Nature-Inclusive Urban-Coastal Management-Framework

Sustainable and Resilient Coastal Cities

Interreg

EUROPEAN UNION

2 Seas Mers Zeeën

SARCC

European Regional Development Fund

Colophon:

Sarcc:
Interreg 2 seas mers zeeën sustainable and resilient coastal cities (SARCC) is a European union development Fund

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Contents

Introduction

Since the beginning of time, coastal areas have been fertile and pleasant places where humans like to live. Over time the natural relation of human settlements changed due to subsidence or erosion, and also current climate changes such as sea level rise. Each coastal area is morphologically specific and is vulnerable in its own way. To respond to these challenges, region-specific insights and solutions are developed. These solutions can negatively impact the stakeholders and it can be hard to find consensus on how to deal with the vulnerability. Continuing to implement well-known and highly advanced solutions is often convenient and easy. But, these so-called 'grey infrastructures' do not contribute to a paradigm shift in which we need to be more sustainable and resilient to mitigate the impact of climate change in the long-term. The question is how to do it differently and work with nature to make our coastal zones less vulnerable and more resilient.

This booklet presents the methodology Nature-Inclusive Urban-Coastal Management-Framework (NUM). This is a Project Guide for the Implementation and Monitoring of Nature Based Solutions (NBS) to create Climate Resilient Coastal Cities. This is specially developed for professionals working in urban (coastal) development such as municipalities to support the inclusion of nature as a way of coastal protection. It is developed by the academic partners in the Sustainable and Resilient Coastal Cities (SARCC) project: EXO Environmental, HZ University of Applied Sciences, Maritime Archaeological Trust, TU Delft, and Vives University of Applied Sciences. The NUM is developed and tested in the seven SARCC pilot projects that are aimed at creating experience and evidence in prioritizing nature-based solutions in urban coastal areas. The participating pilot partners have been building nature-based solutions (NBS) in their city, the academic partners focussed on methodological support to these projects and consolidating what is learned in the NUM. The methodology consists of two instruments, the Project Design Development Framework and the Evaluation & Monitoring Framework that work in an interactive and iterative manner.

The project revealed how the coastal regions of Belgium, France, Netherlands and the UK looked in the past, how natural and/or man-made constructions are currently protecting our coast, and how they can better protect them against climate change in the future with NBS. In order to bring the implementation of nature-based solutions to an even higher level, the implemented pilot projects within SARCC are monitored. This ranges from the technical, social, economic and environmental aspects of a NBS to the different actors involved in its successful implementation.

The unique aspect of the SARCC project is that it looks at different themes that are all linked to NBSs through the diverse number of partners that each participates with their own expertise. These give new insights that we can use to encourage the implementation of nature-based solutions in coastal regions. Due to the transnational and transdisciplinary nature of SARCC, the knowledge institutes gain many new insights. These are instructive and promising for the future of nature-based solutions. Despite the complexity of coastal regions, it is worthwhile for each coast to consider NBS to protect us against floods and storms.

NUM instrumentalizes looking at the long-term, natural, and political processes and how to include historical, geomorphological, and paleo-environmental data sources. The Maritime Archaeological Trust provided evidence for historical coastal processes while TU Delft, the Department of Urbanism and the Department of Hydraulic Engineering (together with HZ University of Applied Sciences) assessed urban development patterns, construction, and flood risk in the urban settings that are consolidated in the Project Design Development Framework. HZ University together with Vives assessed the direct and indirect impact of pilot projects to develop the Evaluation & Monitoring Framework.

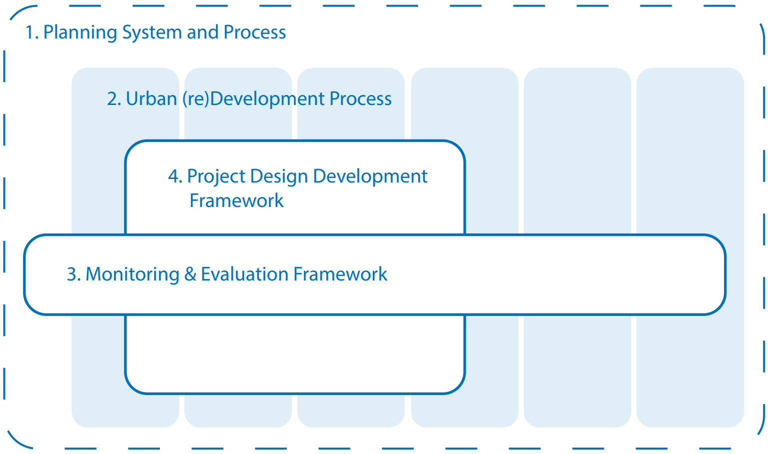
The aim of this booklet is to inform local professionals working in the domain of urban (coastal) development such as municipalities and consultancy practices on the implementation of NBS in coastal cities. This target group works together with two other 'clients' of the SARCC project, the urban decision-makers, and local citizens. To support urban decision-makers a guide book produced to inform urban decision-makers, leaders, and members of staff that are involved in coastal management and policy on how to integrate nature-based solutions (NBS) into coastal management plans and policies. The citizens are supported by the visualization in which information on history, planning, spatial qualities, and engineering are easily accessible.

The first chapter of this booklet concisely presents the NUM methodology that is presented in the application to the pilot cases in the second and third chapters. The second and third chapters are respectively dedicated to the Project Design Development Framework and the Evaluation & Monitoring Framework. The final chapter is presenting the learnings from the SARCC project and presents recommendations to the readers.

The partners in the SARCC project are:

Southend Borough Council (UK), Marine Archeological Trust (UK)
Environment agency (UK), Municipality of Blankenberge (BE)
Municipality of Vlissingen (NL), City of Gravelines (FR)
Exo Environmental Ltd (UK), University of Technology Delft (NL)
Flemish Government (BE), Agency of Maritime and Coastal Services (BE)
Town of Middelkerke (BE), City of Ostend (BE)
HZ University of Applied Sciences (NL), Vives University of Applied Sciences (BE)

Nature-Inclusive Urban-Coastal Management-Framework



Situating (3) Project Design Development Framework inside the (2) Urban Development Process within the (1) Planning Process

1 Planning System and Process(es)

The planning system is a process in which the spheres of law, regulations, policy and institutions work together at different scales, influence each other and set the planning conditions for urban redevelopment. Before the urban development process, a conceptual phase usually occurs that aims to connect policy to the project level.

2 Urban (re)Development Process

The urban redevelopment process consists of six key phases: (i) Initiation , (ii) Masterplan, (iii) Urban Design, (iv) Construction, (v) Maintenance, and (vi) Feedback. Phases i, ii, and iii are considered to be part of the 'Planning Process', whereas iv, v, and vi are part of the 'Implementation Process'. Although these phases are variable, this division serves to distinguish planning from actual implementation of the plan. This mainframe is applicable to the four countries in the the SARCC project.

2 Urban (re)Development Process

Initiation

Start of the project Design Development framework and vision

General information is processed to make decisions for the project, while creating carrying capacity amongst stakeholders.

Masterplan

Strategy to shape of the urban project

The master plan (structural plan) is the physical translation of the vision and program at the larger scale of an area.

Urban Design

Design of the urban project

The urban plan is a detailed phase of development in line with the masterplan, and is directly connected to spatial quality.

3 Monitoring & Evaluation Framework; recommendations for ○ Governance and ● Ecosystem Service (ESS)

Initiation:

- ● Look for priority settings of Ecosystem services (ESS) based on the participation process.
- ○ Align spatial developments, coastal heritage and flood risk management in the longue Durée.

Masterplan:

- ○ Projects can contribute to test the feasility of NBS approaches for the urban coastal zone.
- ○ Find boundary spanners to advocate for lessons learned across different admin and sector levels to mainstream NBS.
- ● Calculate benefits of ESS in advance across different scenarios.
- ○ Involve enough (local) actors and the population according to local area knowledge.
- ○ Find sufficient and innovative financing, maintenance, and monitoring.

Urban Design:

- ○ Create demarcated learning environment, with a tailor-made process design and ability to organize this as a project on its own.
- ● Develop narratives on ESS, flood risk and heritage to improve public engagement processes.

Monitoring & Evaluation Framework; methods

Governance context: Understand the local balance of responsibilities and networks in a multisector (flood risk, spatial planning and ecosystems) and multilevel context.

Baseline monitor: Identify which conditions are important for the success of experimental NBS projects concerning position of the project in the governance context, resources, participants, process- and project design.

4 Project Design Development Framework

1 Longue Durée

Drawing long lines of human nature relationship

Maritime Atlas
Evaluate the geomorphological processes and how human interacted and intervened over time.

Landscape Atlas
Evaluate the Landscape (soil and water) & Urban morphology and Infrastructure (historical dikes) on the regional scale.

Planning Atlas
Historical Assessment of Planning Policies to understand the past decision-making process, impact of the policies on spatial factors of coastline coastal defence.

2 Urban Project

Analysis of the spatial system

Flood Atlas
Mapping the Bathymetry, Inlet boundary conditions and Coastal roughness feed into numerical simulations (Delft3D) to test spatial solutions.

Urban Atlas
Mapping the heritage of the project area: built heritage, art, photographs, maps and charts. Mapping the urban construction and systems: water, energy, civil construction and ecology. Mapping expected urban trends.

3 Synergy

Organise multidisciplinary workshops to perform interdisciplinary investigations across coastal and urban areas to inform the vision, strategy and design phases.

4 Vision

Envisioning new futures with nature in the long-term context

Problem Definition
Findings from the previous phase leads to the common definition of the problem in a multidisciplinary workshop in which discipline prepared their data.

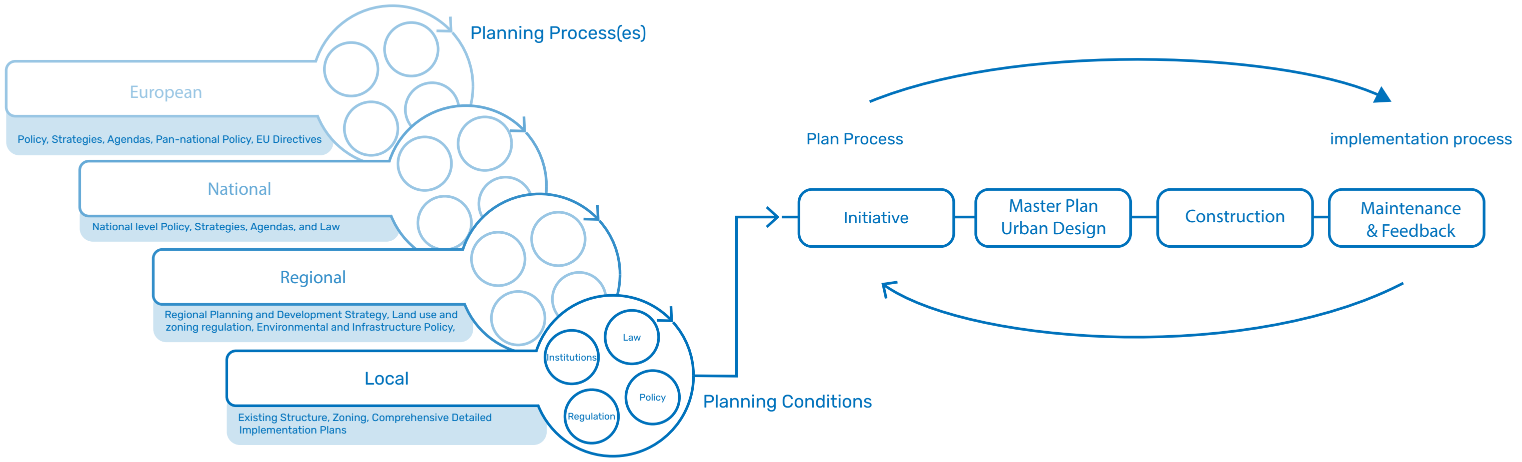
Solution Concepts
Alternative approaches are discussed, and assumptions are balanced out between multidisciplinary teams and their disciplinary solutions.

Synergy
The problem definition and solution concepts leads to the development of a shared vision. The vision is based on the determination of shared assumptions and alternative futures.

Guide for the Implementation and Monitoring of NBS to create Climate Resilient Coastal Cities

Planning System and Process(es)

Urban (re)Development Process



Construction

Building of the urban project

During the building phase, all data and information should be at the table and translated into construction plans.

- Incorporate new discoveries and successes into programme of positive dissemination.
- Use preliminary results of implementation phase can be leveraged to convince policy makers and general public about the effectiveness of NBS.

Maintenance

Life of the urban project

Project requires regular maintenance and monitoring effort to regulate performance.

- Use projects as policy instruments to identify policy gaps in proper maintenance.
- Conduct regular maintenance and monitoring of NBS to improve its performance and prove long term effectiveness of NBS.
- Identify clearly the role and responsibilities for NBS maintenance.

Feedback

Reflecting of the urban project

Iterative feedback of project performance from technical, ecological and socio-economic criteria to optimize value.

- Use project feedback to prove the effectiveness of NBS for coastal safety, consensus building, increasing local awareness, and replication in other locations.
- Evaluate ESS to understand and validate effectiveness.
- Assess the physical, cultural and social outcomes of a sea defence such as sustainability, retained or enhanced heritage value and social satisfaction.
- Integrate the feedback of citizens and other stakeholders into the design of the project .

Monitor and evaluate: consider with project management and external stakeholders which conditions contribute to the internal and external success of the NBS project and how strategies can be adapted to result to have succesfull impact

5 Strategy

Guidelines how to get there

Guidelines
In the strategy clear guidelines are derived from the vision of how decisions in space should be taken.

Modeling
This strategy is tested through the flood risk model.

6 Urban Project

Spatial plan

Flood Atlas
The hydraulic model allows a feasibility assessment and the identification of the detailed spatial conditions necessary for the realisation of the strategy in the project area.

Urban Atlas
The strategy is projected onto the urban atlas and stakeholders are involved with a clear narrative, and the program is developed.

7 Design

Spatial design with nature

Alternatives
Public space design that integrates human and nature needs and is legible in this relation over time. Alternatives of high-quality spatial designs are tested.

Integrated Benefits
Social, environmental, economical, and heritage values are synergised into the spatial design to enhance spatial quality and legibility

Evaluate and feedback
Assess achievement of project objectives, impact on flood risk, ecosystem services and integrated benefits. Adapt the Urban Development Process where necessary. Identify and share lessons learned to improve and extend implementation of NBS

8 Design & Assess

The inter-functionality of the area development and willingness ‘to do it differently’ is processed through an intensive design & assessment process of modeling and spatial strategy, plan and design development.

SARCC Projects

Middelkerke (Belgium)
Local and regional authorities (municipality and MDK - Flemish government)

Dune in front of dike.

Oostende (Belgium)
Local and regional authorities (municipality and MDK - Flemish government)

Dune growth, via vegetation experiments.

Blankenberge (Belgium)
Local authority (municipality)

Dune growth, by making space via infrastructure reconstruction.

Vlissingen (The Netherlands)
Local authority (municipality)

Acceptance of overtopping water with retention in green/blue urban infrastructure.

Southend-on-Sea (The United Kingdom)
Local authority (Southend council)

Greening flood protection infrastructure via vertipools, pilling habitats, gabion baskets, eco-terrace, vegetated shingle.

Newlyn (The United Kingdom)
Regional coastal authority (environmental agency)

Eco-blocks for more ecofriendly water breaker.

Gravelines (France)
Local authority (municipality)

Dune growth via fences and vegetation.

1

Methodology NUM

The academic partners in the project conceptualized and developed the methodology Nature-Inclusive Urban-Coastal Management-Framework (NUM). This is a Project Guide for the Implementation and Monitoring of Nature Based Solutions (NBS) to create Climate Resilient Coastal Cities. It is specially developed for professionals working in the field of urban (coastal) developments in municipalities and consultancy offices to support the inclusion of nature as a way of coastal protection. The methodology consists of two instruments, the Project Design Development Framework and the Evaluation & Monitoring Framework that work in an interactive and iterative manner.

Project Design Development Framework

This framework supports interdisciplinary design by providing process steps of interdisciplinary integration in the urban project process with the vision on NBS.

The prioritization of nature-based solutions in urban-coastal areas is supportive of an interdisciplinary approach in which the urban design is the result of a co-creation process between maritime archaeology, hydraulic engineering and urban design. The Project Design Development Framework provides insight into when and how the integration of different sectors should take place in the urban project process. The framework is focused on the masterplan and urban design phases of this process.

Figure 1:

Steps of the Project Design Development Framework with the elements per step and iterative relations

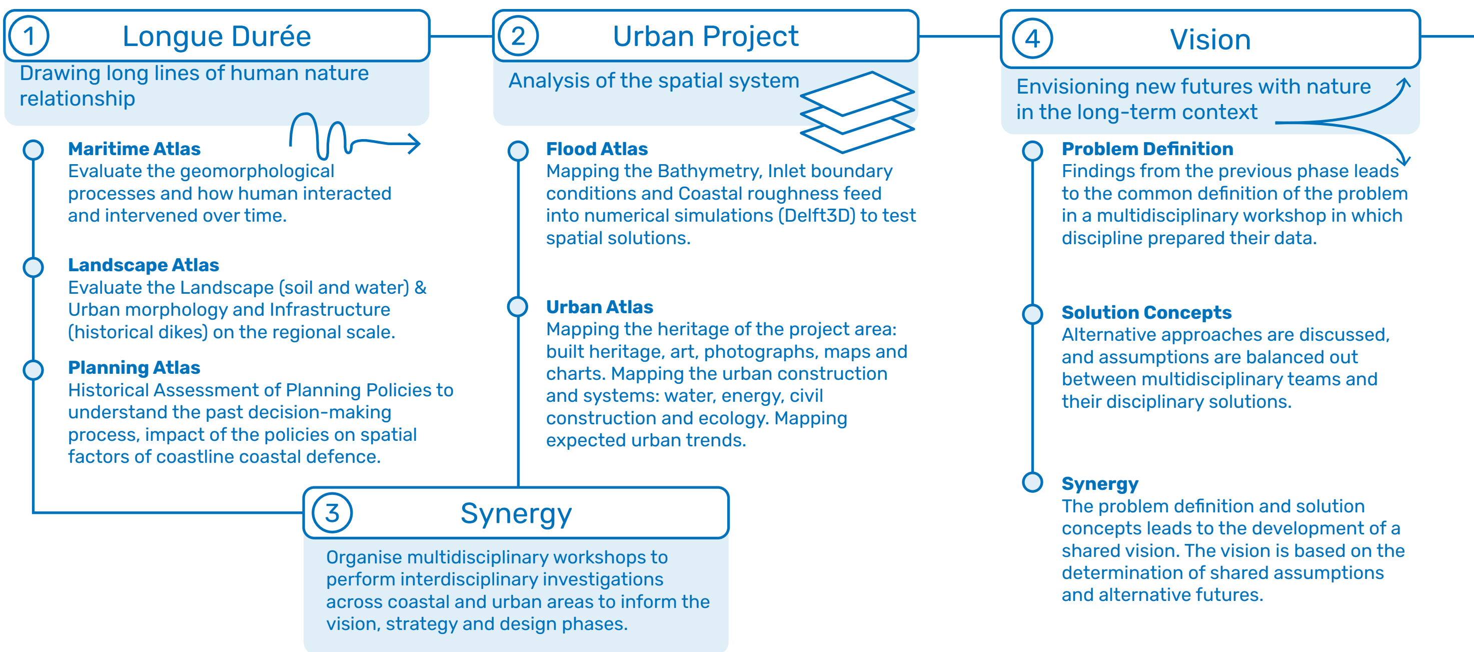
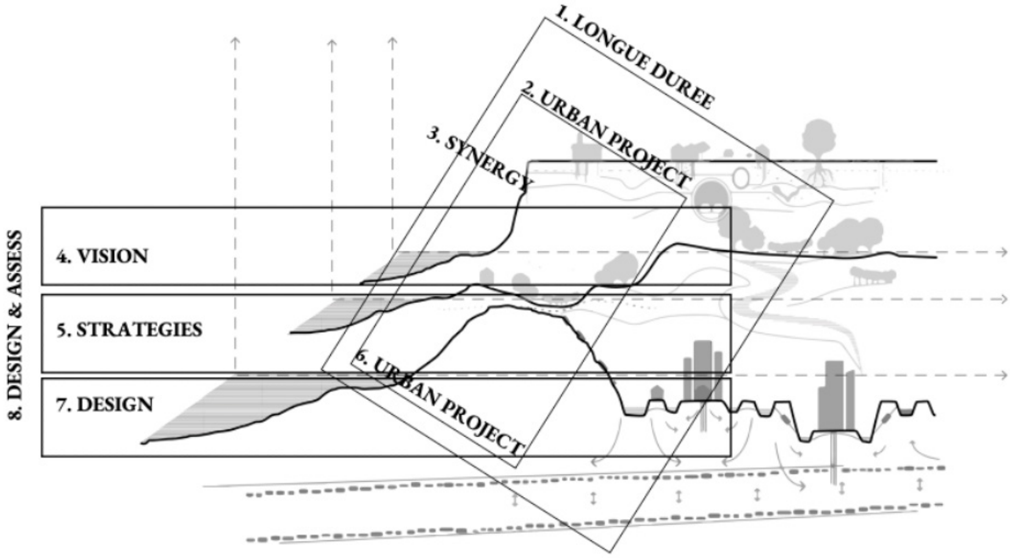


Figure 2:

Conceptual image of the new framework of how the different steps are relations and scales connected



The Project Design Development Framework consists of eight iterative steps that are visualized in figure 2. The first step starts on the larger scale of place and time, the Longue Durée and should be connected to the scale of the urban project (step 2) and brought into synergy (Step 3). The creation of a vision responds to the problem definition and solution concepts (step 4). The vision leads to different strategies (step 5) that are projected on the urban project in more detail (step 6) and form the base of the specific design of the project (step 7). The last three steps are developed in an iterative manner and brought together in the Design & Assess methodology (step 8). The steps are presented with greater detail in figure 3 and will be explained in the following paragraphs.

