the protection system; (5) impact on feasibility of nourishments; (6) if sand nourishments will continue to be a good adaptive strategy.

What are the differences between the two definitions?

In the policy, there is a belief that the main strategy is sufficient for the remaining of the century. However, new insights on climate change could bring the need for re-evaluation. According to the policy, there is enough sand to keep the system safe. Furthermore, the delta scenarios take into account different possible levels of alterations in the climate. The adaptive strategy allows for flexibility in responding to these differences. Nonetheless, some uncertainties are recognized, such as about the speed of increase in storm events.

SITUATION 5: UNCERTAINTIES RELATED TO THE USE OF SAND NOURISHMENT FOR DIFFERENT PURPOSES

What are the main stakeholders involved?

- All stakeholders

How is the situation defined in the policy?

- Apart from the safety challenge, regional challenges to be addressed to achieve an attractive and economically viable coast have their own urgency and approach. These challenges include the maintenance and development of the unique character of coastal resorts, multifunctional use of flood defenses, accessibility and the development of ports and marinas It is essential that the work involved does not prevent safety measures being put in place in future. This requires an innovative and integrated view of the approach to the coast that will attract new investment to the coastal zone. (Delta Programme | Coast, 2013 p.125)
- The obstacles to multifunctional use of flood defenses and the possibility of removing these obstacles can be classified as financial-economic, spatial, technical and legal instruments. Research has shown that, in principle, current national policy and instruments permit multifunctional shared use. The biggest obstructions are dealing with financial liabilities and risks and the lack of a method for allocating the costs and benefits of shared use. Reference is also made to the need for research into the behavior of sand around hard structures such as buildings. Shared use currently has to be considered on the basis of estimates of uncertainties because there is a lack of fundamental knowledge. (Delta Programme | Coast, 2013 p.105-106)
- It is possible to use sand replenishments in such a way that they contribute not only to flood risk management but also, and to the maximum extent possible, to local and

regional objectives to ensure a coast that is economically robust and attractive. (Delta Programme, 2015 p.41)

- If the use of sand replenishments for purposes other than flood risk management leads to additional costs, other parties will contribute to the financing, depending on the degree to which the sand replenishments benefit them and help them accomplish their social task. The principle of co-funding has been elaborated in the National Framework for Coastal Development (2011). (Delta Programme, 2015 p.41-42)

How was the situation defined by the stakeholders?

Stakeholders see the possibility of using sand nourishments for different purposes. They question: (1) the availability of sand; (2) the impact on nature; (3) different behaviors; (4) applicability of sand nourishments; (5) impact on recreation; (6) what are other uses for the nourishments; (7) the responsibility for financing these nourishments; (8) the benefits for different functions of the coast.

What are the differences between the two definitions?

The policy already accounts that an innovative and integrated view of the approach to the coast is needed in order to attract new investment to the coastal zone. This means that, the investments for such uses of nourishments are not covered by the policy. Recognizably, the policy refers to obstacles to multifunctional use of flood defenses as financial-economic, spatial, technical and legal instruments. With biggest obstruction being dealing with financial liabilities and risks and the lack of a method for allocating the costs and benefits of shared use.

In general terms, the stakeholders are concerned with the relationship between the impacts of nourishments (socio-economic and environmental) and benefits. While, most is already mentioned in the policy, the question about financing multi-purpose nourishments remains as an uncertainty.

SITUATION 6: UNCERTAINTIES RELATED TO PARTICIPATION IN THE POLICYMAKING PROCESS

What are the main stakeholders involved?

All stakeholders.

How is the situation defined in the policy?

- Research has shown that the various parties involved in the governance of the coast would like to collaborate with the water sector and other sectors, mainly by combining work on safety with work on developing the coast more often. (Delta Programme | Coast, 2013 p.61)
- By adopting such an integrated approach, they can combine the locations of attention for safety and the development challenges. This also requires a change in the way that government bodies collaborate in the coastal zone, i.e. a tailored approach.

Sometimes, parties already communicate well with each other and are following a continuous process of learning by collaborating. (Delta Programme | Coast, 2013 p.61)

- In other places, intensification of the collaboration can result in breakthroughs. This applies not only to the improvement in the process of programming sand nourishments (with a scope of four years), but also to the improvement in the governance of the coast in the longer term and to larger integrated interventions to promote the innovative and more multifunctional use of the coast. (Delta Programme | Coast, 2013 p.61)
- In practice, each municipality and province currently does what is within its own powers and regards other authorities more as competitors than as co-creators of a powerful coastal development. (Delta Programme | Coast, 2013 p.62)
- Transparency is required for the structure, control and progress of the Delta Programme's sub-programmes. Adaptive delta management is the transparent way of taking account of uncertainty about future trends in the decision-making process. (Delta Programme | Coast, 2013 p.117)
- In the decision- making process, the Delta Programme takes an adaptive approach to uncertainties about future trends. Experimentation and innovation are important aspects of the way we work. We regard the coastal community as an evolving organizational structure. (Delta Programme | Coast, 2013 p.111)

How was the situation defined by the stakeholders?

The stakeholders are in favor of promoting participation in the decision-making process, and have the following uncertainties in relation to the policy: (1) what is the importance of the media; (2) when, where and how the nourishments are used has an impact on the view of different groups; (3) in different levels of government and across different fields of expertise people tend to stick to their conventions and are not necessarily willing to change their ways, then how can increased participation work towards bringing people with different ideas together?; (4) increased participation does not translate, necessarily, into better policy, what are the risks?; (5) the benefits for different functions of the coast; (6) increased participation means including people who may question if sand nourishments will continue to be a good adaptive strategy.

What are the differences between the two definitions?

The policy states that different parties are willing to collaborate in the water sector, which is also verified by the stakeholders, and the policy already accounts for a need in a change in how this collaboration happens, with a need for the improvement in the governance of the coast in the longer term and to larger integrated interventions.

The policy does not address how the participation should occur or the degree of participation. Furthermore, it is not mentioned how to bridge differences or how to make sure the process doesn't become too vague without reaching a concrete solution.

CHAPTER 5: **BRIDGING GAPS IN WATER GOVERNANCE**

5.1 RELATION BETWEEN THE IDENTIFIED UNCERTAINTIES AND GAPS IN WATER GOVERNANCE

The 2014 report from the OECD, states the potential of the Delta Programme in bridging the following five gaps in the Dutch water governance: accountability gap; capacity gap; information gap; policy gap; and objective gap. The following paragraphs offer a short description of these gaps and Table 18 presents a summary.

TABLE 18: GAPS IN WATER GOVERNANCE

GAPS IN WATER GOVERNANCE	
Accountability gap	Difficulty ensuring the transparency of practices across the different constituencies, mainly due to insufficient users' commitment' lack of concern, awareness and participation.
Capacity gap	Insufficient scientific, technical, infrastructural capacity of local actors to design and implement water policies (size and quality of infrastructure, etc.) as well as relevant strategies.
Information gap	Asymmetries of information (quantity, quality, type) between different stakeholders involved in water policy, either voluntary or not.
Objective gap	Different rationales creating obstacles for adopting convergent targets, especially in case of motivational gap (referring to the problems reducing the political will to engage substantially in organizing the water sector).
Policy gap	Sectoral fragmentation of water-related tasks across ministries and agencies.

Adapted from OECD (2011)

According to the framework each gap can be characterized as follows (for a more detailed description see OECD (2011)).

An ***accountability gap*** refers to the absence of transparency in water policy making, as well as to issues of quality and integrity. Transparency across different levels of government is fundamental for the effective implementation of water policies, and requires the local governments to have the capacity to monitor investments and the civil society to be engaged.

The ***capacity gap*** is caused by a deficit in scientific and technical expertise and infrastructure for designing and implementing water policies. In order to implement national water policies, the sub-national authorities need to have appropriate organizational, technical, procedural, networking and infrastructure capacities. Similarly, the national government has to be able to manage multi-level relations, distributing responsibilities and funds, as well as ensure coordination and coherent policy approaches among actors.

An ***information gap*** is characterized by uneven distribution of information throughout ministries, between different levels of government, and across local actors involved in the water policy. The main concern is the lack of information to guide the decision making process. However, even if enough information is available, it has to be shared at the different levels of government. In practice, sub-national government tends to have more information on local needs and preferences as well as about the implementation and costs of local policies, which should be communicated to the central government to avoid information gaps. The national government plays a fundamental role of managing the information in order to support a broader vision of public policy objectives,

which indicates a relationship of mutual dependence. It is safe to assume the relevant information does not reside exclusively with one level of government, and actors depend on each other's knowledge to avoid information gaps.

The ***objective gap*** occurs when contradictory or diverging objectives between levels of government or ministries compromise targets for integrated water policies. This gap reflects the challenge in implementing strategic planning in water policies, given that the engagement of the relevant stakeholders must go beyond political changes and electoral calendars. The time frame for decisions is of vital importance, and the prospects of success are greater when the timeframes of activities in different policies are aligned.

The ***policy gap*** is related to the fragmentation of water related tasks throughout ministries and public agencies. Incoherence may appear between sub-national policy needs and national policy initiatives and, therefore, reduce the successful implementation of cross-sectoral policies. In this sense, the policy gap refers to a lack of policy coherence at the central government level, which is necessary for a better cross-sector coordination at the sub-national level of policy initiatives designed at the central level and implemented at the sub-national level.

The assumption made in this thesis argues for a relation between the identified interrelated uncertainties and the gaps in water governance, which is summarized in Table 19. The following paragraphs are devoted at explaining to which gaps each of the six previously defined situations (comprising the interrelated uncertainties) are related to, and what the relation is.

In this study, one uncertainty could be related to more than one gap at once, which resulted in a total of 62 gaps being associated with the identified uncertainties. From these total 48% are information gaps, 18% policy gaps, 16% capacity gaps, 10% accountability gaps and 8% objective gaps. Which means that most of the uncertainties identified by the different stakeholder are related to the information gap. One important aspect of this characterization is the subjectivity involved in the coupling of the uncertainties with the gaps.

TABLE 19: RELATIONSHIP BETWEEN THE IDENTIFIED UNCERTAINTIES AND THE GAPS IN WATER GOVERNANCE

		GAPS IN WATER GOVERNANCE				
		Accountability	Capacity	Information	Objective	Policy
Situation 1:	uncertainties related to the effectiveness of sand nourishments	2	1	4	0	1
Situation 2:	uncertainties related to contracts for the implementation of sand nourishments	0	0	3	2	1
Situation 3:	uncertainties due to munition from WWI&II	1	4	4	0	1
Situation 4:	uncertainties due to the impact of climate change on sand nourishments	1	4	7	0	1
Situation 5:	uncertainties related to the use of sand nourishment for different purposes	1	1	8	1	3
Situation 6:	uncertainties related to participation in the policymaking process	1	0	4	2	4

SITUATION 1: UNCERTAINTIES RELATED TO THE EFFECTIVENESS OF SAND NOURISHMENTS

The uncertainty about the effectiveness of mega nourishments can be related to the accountability gap, since much research is still needed to make this evaluation. Recognizably, the policy already mentions the need for further studies to consolidate the use and applicability of large scale nourishments as well as it points out to the quality of "learning and innovating by experimenting". However, it fails to mention the possible downsides to the implantation, thus falling into the category of accountability gap due to lack of transparency and capacity gap given the lack of expertise. Some stakeholders pointed to the lack of emphasis given to the potential of the nourishments to harm the environment, considering the excavation, the type of sand used and the impact on the local ecosystem, on the coast and on the seabed. This uncertainty can be related to the information gap, with lack of information to guide the decision making process.

There are two gaps associated with the uncertainty about the reliability of models. The first is the capacity gap, the missing technical expertise and the different frames involved can result in the use of diverging models. The second is the information gap. Within the different levels and institutions of the government, different models may be used given the preferences of the different practitioners, which can result in information mismatches. Concerning the location of implementation of the nourishments, there is a relation to the information gap, understood as a deficit in information for the design and implementation of policies. This lack of information is spread out in all three different parts of the system (natural, technical and social). However, the most noticeable, according to the interviewees, refers to the impact on the economy (social system) and environment (natural system).

There is uncertainty about in which cases the nourishments should be implemented, with groups advocating for the natural process to be allowed to follow their course without interference if there is no loss to human safety. This uncertainty can be related to the accountability gap, groups arguing in favor of nature may diverge in opinion with other stakeholders primarily focused on safety or maintenance of the basic coastline. Given that some groups may have political interests and only be engaged according to the electoral calendar, making it more difficult to devise and implement medium and long term measures. Similarly, different stakeholders may diverge on the main objectives of the policy (safety, spatial planning, economy). It can also be associated with the information gap,

Considering the uncertainties about the effectiveness of sand nourishments, there is a relation to the policy gap about it being considered or not a good adaptive strategy for the policy. If the demand for nourishments increase in the future, then there might be an incoherence between sub-national needs and the capacity of the national policy in address them in suitable time.

SITUATION 2: UNCERTAINTIES RELATED TO CONTRACTS FOR THE IMPLEMENTATION OF SAND NOURISHMENTS

The first gap associated with the uncertainties identified in this situation refers to information. In this case, multiple uncertainties are linked to this gap. The lack of proper information can be found in the uncertainty regarding the lifespan of the nourishments. Some stakeholders are concerned with the occurrence of structural damage due to erosion of sensitive areas, especially after heavy

storm events. However, in the view of Rijkswaterstaat, most of the coastal erosion in the Netherlands is not storm driven, and the long term planning of the nourishments are designed to compensate for erosion caused within the nourishment's duration. In this sense, there is a need to improve the communication between these actors in order to avoid mismatched information.

Still concerning the information gap, one important uncertainty refers to the impact of lack of information to local businesses. When the information of the implementation does not reach the local entrepreneurs and owners of beach properties, there is uncertainty about the extent of the economic impact caused by the implementation. In theory, the plans for the implementation are update yearly and are open for consultation. Furthermore, the contractors should inform Rijkswaterstaat of the implementation at most six weeks prior to the beginning of work. However, other stakeholders found that this information often arrives at the municipality level only two weeks prior to the start of the project.

Another gap associated here is the objective gap. The flexibility given to contractors is, on the one hand, beneficial for cost reductions, which is highly desirable for the stakeholders responsible for the investment and management. On the other hand, regional and local stakeholders, such as province and municipality, may be concerned with the occurrence of damages if the contractors opt for implementing the nourishment only towards the end of the contract period. Another uncertainty associated concerns when in fact the implementation will take place, with a large influence of the national and international demand for sand works.

Lastly, there is the policy gap related to the ambiguity about changes in the contract structure in case of economic or safety risks. Here, the province of Zeeland believes that a special provision in the contract should be made. Therefore, there is a confusion between sub-national needs and the national policy.

SITUATION 3: UNCERTAINTIES DUE TO MUNITION FROM WWI&II

In the matter of dumped munition from WWI&II, the first gap identified is the accountability gap in reference to the uncertainties about accidents with these munitions. There is still limited knowledge of the location of the dumpsites and dredging works are arranged to avoid known locations. The lack of a defined acceptable risk contributes to the existence of this gap. Still in relation to this uncertainty there is a capacity gap as well. Knowing the location of the dumpsites as well as to develop and implement measures to avoid accidents require the policy to close deficits in scientific and technical expertise.

There are gaps related to information concerning the uncertainties about the behavior of people and the media about the perception of people to the risks about the presence of munition either during the extraction phase, or after on the beach, due to the implementation of the nourishments. The matter of responsibility for dealing with this situation falls under the objective and policy gap. Similarly, the use of models and methodologies fall under the information and capacity gaps to address the acceptable risk and to include in the policy, management, and implementation aspects how this issue should be handled.

SITUATION 4: UNCERTAINTIES DUE TO THE IMPACT OF CLIMATE CHANGE ON SAND NOURISHMENTS

There is a relation to the accountability gap in what concerns the uncertainty about the impact of climate change over the feasibility of sand nourishments. On the one hand, some actors believe that the impacts of climate change can reduce significantly the effectiveness of the nourishments. On the other hand, actors with technical knowledge have theoretical background to support their belief in the usability of the nourishments to counteract the impacts of climate change. In this sense, this accountability gap can shift towards an information gap, where the technical knowledge is not transferred equally between different actors.

For this particular situation, the information and capacity gaps can be observed simultaneously for several of the interrelated uncertainties. Going from the uncertainty about the availability of sand, which requires an evaluation of the multiple uses of sand as well as the feasibility of extraction. It also includes the subject of the impact of climate change on the occurrence and intensity of storms as well as on sea levels and wind. In both cases, when the information is available it might not reach all stakeholders involved, and the lack in expertise may compromise the quality of the information used for the elaboration of the plan. Two ambiguities can also be related to the information gap, the first concerning if there is or not climate change and the second about its implication on sea level rise. For both, mismatch in sources of information are the main cause for their existence.

In light of the uncertainties about the impact of climate change on the effectiveness of sand nourishments, there is a relation to the policy gap in reference to the uncertainty about it being considered or not a good adaptive strategy for the policy. If the demand for nourishments increase with climate change, then there might be an incoherence between sub-national needs and the capacity of the national policy in address them in suitable time.

SITUATION 5: UNCERTAINTIES RELATED TO THE USE OF SAND NOURISHMENT FOR DIFFERENT PURPOSES

The accountability gap can be verified in the uncertainty about which are the cases when sand nourishments should be implemented, also associated with the information gap. Here, transparency and proper information are crucial for the policy. The information gap can also be seen throughout other uncertainties: in regard to the availability of sand, as previously mentioned; concerning the impact of these nourishments to nature; related to the behavior of people and the media, and to how much are people willing to change; including uncertainties about the location of the implementation and the impact on recreation. In all the above mentioned uncertainties, either the lack of information or mismatch of information between different actors can be linked to the referred gap.