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STEP 1. Map the LONGUE DURÉE

In this first step, the different specialists gather information on the larger scale and time frame to create the maritime atlas, landscape atlas and planning atlas.

Maritime atlas

The evaluation of the geomorphological processes that shaped the area by researching historical anthropogenic and natural processes is an important first step. The long-term relationship between land and sea has shaped the coastline, but the understanding of these past trends is seldom incorporated into our understanding of ongoing patterns of change that can be projected into the future. As a result, coastal developments and the construction of grey infrastructure to defend the shoreline have often worked in opposition to the prevailing forces. This presents a juxtaposition - contrasting effect - that, in the long-term, is hard to sustain. Therefore, to increase our understanding of coastal sustainability, we have considered the long-term influences on change along the coastline. Where these processes continue we have looked at the consequences of human intervention along the coastline, identified areas and sites under greatest threat and addressed methods of presenting the outputs to the public. To achieve these objectives, a ranking system and historical analysis were developed to quantify and assess historical and archaeological data that will inform understanding of the evolving coastline.

This ranking system evaluates: (1) their contribution to the understanding of sea level change, (2) past environmental change, and (3) whether the data archive contained evidence of temporal continuity, allowing us to monitor changes through time. An additional value (4) was applied to indicate whether sites, features, or deposits were known to still be in existence and accessible, and as such whether they would be useful for further analysis. An example of a high-scoring site would be a submerged sequence of organic deposits, containing archaeological material, that were laid down along the coastline as sea levels rose.

The historical analysis of maps, charts, artworks, photographs, and postcards have at the same time an immediacy when demonstrating change to a broad audience of stakeholders. The criteria used to validate the artworks included the accuracy of artistic style, the medium used, the value of the subject matter and the value of the time period when produced. Historic maps and charts were ranked against their chronometric, topographic and geometric accuracy. Three scoring criteria were used for historic photographs and postcards: (1) the coastal view (2) the heritage view and (3) clarity and quality of the image. A non-scoring criteria was applied where the purpose of the photographs or postcards were characterized as private, touristic, scientific (geology, geomorphology, archaeology), or unknown. The results of the analysis were then collated and combined to provide collective assessments. The highest scores were given to the sites with the greatest potential to aid coastal management strategies.
Within the SARCC project over 3,300 archaeological sites and historical documents from the pilot, areas have been analysed and placed in the SARCC database. many of which are now accessible via a Maritime Atlas viewer.

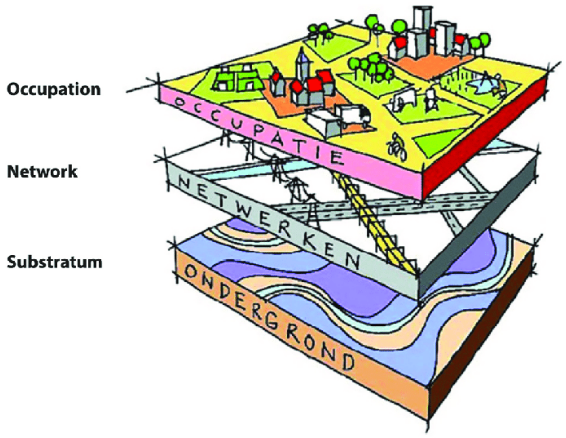
Landscape atlas

The landscape atlas is the result of mapping the landscape and urban morphology and the infrastructure (historical dikes) on a larger scale and over time. The Dutch Layers approach can be used to map, and the 3x3x3 methodology to present the scale of time. The Dutch Layers approach distinguishes three layers: the occupation (fast change in human functions and building), network (less dynamic human interventions of protection and connection) and substratum layers (the slowest natural system). These layers represent a spatial system that incorporates different rates and types of potential and actual, spatial development and change. The 3x3x3 methodology is presenting these three layers of the Dutch Layers approach on 3 scales and in 3 moments in time. This enables reading the area of time and analyses of spatial transition based on the three layers and their interconnection.

Figure 3:

The Dutch Layers Approach

Source:
M. de Hoog, D. Sijmons, S. Verschuuren (1998) Laagland. HMD (Het Metropolitane Debat) Herontwerp: Amsterdam.



Planning Atlas

The planning atlas gives in parallel to the maritime and landscape atlas the Longue Durée of human interaction with their territory and how they organized this. It is important to review the past decision-making process through planning system definition to be able to understand the current conditions in the project area. By understanding the impact of the policies on urban morphology in relation to the spatial factors of the impacts in relation to coastline coastal defence policies. To describe the planning system (and to compare it to others) COMMIN framework makes heterogeneous planning systems comparable in 5 categories: constitutional, national scale, regional scale, local scale and participation. For each of the countries involved, it identified the guiding principles and objectives defined for planning, as well as principal planning institutions. Secondly, it summarised the Planning Acts and other legally binding contexts and planning documents that are commonly used and generally recognized. For each category, the question should be raised as to if and how flood risk management is handled.

The planning atlas has four governance levels: European, National, Regional and Local and should (minimally) present topics on nature (Natura 2000), water (Water Framework Directive) and urbanization policies.

STEP 2. Map the URBAN PROJECT

In this second step, the specialist gathers information on the urban scale and creates the flood atlas and the urban atlas of present and future artefacts.

Flood atlas

The areas within the urban environment that are subject to coastal flooding can be identified through detailed numerical simulations, showing the behaviour of incoming water during extreme flood events. These simulations required the following inputs:

1. The bathymetry of the area of interest, obtained with a resolution of 10 m.

2. Inlet boundary conditions, which included the overtopping discharge along the coastline during a storm. This computation required the following parameters:

   a. Hydrological data, including sea water level and wave characteristics (wave height, period). For these values, different return periods were considered, depending on the local guidelines (i.e. Vlissingen: 1,000 years, Southend-on-Sea: 200 years). The influence of climate change projections for 2100 (Sea Level Rise, SLR) were also taken into account.

   b. The geometry and elevation of the current coastal protection, identified based on surveys, information from the authority and image analysis.

   c) A synthetic storm, typical of the area investigated and derived based on previous historical events.

Combining data obtained at steps 2a, 2b and 2c, the overtopping discharge can be computed through the empirical model of the EurOtop (2018) manual. These computations estimated the temporal evolution of the overtopping discharge during extreme conditions.

3. The roughness value during the simulation is uniformly assigned with a manning coefficient of 0.06 [s/m^1/3], common for floodplain areas.

Based on these three inputs, numerical simulations can be conducted using Delft3D Flexible Mesh (FM) developed by Deltares (Netherlands), which is a hydrodynamic model used to calculate non-steady flows that result from different hydrometeorological conditions like storm surges, hurricanes, tsunamis, detailed flows and water levels, waves, sediment transport and morphology on a regular grid. Results show the detailed propagation of overtopping discharges through the urban environment during a typical storm, providing an estimation of the volumes that would accumulate over time. These numerical simulations need to be repeated for various (nature-based) solutions, providing a direct comparison of the effectiveness of these measures.

Urban Atlas

The historical analysis of the lower-scale project area will present data on built and cultural heritage depicted in art, photographs, maps and charts. This supports the analysis over time on the larger scale. The Spatial analysis is mapping the status quo of the urban construction and systems of the project area on the following topics: water, energy, civil construction and ecology, following the System Exploration Environment and Subsurface (SEES). The SEES stems from the Dutch Layers approach and has six functional layers with different dynamics, professionals and knowledge fields: people, metabolism, occupation, public space, infrastructure and subsurface. SEES connects the subsurface information, urban construction of the area, with the urban surface in order to inspire and set clear boundaries for the development of the urban surface. It is used for analysing potential problems, chances, demands and supports a creative interaction early in the process of urban planning. The final step is mapping current and expected urban trends in the vicinity of the area.

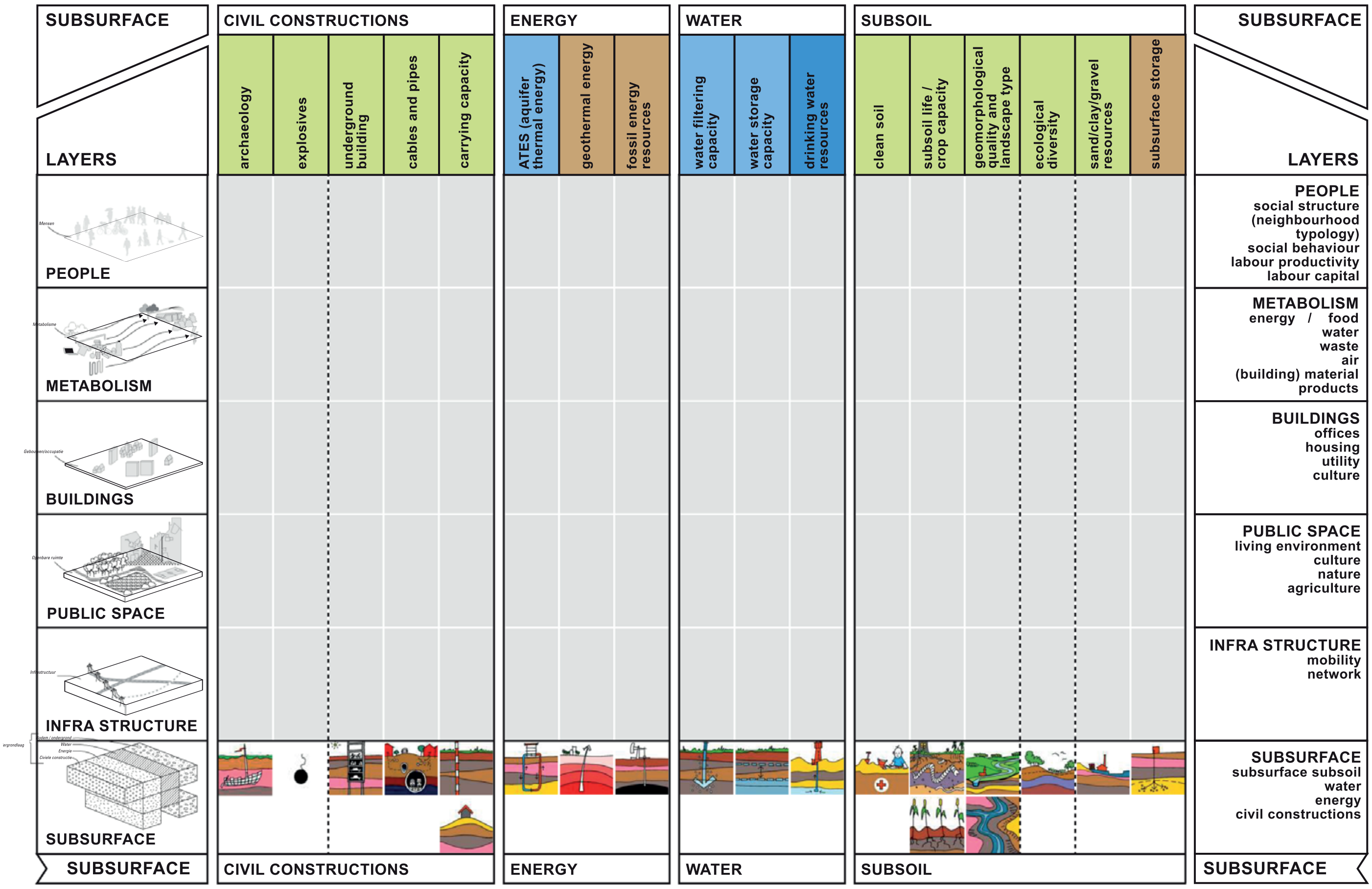


Figure 4:
System Exploration Environment and Subsurface (SEES)

Source:
F.L. Hooimeijer, and L. Maring, (2015) Machinekamer van de stad. Land en Water, no. 11, 2015

STEP 3 Synergize analysis over time, scale, and in context.

Subsequently, a workshop is organized to bring together specialists and synergize the findings of steps 1 and 2.

The interdisciplinary investigations across coastal and urban areas need to be synthesized systematically to inform the following phases. Long-term patterns of coastal and urban development highlight the causes that created the current baseline. The current state and construction together with the social-economical are analysed on the project scale. These are brought into synergy in the context, over scale and time.

Specialist selection and collection of necessary data. In the case of NBS, the following experts should be included in the project:

Archaeologist / Historian
Urban designer / Landscape Architect
Hydraulic Engineering
Water Management
Ecologist

In the multidisciplinary workshop, the problem discovery is done by exploring the results from the first two steps and making the shared problem discovery and definition. This will inform the vision, strategy and design phases by being able to draw the line of time from past to future to anticipate long-term patterns of urban-coastal processes. With this there is also a line drawn through scales, connecting the regional and urban scale.
The SEES can be used as an agenda to discuss the material and then the problem discovery and definition can be summarized.

STEP 4. Create a VISION by analysing problem definition and solution concepts.

The next step is that each involved discipline makes the shared problem definition more precise for their field and explores disciplinary solutions. In the follow-up workshop, the disciplinary problem definition and solutions are presented and alternative approaches are discussed, assumptions are balanced out. This leads to the development of a vision that is based on the determination of shared assumptions and alternative futures. Especially the preference for NBS in this phase is steering the solution space which also makes it easy to merge concepts and ideas of different disciplines.

STEP 5. Create STRATEGIES based on guidelines and modeling

In the strategy, clear guidelines are derived from the vision of how decisions in space should be taken. This strategy is tested through the flood risk model. The inter-functionality of the area development and willingness ‘to do it differently’ is processed through an intensive Design & Assess process of the interdisciplinary benefits.

STEP 6. Elaborate the strategy on the scale of the URBAN PROJECT

The strategy is projected onto the urban atlas (Step 2) and stakeholders are involved with a clear narrative, and the program is developed. Data that concerned sea level rise, future flood risk, and water volumes supported the definition of integrated urban projects.
The hydraulic model allows a feasibility assessment and the identification of the detailed spatial conditions necessary for the realisation of the strategy in the project area.

STEP 7. Create the DESIGN which integrates NBS with flood safety and spatial quality

The final result is an integrated public space and landscape design through which are tested alternatives, high-quality, spatial designs that combine social, environmental, and economic benefits. These integrated benefits of social, environmental, and economical values are synergised into the spatial design to enhance spatial quality and legibility.

STEP 8. Design & Assess

The inter-functionality of the area development and willingness 'to do it differently' is processed through an intensive Design & Assess process of modelling and spatial strategy, plan and design development during steps 5, 6 and 7.
The interdisciplinary "Design & Assess" framework brings together design strategies with flood damage models and cost/benefit analyses to compare the effectiveness of different strategies and designs in dealing with extreme SLR.

General impact of these steps:

- Is a well-coordinated, and development of, communication of information of different nature owned by different disciplines.
- Enables engineering to participate in the urban development process and think with other approaches towards flood management that are not aimed at creating grey infrastructure but also needs their knowledge.
- Includes NBS to make a flood management strategy over a longer time as part of urban development.
- Makes NBS is a shared goal, whilst in multidisciplinary settings each discipline has other goals with NBS (flood management or sustainable cities).
- Automatically connects NBS to manage flood risk to other urban challenges like pluvial floods, heat stress and biodiversity increase.
- Brings design as proposition and engineering as creating evidence in an integrated process.
- That connects scales of time and space.

Monitoring & Evaluation Framework

This framework aims to guide urban authorities on how to select the most suitable NBS to deploy along coastal urban landscapes, by providing empirical knowledge about new aspects and benefits of NBS in terms of ecosystem services.

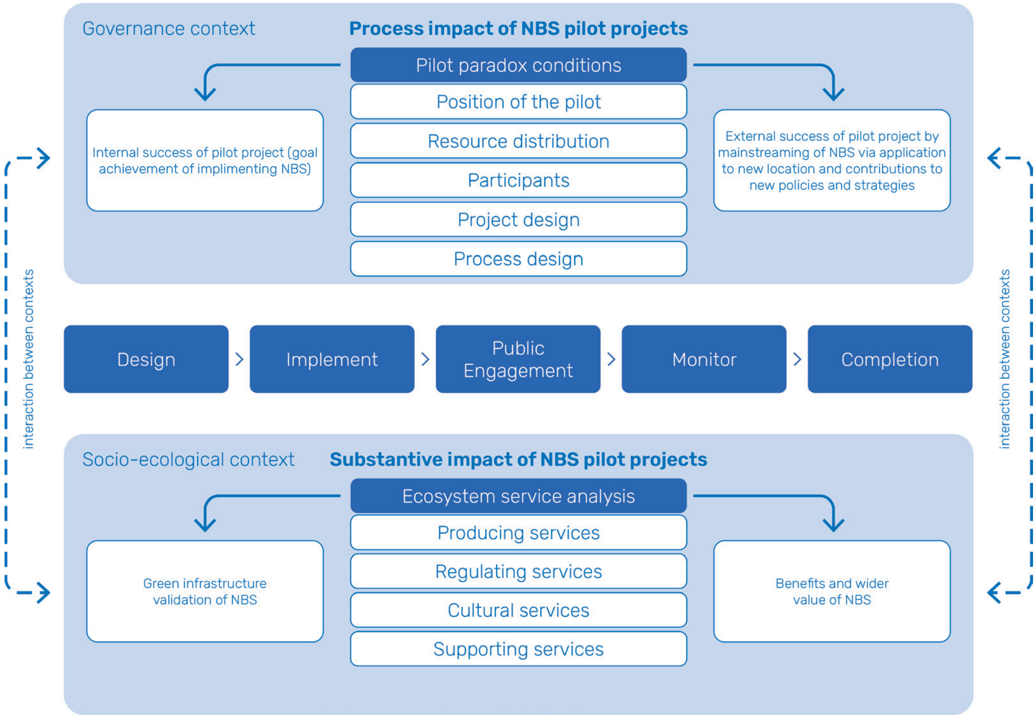
The Monitoring and Evaluation Framework aims to guide urban authorities on how to select the most suitable NBS to deploy along coastal urban landscapes, by understanding the impact of implementing NBS as well as the process before and during their implementation. Moreover, the framework provides empirical knowledge about new aspects of NBS in coastal areas such as the importance of different stakeholders (e.g. local authorities, residents) for the start, design, public engagement, implementation and completion phase of a specific NBS. Likewise, the framework gives insights into the benefits of NBS in terms of ecosystem services.