Another gap that appears more than once is the policy gap. In this case, it is related to the uncertainties about other purposes for sand nourishments and how they could benefit the coast. Although safety is the primary function of the policy, other pillars include a link to sustainability, spatial planning and economic feasibility. The use of sand nourishments considering these attributes could align with sub-national needs while not being fully addressed by the national initiative. Furthermore, the uncertainty about financing such alternative uses can be related to both the policy and objective gap. For the policy gap it relates to the reason previously mentioned, and

for the objective gap, different actors, from national down to local level, have different views on their own objectives, as well as distinct levels of being able to finance such expensive projects.

SITUATION 6: UNCERTAINTIES RELATED TO PARTICIPATION IN THE POLICYMAKING PROCESS

Similar to the previous situation, the accountability gap can be verified in the uncertainty about which are the cases when sand nourishments should be implemented, also associated with the information gap. The information gaps are related to the unpredictability in the behavior of people and media as well as on the uncertainty about where the nourishments should be implemented. The lack of information or mismatch of information between different actors is the main drive of these uncertainties.

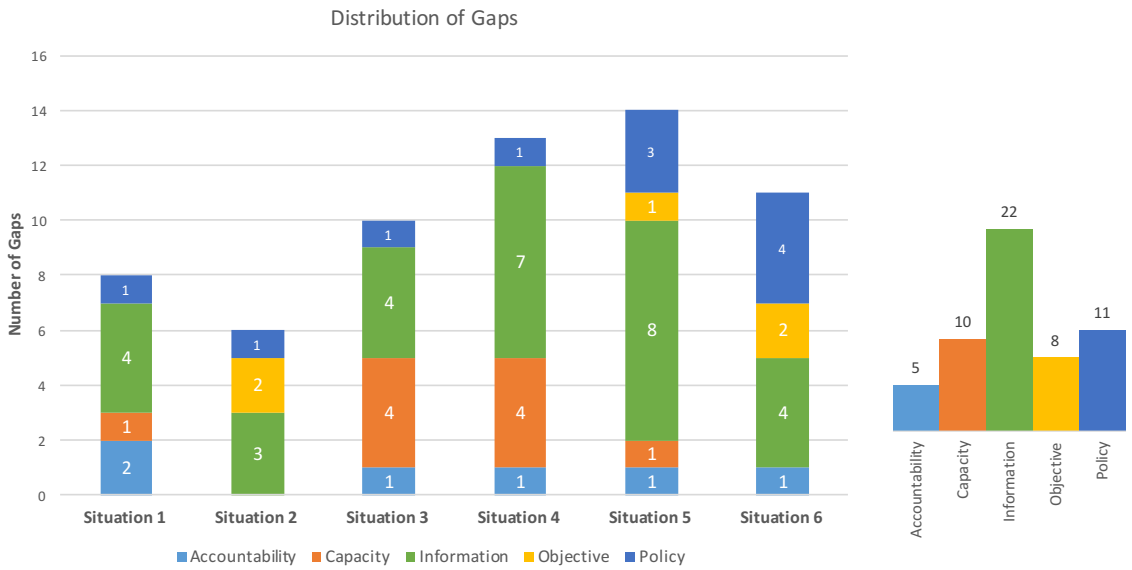
The policy gap is also very present in this situation and often it is combined with the objective gap. In the uncertainty regarding the effect of more participation in the policymaking process and on how to integrate policy and implementation strategies these two gaps can be associated. Here, opposing or diverging objectives driving different stakeholders, varying from national to local, can be considered a source of disruption for the policy. Which can be directly associated to the policy gap in reference to the uncertainty about sand nourishment being considered or not a good adaptive strategy for the policy, since more involvement increases the possibility of more distinct views that, if left out of the policy can be the cause of conflicts.

5.2 STRATEGIES TO COPE WITH THE IDENTIFIED UNCERTAINTIES AND THE BRIDGING GAPS IN WATER GOVERNANCE

Most commonly than not, only identifying and treating the sources of uncertainties in insolation results in policies that lack preparation to manage multiple risks at once (Jensen and Wu, 2016). Moreover, Dewulf et al. (2005) states that while attempts have been made to address uncertainties resulting from imperfect knowledge and in the measurement of unpredictability, efforts in addressing unpredictability and dealing with ambiguity from multiple knowledge frameworks has been sarce.

Figure 17 shows the distribution of the gaps within the different situations of uncertainty previously identified and explained as well as the total number of gaps per gap type. As mentioned above, the information gap appears the most in connection with the identified uncertainties. One possible strategy to cope with the uncertainties and bridge the gaps in water governance is to develop measures to address the different gaps, in relation to the uncertainties associated with ech gap. Here, however, the coping strategies provided are related to the situations of uncertainties that resulted from the interviews with the different stakeholder groups. At this point, new coping strategies are mentioned as well as the ones currently being used by the Delta Programme.

FIGURE 17: DISTRIBUTION OF GAPS WITHIN THE IDENTIFIED SITUATIONS OF UNCERTAINTIES



The following paragraphs present the coping strategies suggested for each situation of uncertainties. It is important to mention that some of the coping strategies indicated, extracted from the literature, are directly related to the nature of the uncertainty it refers to. Therefore, given the subjective characteristics of the distribution of the identified uncertainties within the matrix of uncertainties (Table 17), it is possible that different coping strategies would be advisable if the couple uncertainty was allocated differently.

SITUATION 1: UNCERTAINTIES RELATED TO THE EFFECTIVENESS OF SAND NOURISHMENTS

For the uncertainties from incomplete knowledge, one important strategy is to gather more data and conduct more scientific research to improve the knowledge base. This new knowledge can be beneficial in bridging the information gap in the case of the impact of mega nourishments on the environment as well as about the location for the implementation. Moreover, factual data can be used to improve transparency, which can go towards closing the accountability gap. Similarly, this improvement on the knowledge base can help the identification of when the nourishments are suitable.

As mentioned before, the Delta Programme is already built on the approach of "learning and innovating by experimenting", which is supposed to work with the embedded uncertainties surrounding the coastal system. However, much of the focus I given to the technical aspects of the sandy system and the interaction with other elements either composing or affect is somewhat less explored.

There are two ambiguities present in this situation, one about the models used and the other on the acceptability of sand nourishment as an adaptive policy. For the first one, one strategy that could help close the gap about information is promoting dialogues and learning through the engagements of stakeholders in an interactive communication process to reach a joint problem definition and a subsequent result that is beneficial to all of them. The same strategy could be used

to address the second ambiguity, or either persuasive communication where informing the purposefulness of one particular reference frame may dissolve ambiguities.

Table 20 presents the coping strategies for the different uncertainties showing in bold the strategies discussed above.

TABLE 20: COPING STRATEGY RELATED TO THE EFFECTIVENESS OF SAND NOURISHMENTS

	UNCERTAINTIES		COPING STRATEGIES
INCOMPLETE KNOWLEDGE	[4]	What is the impact of large scale sand nourishments on the environment?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Use simulation models to evaluate implications of imperfect knowledge
	[11]	In which cases should sand nourishments be implemented?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Use simulation models to evaluate implications of imperfect knowledge
	[13]	What is the effectiveness of large scale sand nourishments for protection of the coast?	• **More data gathering and scientific research to complete or improve factual knowledge base** • **Use simulation models to evaluate implications of imperfect knowledge** • Uncertainty propagation in models
	[21]	Where should the nourishments be implemented?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Use simulation models to evaluate implications of imperfect knowledge
MULTIPLE KNOWLEDGE FRAMES	[15]	Which models are reliable and should be used?	• Cognitive problem solving • **Dialogical learning** • Negotiation approach
	[33]	Is sand nourishment a good adaptive strategy?	• Cognitive problem solving • Persuasive communication • **Dialogical learning** • Negotiation approach

SITUATION 2: UNCERTAINTIES RELATED TO CONTRACTS FOR THE IMPLEMENTATION OF SAND NOURISHMENTS

For the uncertainties from incomplete knowledge, both related to the information gap, more data and research could be used to, in the case of the uncertainty about the lifespan of the nourishment, help identify situation in which adaptations are needed, which may require simulations to evaluate possible scenarios. Concerning the impact on the lack of timely information of the implementation of the nourishments to the local businesses, this data gathering may come in the form of surveys and researches to investigate the different impacts, especially socio-economic.

For the unpredictability concerning when the contractors will in fact implement the nourishments, it is possible that with better communication between different stakeholders, the objective gap can be closed. This approach diverges from the coping strategies from other unpredictabilities due to this uncertainty being very close to an ambiguity, calling for different actors to align their frames in other to achieve a better result.

Each of the three ambiguities identified for this situation can be linked to a different gap. The uncertainty about when Rijkswaterstaat and the contractors should inform regional and local stakeholders of the implementation of the nourishments is connected to the information gap. This strategy's outcome is expected to be a settlement of a fair deal resulting from calculative involvement where actors engage in information exchange and positioning strategy, using negotiation skills despite the frame differences.

The next ambiguity, referring to the length of the contracts for the implementation of the nourishments can be linked to the objective gap. Here, the difference in view of the national government, interested in the rational use of taxpayer's money, and regional/local agencies, with their own socio-economic interests can be a source of conflict. For this gap, either the negotiation approach can be used, similar to the previous paragraph, or the cognitive problem solving strategy, invoking scientific evidence to arbitrate the frame differences, where a scientist or expert makes use of factual information to convey insights objectively to other about a problem Similarly, concerning the last ambiguity, which is related to the policy gap, the same strategy could be used.

Table 21 presents the coping strategies for the different uncertainties showing in bold the strategies discussed above.

TABLE 21: COPING STRATEGY RELATED TO THE CONTRACTS FOR THE IMPLEMENTATION OF SAND NOURISHMENTS

	UNCERTAINTIES		COPING STRATEGIES
UNPREDICTABILITY	[16]	When will the sand nourishments be implemented?	• **Improve communication between different stakeholders**
INCOMPLETE KNOWLEDGE	[14]	What should be the timescale of the nourishments?	• **More data gathering and scientific research to complete or improve factual knowledge base** • **Use simulation models to evaluate implications of imperfect knowledge**
	[19]	What is the impact of lack of information to local businesses?	• **Perform surveys to investigate the impact on local businesses**
MULTIPLE KNOWLEDGE FRAMES	[26]	When should RWS inform the province/municipalities of the implementation of SN?	• Dialogical learning • **Negotiation approach**
	[27]	How long should the period the contractors have to implement the SN be?	• **Cognitive problem solving** • Dialogical learning • **Negotiation approach**
	[28]	Should there be a provision in the contracts allowing for shorter timeframe for implementation in case of safety/economic risks?	• **Cognitive problem solving** • Dialogical learning • Negotiation approach

SITUATION 3: UNCERTAINTIES DUE TO MUNITION FROM WWII

There are two uncertainties from unpredictability related to the behavior of people and the media and both can be associated with the information gap. In both cases, the unpredictable behavior may be related to a lack of awareness about sand nourishments or by insufficient information from reliable sources reaching them. In any case, one strategy to cope with this unpredictability is to devise damage control measure, which, in this case, are translated into the governmental bodies responsible for the policy and implementation of sand nourishments having efficient personal capable of gathering and transmitting proper information as well as handling situations of adverse behaviors.

Concerning the incomplete knowledge about the location of dumped munitions, how to avoid accidents and how to measure the risks involved, one common gap is the capacity. In all cases, more data gathering associated with proper scientific research to complete or improve the knowledge base is a beneficial strategy. The uncertainty about the location also involves the accountability gap, where more transparency is needed to solve this issue. In this case, the quality of the data acquired combined with the opinion of experts can be used to bridge this gap. The uncertainty about the risks involved with munition can also be linked to the information gap. One alternative is to devise what the acceptable risk is in alliance with different stakeholders involved.

There are two ambiguities present in this situation, one about the models used and the other on the attribution of responsibility for handling the issue of munition in relation to the implementation of sand nourishments. For the first one, one strategy that could help close the gap about information is promoting dialogues and learning through the engagements of stakeholders in an interactive communication process to reach a joint problem definition and a subsequent result that is beneficial to all of them. The same strategy could be used to address the second ambiguity, or either persuasive communication where informing the purposefulness of one particular reference frame may dissolve ambiguities.

Table 22 presents the coping strategies for the different uncertainties showing in bold the strategies discussed above.

TABLE 22: COPING STRATEGY RELATED TO MUNITION FROM WWI&II

	UNCERTAINTIES		COPING STRATEGIES
UNPREDICTABILITY	[17]	How will beachgoer behave?	• **Damage control** • Develop solutions robust to multiple possible futures
	[18]	How will the media, especially social media behave?	• **Damage control** • Develop solutions robust to multiple possible futures
INCOMPLETE KNOWLEDGE	[5]	Where are the munition of the WWI&II located?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Use simulation models to evaluate implications of imperfect knowledge • Uncertainty propagation in models • **Use expert opinions**

	UNCERTAINTIES		COPING STRATEGIES
	[10]	How to avoid accidents with munition from WWI&II?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Use simulation models to evaluate implications of imperfect knowledge • Use expert opinions
	[22]	What are the risks of munition to people and structures?	• More data gathering and scientific research to complete or improve factual knowledge base
MULTIPLE KNOWLEDGE FRAMES	[15]	Which models are reliable and should be use?	• Cognitive problem solving • **Dialogical learning** • Negotiation approach
	[31]	Who should be responsible for dealing with munition found on the coast?	• Cognitive problem solving • Persuasive communication • **Dialogical learning** • **Negotiation approach**

SITUATION 4: UNCERTAINTIES DUE TO THE IMPACT OF CLIMATE CHANGE ON SAND NOURISHMENTS

There are two uncertainties from unpredictability in this situation and both can be related to the information gap. The first one refers to the impact of climate change on the occurrence and intensity of storms and the second on the impact of these storms on the Dutch coast. A possible strategy to counteract these uncertainties and to close the gap is to develop solutions that are adaptable for different possible futures.

The Delta Programme already affirms that the consequences of climate change on the flood safety can be dealt with if the management and maintenance of the coast are kept for the coming century. All the forecasts used are based on delta scenarios having as input climatological data from KNMI and socio-economic data from WLO. These scenarios predict the increase of storms, but points towards the uncertainty of the speed of development. According to Rijkswaterstaat, the main cause for coastal erosion is not storm driven. Therefore, to manage this gap one alternative is to improve the reach of this information across different stakeholders.

Two of the uncertainties from incomplete knowledge can be related to the gaps in information and capacity. The first one concerns the sand availability and the second the impact of climate change on sea levels and wind. In both cases a coping strategy is gathering more data associated with proper scientific research to complete or improve the knowledge base.

In the Delta Programme it is stated that enough sand is available to keep the coast safe with good extraction sites close to the coast with extraction up to a layer of 10 meters. With this in mind, it is important to diffuse this information and keep the studies up to date with current trends for sand demand and sea level rise. Furthermore, the program also mentions that the current sand replenishments have to be gradually adapted (in terms of volume) to balance the rise in sea levels.

The last uncertainty from incomplete knowledge refers to the impact of climate change on the feasibility of the nourishments, being related to the accountability and information gaps. In case of the accountability, the lack of transparency comes from suppressing negative characteristics of sand nourishments or giving only emphasis to the positive effects. The lack of data on the impacts of the nourishments over the environment in light of climate change is associated with the information gap. A possible coping strategy is to gather data and model the nourishments, considering its implications for the different aspects of the system (social, economic, environmental) in order to disclosure possible improvements in the current practice as well as enhance the quality of information and decisions regarding the nourishments.

From the ambiguities identified in this situation, three can be associated with the information gap: the ambiguity about the existence of climate change, on the rise in sea level, and on the models to be used. For the first two, scientific data on the existence and effects of climate change is very prominent, an alternative to cope with frames diverging from the scientific evidences is to use persuasive communication strategies, such as awareness raising campaigns. These campaigns basically consist of systematically communicating through a media outlet a specific concern, in this case about the importance of climate change. For the third one, one strategy that could help close the gap about information is promoting dialogues and learning through the engagements of stakeholders in an interactive communication process to reach a joint problem definition and a subsequent result that is beneficial to all of them, which also addresses the capacity gap associated with this uncertainty. The same strategy could be used to address the ambiguity about sand nourishments as adaptive strategy, or either persuasive communication where informing the purposefulness of one particular reference frame may dissolve ambiguities.

Table 23 presents the coping strategies for the different uncertainties showing in bold the strategies discussed above.

TABLE 23: COPING STRATEGY RELATED TO THE IMPACT OF CLIMATE CHANGE ON SAND NOURISHMENTS

	UNCERTAINTIES		COPING STRATEGIES
UNPREDICTABILITY	[1]	What is the impact of climate change in the occurrence and intensity of storms on the Dutch coast?	• **Develop solutions robust to multiple possible futures**
	[9]	What is the impact of more storms on the coastal protection system?	• **Develop solutions robust to multiple possible futures**
INCOMPLETE KNOWLEDGE	[2]	How much sand is available?	• Range estimation (confidence intervals) • **More data gathering and scientific research to complete or improve factual knowledge base**
	[3]	What is the impact of climate change on sea levels and wind?	• Range estimation (confidence intervals) • **More data gathering and scientific research to complete or improve factual knowledge base**
	[12]	What is the impact of climate change on the feasibility of sand nourishments?	• **More data gathering and scientific research to complete or improve factual knowledge base** • **Use simulation models to evaluate implications of imperfect knowledge** • Use expert opinions

	UNCERTAINTIES		COPING STRATEGIES
MULTIPLE KNOWLEDGE FRAMES	[6]	Is there climate change?	• Cognitive problem solving • **Persuasive communication** • Dialogical learning
	[7]	How much is the sea level rising?	• Cognitive problem solving • **Persuasive communication**
	[15]	Which models are reliable and should be used?	• Persuasive communication • **Dialogical learning** • Negotiation approach
	[33]	Is sand nourishment a good adaptive strategy?	• Cognitive problem solving • **Persuasive communication** • **Dialogical learning** • Negotiation approach

SITUATION 5: UNCERTAINTIES RELATED TO THE USE OF SAND NOURISHMENT FOR DIFFERENT PURPOSES

The three uncertainties due to unpredictability related to this situation can be linked to the information gap. As mentioned before, the two uncertainties related to the behavior of people and the media and both can be associated with the information gap. In both cases, the unpredictable behavior may be related to a lack of awareness about sand nourishments or by insufficient information from reliable sources reaching them and the same coping strategy applies. For the uncertainty about the impact of sand nourishments on nature a coping strategy is to make sure all stakeholders are aware of the adaptive quality of the policy, and that the solution is equipped to handle multiple possible futures.