Framework development and theoretical approaches

To integrate NBS as a flood control measure in urban development is new for both the governance and the socio-ecological context. Within the governance context, for the understanding of experimental projects, the concept 'pilot paradox' can be used. The pilot paradox concept (developed by Arwin Van Buuren, Erasmus University Rotterdam), enables us to assess conditions for goal achievement (internal pilot process) and mainstreaming (external pilot process) during the implementation. The urban development project should be considered within their socio-ecological and governance contexts. Figure 5 presents the Monitoring and Evaluation Framework. In the next sections, the methods of this framework are further explained.

Figure 5:

Monitoring and Evaluation Framework of conditions to select an implement NBS in coastal urban landscapes



Pilot paradox to assess process impact of the urban projects

The project development process can be monitored for relevant milestones by applying the pilot paradox concept. The pilot paradox is a useful concept to monitor urban projects that apply innovative approaches (van Buuren, 2017), in this case taking NBS as a measure for urban flood protection, instead of grey infrastructure (that is well known). The pilot paradox concept states that the same conditions that enable the project process can also hinder the upscaling of the project results. The conditions that influence the internal and external process of a project are the position of the project, resources distribution, participants, process design, and project design (see Figure 5). The internal conditions will determine the success of the project itself, for example, if the project achieved the goal as set at the start. Whilst the external process will identify the conditions that support horizontal and/or vertical mainstreaming of NBS. Horizontal mainstreaming occurs when the project is replicated somewhere else, and vertical mainstreaming is when the project influences policy change.

Data collection and analysis of conditions for process impact

For the collection of data, the following techniques are recommended:
• Document analysis: reports of the project to gain insight into the governance context, progress of the project, and relevant issues concerning the implementation of NBS in coastal urban areas.
• Questionnaire per development phase. The project management needs to reflect per phase to monitor the development of the pilot and to assess the conditions of the pilot paradox. Within SARCC, each pilot project management is asked to provide scores for specific conditions and to explain the reasons for the provided scores.
• Semi-structured interviews with project managers and key stakeholders from multiple sectors and governance levels such as local, regional and national governmental authorities (politicians, civil servants, urban planners, alderman) and experts on NBS (engineers, scientists). The purpose of the interview was to get their perspective on success and mainstreaming NBS for coastal protection.

• Observations during and before the implementation phase of NBS interventions. The observations were based on paying attention to key works such as sectors, stakeholders, challenges/ issues faced, impacts, and interdisciplinary benefits of the project process.
Project managers scored the questionnaire statements from 1-5 (1=strongly disagree…5=strongly agree). These scores were averaged per phase across projects, separately for the internal and external project process. The results were presented in bar charts and explained with the qualitative data collected through interviews, questionnaires, observations and document analysis (see results in chapter 3). The findings from questionnaires, interviews and project documents were analysed by thematic coding and colouring. The codes can become keywords of the questions/ statements such as 'main challenges' was the code for the question 'what were the main challenges encountered during the design phase?' In the case of multiple projects, the scores can be analysed by doing a case study comparison between NBS projects. The findings can be compared by looking for patterns between the projects and grouping these into themes. These themes are interpreted in relation to the scores, the governance context of project and academic literature, in order to provide insight into relevant conditions for the horizontal and vertical mainstreaming processes of NBS projects.

Ecosystem services

Ecosystem Services (ESS) are an important factor to consider in the design and implementation of NBS. Before addressing the topic of ESS, it is important to understand what ESS are and how relevant they are for coastal defence. Definitions of ESS vary between countries and regions. ESS are most of the times described as 'the benefits humans derive from ecosystems'. This can include the natural protection of dunes from flooding, climate regulation, pollination by wild insects, natural water purification, food from trees, etc. Everyone in the world is completely dependent on the Earth's ecosystems and the services they provide. ESS are usually divided into 4 major groups:

- Producing services such as food, water and timber;
- Regulating services that influence climate, floods, diseases and water quality;
- Cultural services that provide recreational, aesthetic and spiritual services;
- Supporting services such as soil improvement, photosynthesis and nutrient cycling.

The importance of ESS

Each coastal region is characterized by a network of ecosystems, a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit of which humans are an integral part. An ecosystem produces valuable ecological and socio-economic values or services which are needed for a healthy society. The theory of ESS makes it possible to indicate the importance of an ecosystem as a basis for those values. It reveals the extent to which different sectors in societies in coastal regions depend on the well-functioning of ecosystems. ESS provides a large amount of human welfare on Earth.

Figure 6:

ESS From nature.

Source:
NatureScot

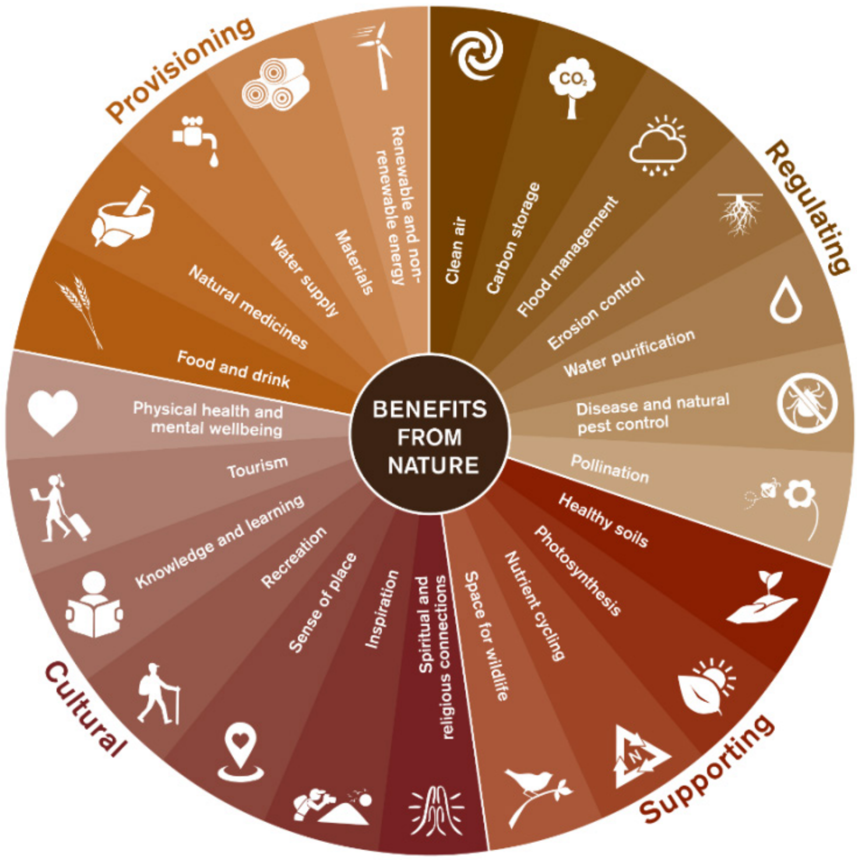
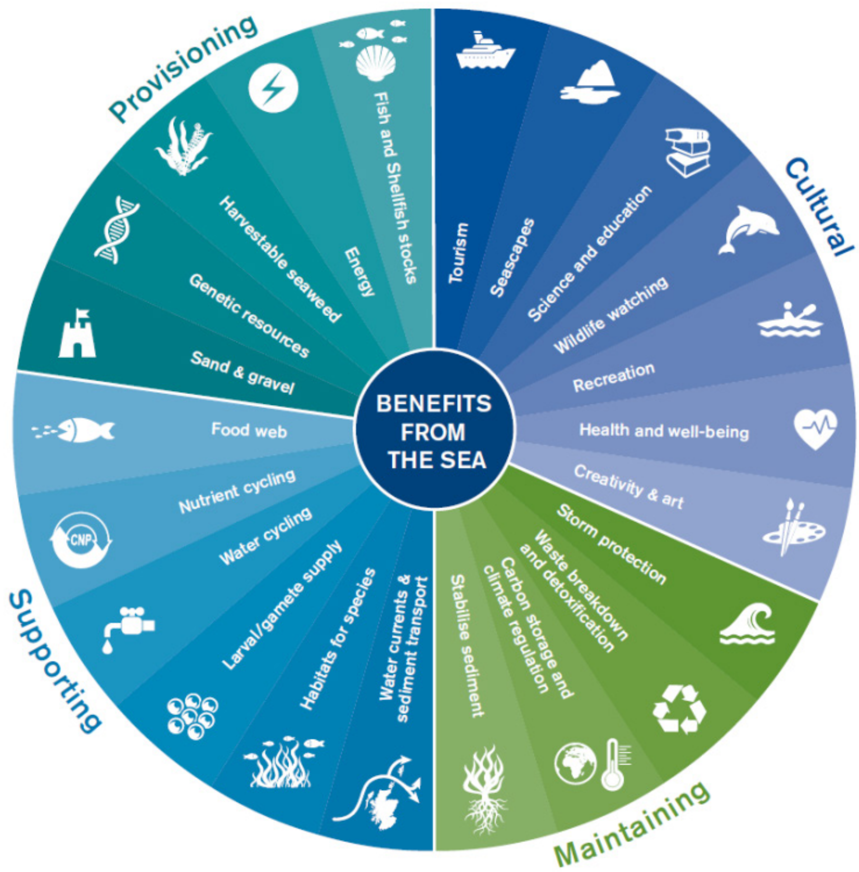


Figure 7:

ESS From the sea.

Source:
NatureScot



Because ESS are often not directly related to NBS or they are not quantified in monetary value (euros or pounds), they do not often get the focus or attention in policy decisions and urban coastal designs. This is because the benefits associated (local, regional or global) with them are not directly linked to NBS but they provide benefits to external persons who are not directly paying for these. Consequently, ecosystems are mismanaged. By not including the ESS, one risks that a project or design will not be sustainable in the long-term. This is because the total value of ESS is unending as these services are supporting life on Earth. It would be beneficial for humanity to monetise the value of ESS. In the past decades, many studies have been conducted on estimating and calculating the value of ESS. The difficulty lies in the fact that ESS are non-market goods (these are goods that are consumed but cannot be traded in markets) and need hypothetical market prices. These prices can be derived from indirect calculations such as market values derived from the effects of behavioural change linked to a particular service. An example of this is the willingness to pay (WTP) for getting a change such as for example a NBS with more green infrastructure. Costanza and partners report in there publication ***The value of ecosystem services and natural capital*** (1997) for example calculated indirectly that the annual average total value of 17 analysed ecosystem services provided on Earth is $33 trillion for 1997 (or 31,9 trillion euros or 27,9 trillion pounds calculated with the exchange rate of 11/2022).

Evolution of ecosystem services in the last 50 years

Ecosystems and the related services interfere with a rapidly changing world. The growing population in the last 50 years demanded more food, water and other resources such as fuel which resulted in altered ecosystems. As a result, human well-being and economic development rose significantly. However, the management and alteration of ESS also have consequences. Research indicated that 60% of the existing ESS defined by the Millenium Ecosystem Assessment (MEA) are in degradation or they became unsustainable. Examples are freshwater, regulation of regional and local climate and fisheries. As a result, the usage and benefits of ESS are unequally distributed on earth which strengthens the inequality between groups of people leading to poverty and social conflict.

Methods for data collection and analysis of ESS

To integrate nature in urban development it is important to deliver robust evidence of the environmental and economic developments of new NBS and ESS is developed to do this. The methodology to calculate the ESS of NBS needs to be easily adopted by - and be upscaled to - other coastal regions. A wide range of tools were analysed and tested on the following criteria: free to use, science-based, usefulness for NBS, completeness, easy-to-use, maturity and reviews. The GI-Val (Green Infrastructure Validation) and B£ST (Benefits Estimation Tool) came out as most appropriate.

• GI-Val is a green infrastructure valuation toolkit developed by The Mersey Forest (cf. a growing network of woodlands and green spaces across Cheshire and Merseyside). The current prototype of GI-Val is free-to-use, open source (see usefull links chapter). With this tool monetary values are calculated for the social, economic and environmental ESS that green infrastructure provides. These three themes are divided into 11 benefits (e.g. climate adaptation and mitigation, water and flood management, health and wellbeing). Per benefit, several factors can be calculated (e.g. carbon sequestration, a factor linked to climate adaptation and mitigation, and reduced mortality is linked with health and wellbeing). Each factor has its own tool that calculates the impact of the benefit. For an extensive and detailed overview of all factors and tools per category, the GI-Val user guide can be consulted (2011). The GI-Val tool has two limitations: (i) some of the ESS cannot be assigned a direct monetary value for the reason that limited evidence exists for a good well-argued calculation and (ii) the results of the tool are intended as an indicative project appraisal. It therefore does not replace a cost-benefit analysis but provides new insights regarding ESS.

• B£ST is used to assess and monetise the provisioning and supporting of the cultural and regulating ESS of blue and green infrastructure. To evaluate these ESS, different benefits are calculated (e.g. for cultural ESS amenity and education is calculated, for supporting ESS biodiversity and ecology is calculated). To calculate each benefit, qualitative data is needed (e.g. for amenity the number and types of homes/commercial properties and the number of people impacted by the scheme is needed). The tool is developed by Susdrain (cf. a community that provides a range of resources for those involved in delivering sustainable drainage systems). The results of the toolkit enable users to understand and quantify the wider value of sustainable urban drainage systems and natural flood management measures. B£ST is freely accessible (naturalseadefence.eu)

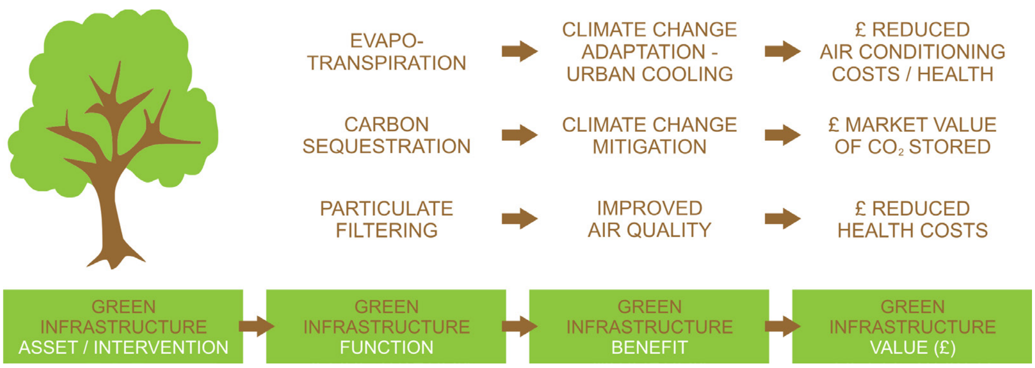
Both tools (GI-Val and B£ST) require knowledge and data collection of the targeted NBS project they want to assess. Quantitative and qualitative data was gathered in different ways (literature reviews, interviews with pilot managers, questionnaires, data analysis in GIS software, etc.).

It is not easy to say if a particular NBS is better or worse than others on the delivered ESS. Society is very diverse so each has its own interests in certain ecosystem services (fisheries, recreation). More research is needed on the ESS through which sensibilization regarding climate change and coastal safety measures can be carried out. In chapter 4.4 results of the ecosystem services can be found for the Belgium pilots.

Figure 8:

Example of how the GI-Val toolkit evaluates ecosystem services.

Source:
The Mersey Forest Partnership



2

Application: Project Design Development Framework

This paragraph contains the result of the application of the Project Design Development Framework of the Nature-Inclusive Urban-Coastal Management-Framework (NUM). This is the Project Guide for the Implementation and Monitoring of Nature Based Solutions (NBS) to create Climate Resilient Coastal Cities. The first section delves into the Longue Durée of the projects that were part of SARCC. The second section is presenting the result of the project in Vlissingen. Vlissingen is an actual implementation to provide a long-term and regional approach with NBS.

Longue Durée

The Longue Durée is examined to explain how human and natural influences contributed to the evolution of the coastline. The historical maritime atlas that are prepared for the SARCC pilots are presented in this section.

The concept Longue Duree is created by Fernand Braudel (1902-1985) who wrote La Méditerranée et le Monde Méditerranée á L'Epoque de Philippe II (1949) (The Mediterranean and the Mediterranean World in the Age of Philip II). Braudel is famous for his vast panoramic view and the use of insights from other social sciences. The concept of the Longue Durée is the first of three time levels and involves the geographical/environmental time, with its slow, almost imperceptible change, its repetition and cycles wherein change is irresistible. The second level of time comprises social and cultural history and the third level the one of events, respectively fast and fastest.

The Longue Durée is examined to explain how human and natural influences contributed to the evolution of the coastline. This is achieved by the creation of a historical maritime atlas containing sites that can inform on the long-term process of coastal change, sea level rise and in some cases, climate change. To do so, data is gathered from historical sources including art, archaeology, maps, charts, photographs and the palaeo-environment. The evidence is described, scored and interpreted to qualify past events and patterns of change. The results are viewed and queried through an online portal where the highest scoring sites are used to help determine the long-term impacts and influences on the coastline in the pilot area case studies. The most significant results are accessible via a Maritime Atlas viewer (Figure 9). These provide a valuable data source to be used by coastal authorities to inform the design phase of a development and disseminate the need to the public.

Newlyn - The United Kingdom

The survival of a 5,000 year old intertidal prehistoric landscape shows that this part of Mounts Bay was protected from the ravages of an open sea when the water rose during the last stages of the marine transgression. The sheltered conditions at that time enabled sediment to settle, cover and protect the ancient land surface; being a feature that can remain for millennia if undisturbed. However, when it becomes exposed, palaeo-environmental material and any associated archaeological features, can degrade within years, although large sections can be lost in a single storm. These deposits are particularly important as they provide evidence of coastal and climatic evolution as the sea rose, the climate changed and the shoreline was realigned (Figure 10). Significantly, the exposure of the submerged landscapes off Newlyn Harbour over the last century indicates a new phase of erosion.

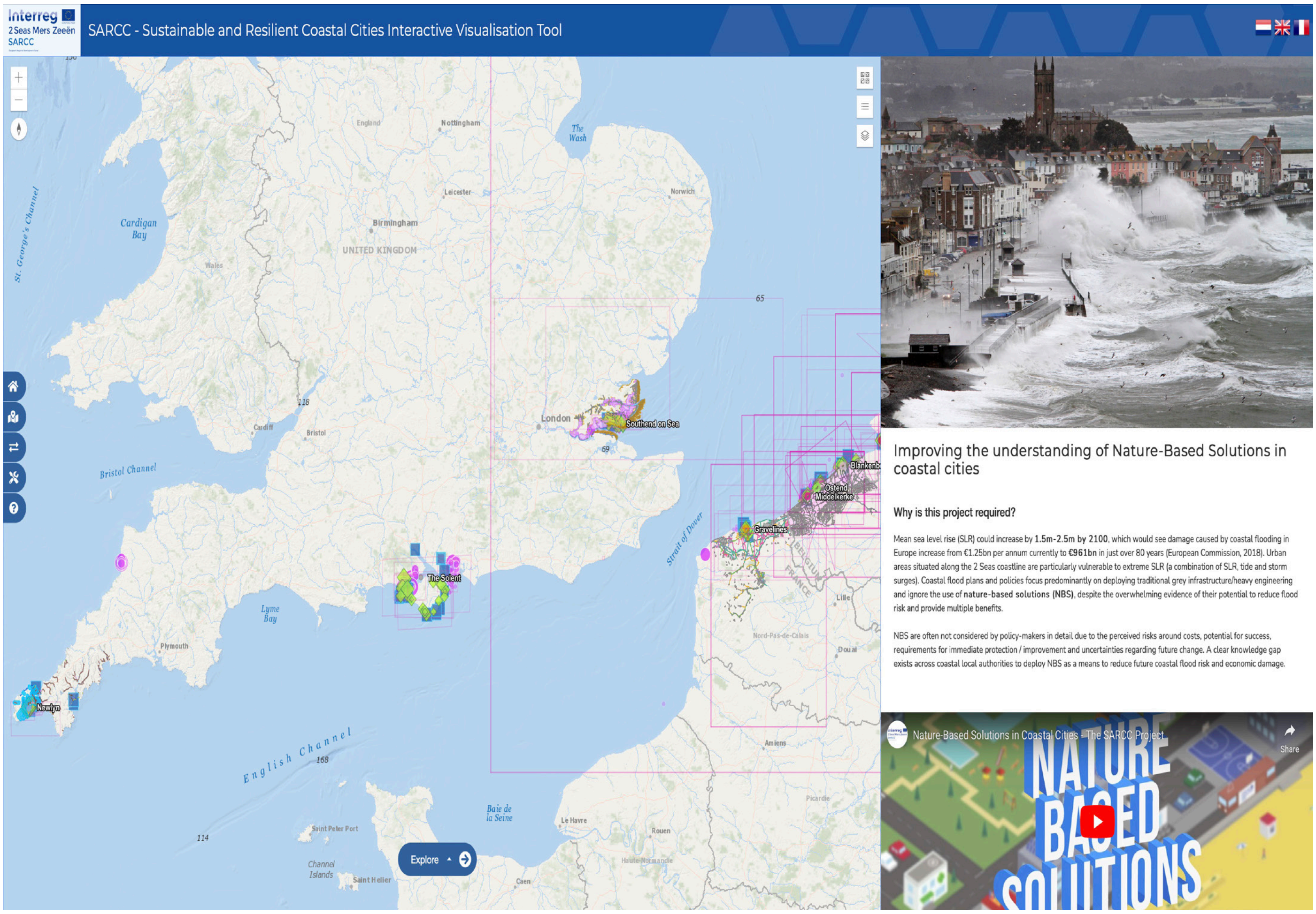


Figure 9
SARCC Visualisation tool

Source:
Maritime Archaeology Trust
(naturalseadefence.eu)

Figure 10:

Exposed intertidal landscape eroding from the peat at low water dated to 2571 – 2347 BC along the Solent case study area. The remains of tree routes can be seen in the foreground and a line of fallen tree trunks extend towards the water.

Source:
Maritime Archaeology Trust

The historical and artistic record has documented changes to the landscape, the beach and coastline. They show that erosive processes have increased over the last two centuries due to construction around the bay (Figure 11). The factors that have caused the greatest impacts are the development of the port in the late 19th century where the North Pier channels the water directly into the mouth of the Coombe River, and where restriction of the Coombe River channel with the loss of it's flood plain that has now been built upon (Figure 12). This has resulted in a lowering of beach levels and flooding of Tolcarne during storm events at high tide.

Southend on Sea - The United Kingdom

Around 4,000 years ago the river Thames flood plain was lined with salt marsh that was covered with each rising tide. The marshes formed a protective buffer against flooding inland but, from the thirteenth century, as populations grew, the Thames saw progressive reclamation and dike building. This created new land but it also narrowed the river channel, inadvertently increasing the height of the incoming tide and with it, an increased risk of overtopping the riverbanks. The reclamation of Canvey Island, Hoo, Coney Island and Foulness Island alone almost halved the area that the sea previously covered at the mouth of the Thames during storm surges (Figure 13).

Southend on Sea lies on the northern shores at the outer Thames Estuary. Historical markers on charts and maps, and artwork can be used to monitor change and notably erosion, by comparing the relationship of recorded structures along the shoreline to the high water mark (Figure 14). Currently, the south-facing shoreline is fixed, which has removed the adaptive capacity of the beach and resulted in drawdown, while causing scour that, in some places, is underpinning the hard frontage. The study also identified where the sediment flow had been interrupted by human actions and construction along the east-facing coast off Shoeburyness. As a result, erosion has accelerated along East Beach which now needs to be protected (Figures 15 and 16). The truncation of an Iron Age Hill fort by coastal erosion in the last 200 years indicates the scale of recent erosion where it can be used as a marker to monitor rates of loss.

Accelerating erosion and instability along a coastline can have implications for property insurance and the cultural value of a landscape. Revegetation of selected areas around some of the pilots is now underway to restore habitat and provide a natural defence.

Gravelines - France

Figure 11:

Exposed intertidal landscape eroding from the peat at low water dated to 2571 – 2347 BC along the Solent case study area. The remains of tree routes can be seen in the foreground and a line of fallen tree trunks extend towards the water.

Source:
’Reproduced with the permission of the National Library of Scotland’ Under licence (CC-BY)

Figure 12 a b:

Left to right - Old Tolcarne Bridge, Newlyn Henry Pendarves Tremenheere 1804 Image courtesy Penlee House Gallery & Museum, Penzance. Today, the Old Tolcarne Bridge is now squeezed by development and prone to flooding (November 2020 MAT).

Source:
a. Permission from Penlee House Gallery & Museum Penzance

b. Maritime Archaeology Trust

Figure 13:

Extensive sand banks stretch from East Beach into the North Sea showing an area of sedimentation at the Chart of the mouth of the river Thames c. 1544

Source:
Southend museums services licenced under (CC BY-NC-SA)

Figure 14:

The Crowstone 1809 Unknown artist

Source:

'Shoeburyness a history' by Judith Williams 2016

Figure 15:

East Beach in the late 19th century, in an area that is eroding quickly.

Source:
John Bennett Southend City Council

Gravelines grew within a small sheltered estuary that developed during the last stages of the marine transgression three to five thousand years ago. From the 9th century AD this attracted a fishing community and the sheltered inlet steadily developed into an important port, flourishing in the twelfth to seventeenth centuries as a trading hub and strategic military centre (Figure 12). Historical evidence shows how long-term sediment transport restricted navigation within the river mouth, but due to its significance, an additional channel was cut through the dune system and beach (Figure 13). This subsequently required ongoing maintenance and was sporadically extended further out to sea to prevent it from silting up. An unintended consequence is that it now acts as a groyne allowing dunes to develop in the west, while the structure funnels the sea towards the town on the east. Here, the dune complex has been compromised by house building, limiting the adaptive capability of the coastline and increasing the risk of overtopping, and flooding (Figure 14).
A better understanding of the long-term movements of the foreshore sediments would have helped earlier societies predict patterns of change along the coastline and manage the sediment budget more effectively. While technology has advanced over the centuries, the core challenges presented by the underlying coastal processes have not. An appreciation of the site's history is of value to inform coastal managers today.

Middelkerke, Ostend and Blankenberge - Belgium

As sea level began to slow during the post-glacial thaw around 5,000 years ago, coastal processes off Flanders changed from inundation to progradation. High levels of sediment deposition from the rivers and estuaries advanced the land seaward. River banks evolved into salt-marsh around the Rhine, Meuse and Scheldt estuarine complexes and barrier dune systems built up along the coastline as longshore drift carried marine sand from the northwest. By the middle of the 2nd millennium BC, modelling has shown that the land at the mouth of the Ostend valley extended a further 10km out to sea when compared with the contemporary coastline, while, coastal peat marsh stretched almost 20km inland.

Sea level rise slowed dramatically by the first millennia BC. The coastline became relatively stable until the status quo was undermined by human influence. Peat extraction, primarily by the Romans, removed the surface deposits, drained the land, compacted the soil and lowered ground levels to reverse the earlier depositional processes (Figure 15). Subsequently, dikes were built that constrained the water along the estuarine tributaries, but this also caused the water to be funnelled into narrower channels, whereby increasing the river level on high tides. This made flooding more devastating when defences were overtopped as large areas of land in Flanders were now many metres below sea level. Paradoxically, in areas where processes were able to follow their natural course, sediments laid down by the rivers raised the land naturally and settlements were able to return to the coastal fringe, as happened in the late medieval period (Figure 16). In the 14th to the 16th centuries flooding was a relatively common occurrence, however engineering solutions advanced and larger dikes were built giving people more confidence to move to the places with increased protection, inadvertently making flood events even more catastrophic.
In more recent times, the whole coastline has been delineated by fixed dikes, while the estuarine drainage system has been infilled/poldered. These changes can be charted on historic maps, which when compared with contemporary flood risk maps, show that the areas at greatest risk of flooding inland are the old,

Figure 16:

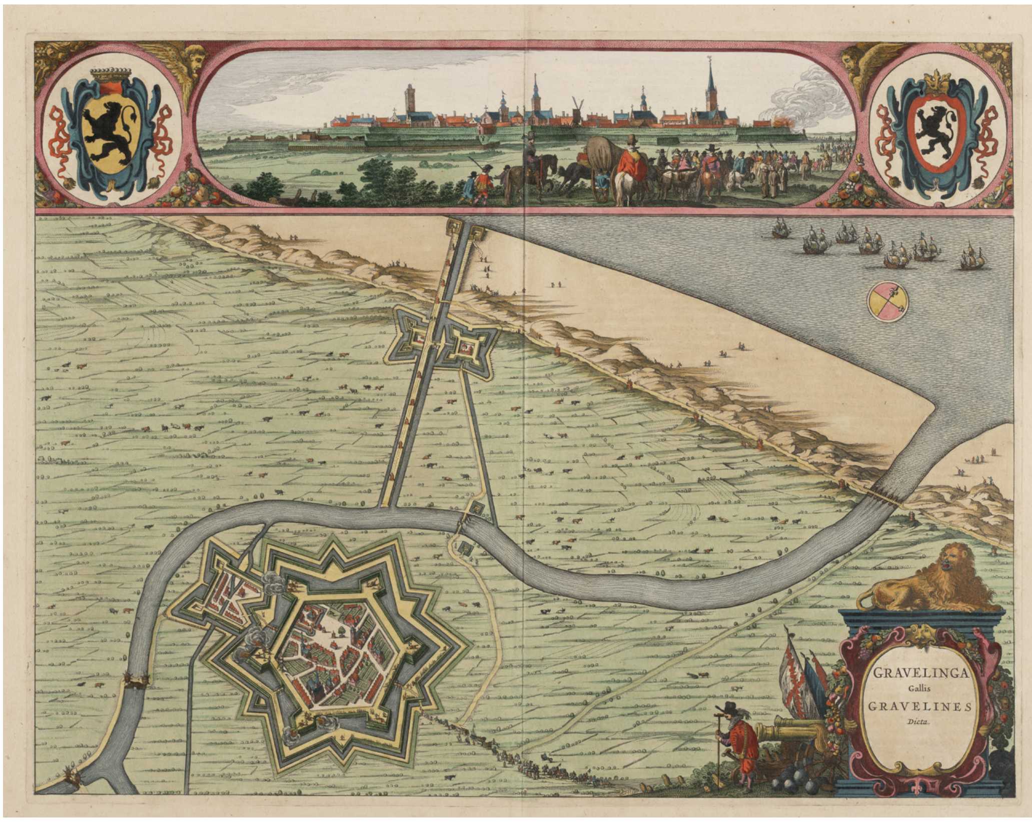
The cliff has been reshaped and the toe is now protected by rock armour to help dissipate the wave energy and slow down erosion.

Source:
Wikimedia commons

Figure 17:

Gravelines by J Blaeu 1649

Source:
St Elizabeth Day flood, Master of the St Elizabeth Panels
c1490 - c 1495.



poldered estuarine channels. Along the coastline, the historical record shows how the building of coastal dikes, promenades, roads and tramlines has interrupted the natural system by stopping the interplay between the beach and the dunes, and restricting the ability of the coastline to adapt. Hard defences deflect the swash, increasing the strength of the backwash, contributing to the erosion and the stripping of the beaches. The hard defences are then being undermined, compromising their ability to mitigate against the impact of storm surges as the climate changes (Figures 17 and 18).

Within the SARCC project, Nature Based Solutions are being re-introduced by coastal authorities at the pilot sites to recreate dunes systems in front of the new sea defences and coastal roads. This is returning the coastline to a more resilient state and closer to that which is seen in the past. The historical records can be used to justify the need for change and help advocate the most appropriate solution.

Conclusion

The assessment of the pilot sites by reviewing historical data sets, as summarised above, has shown how past human influence along the coastline can cause detrimental long-term impacts. In many cases, particularly in the deltaic low countries, it is impractical to reverse these actions. However, with wisdom from hindsight, similar mistakes can be avoided in comparable low-lying regions where decisions still have to be made when managing the coastline.

This project has shown how an assessment of the Longue Durée provides an understanding of causal mechanisms that have shaped the coastline. Where these processes are identified as ongoing, this can inform coastal managers about the long-term forces acting on the coastline and contribute to a positive decision-making process. This provides historically derived baseline data that can be firmly integrated into the Project Design Development Framework.

Visual representations from historical documents and artworks can be a very valuable tool when telling the story of the transient nature of a coastline to the public.

Project Design Development Framework: Vlissingen

This section presents the application of the Project Design Development Framework on the SARCC pilot of Vlissingen.

Vlissingen is a middle-sized city (44,370 inhabitants) situated in the outlet of the Western Scheldt River on the North Sea coast. Due to its strategic geographical position, it has become a crucial harbour since the XIV century. Its internal areas, as most of its province, are below mean sea level and are thus protected by a flood defence system. Vlissingen's primary flood defence structure is composed of the following elements: (i) a reinforced concrete slope along the sandy coastline; (ii) storm walls with bullnose above which lays the waterfront boulevard; (iii) the first row of buildings made by a mix of traditional 3-story row houses and towers of different heights with commercial activities on the ground floors (some of which are accessible from a raised plaza with underneath parking); (iv) a raised dike on the back of the buildings, in the western part of the main boulevard.

Vlissingen, like many parts of the Netherlands, has had to learn to cope with many episodes of devastating floods over centuries and develop the best ways to prevent or minimise such occurrences. The SARCC project provides the design and implementation of a new way of thinking about climate-adaptive public spaces in urban areas by the sea. The objective is to focus on natural and green sustainable measures, which in the long-term will protect the urban area against flooding during storms.

Figure 18:

Vlissingen is a cape-town situated on the (former) island Walcheren at the mouth of the Western Scheld.

Source:
Muncipality Vlissingen

STEP 1 Map the LONGUE DURÉE

In this first step, the different specialists gather information on the larger scale and time frame to create the maritime atlas, landscape atlas, and a planning atlas.

Maritime Atlas

Vlissingen is a city that developed in a very challenging, albeit strategic location where it is directly exposed to severe weather events rather than being in harmony with natural forces. Therefore Vlissingen shows a clear development on the basis of the relationship between land and sea. It benefited from the natural conditions and urbanization behind the dike from the time it was established in the 12th century.

The name 'Vlissingen', or Flushing in English, refers to the original function of the Spuikom (= 'flushing bowl'). Originally, the 'Spuikom' was part of a larger water system of the city and the surrounding polder land. The Spuikom itself was not only designed for drainage purposes, but also to drain the harbour basin frequently, in order to get rid of redundant sediment deposits. A restoration of this water system at a larger scale might be helpful as an extended catchment system for overtopped sea water as well as for stormwater.

Morphological change

The morphological history of the area goes back to around 5,000 years ago when sea level rise slowed and the balance changed from landscape inundation to progradation where new land was created by high levels of sediment deposition from the rivers and estuaries. Barrier bars grew to protect the land from the sea and riverbanks evolved into saltmarsh around the Rhine, Meuse and Scheldt estuarine complexes from the beginning of the 3rd millennium BC. Progradation of the coastal zone in the region continued until the end of the first millennia BC when sea level rise slowed. A stable equilibrium might then have been established

if it were not for human influence. Peat extraction, primarily by the Romans, removed the surface deposits, drained the land, compacted the soil, and lowered ground levels to reverse the earlier depositional processes. The peat was an important source of fuel and was used in the process of marine salt manufacture. The Romans' land management practices were very destructive and by 450 AD the sea overran the depleted coastal peat lands and the estuaries opened into wide channels. However, when natural processes were able to dominate once more, the salt marsh expanded. By the Medieval period, people reoccupied the landscape in small-scale dwellings and reintroduced spaces for grazing.
From the 13th century dikes were built to protect the continuous subsiding landscape, creating the well-known cooperative character of the Dutch: dikes must be built in rings and managed by the community. Consequently, when the dikes did collapse, the impacts of floods were more devastating than the inundations that had occurred before their construction.
Over the next three hundred years protection along the Dutch coast was generally more successful. However, ongoing maintenance and rebuilding were still required, but it was still unable to prevent the city from the storm surge of 1953 that killed thousands and flooded almost ten per cent of Dutch farmland. This tragic event precipitated the building of much more substantive coastal defences that have, so far, prevented further catastrophes. This is reassuring, but the continued building of traditional grey coastal defence infrastructures does not necessarily solve the challenge in the long term and the SARCC pilot project, where a nature-based solution is being trialled, offers a new approach for Vlissingen.

Storms and Flooding Patterns

The low-lying estuaries along the Dutch coast are vulnerable to westerly and north-westerly gales. The impact of storm surges became increasingly destructive as the land was lowered by peat extraction and then the waterways were lined with dikes. These had the effect of funnelling the water, raising river levels, and causing the banks to overtop. Subsequent floods that took thousands of victims were recorded in the 11th, 12th, and 13th centuries.

By the 14th century, a series of devastating floods led to the appointment of 'Dike Counts' and the first organised form of joint dike monitoring. Despite the initiative, dikes continued to be breached causing even more catastrophic flood events throughout this and the following centuries (Figures 19 and 20). Following these events, and the formation of the Dutch Republic, the defences were strengthened further and despite large storms of the later part of the 16th and then the 17th centuries, flood events became fewer.

Figure 19:

The altarpiece depicting the St Elisabeth's Day flood across the Grote Hollandse Waard to the east of Vlissingen

Source:
Master of the St. Elizabeth Panels, Rijksmuseum Amsterdam

Figure 20:

The breach of the Saint Anthony's Dike near Amsterday by Jan Asselijn

Source:
Rijksmuseum Amsterdam

By the 19th century and beyond, storms continued to have impacts, especially at the most exposed locations. This included Vlissingen which was forced to maintain and even rebuild its western-facing sea dikes and was the victim of the ruinous floods in 1808 despite its extensive defences (Figure 21). Breaches occurred again in 1906, 1953 and there was the flooding of the harbour in 2013 (Figure 22).

Figure 21:

Overstroming in de Palingstraat te Vlissingen, 1808, Izaak Jansz. de Wit, after Johannes Hermanus Koekkoek, 1808

Source:
Rijksmuseum Amsterdam

Figure 22:

Oude Market, Vlissingen. 12th March 1906. Published by G C Reyers Jr.

Source:
City Archive Vlissingen

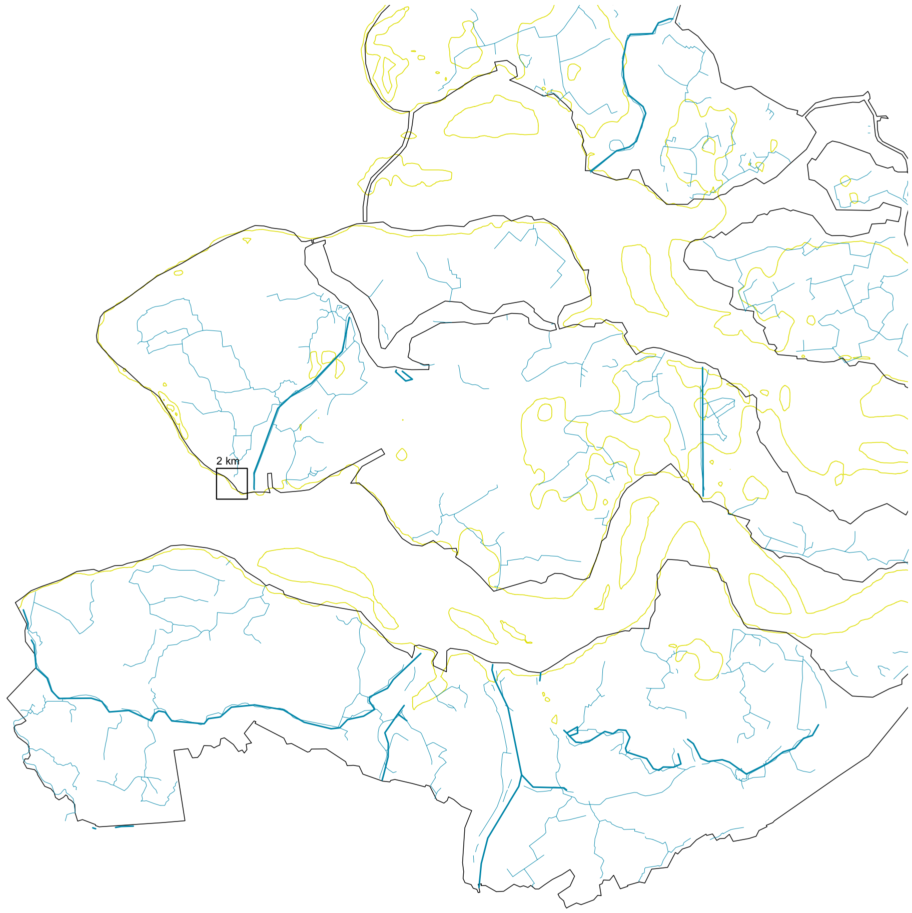
Figure 23:

1953 flood. In February 1953 an exceptional storm surge damaged the Boulevard and sea wall. A total of 1850 fatalities were reported in the Netherlands (source: Hart van Vlissingen)

Source:
City Archive Vlissingen

Figure 24 a b :

Vlissingen in Zeeland: urbanized areas on the left; terrain levels and surface water network on the right.