The uncertainty of the sand availability from incomplete knowledge can be related to the gaps in information and capacity, a coping strategy is gathering more data associated with proper scientific research to complete or improve the knowledge base. Other uncertainties from incomplete knowledge can be associated with the information gap. Concerning how much people are willing to change, one strategy is to improve the communication between scientists and decision makers. People working either on policies or on the implementation may have differences in how to perceive the relation between problem and solution and a good channel of communication can help bridge this gap. For the uncertainties about in which case should the nourishments be implemented, where should the nourishments be implemented, and what is the impact of nourishments for the recreation, the coping strategy devised is to gather more data associated with proper scientific research to complete or improve the knowledge base. This data and research should be used to make sure all stakeholders involved are well informed.

The uncertainty about in which cases the nourishments should be implemented is also related to the accountability gap, requiring increase in transparency. The Delta Programme already recognizes the need for transparency in itself, referring to adaptive delta management as the transparent way to account for uncertainty in the decision-making process.

All three ambiguities can be associated with the policy gap. The ambiguities about other purposes for sand nourishments and the benefits of sand nourishments for other attributes of the coast can be managed with dialogical learning, through the engagements of stakeholders in an interactive communication process to reach a joint problem definition and a subsequent result that is beneficial to all of them.

For the ambiguity about financing sand nourishments for other purposes, which is also associated with the objective gap, a coping strategy could be using cognitive problem solving, finding solutions to a problem by trying invoking scientific evidence to arbitrate the frame differences. Another option is through the negotiation approach, where, despite the frame differences, the outcome is expected to be a settlement of a fair deal resulting from calculative involvement where actors engage in information exchange and positioning strategy.

Table 24 presents the coping strategies for the different uncertainties showing in bold the strategies discussed above.

TABLE 24: COPING STRATEGY RELATED TO THE USE OF SAND NOURISHMENT FOR DIFFERENT PURPOSES

	UNCERTAINTIES		COPING STRATEGIES
UNPREDICTABILITY	[8]	What is the impact of sand nourishments on nature?	• **Develop solutions robust to multiple possible futures** • Combine multiple strategies
	[17]	How will beachgoers behave?	• **Damage control** • Develop solutions robust to multiple possible futures
	[18]	How will the media, especially social media behave?	• **Damage control** • Develop solutions robust to multiple possible futures
INCOMPLETE KNOWLEDGE	[2]	How much sand is available?	• Range estimation (confidence intervals) • **More data gathering and scientific research to complete or improve factual knowledge base**
	[11]	In which cases should sand nourishments be implemented?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Uncertainty propagation in models • **Use expert opinions**
	[20]	How much are people willing to change?	• Use expert opinions • **Improve communication between scientist and decision makers**
	[21]	Where should the nourishments be implemented?	• **More data gathering and scientific research to complete or improve factual knowledge base** • **Use simulation models to evaluate implications of imperfect knowledge**
	[23]	What is the impact of sand nourishments for recreation?	• **More data gathering and scientific research to complete or improve factual knowledge base**

	UNCERTAINTIES		COPING STRATEGIES
MULTIPLE KNOWLEDGE FRAMES	[29]	What are other possible purposes for sand nourishments?	• Cognitive problem solving • Persuasive communication • **Dialogical learning**
	[30]	Who should finance sand nourishment for these other purposes?	• **Negotiation approach** • **Cognitive problem solving** • Persuasive communication
	[32]	How can sand nourishments benefits other attributes/uses of the coast?	• Cognitive problem solving • Persuasive communication • **Dialogical learning**

SITUATION 6: UNCERTAINTIES RELATED TO PARTICIPATION IN THE POLICYMAKING PROCESS

As mentioned before, the uncertainty related to the behavior of the media can be associated with the information gap. The unpredictable behavior may be related to a lack of awareness about sand nourishments or by insufficient information from reliable sources reaching them and the same coping strategy applies.

There are several uncertainties from incomplete knowledge. The uncertainty about in which cases the nourishments should be implemented is also related to the accountability gap, requiring increase in transparency, which has been already mentioned before. It is also linked to the information gap, where more data associated with proper scientific research can be used to complete or improve the knowledge base. The same is valid for the uncertainties about where should the nourishments be implemented, and what is the impact of nourishments for the recreation. There are two uncertainties related to the policy and objective gaps, the first about the effect of more participation and the second on the integration of policy and practice. For the first, more data associated with proper scientific research can be used to complete or improve the knowledge base associated with improving the communication between scientists and decision makers. People working either on policies or on the implementation may have differences in how to perceive the relation between problem and solution and a good channel of communication can help bridge this gap, which can also be used for the second uncertainty.

There are two ambiguities related to the policy gap. The ambiguity about the benefits of sand nourishments for other attributes of the coast can be managed with dialogical learning, through the engagements of stakeholders in an interactive communication process to reach a joint problem definition and a subsequent result that is beneficial to all of them. The same strategy could be used to address the ambiguity about sand nourishments as adaptive strategy, or either persuasive communication where informing the purposefulness of one particular reference frame may dissolve ambiguities.

Table 25 presents the coping strategies for the different uncertainties showing in bold the strategies discussed above

TABLE 25: COPING STRATEGY RELATED TO PARTICIPATION IN THE POLICYMAKING PROCESS

	UNCERTAINTIES		COPING STRATEGIES
UNPREDICTABILITY	[18]	How will the media, especially social media behave?	• **Damage control** • Develop solutions robust to multiple possible futures
INCOMPLETE KNOWLEDGE	[11]	In which cases should sand nourishments be implemented?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Uncertainty propagation in models • **Use expert opinions**
	[20]	How much are people willing to change?	• Use expert opinions • **Improve communication between scientist and decision makers**
	[21]	Where should the nourishments be implemented?	• **More data gathering and scientific research to complete or improve factual knowledge base** • **Use simulation models to evaluate implications of imperfect knowledge**
	[24]	What is the effect of more participation on the policymaking process?	• **More data gathering and scientific research to complete or improve factual knowledge base** • Use expert opinions • **Improve communication between scientist and decision makers**
	[25]	How to integrate policy and implementation strategies?	• Use expert opinions • **Improve communication between scientist and decision makers**
MULTIPLE KNOWLEDGE FRAMES	[32]	How can sand nourishments benefits other attributes/uses of the coast?	• Cognitive problem solving • Persuasive communication • **Dialogical learning**
	[33]	Is sand nourishment a good adaptive strategy?	• Cognitive problem solving • **Persuasive communication** • **Dialogical learning** • Negotiation approach

In general, the coping strategy being suggested are summarized in Table 26. By far, the strategy appearing the most refers to more data gathering and scientific research to complete or improve factual knowledge base. The ambiguities are the uncertainties with the most diverse distribution of coping strategies, while for unpredictability and incomplete knowledge there were only two strategies suggested for each. This high demand for more data and scientific research can be associated to the high number of uncertainties related to the information gap, being a mechanism to be used in order to reduce the lack of proper information or the mismatch of information across different actors.

TABLE 26: COPING STRATEGIES SUGGESTED TO BRIDGE GAPS IN WATER GOVERNANCE

	COPING STRATEGY	APPEARANCES
UNPREDICTABILITY	Develop solutions robust to multiple possible futures	3
	Damage control	2
INCOMPLETE KNOWLEDGE	More data gathering and scientific research to complete or improve factual knowledge base	14
	Improve communication between scientist and decision makers	3
AMBIGUITY	Cognitive problem solving	2
	Persuasive communication	2
	Dialogical learning	5
	Negotiation approach	2

The use of dialogical learning for handling ambiguities seems appropriate since the reason behind it is that actors can learn about each other's perspectives using constructive and reciprocal communication in order to develop a mutual understanding. Therefore, the effectiveness of the process outcome is dependent on the involvement of as many actors as possible (Brugnach et al., 2011), which is one of the aims of the Delta Programme.

The success of this strategy, according to Vansina and Vansina-Cobbaert (2008), relies on the willingness of the actors to overcome frame differences to develop a joint problem definition rather than impose their own views. In this sense, the differences should be regarded as opportunities to explore different perspectives, provide access to resources, skills and competences that could be implemented to address the problem more effectively (Brugnach et al., 2011).