Landscape Atlas

Vlissingen is a typical cape-town with an old centre in a citadel and on the east side a large industrial area, port and channel to the Veerse Meer. It is situated on a former island Walcheren that by reclaiming land has become a peninsula with the former island Zuid Beveland, connected to the mainland. It is encircled by a large dike, the inlands are polders that are drained by pumps 24/7.

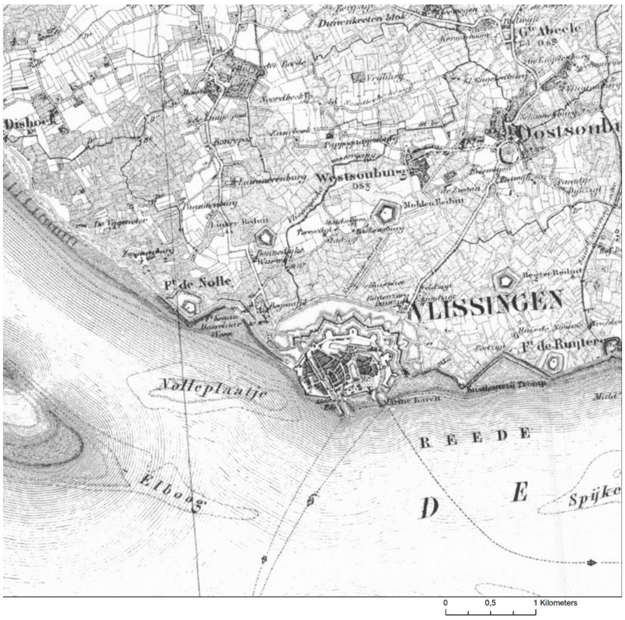


Figure 25:

The historical dike structure in the larger area of Vlissingen (Volkstelling map, 1795)

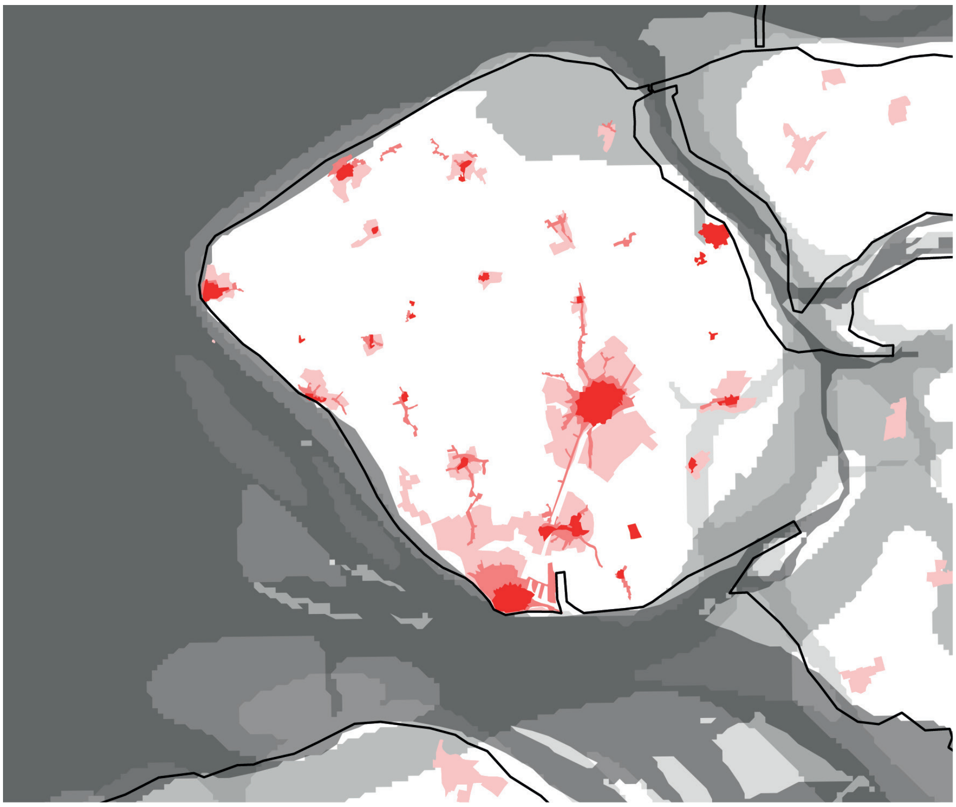


Figure 26:

The urban evolution in Walcheren

Planning Atlas

The strong Dutch flood safety and water management tradition has had quite an impact on morphology that is characterized by a historical citadel (cape-town model) with an industrial port area outside the dike, and a transport channel to the Veerse Meer. Northwest of this centre is a large housing expansion, beyond which are holiday houses and campsites. Land-use development at the coast has been restricted. As a coastal town, Vlissingen has a high mix of land-use being industrial, port, tourism, campsites and nature preservation areas like the dunes. There is a strong tradition of tuning land-use planning and tuning the vulnerability of functions with reducing flood risk. The paradigm in which flood safety is taken care of on a national scale without including urban development is quite strongly applicable to Vlissingen.

STEP 2 Map the URBAN PROJECT

In this second step, the specialist gathers information on the urban scale and creates the flood atlas and the urban atlas of present and future artefacts.

Flood atlas

The high Dutch protection standards, implemented in the Delta Works after the disaster of 1953, have made significant parts of the primary dike defences along the coast of the Netherlands, and more specifically in Zeeland, have protection levels to resist storms that can be present every 10,000 years (or the equivalent return period of 10000 years). Indeed the wave wall deflector built in front of De Spuikom has a total water level design of around 8.7m according to Oranjewoud, 2008 (5.65m surge + 3.1m significant wave height). This value is close to the value reported in the model HydraNL, for the 10000 years return period (8.57m).
Note: Hydra-NL is a probabilistic model that calculates the statistics of the hydraulic loads (water level, wave conditions, wave overtopping) for the assessment of the primary dikes and structures in the Netherlands (Rijkswaterstaat, 2019). To build the bathymetry/topography, a digital surface model (DSM) and a digital elevation model (DTM) were acquired for the whole area (~50cm resolution). The difference between these two is that the first one includes buildings, cars, and trees (following the surfaces of the shapes present in the city), and the second one follows what should be the terrain/ground elevation (see figure 28). From this information, special manual filtering was applied for the trees and the cars, especially at the De Spuikom area. Finally, the bathymetry was built and is displayed in figure 28.

The following results were obtained by distributing along the coast a discharge flow of 100lts per second of overtopping along the dike in front of the De Spuikom area and the dike in front of the reptile zoo (see figure 29). From these preliminary results, we can observe that the primary streets by which the water diverges to De Spuikom are the streets of Kommedijk and Buskenstraat. From the same figures, it can be concluded that the front-line building construction protects the backward houses and buildings from being flooded under this scenario, although there are a few small streets/passages that can allow to entry the water inland (figure 29).

Figure 27:

Geology of the region.

Source:
Dinoloket (see website)

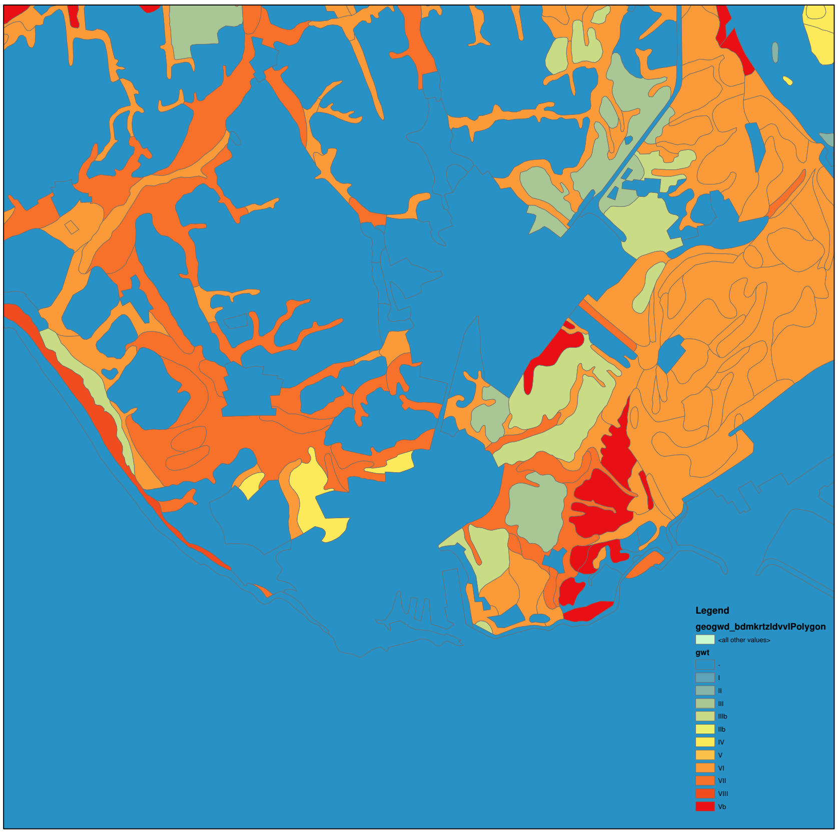


Figure 28:

Showing the hydrodynamic model (Bathymetry)

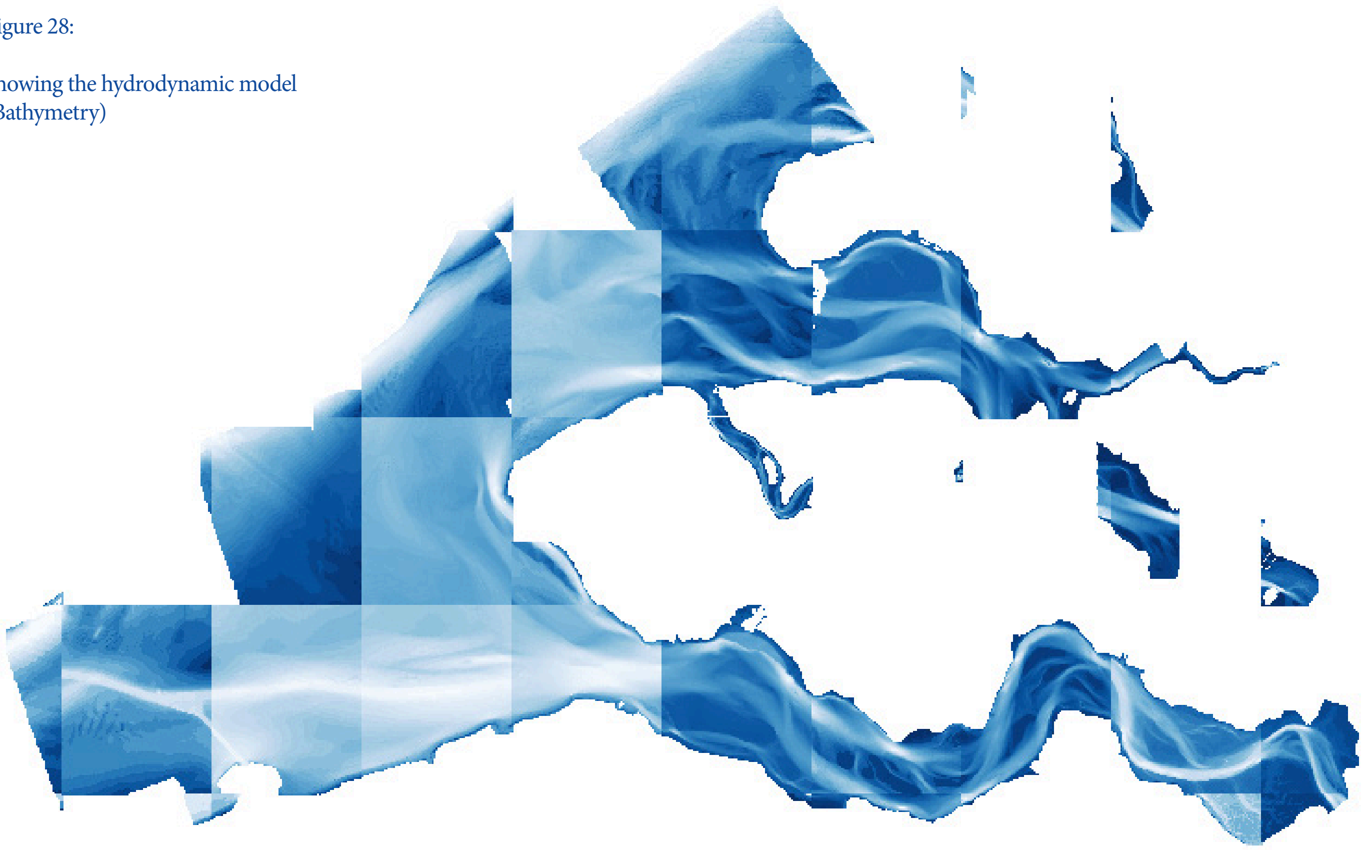
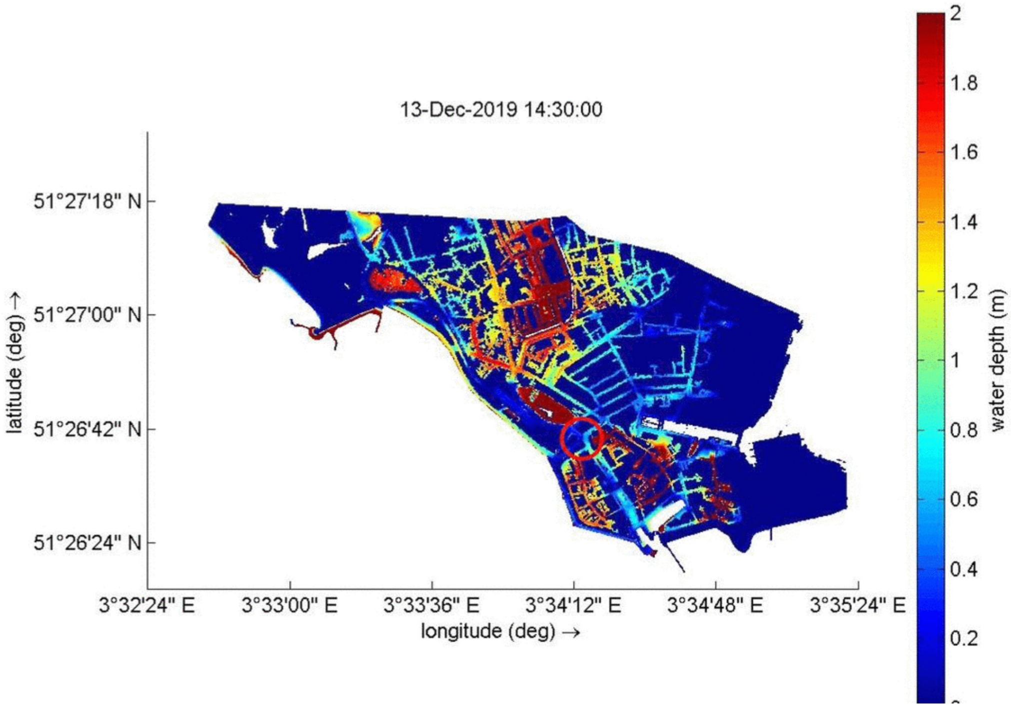


Figure 29:

Hydrodynamic simulation of Urban flooding of city center of Vlissingen (left: 30 min event and left: 5.5 hr event)



Urban atlas

The Urban Atlas presents the construction of the area, this is important to evaluate specific interventions. Especially in understanding the current urban water system is important to an area development that will include acceptance of water. The project area is analysed on the basis of data on historical developments and use of the System Exploration Environment and Subsurface (SEES). The data process by use of the SEES (on water, ecology, civil constructions and energy) was synthesized in four maps presented in figures 31 a, b and c.

Figure 30:

The past (in red) and present (in blue) surface water show the reduction of the Spuikom extension since the 1980s (at the center of the image)
Source:
Kadaster, Netherlands

Figure 31 a b c d:

The context analysis:
a) subsurface, sewer network and potential soil infiltration;

b) intensity of vegetation cover (darker = more intense);

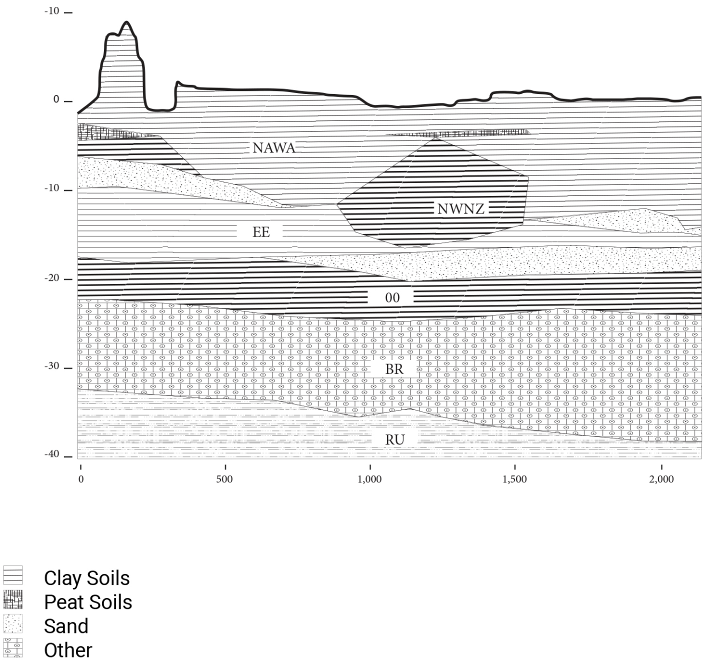
c) roads and dikes (in black);

d) terrain levels (darker = deeper).

Figure 32:

Section in the area.

Source:
Dinoloket (see website)



STEP 3 Synergize analysis over time, scale, and in context.

Subsequently, a workshop is organized to bring together specialists and synergize the findings of steps 1 and 2.

The conclusion of the analysis is that the Spuikom area is considered a hydrological and spatial artefact that represents the logic of the urban tissue in the area. Creating the storage spatially fits well with the logic of the urban area, the water management situation and will give a strong identity for the further development of the area. The flood management approach needs to focus on only the stretch of the boulevard as a dike part, and disconnected from flooding of areas around to make the storage of water feasible.