Brugnach et al. (2011) warns about a possible setback of the dialogical learning strategy regarding its requirement for high social skills and the willingness to engage in a constructive dialogue. Moreover, the success of collaborative processes could be jeopardized by the occurrence of stereotyping, distrust, power games, lacked of shared vision, and conflictive personalities (Gray, (1989); Vansina, Taillieu and Schruijer (1998); Schruijer (2006)). Here, one important limiting factor is time. If not managed well, the process of dialogical learning can become vague and not reach concrete points, hampering the legitimacy and urgency of the process. Complementary, there is a need to access and evaluate the risks involved in implementing such coping strategy, which is also valid for the other measures proposed.

CHAPTER 6: **CONCLUSION AND RECOMMENDATIONS**

In the research objective of this research was to *"To identify possible uncertainties based on the interpretation of different stakeholders regarding the use of sand nourishments in the context of Dutch coastal adaptation to climate change, to relate them with the gaps in water governance and propose coping strategies in order to bridge the existing gaps."* For that purpose, three research questions were drawn and can be answered:

1. **What are the characteristics of the stakeholders interviewed?**
   1.1. Which stakeholders will be considered for this research?
   1.2. What are their power and interests?
   1.3. What are their frames on the use of sand nourishments in this context?

In this research six of the 10 potential stakeholder groups were interviewed and the other 4 groups, due to time limitations, could not be included in this analysis. For the purpose of this research, and considering the time limitation, the group of stakeholders interviewed already provide significant insights for the development of conclusions and can be characterized as follows.

The Ministry of Infrastructure and Environment, Rijkswaterstaat and the water board are classified as ***definite stakeholders*** when it comes to sand nourishments along the Dutch coast due to the responsibilities attributed to them by force of law, with a primarily focus on safety: of the coastline for the Ministry of Infrastructure and Environment and Rijkswaterstaat, and safeguard the primary function of flood protection of the dunes for the water board. The province is classified as a ***dominant stakeholder*** with an indirect relation to the management of the coast. The coastal provinces are the link between the national government and the local authorities and other private groups along the coast. Another moderate stakeholder is the nature group, considered a ***dependent stakeholder***. Their main limitation is power, since they are not directly included in the decision making process, other than during consultation phases, and thus depending on others for the power to protect their interests. The board of tourism represents the interests of visitors and local businesses affected by changes on the Dutch coast. Their little influence in decision processes and relevantly little sense of urgency makes them ***discretionary stakeholders***.

Their frames can be summarized as:

Ministry of Infrastructure and Environment	• Sand nourishments are an efficient way to protect the coast against floods in face of changes posed by climate change
Rijkswaterstaat	
Water Board: Hollands Noorderkwartier	• Sand nourishments are an important measure for the safety of the coast
Province of Zeeland	• Sand nourishments are an important measure to maintain the economic and recreational functions of the coast • Knowing when the implementation of sand nourishments is going to occur, specially beach replenishments, is considered very important
Nature NGO Natuurmonumenten	• Sand nourishments should not reduce the quality of the existing nature
Board of Tourism	• Sand nourishments can be beneficial for coastal tourism

2. What are the characteristics of the identified uncertainties?

2.1. What are the main uncertainties according to the stakeholders? (obtained directly or indirectly from the interviews)
2.2. How are these uncertainties interrelated?
2.3. How do the interrelated uncertainties appear in the context of the Delta Programme?

From the interviews, 33 uncertainties were identified. All uncertainties were either explicitly or implicitly mentioned by one or more stakeholders, with direct uncertainties representing 45% of the total. Considering the nature of the uncertainties identified, the ones from Incomplete Knowledge represent 49% of the total (12% direct / 37% indirect), whereas ambiguity comprises 36% (21% direct / 15% indirect), and unpredictability 15% (12% direct / 3% indirect). When it concerns the location in the system, 55% of the uncertainties appear in the social part and 24% in the natural part and 21% in the technical. Combining the three aspects (Direct/indirect, nature and location in the system), the largest number of uncertainties identified are from the indirect incomplete knowledge in the social system, with 5 uncertainties (or 15% of the total). These uncertainties were grouped into six situations of interrelated uncertainties:

		NUMBER OF UNCERTAINTIES	IN DELTA PROGRAMME
Situation 1:	uncertainties related to the effectiveness of sand nourishments	6	Yes
Situation 2:	uncertainties related to contracts for the implementation of sand nourishments	6	No
Situation 3:	uncertainties due to munition from WWI&II	7	No
Situation 4:	uncertainties due to the impact of climate change on sand nourishments	9	Yes
Situation 5:	uncertainties related to the use of sand nourishment for different purposes	11	Yes
Situation 6:	uncertainties related to participation in the policymaking process	8	Yes

The situation concerning the uncertainties related to the use of sand nourishments for different purposes presents the highest number of interrelated uncertainties, 11. Both the situation of the uncertainties related to the effectiveness of sand nourishments and the situation of uncertainties related to contracts for the implementation of sand nourishments have the least number of interrelated uncertainties, with six each. For two out of the six situation, no information was found in any of the documents selected, concerning the situation of uncertainties related to contracts for the implementation of sand nourishments and the situation of uncertainties due to munition from WWI&II. For the remaining four, although they were mentioned in the policy, the framing given by the policy usually diverged from the one of the stakeholders.

3. How can the identified uncertainties improve the ability of the Delta Programme in bridging gaps in water governance?

3.1. What is the relation between the identified uncertainties and the gaps in water governance according to the OECD framework?
3.2. What is the relation between the coping strategies for the identified uncertainties and the potential of the Delta Programme in bridging the existing gaps in water governance?

The characterized and interrelated uncertainties could be related to the different gaps present in the Dutch water governance. From the resulting coupling, the information gap is the one that

appears the most in connection with the identified uncertainties, being associated 22 times, followed by the policy gap with 11 times, capacity gap with 10, objective gap with 8, and lastly the accountability gap with 5 mentions. Considering the high number of times the information gap occurs, one possible conclusion is that although must is already done by the Delta Programme in regard to the uncertainties mentioned by the stakeholder and, still, the information does not reach every different sector equally. Once again, the situation concerning the uncertainties related to the use of sand nourishments for different purposes presents the highest number gaps in water governance associated to the identified uncertainties, with a total of 14 gaps identified.

The coping strategy mentioned the most, in reference to uncertainties from incomplete knowledge, is to gather more data and conduct scientific research to complete or improve factual knowledge base, appearing 14 times. The ambiguities are the uncertainties with the most distribution of coping strategies. The high demand for more data and scientific research can be associated with the high number of uncertainties related to the information gap, and act as a mechanism to reduce the lack of proper information or information mismatch, when associated with good communication strategies.

Limitations

There are limitations regarding the matrix of uncertainty. The first one concerns the impossibility of linking one uncertainty to more than one component of the system (natural, technical, social). The second refers to the subjectivity of the classification, which in this case is bound to the interpretation of the researcher over the information provided by the stakeholders (for the uncertainties obtained indirectly), or to the interpretation of the stakeholders (for the ones obtained directly). The third limitation involves the level of participation required from the people interviewed. When the interviewees are more familiarized with the matrix or with concepts of uncertainties, it becomes easier for them to fill the matrix. The observation of the researcher is that, more often than not, the stakeholders do not have full capacity to fill the matrix on their own, or did not show interest in the method. Limitations are also present in the use of the cascade of uncertainties. In this case, the main limitation verified is the one directional characteristic of the cascade. One main limitation concerning the research is the high level of subjectivity involved in different characterizations, of the uncertainties, the interrelations, the gaps in water governance and coping strategies. Another significant limitation was time. Due to time constraints, the window for interviewing the stakeholders was very short, and some groups were not interviewed. Furthermore, this time restriction also prevented the application of a second moment with the stakeholders to validate the information obtained.

Recommendations for further research

The first recommendation is to include the other stakeholders that were suppressed due to time constraints. More moments of contact with the stakeholder could be beneficial to validate the information as well as to clarify possible doubts. One other important point not addressed in this research is the different level of importance of each of the identified uncertainties as well as the risks associated to the coping strategies proposed.

Final remarks

In short, the Delta Programme provides already an important step towards an adaptive and integrative process for water management, with this research focusing on the use of sand nourishments as the main strategy to manage the Dutch coast in light of sea level rise. However, interviews with different stakeholder groups, that are either involved in the implementation of sand nourishments or are affected by them, shows that there are many uncertainties involved. As proposed by the working assumption earlier made in this research, there is a relation between these uncertainties and the gaps in water governance. Therefore, managing these uncertainties also impact the existence and extent of these gaps and their repercussion to the Dutch water governance. Although the findings of this research are limited and subjected to the interpretation of the researcher, and more emphasis is needed for the validation process of the information, it provides a good starting point for further discussions in how to improve, not only the Delta Programme, but the water governance of the Netherlands.

REFERENCES

Benford, R.D. and Snow, D.A. (2000) 'Framing processes and social movements: an overview and assessment.', *Annual Review of Sociology*, vol. 26, pp. 611-639.

Bouwen, R., Dewulf, A. and Craps, M. (2006) 'Participatory development of technology innovation projects: collaborative learning among different communities of practice.', *Anales de la Universidad de Cuenca*, pp. 127-142.

Brown, J. (2004) 'Knowledge, uncertainty and physical geography: towards the development of methodologies for questioning belief', *Transactions of the Institute of British Geographers*, vol. 29, no. 3, pp. 267-381.

Brugnach, M., Dewulf, A., Henriksen, H.J. and Keur, P.v.d. (2011) 'More is not always better: Coping with ambiguity in natural resources management ', *Journal of Environmental Management*, vol. 92, pp. 78-84.

Brugnach, M., Dewulf, A., Pahl-Wostl, C. and Taillieu, T. (2008) 'Toward a Relational Concept of Uncertainty: about Knowing Too Little, Knowing Too Differently, and Accepting Not to Know', *Ecology and Society*, vol. 13, no. 2.

Brugnach, M., Henriksen, H.J., van der Keur, P. and Mysiak, J. (2009) *Uncertainty and Adaptive Water Management Concepts and Guidelines*, Osnabrück: University of Osnabrück, Institute of Environmental Systems Research.

Brugnach, M. and Ingram, H. (2012) 'Ambiguity: the challenge of knowing and deciding together ', *Environmental Science & Policy*, vol. 15, pp. 60-71.

Burton, I., Diringer, E. and Smith, J. (2006) *ADAPTATION TO CLIMATE CHANGE: INTERNATIONAL POLICY OPTIONS*, Pew Center on Global Climate Change.

Cairney, P., Oliver, K. and Wellstead, A. (2016) 'To bridge the divide between evidence and policy: reduce ambiguity as much as uncertainty.', *Public Administration Review*, vol. 76, no. 3, pp. 399-402.

Clarkson, M. (1994) *A risk based model of stakeholder theory*, Toronto: Center for Coporate Social Performance & Ethics, University of Toronto.

Cooke, B., Jones, A., Goodwin, I. and Bishop, M. (2012) 'Nourishment practices on Australian sandy beaches: a review', *Journal of Environmental Management*, vol. 113, pp. 319-327.

Crane, A. and Ruebottom, T. (2011) 'Stakeholder Theory and Social Identity: Rethinking Stakeholder Identification', *Journal of Business Ethics*, vol. 102, March, pp. 77-87.

Davoudi, S., Crawford, J. and Mehmood, A. (2009) *PLANNING FOR CLIMATE CHANGE: STRATEGIES FOR MITIGATION AND ADAPTATION FOR SPATIAL PLANNERS*, London: Earthscan.

de Ruig, J.H.M. (1998) 'Coastline management in The Netherlands: human use versus natural dynamics', *Journal of Coastal Conservation*, vol. 4, pp. 127-134.

de Schipper, M.A., de Vries, S., Ruessink, G., de Zeeuw, R.C., Rutten, J., van Gelder-Maas, C. and Stive, M.J.F. (2016) 'Initial spreading of a mega feeder nourishment: Observations of the Sand Engine pilot project', *Coastal Engineering*, vol. 111, pp. 23-38.

Delta Programme | Coast (2013) *National Coastal Strategy - Compass for the Coast*, The Hague: Delta Programme | Coast.

Delta Programme (2014) *Working on the delta: Promising solutions for tasking and ambitions*, The Hague.

Delta Programme (2015) *Working on the delta: The decisions to keep the Netherlands safe and liveable*, The Hague.

Delta Programme (2017) *Work on the delta: Linking taskings, on track together*, Ministry of Infrastructure and the Environment and Ministry of Economic Affairs.

Delta Programme Commissioner (2017) *What is the situation regarding the rising sea level?*, [Online], Available: https://english.deltacommissaris.nl/delta-programme/question-and-answer/what-is-the-situation-regarding-the-rising-sea-level [6 April 2017].

Dewulf, A., Craps, M., Bouwen, R., Taillieu, T. and Pahl-Wostl, C. (2005) 'Integrated management of natural resources: dealing with ambiguous issues, multiple actors and diverging frames', *Water Science & Technology*, vol. 52, no. 6, pp. 115-124.

Fleming, A. and Howden, S.M. (2016) 'Ambiguity: A new way of thinking about responses to climate change', *Science of the Total Environment*, vol. 571, November, pp. 1271-1274.

Freeman, R.E. (1984) *Strategic management. A stakeholder approach*, Boston: Pitman.

Fylan, F. (2005) 'Chapter 6: Semi-structured interviewing', in Miles, J. and Gilbert, P. *A Handbook of Research Methods for Clinical and Health Psychology*, Oxford: Oxford Press.

Gray, B. (1989) *Collaborating: Finding Common Ground for Multiparty Problems.*, San Francisco: Jossey-Bass.

Hamm, L., Capobianco, M., Dette, H.H., Lechuga, A., Spanhoff, R. and Stive, M.J.F. (2002) 'A summary of European experience with shore nourishment', *Coastal Engineering*, vol. 47, pp. 237-264.

Hartmann, A. (2016) *Research Methodology & Academic Skills*, Wiley Custom.

Heuvel, T.v. (2011) 'Sand Nourishment ', in Misdorp, R. *Climate of Coastal Cooperation*.

Hoek, R.E.v.d., Brugnach, M., Mulder, J.P.M. and Hoekstra, A.Y. (2014) 'Analysing the cascades of uncertainty in flood defence projects: How ''not knowing enough'' is related to ''knowing differently'''', *Global Environmental Change*, vol. 24, January, pp. 373-388.

IISD & TERI (2006) *Designing policies in a world of uncertainty, change, and surprise: Adaptive policy-making for agriculture and water resources in the face of climate change*, Ottawa: International Institute for Sustainable Development (IISD) & The Energy and Resources Institute (TERI).

IPCC (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]*, Geneva: IPCC.

Jensen, O. and Wu, X. (2016) 'Embracing Uncertainty in Policy-Making: The Case of the Water Sector', *Policy and Society*, vol. 35, no. 2, pp. 115-123.

Klein, R.J.T., Nicholls, R.J. and Mimura, N. (1999) 'Coastal adaptation to climate change: Can the IPCC Technical Guidelines be applied?', *Mitigation and Adaptation Strategies for Global Change*, vol. 4, pp. 239-252.

Leeuwis, C. (2000) 'Reconceptualizing participation for sustainable rural development: towards a negotiation approach.', *Development and Change*, vol. 31, no. 5, pp. 931-959.

Lincoln, Y.S. and Guba, E.G. (1985) *Naturalistic Inquiry*, Sage.

Mitchell, R., Agle, B. and Wood, D. (1997) 'Towards a theory of stakeholder identification: defining the principle of who and what really counts', *Academy of Management Review*, vol. 22, no. 4, pp. 853-886.

Mulder, J.P.M., Hommes, S. and Horstman, E.M. (2011) 'Implementation of coastal erosion management in the Netherlands', *Ocean & Coastal Management*, vol. 54, December, pp. 888-897.

OECD (2011) *Water Governance in OECD Countries: A Multi-level Approach, OECD Studies on Water*, Paris: OECD Publishing.

OECD (2014) *Water Governance in the Netherlands: Fit for the Future?*, Paris: OECD Publishing.

OSPAR Commission (2010) *Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area 2010 update*, [Online], Available: https://www.ospar.org/documents?v=7258.

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D. and Taillieu, T. (2007) 'Social learning and water resources management', *Ecology & Society*, vol. 12, no. 2, p. 5 [online].

PBL (2016) *Keeping track of adaptation in the Dutch Delta - Design of a reflexive monitoring and evaluation framework for the Delta Programme*, The Hague: PBL Netherlands Environmental Assessment Agency.

Refsgaard, J., van der Sluijs, J., Højberg, A. and VanRolleghem, P. (2007) 'Uncertainty in the environmental modelling process–a framework and guidance', *Environmental Model Software*, vol. 22, pp. 1543-1556.

Schasfoort, F.E. and Janssen, S.K.H. (2013) *Delta Facts: Sand Nourishments*, [Online], Available: http://deltaproof.stowa.nl/Publicaties/deltafact/Sand_nourishments.aspx?pId=53 [15 May 2017].

Schruijer, S.. (2006) 'Research on collaboration in action', *International Journal of Action Research*, vol. 2, no. 2, pp. 222-242.

Taal, M., Mulder, J., Cleveringa, J. and Dunsbergen, D. (2006) *15 years of coastal management in the Netherlands, Policy Implementation and Knowledge Framework.*, The Hague: ijkswaterstaat, National Institute for Coastal and Marine Management / RIKZ.

Termeer, C., Dewulf, A., Rijswick, H.v., Buuren, A.v., Huitema, D., Meijerink, S., Rayner, T. and Wiering, M. (2011) 'The regional governance of climate adaptation: A framework for developing legitimate, effective, and resilient governance arrangements', *Climate Law*, vol. 2, pp. 159-179.

Trochim, W.M.K. (2006) *Qualitative Validity*, [Online], Available: https://www.socialresearchmethods.net/kb/qualval.php [22 March 2017].