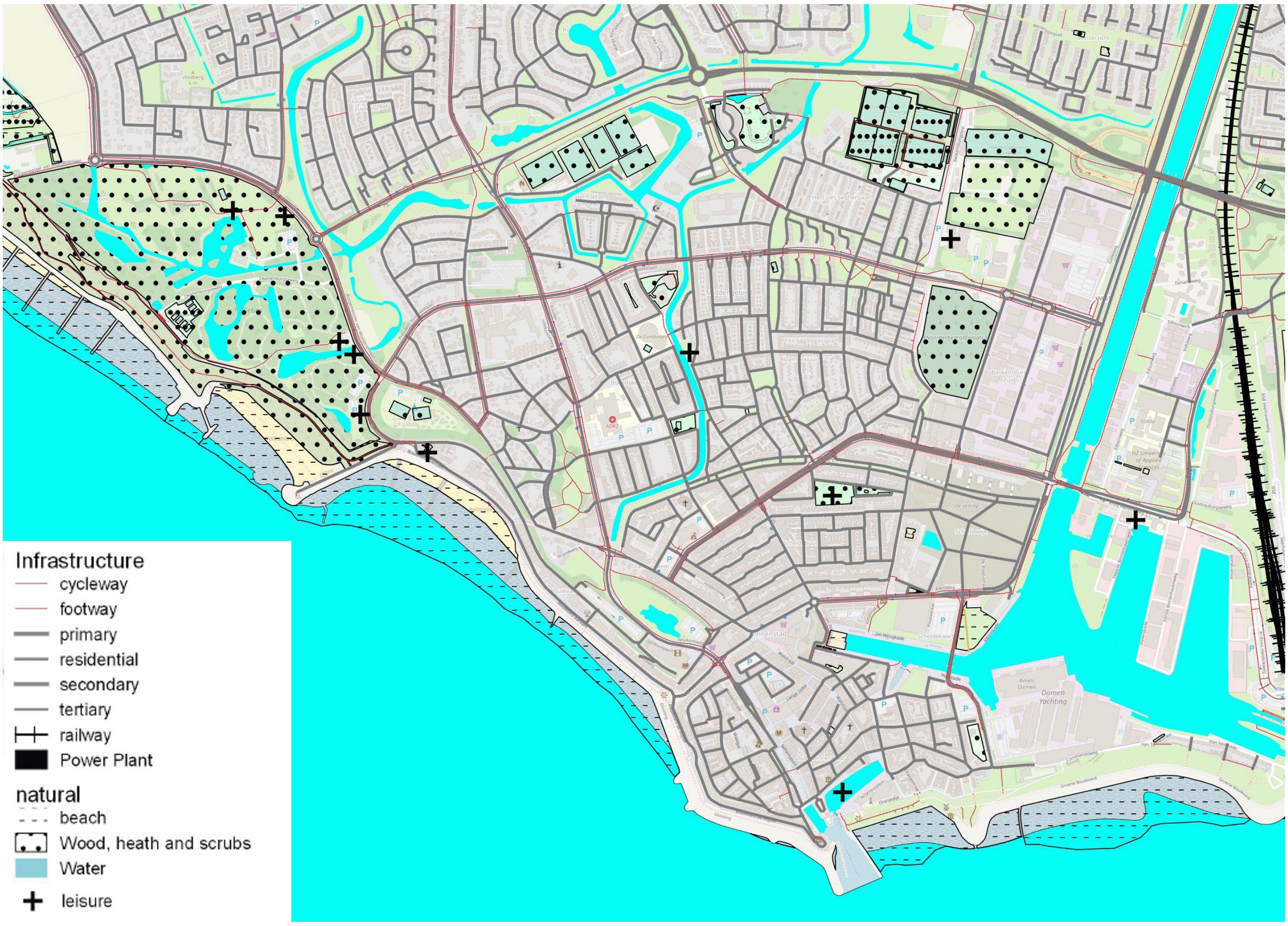


Figure 33:

Conclusion map of the Urban Atlas

STEP 4 Create VISION

Problem definition

In relation to the societal needs of the city centre of Vlissingen and the challenges of climate change that we are facing the problem definition was based on the following points:

- Rising sea level demands anticipation of raised risk in the development of the coastal zone either in reducing probability or reducing consequences.
- The historical value of the buildings along the boulevard is at risk when probability is reduced by raising the dike.
- The historical and green value of the Spuikom needs to be preserved because it represents the urban logic of the urban area.
- The changing paradigm in flood management is a difficult step, but by the municipality seen as part of the local identity of Vlissingen.

Solution concepts

The Spuikom appears today as an empty urban space, partially covered with spontaneous vegetation partially inundated, and used as a car park. It is located in a central area, behind the dike, in-between the historical city centre and an area of more recent development. It is the residual of a larger water reservoir that was in the past connected with the harbour and the sea, partially filled up in the second half of the twentieth century to allow new urban developments.

Today, the Spuikom and its surrounding are the focus of a long-term vision by the municipality that aims to transform it into a mixed-use urban development (with commercial, residential, and leisure functions) serving also as a water retention basin (or "overtopping sump") in case of exceptional flood events.

The present prevailing flood risk management paradigm in which the risk is assessed by probability x consequences, is aiming for reducing the probability of a flood event to occur, largely by means of grey infrastructure. However, the municipality of Vlissingen would like to challenge this and aim for the reduction of the consequences as a feasible and acceptable approach. Instead of exposure and vulnerability reduction by means of grey infrastructure, consequences are reduced by adapting the urban environment. Moreover, the reduction of the vulnerability is addressed by looking into the balance between on the one hand natural conditions and on the other man-made interventions.
The solution is therefore accepting water over the dike. Since this is quite a radical approach no other solutions are considered. The Spuikom Model concerns the implementation of an overtopping sump area.

Figure 34:

The Spuikom Model concerns reducing the consequences and not the probability.

Risk =

Probability	**x**	**Consequences**
power		damage
strength		victims
		societal impact

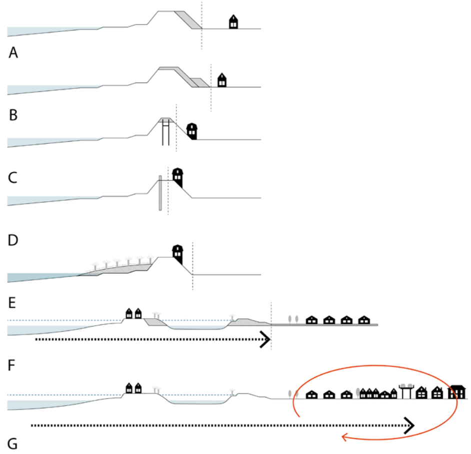
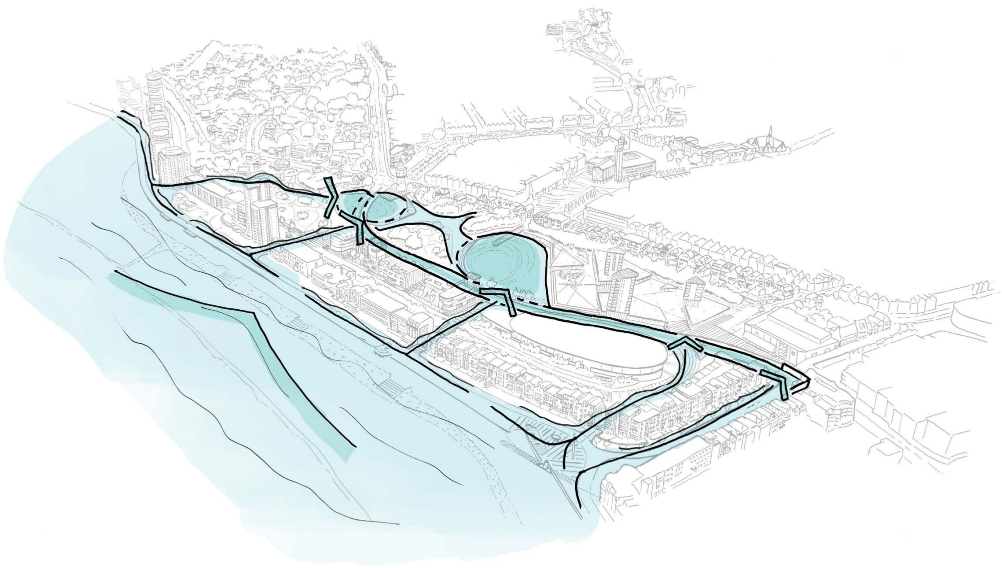


Figure 35:

The Spuikom Model concerns the conveyance of overtopping water and the implementation of an overtopping sump area.
(Bureau Ma.an)



Synergy
The concept solution is integrating another approach of flood management, focusing on reducing the consequences, with sustainable development in which the values of heritage and nature are preserved and forming the basic qualitative conditions.

STEP 5 Create STRATEGIES

The development of the vision and the guidelines that would steer the implementation of this vision can be combined into different strategies. These can be modelled and tested on the desired spatial configurations in the project area. For Vlissingen the Spuikom Model was elaborated on, two other strategies were also tested and modelled as a benchmark for the research.

Guidelines
The Spuikom Model meets the criteria of the Dutch three-layer approach including:

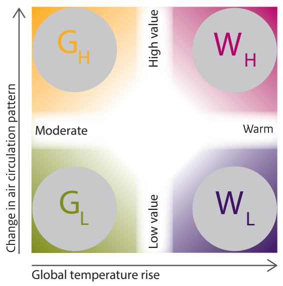
a) the reduction of flood risk through the use of movable barriers;
b) the adaptation of streets and public space to retain water overtopping and;
c) the realisation of high-rise buildings that can serve as 'vertical evacuation'. The following guidelines are defined:
- Conveying water from the boulevard to the Spuikom (5 'holes' in the building front).
- Making the buildings and public space along the boulevard resilient to water by dry-proofing and wet-proofing.
- Preparing the Spuikom spatially as a water storage area.
- Developing new real estate as part of the route in which the water is conveyed to the Spuikom.

Modelling
To support the solution of accepting water over the dike, overtopping and creating storage behind the dike, a hydrodynamic model was used to simulate a storm in a future scenario. As for the boundary conditions, the overtopping discharge flow values produced by a storm with a return period (RP) of 10,000 and two climate change (CC) scenarios, extreme W+ and moderate G, at the year 2100 were tested. This scenario considers a sea level rise of 1m by 2100 and a RP 1:10.000; these values are taken to perform the comparison between the current situation (baseline strategy) and the Spuikom Model for coping with sea level rise.

According to the hydrodynamic model, 275,000 m3 of excess water is estimated to flood the Spuikom at the peak of the storm. On the other hand, the recovery of additional storage capacity makes it possible to achieve a retention capacity for the Spuikom of 186,000 cubic meters (140,000 m3 on S2 and 46,000 m3 on the S1). The remainder (89,000 m3) must be managed by the Watersgang. With an outflow of 5 m3/s generated by a pump installed at the opposite end of the channel, the Watersgang can drain up to 18,000 m3 over the storm duration. The remaining 71,000 m3 can be stored in the channel itself, resulting in an increase in the average water level of 0.41 m.

Figure 36 and 37:

KNMI Climate Change scenarios and Deltares sea level rise predictions.



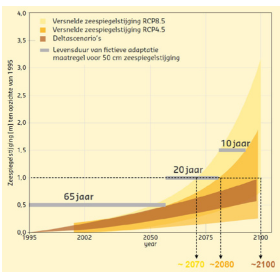


Figure 38:

Modeling of the overtopping leading to inundation in the area during a storm in the WARM+ KNMI scenario

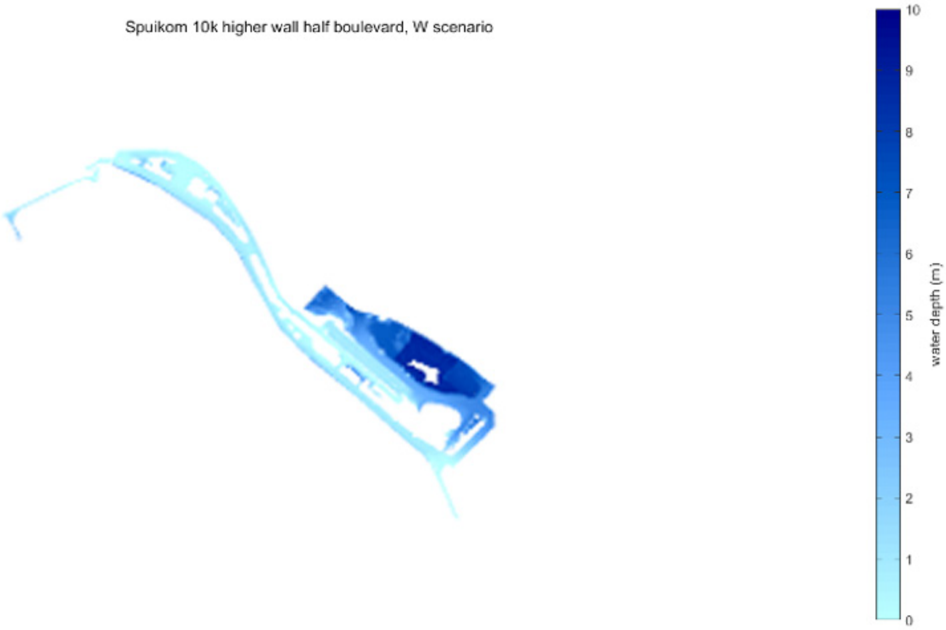
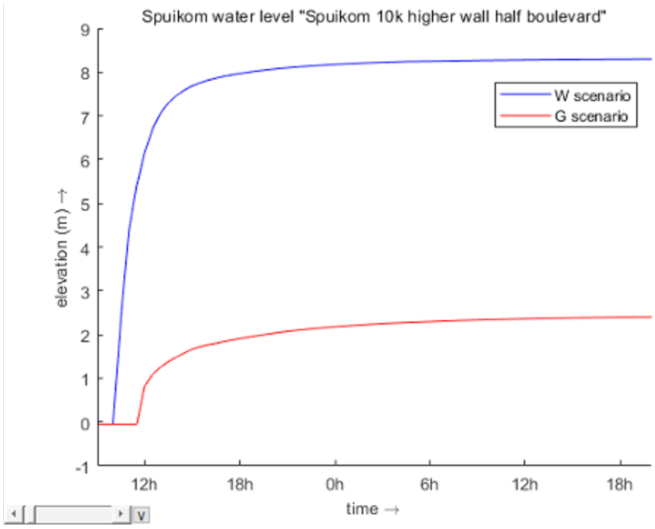


Figure 39:

Modeling of the overtopping leading to inundation in the area during a storm in the MODERATE (G) KNMI scenario.

Figure 40:

The comparison of the water overtopping the area of the WARM+ and MODERATE (G) KNMI scenarios.



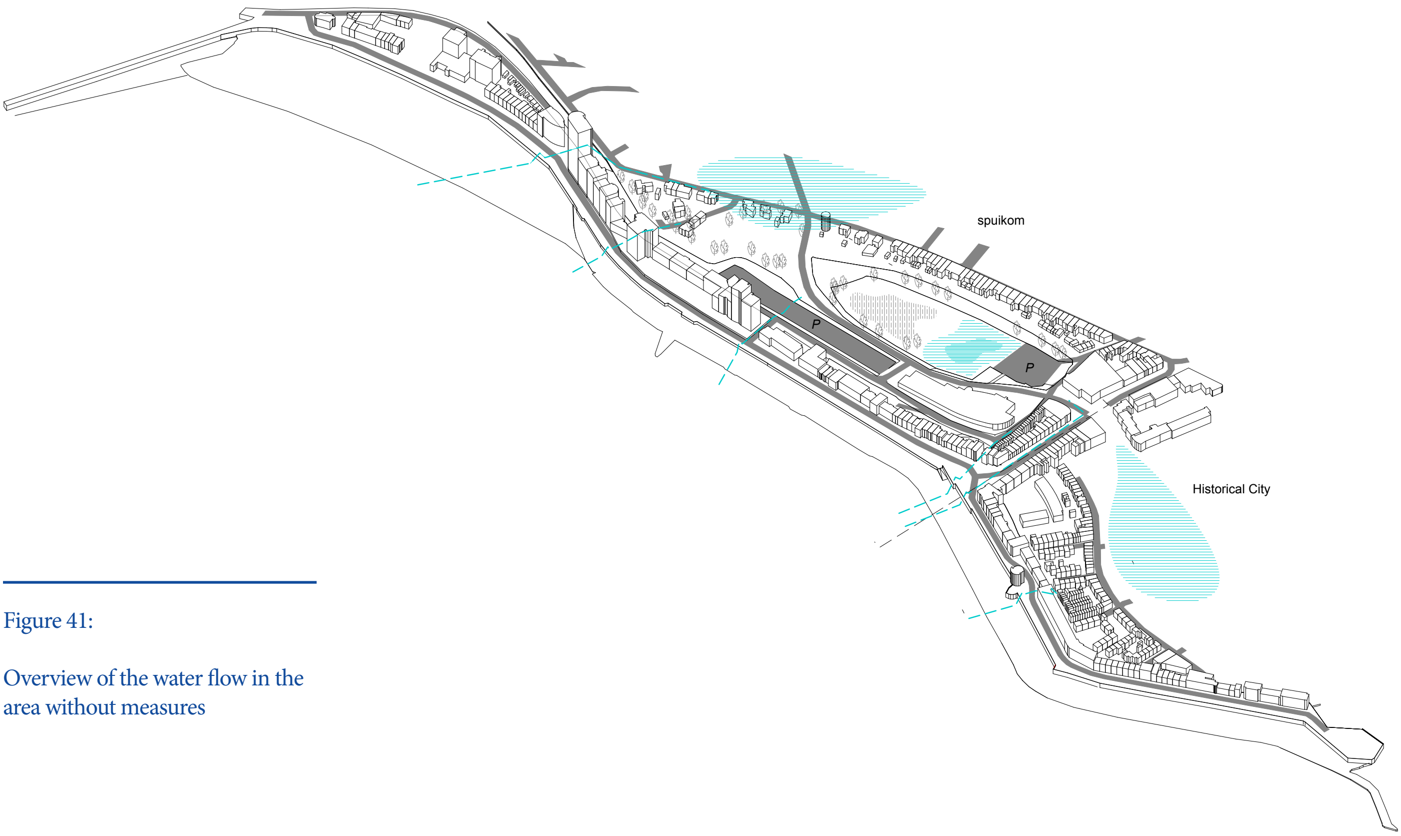


Figure 41:

Overview of the water flow in the area without measures

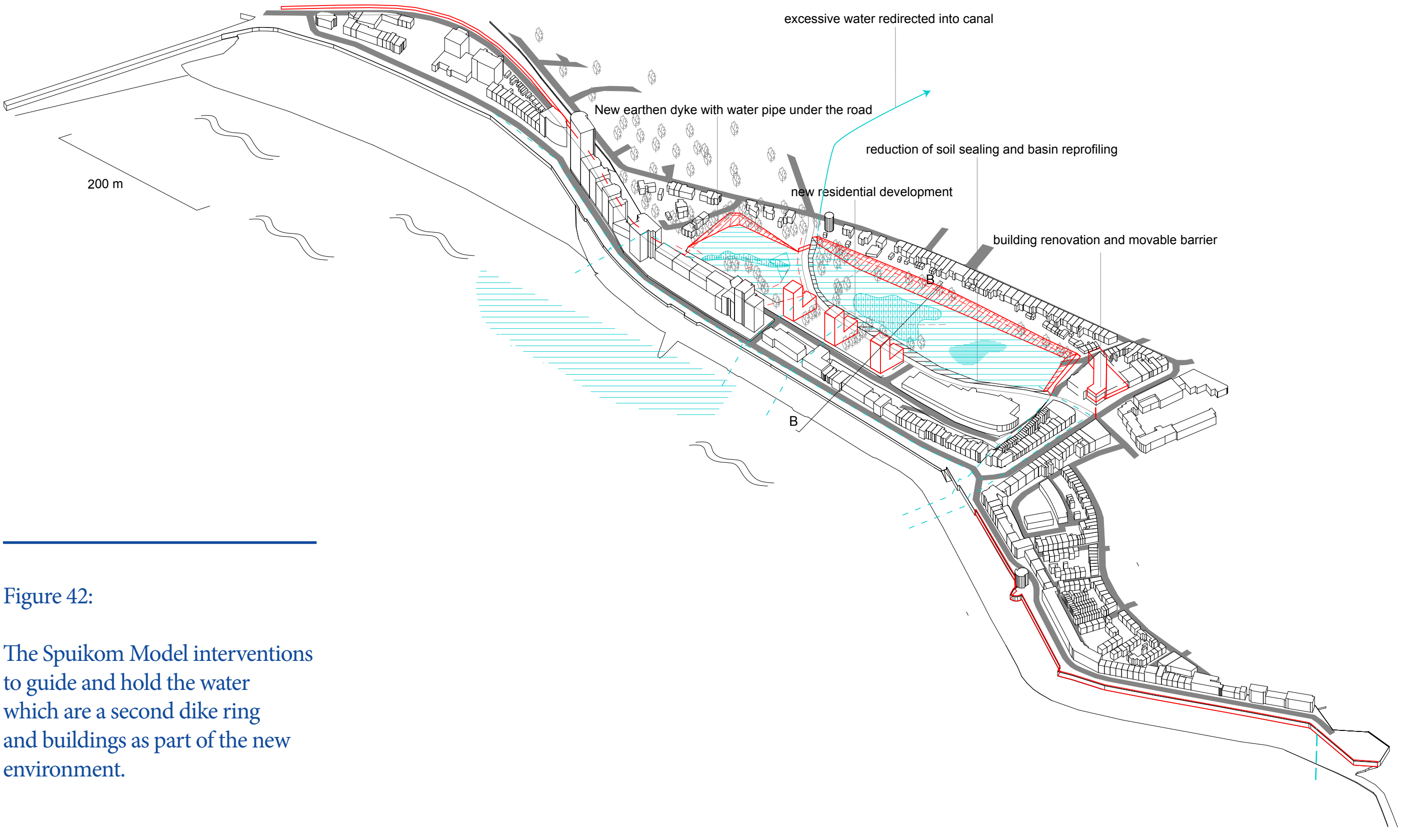


Figure 42:

The Spuikom Model interventions to guide and hold the water which are a second dike ring and buildings as part of the new environment.