UNDP (2004) *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*, Cambridge: Cambridge University Press.

van Buuren, A., Driessen, P.P.J., Rijswick, M.v., Rietveld, P., Salet, W., Spit, T. and Teisman, G. (2013) 'Towards Adaptive Spatial Planning for Climate Change: Balancing Between Robustness and Flexibility', *Journal for European Environmental & Planning Law*, vol. 10, no. 1, pp. 29-53.

van Buuren, A., Driessen, P.P.J., van Rijswick, M., Rietveld, P., Salet, W., Spit, T. and Teisman, G. (2013) 'Towards Adaptive Spatial Planning for Climate Change: Balancing Between Robustness and Flexibility', *Journal for European Environmental & Planning Law*, vol. 10, no. 1, pp. 29-53.

van den Hoek, R.E. (2014) *Building on Uncertainty: How to cope with incomplete knowledge, umpredictability and ambiguity in ecological engineering projects*, Enschede: University of Twente.

van den Hoek, R.E., Brugnach, M., Mulder, J.P.M. and Hoekstra, A.Y. (2014) 'Analysing the cascades of uncertainty in flood defence projects: How ''not knowing enough'' is related to ''knowing differently'''', *Global Environmental Change*, vol. 24, January, pp. 373-388.

van der Keur, P., Henriksen, H.J., Refsgaard, J.C., Brugnach, M., Pahl-Wostl, C., Dewulf, A. and Buiteveld, H. (2008) 'Identification of Major Sources of Uncertainty in Current IWRM Practice. Illustrated for the Rhine Basin', *Water Resource Management*, vol. 22, pp. 1677-1708.

Vansina, L., Taillieu, T. and Schruijer, S. (1998) ''Managing' multiparty issues: learning from experience.', in Pasmore, W. and Woodman, R. *Research in Organi- zational Change and Development,* Stamford: JAI Press.

Vansina, L. and Vansina-Cobbaert, M.-J. (2008) *Psychodynamics for Consultants and Managers: From Understanding to Leading Meaningful Change.*, The Atrium, Southern Gate, Chichester, West Sussex: John Wiley and Sons Ltd.

Walker, W.E., Harremoes, P., Rotmans, J., Sluijs, J.P.v.d., Asselt, M.B.A.v., Janssen, P. and Krauss, M.P.K.v. (2003) 'Defining Uncertainty. A Conceptual Basis for Uncertainty Management in Model-Based Decision Support', *Integrated Assessment*, vol. 4, no. 1, pp. 5-17.

Weick (1995) *Sensemaking in Organizations*, Thousand Oaks: Sage Publishing.

Cover Images:

http://deltaproof.stowa.nl/Publicaties/deltafact/Sand_nourishments?subject=2

http://www.naturecoast.nl/home

Delta Programme (2015)

https://www.fastcodesign.com/1681986/this-dutch-sand-engine-uses-natures-destructive-power-to-protect-from-flooding

APPENDIX A: **SEMI STRUCTURED INTERVIEW**

Q1 Tell me a little bit about ____. What does ____ do?

Q2 Do you think the coast is important for ____? Why?

Q3 Where does _____ stand on climate change?

Q4 Is sea level rise something important to be discussed? What is the view of ____?

Q5 What about floods? Is ____ concerned with floods? Why?

Q6 And how should we deal with floods? For example, should we be protected against floods, or learn and adapt to them? How? Or something else…

Q7 Which aspects are most important in the view of ____?

Q8 What is the opinion of ____ on the motto "soft when possible, hard where necessary"?

Q9 How does ____ feel about sand nourishments? Does it have any direct impact? How?

Q10 How does ____ classify the current strategy of the government?

Q11 What are the responsibilities of ____ regarding sand nourishments?

Q12 Who else is involved? Who else should be involved? And who shouldn't? Why?

Q13 What is the relationship of ____ with these other groups? How does ____ relate to them? What does ____ need from them and what does ____ provide?

Q14 How much do you think ____ can influence changes or decisions? What about the other groups?

APPENDIX B: DETAILED INFORMATION FOR INTERVIEW

UNIVERSITY OF TWENTE.

1

UNCERTAINTIES RELATED TO THE SAND NOURISHMENT STRATEGY OF THE DELTA PROGRAMME FOR THE DUTCH COAST

BACKGROUND: WHY THIS RESEARCH IS RELEVANT

Climate change has introduced a new set of uncertainties for policy-making. In The Netherlands, the main policy concerning the adaptation to the possible effects of climate change is the Delta Programme. When it comes to coastal management and, more specifically, to the adaptation to sea level rise due to climate change, the preferred strategy is to make use of sand nourishments when and where possible.

We argue that in order to maximize the potential for adaptation of the policy (in terms of assessment and implementation of strategies) these uncertainties need to be taken into account, not only in the classical reductionist way, but also embracing ambiguities.

The need for more insights into how uncertainties, particularly ambiguities, affect the sand nourishment strategy embraced by the Delta Programme, is the main reason behind this research. In this sense, the research aims at identifying uncertainties that can arise from the involvement of multiple stakeholders in projects involving sand nourishments, based on their perceptions.

WHAT IS UNCERTAINTY

We understand uncertainty as something we don't know about the system (in this case, the coast). Reasons may be errors in measurements, missing data or information, and lack of understanding of how the coastal system works (known as **incomplete knowledge**), as well as unpredictable and chaotic behavior of the system itself (known as **unpredictability**). These types of uncertainty can, in theory, be reduced with more research or with more and better data collection. In problems related to coastal management, not only uncertainty from what is not known about the system can appear, but also from how people see and interpret a situation, which is influenced by their experiences, beliefs, values, know-how, interests, and position in the society (referred to as **ambiguity**). More often than not, people share different perceptions and conflicting views about a situation. This type of uncertainty is not necessarily solved with more information, which could lead to more confusion, but rather recognizing that more than one way of seeing a situation can be equally valid and developing a common understanding.

These uncertainties can relate to different aspects of the system to be managed, namely natural, technical, and social systems:

- **Natural system:** incorporates climate impacts along with its aspects, sediment quality and quantity, and ecosystem values;
- **Technical system:** consists of the elements/artefacts employed to modify the natural system, both with infrastructure and technologies (e.g. hard structures and sand nourishments);
- **Social system:** comprehends economic, cultural, legal, administrative, and organizational aspects.

To better understand and characterize the uncertainties, we can relate the different forms of uncertainties to these three systems in the form of a table. An example is provided on page 3, also explaining each cell of the table. Following, a blank table is provided where you can fill in the uncertainties you can already think of related to sand nourishments.

UNIVERSITY OF TWENTE.

2

NOW IT IS YOUR TURN

Before the actual interview it would be beneficial if you could already think of what is uncertain for you when it comes to sand nourishments, and fill in the next table in the best of your abilities.

	NATURAL SYSTEM	TECHNICAL SYSTEM	SOCIAL SYSTEM
AMBIGUITY			
INCOMPLETE KNOWLEDGE			
UNPREDICTABILITY			

UNIVERSITY OF TWENTE.

3

EXAMPLE: MARS EXPEDITION

Scenario: continuing population growth is close to reach numbers that cannot be sustained by our planet. As an adaptation strategy global leaders have decided to expand human occupation to the planet Mars. The following table presents some of the uncertainties identified during the first global Mars commission.

	UNPREDICTABILITY	INCOMPLETE KNOWLEDGE	AMBIGUITY
NATURAL SYSTEM	Nature has a non-linear, chaotic and unpredictable behavior.	We have a limited understanding of natural processes, which translates into models that do not represent the full complexity of the natural system as well as limited data.	People relate and interpret situations concerning nature in different ways.
	e.g. (1) How will the different composition of the atmosphere affect the living organisms? (2) What will be the average temperatures on the surface of Mars?	e.g. (1) What would be the impact of introducing oxygen into Mars atmosphere? (2) Is it possible to have water running on Mars?	e.g. (1) Should we go to Mars or should we adapt to Earth's limitations? (2) To what purposes should we use the surface of Mars?
TECHNICAL SYSTEM	Includes technological surprises or unexpected consequences.	Limited knowledge of the technical components of the system.	People may have different opinions on which infrastructures and/or technologies should be used to modify the natural system.
	e.g. (1) What will be the side-effects of the sun's radiation for the human body under the atmospheric conditions on Mars? (2) What are the implications of long space travels to the human body?	e.g. (1) To what radiation levels can the spaceship resist? (2) How reliable is the calculation of how much oxygen and food to bring?	e.g. (1) Should spare parts be brought or people able to fix broken parts? (2) should people wear oxygen tanks all the time or should the atmosphere be adapted?
SOCIAL SYSTEM	Value and belief diversity, human behavior, social, economic, cultural and political dynamics (societal variability).	Limited knowledge on the social and economic components of the system.	People relate and interpret situations comprehends economic, cultural, legal, administrative, and organizational aspects differently.
	e.g. (1) How will people react to being confined in a spaceship for a long period of time? (2) How will people on Earth react to the cost of sending people to Mars?	e.g. (1) What is the impact of less water or food supply to the crew? (2) How does a delay caused by a malfunctioning of the system affect the travelers?	e.g. (1) Is this strategy economically attractive? (2) Is it clear who will be the competent authority on Mars? (3) Is Mars the best alternative for dealing with population growth? (4) Is it clear how people will be selected to go or stay?