Figure 43:

Measuring of the differences in height over the dike section in the area.

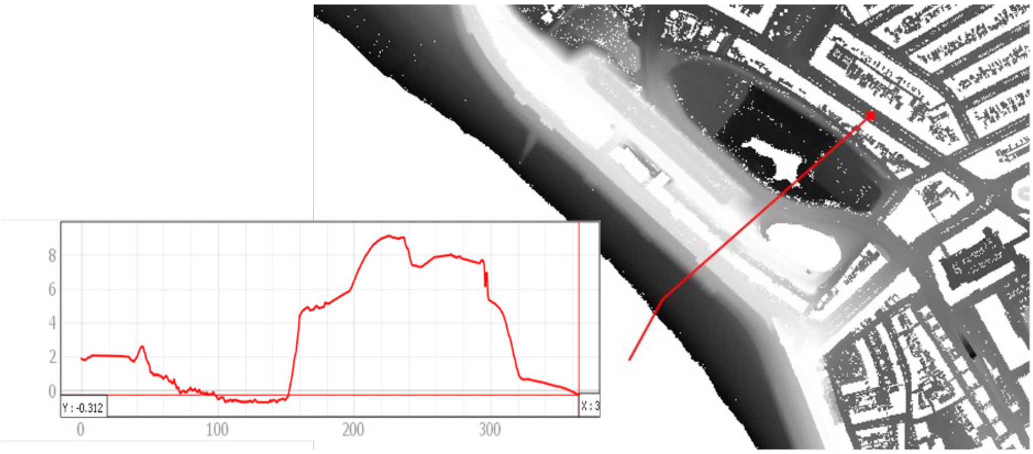
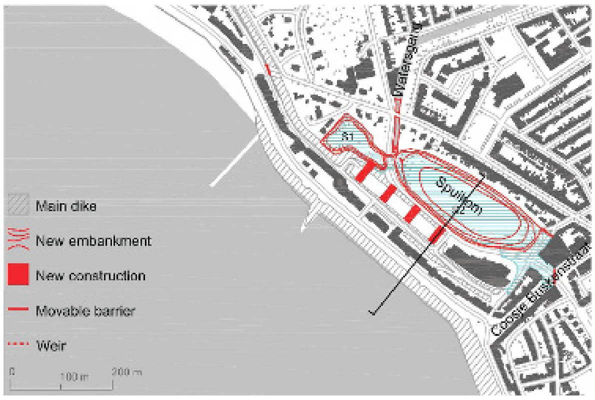


Figure 44:

Setting out the basin to store the overtopping water to measure the capacity of the storage (which is 180.000 m3 water).



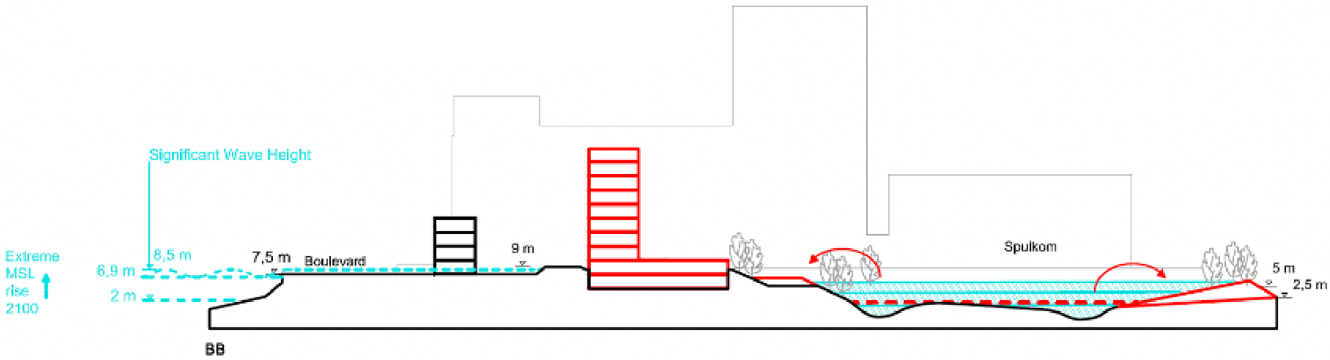


Figure 45:

Aerial photo of the area in Vlissingen.

Source:
Municipality van Vlissingen

STEP 6 URBAN PROJECT

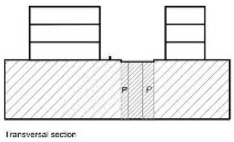
The analysis of the construction of the current state of the area is used to elaborate the strategy onto this scale, which is the urban project. For this step more precisely is looked into how and how much water will be accepted in the design storm in the flood atlas.

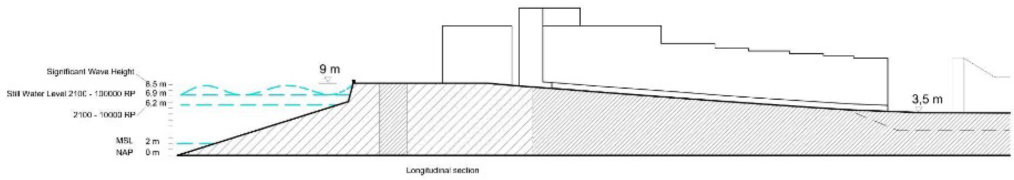
Flood atlas

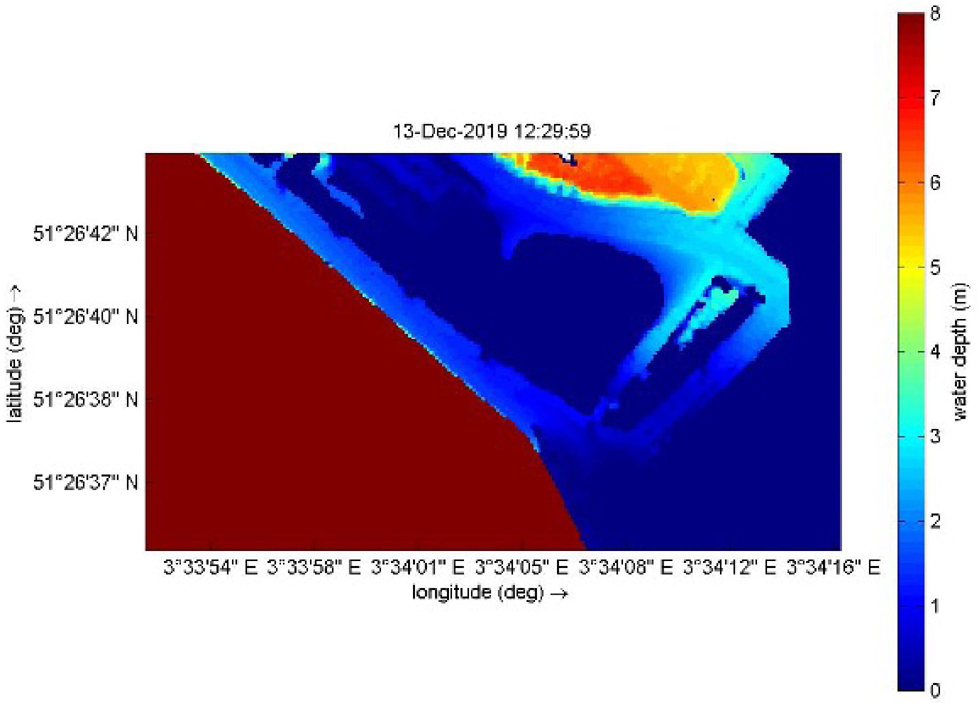
The zoom-in was done on the Coosje Busken street to understand the inundation over time and look more closely into the situation that exists.

Figure 46, 47, 48:

Spatial analysis of the Coosje Buskenstraat to design the street as a river – conveying the water to the Spuikom.







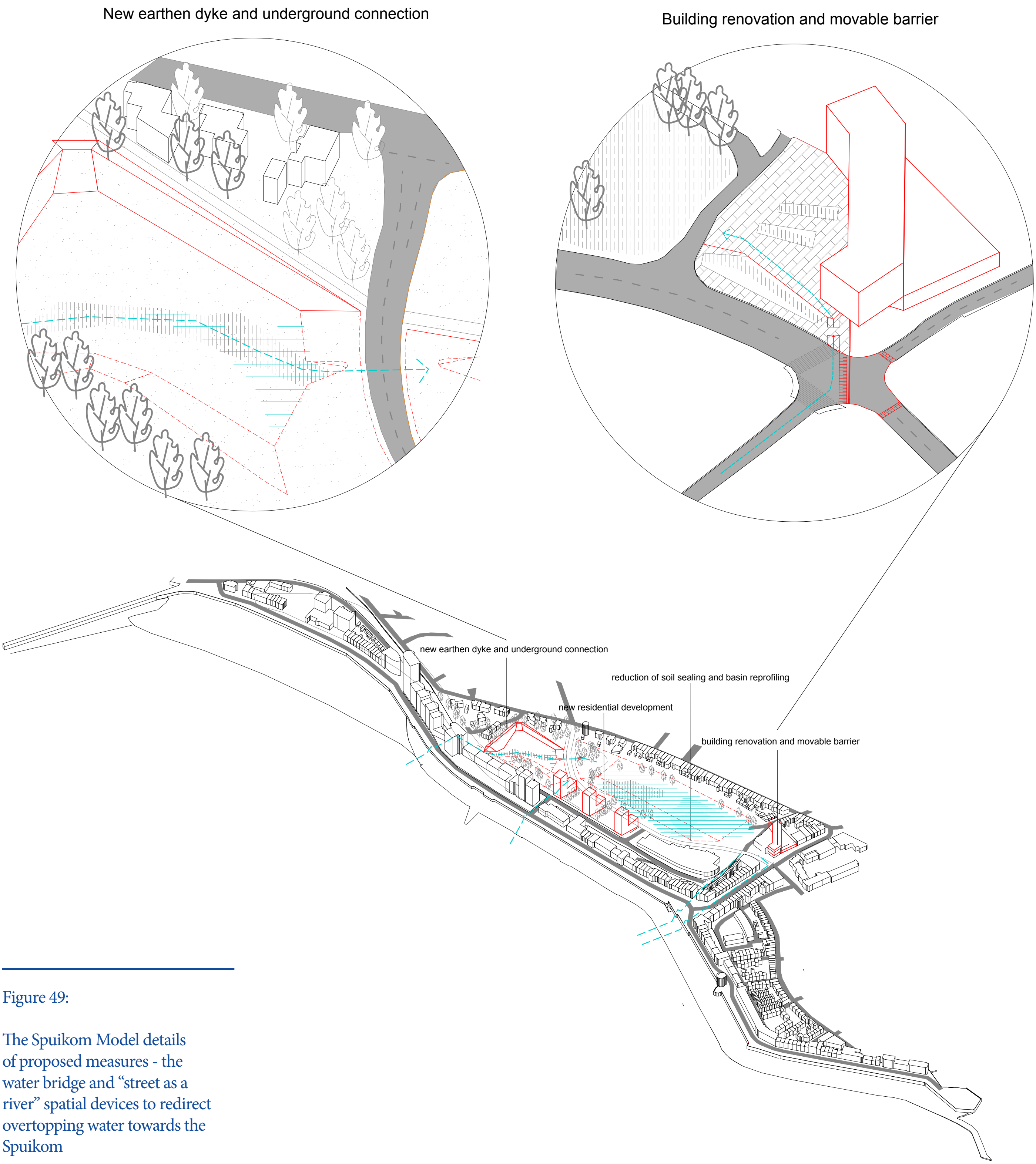


Figure 49:

The Spuikom Model details of proposed measures - the water bridge and "street as a river" spatial devices to redirect overtopping water towards the Spuikom

Urban atlas

The zoom-in was done on the west side of the Spuikom and the Coosje Busken street to understand the physical interventions needed to convey the water to the Spuikom.

STEP 7 Create the DESIGN

The integrated design of flood safety and spatial development is ultimately translated into the spatial design of public space in the Coosje Buskenstraat.

Alternatives

Coosjes Buskenstraat, a road with a relatively steep slope, is transformed into a street as a river. The above sketches convey the spatial integration of covey water and infiltrate rainwater. The shapes shall convey the water coming from the sea in such a way that it is not going outside the street in the walkway and that it is slowed down. At the same time, the shapes work as planted infiltration beds to increase the sponge capacity in cases of severe rainstorms that is also a result of climate change.

Figure 50:

Principal drawing of Street as a river for the Coosje Buskenstraat (source: Ferry, Municipality of Vlissingen).

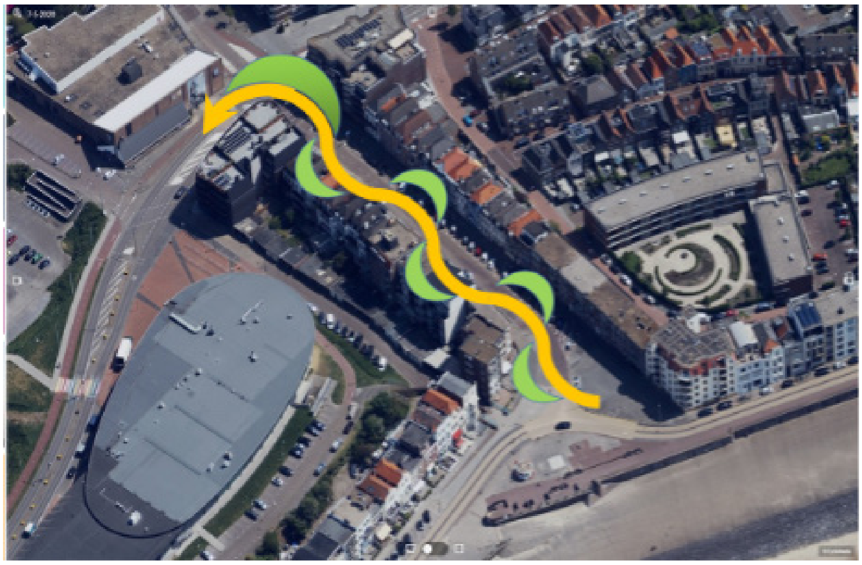


Figure 51:

Design sketches for the shape and materialization of the barriers and infiltration areas in the Coosje Buskenstraat profile as river.

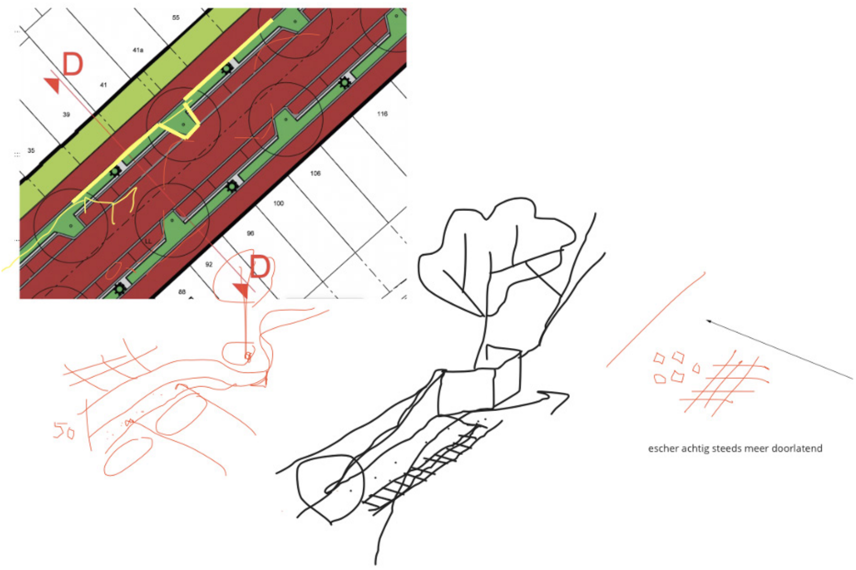


Figure 52 :

The gullies in the pavement with plantings and green barriers redirect the flow of overtopping water accumulated on the Boulevard towards the Spuikom (source: Municipality of Vlissingen).

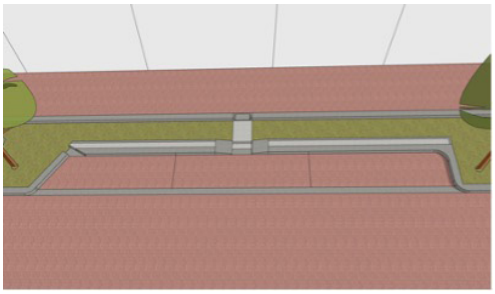
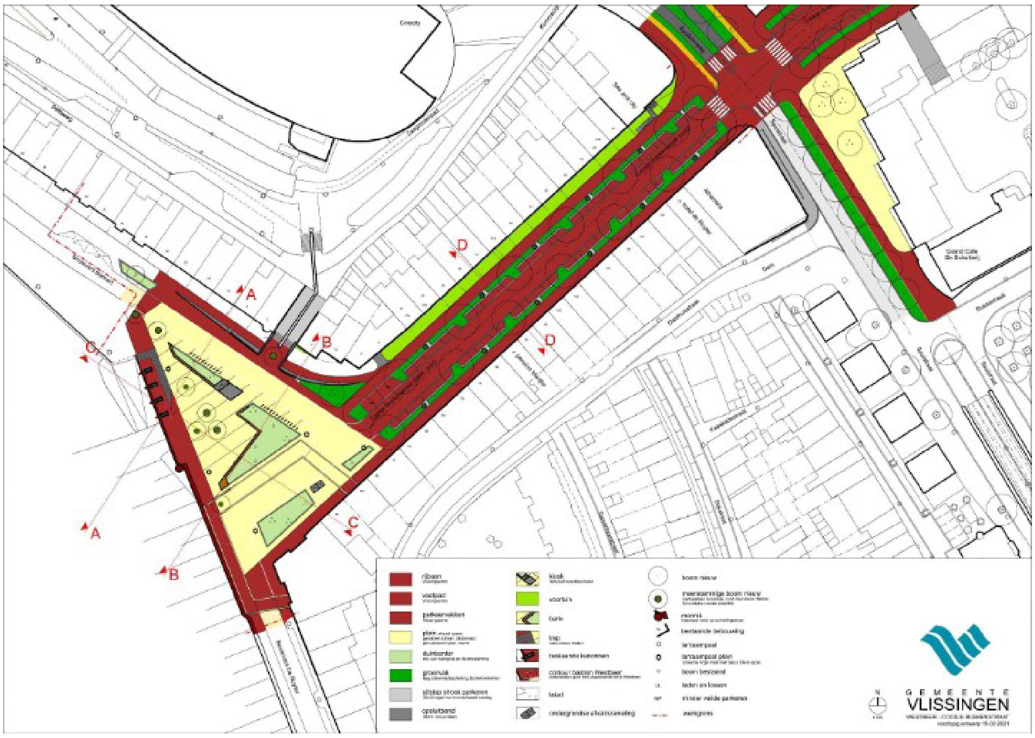
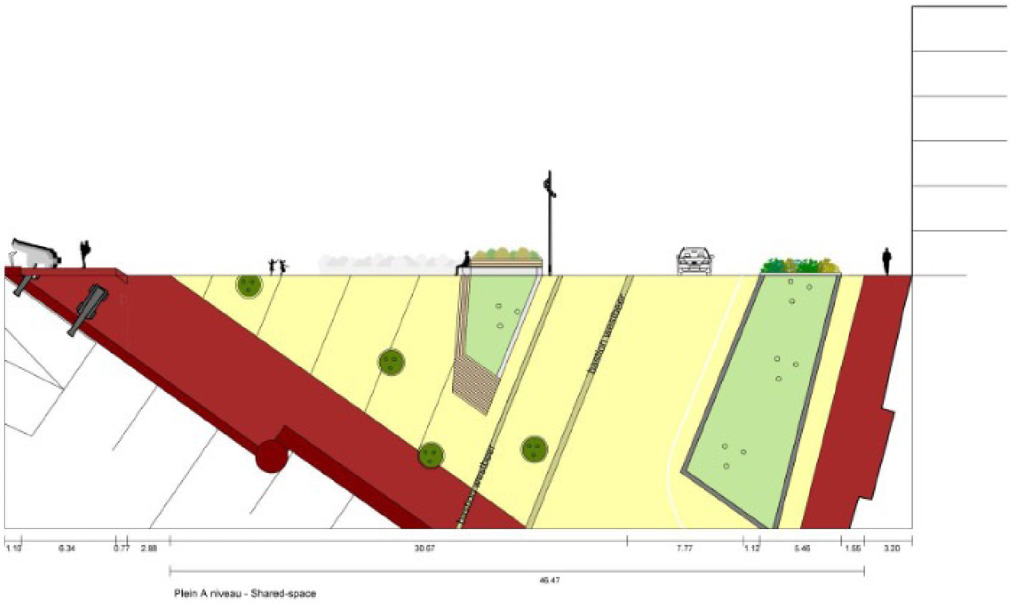


Figure 53:

Design of square Westbeer & Coosje Buskenstraat (source: Municipality of Vlissingen)





Profiel C
Bastion Westbeer | A3 1:200
Concept tekening

Figure 54:

Rendering of the new boulevard during a storm.

Source:
Marije Verlinde
City of Vlissingen

Integrated Benefits

This street design is improving the quality of the public space, making the area safe from sea level rise and will infiltrate rainwater in the case of severe rainstorms. Next to that, it is a strategic intervention that presents the possibility of changing from reducing the probability to reducing the consequences and thus the risk. It is the first step in the new urban design that is made for the area by the landscape architecture office Okra.

Figure 55:

Vision for the spatial quality of the area (Okra landscape architects)

STEP 8. Design & Assess

The Spuikom Model highlights the potential for neighbourhood regeneration through the reactivation of a former water storage basin (the Spuikom) that can serve as a retention sump for overtopping water coming from the seafront boulevard. The inclusion of exposure and vulnerability reduction in urban flood management as a zone, as well as NBS, makes hydraulic engineering modelling a crucial aspect in the design process. The hydraulic model confirmed the technical feasibility of the design strategies for the temporary storage in the inland water system of the Spuikom and Watergang of overtopping water in the case of an extreme climate scenario in 2100. The combination of the hydrodynamic model with land-use maps allowed us to calculate flood damages. This way of working can support the qualitative cost-benefit analysis (CBA) and give insight into societal benefits in the longer term. The CBA of flood risk management becomes part of the CBA for area development which means that longer-term effects can become an integral part to support a paradigm shift in which the consequence reduction becomes part of the CBA as an effect.

Table 1:

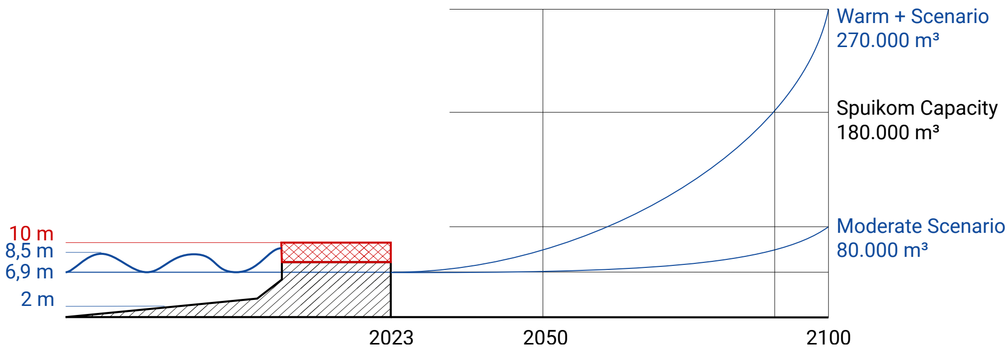
The qualitative CBA for the Spuikom Model

Spatial Interventions	Costs	Benefits	Effects	Risks
Redesign/reconstruction of the Spuikom as a floodable park/green area.	Reservoir of 2 m (= 186,000 m3 capacity) 15,400 m3excavated earth for digging out 4400 m2 of filled water reservoir (= 22,000 m3 capacity) raising the basin's embankments 8,500 m3 extra earth volume for heightening 680 m perimeter of existing water planting of trees and plants.	Increase real-estate value.	Protection of green space from urban development. Improvement urban quality / functionality. Revenue from ecosystem services.	Working of the system on the long term, too much water, too little water. Maintenance disturbance.
New buildings.	building costs.	Revenue m3 Gross floor area. Additional urban functions.	Economic carry capacity. Coherent urban densification	
Street re-design and reprofiling.	Construction costs of public space. Movable barriers.	Reduction of costs related to rainwater stress.	Adaptation to pluvial flooding. Legible public space as part of the new flood defense and rain water adaptation strategy. Spatial functionality. better integrated ecosystems / biodiversity.	Working of the system on the long term, too much water, too little water.

According to the hydrodynamic model, 275,000 m3 of excess water is estimated to flood the Spuikom at the peak of the storm. On the other hand, the recovery of additional storage capacity makes it possible to achieve a retention capacity for the Spuikom of 186,000 cubic meters (140,000 m3 on S2 and 46,000 m3 on the S1). The remainder (89,000 m3) must be managed by the Watersgang. With an outflow of 5 m3/s generated by a pump installed at the opposite end of the channel, the Watersgang can drain up to 18,000 m3 over the storm duration. The remaining 71,000 m3 can be stored in the channel itself, resulting in an increase in the average water level of 0.41 m.

Figure 56:

The results of the two scenarios show that the Spuikom Model is a sustainable solution in a moderate scenario. In the case of the Warm+ scenario, additional measures need to be taken by 2080. solution in a moderate scenario. In the case of the Warm+ scenario, additional measures need to be taken by 2080.



3

Application: Monitoring and Evaluation Framework

The Monitoring and Evaluation Framework is developed to assess the outcomes and impacts of projects that implemented Nature-based solutions (NBS) for coastal urban protection. This chapter describes the application of the framework to a selection of the SARCC projects. The first section includes a brief description of the governance context of the seven projects within their respective countries. The results of the application of the Monitoring and Evaluation Framework are presented in the second section and the conditions which enabled or hindered the implementation and mainstreaming of NBS in practice are discussed. Lastly, a more in-depth study was done to determine the ecosystem services that NBS contribute to.

Governance Context of Pilots

The governance context of the projects in the four SARCC countries determine the conditions in which the NBS are implemented. This section shares these insights for each country.

The governance of flood protection is quite diverse in the participating countries. The UK has quite diversified and balanced flood governance strategies in dealing with pluvial, fluvial and coastal flooding. In the UK, the national government does not have a straightforward legal responsibility to protect its people from flood risks. The national government does not interfere with spatial planning very much. For understanding the governance context results of the STARFLOOD project (EU-KP7) have been used. This is why a high diversity of parties, public and private, central and local, are very much involved in flood risk management.

The Netherlands also has a diversity of strategies but is less balanced than the UK with a focus on water management and less integration with spatial planning. The Netherlands has a history of fluvial, pluvial and coastal flooding where since 1814 the state has had the legal responsibility for flood risk safety. On the other side, the government also has a high involvement with spatial planning, with the size of the territory, soil conditions and land use planning has been done quite carefully leading to a strong tradition and high control.

France and Belgium are both diversified in flood governance strategies, giving equal importance to water management and spatial planning focusing traditionally on flood defence. In both countries, the state is dominant, based on technical expertise. There is high fragmentation, increased by administrative characteristics (federal system in Belgium and distinction between central and decentral levels in France).

Although water management traditionally has a dominant position in flood risk management, in Belgium, France and the Netherlands, there is a significant increase in spatial planning instruments. For the application of the Monitoring and Evaluation Framework, a stakeholder and power/interest analysis has been applied to zoom in on the stakeholders' involvement in the NBS projects. This resulted in differences and similarities characterized by the flood governance in each country. In the UK and Belgium, a diversity of local and regional stakeholders were involved in the decision-making of NBS projects. Local stakeholders were local councils in the UK and municipalities in Belgium. Regional stakeholders were the Environment Agency in the UK and the coastal authority in Belgium (MDK, Flemish Government). In both countries, nature agencies (ANB in Belgium) and marine protection (MMO in the UK) were involved in permit applications to ensure nature conservation. While in France and The Netherlands, only local municipalities were the main authority in the decision-making of the projects. In each country, local authorities are responsible for spatial and urban planning, but have limited responsibilities in flood protection (except for Southend-on-Sea, UK). For the projects in Gravelines (FR) and Vlissingen (NL), there is a discrepancy between the urban planning and flood risk governance context, while in Belgium and the UK projects, there is a higher degree of alignment between government levels and responsibilities in flood protection, spatial planning and nature conservation.

Success conditions per project

There are conditions per project that hinder or enable the implementation of NBS and are determined for the success per project. This section gives the insights for one project per SARCC country.

In this paragraph, the conditions that enabled or hindered the internal and external success of NBS projects are explained. Internal success means the implementation of NBS measures within the project duration (4 years). External success refers to the mainstreaming of NBS into urban coastal management strategies based on project outcomes. Mainstreaming could be either changes in policy goals, practices or coastal management strategies. In this section, the identified conditions will be discussed. The framework has been applied to all projects, for this booklet a selection has been made based on the representation of countries and a variety of NBS measures. The projects are the following: Middelkerke in Belgium, Newlyn in the UK, Vlissingen in the Netherlands and Gravelines in France.

Middelkerke project, Belgium

Benefits of NBS (dune before dike)

The municipality of Middelkerke initiated the project to plant vegetation and build a green dune in front of the existing dike. Figure 57 shows that vegetated dunes have multiple benefits for Middelkerke city: more flood safety, less coastal erosion, and more spatial, ecological, economical and recreation values. Citizens find the beach more attractive, greener and nicer for recreation.

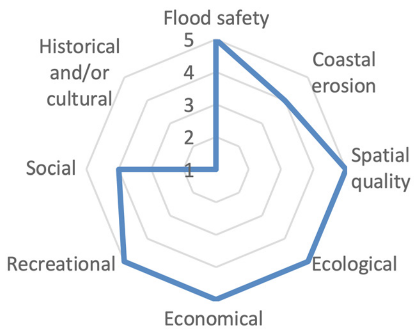


Figure 57:

Benefits of vegetated dunes in Middelkerke (1 highly disagree up to 5 highly agree)

The project was internally successful because the municipality strengthened the coastline with a dune before the dike. This was due to the combination of conditions in four project dimensions: resources distribution, participants, project design and process design (Figure 58).

Figure 58:

Scores for internal (blue) and external success (red), Middelkerke project

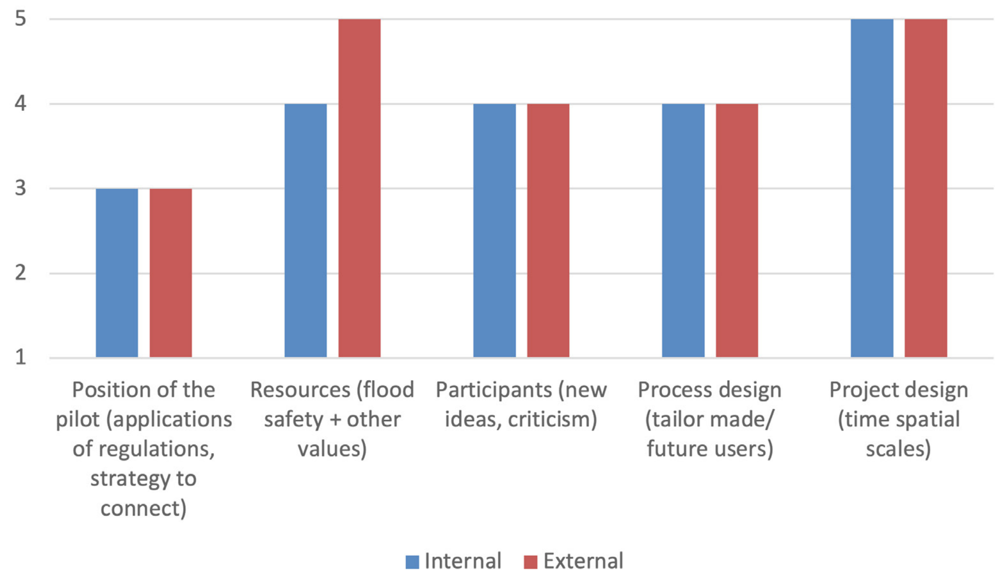


Table 2:

Empirical evidence of conditions for the internal and external success of the Middelkerke project

Project dimensions	Internal project process	External project process
Position of the project	Project provided the freedom to experiment and to learn more about the benefits of NBS. However, if current dunes get protection status, their maintenance will be a challenge.	The strategy used was good dissemination and education campaigns through social media and schools. Moreover, the lessons learned are useful for the coastal vision in Belgium. However, currently there is no legal framework on how to maintain marram grass on dunes
Resource distribution	Enough resources (knowledge, finance, human capacity, raw materials) during SARCC project.	Although the knowledge has increased, more resources to mainstream lessons learned depends on the ambition and willingness of the client to pay.
Participants	Actors were more open to think out of the box after some time. The municipality convinced the nature agency (ANB) and the coastal authority (MDK) to implement NBS. It was challenging to obtain the permit from ANB. The municipality took the role of boundary spanners connecting sectors and governance levels. Citizens acted as ambassadors via social media	Representative actors from the implementation arena: local and regional gov. authorities, private and citizens. Multiple sectors: flood safety, spatial planning, transport, tourism, nature. The municipality of Middelkerke is already replicating this NBS measure in other locations of the beach.
Process design	The project was a collaborative process between public and civil actors. Citizens, ANB and MDK were consulted in the process and their input improved the NBS design.	The first results seem promising. Change in mindset (MDK, ANB, citizens) regarding NBS for coastal protection The coastal authority (MDK) is monitoring the NBS and using the project as a policy instrument to learn about NBS and mainstream NBS.
Project design	During the project, time was limited to monitor and learn about NBS. It took a long time to obtain the permit. Spatial scale was sufficient	More time is needed to monitor and prove the long term effectiveness of NBS for coastal protection. Likewise, spatial scale is limited in Belgium to replicate results

The project process faced a few ups and downs. The municipality had difficulties obtaining the permit from the forestry agency (ANB) because also adding NBS changes the current situation. Also, citizens were worried about losing their sea view. The municipality organized field visits for key actors (ANB, MDK and policymakers) to visit comparable NBS measures in the Netherlands. Moreover, they also shared scientific knowledge about the effectiveness of NBS. This strategy resulted in the acceptance of public authorities (MDK and ANB) and citizens (process design). Next, the municipality developed a 25-year plan to manage the height of the dunes and obtained a special permit from ANB for this period. Currently, the coastal authority (MDK) of the Flemish government took the ownership to monitor the vegetated dunes regularly and publishes the results on their website. By taking initiative and responsibility to develop and share knowledge beyond their legal tasks, the municipality and the Flemish government acted as boundary spanners to enable the implementation of the dune before dike (Table 2).

The project was externally successful because mainstreaming of NBS started during SARCC. This was due to the combination of conditions in all project dimensions (Figure 58). The coastal authority (MDK) took ownership to monitor the dunes and learn about NBS. This knowledge is useful to replicate the project in other locations (horizontal mainstreaming) and in the development of the coastal vision for the Belgian coastline (vertical mainstreaming). The Middelkerke project is considered an inspiring example for other locations in Belgium and abroad (Table 2).

Newlyn project, UK

Benefits of NBS (eco-blocks as water breakers)

The environmental agency (EA) was responsible for this project in Newlyn. It was a research and development project which aimed to test eco-blocks for marine colonization and to reduce wave energy in tidal areas. First results of monitoring show that the eco-blocks offer multiple environmental benefits: ecological (increase marine wildlife), spatial quality, recreational, social, historical and cultural. The effect of eco-blocks on flood safety and coastal erosion still needs to be proven (Figure 59).

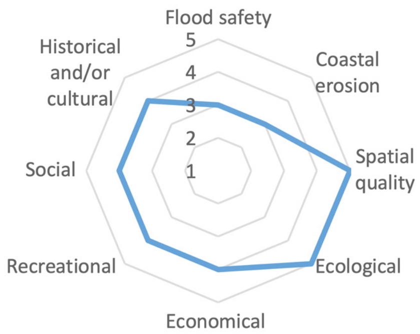


Figure 59:

Benefits of vegetated dunes in Newlyn (1 highly disagree up to 5 highly agree)

The internal and external success of the Newlyn project

At first, the aim of the project had to be changed from full implementation to a R&D project because of high costs of materials (eco-blocks). The R&D project was internally successful because the eco-blocks were implemented and monitored during SARCC. This is mainly supported by a combination of conditions in four dimensions: resources, participants, process design and project design (Figure 60). It was a great achievement to test the eco-blocks in intertidal zones for the first time in the UK. Because of being an innovative solution, the liability of the design was transferred from the designer to the Environmental Agency. Moreover, the current coastal management policies encourage the implementation of NBS but do not provide a clear legal on how to deliver them. This is also a challenge for the mainstreaming of NBS in the UK (Table 3).

Figure 60:

Scores for internal (blue) and external success (red), Newlyn project

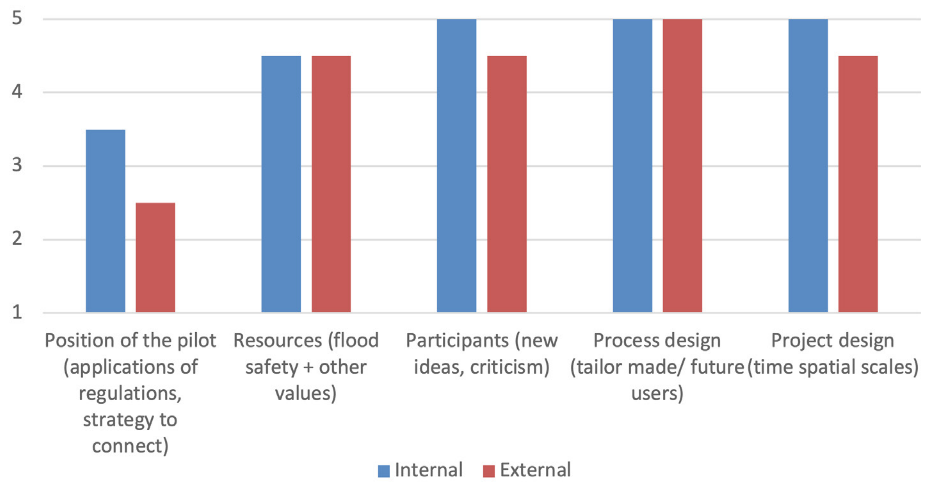


Table 3:

Empirical evidence of conditions for the internal and external success of the Newlyn project

Project dimensions	Internal project process	External project process
Position of the project	Current policies encourage the implementation and mainstreaming of NBS but do not provide clear legal framework on how to deliver them. Thus, there is no freedom and flexibility to experiment with innovative solutions (NBS) for coastal protection.	No strategy in place yet but project results can feed back into the local/ regional coastal management plans (shoreline management plan, 0 emissions 2030).
Resource distribution	Enough resources (knowledge, finance, raw materials) during SARCC. Because of high material costs, the aim of the project had to be changed from implementation to R&D project. At times, there was lack of human capacity due to multiple staff changes.	There is local funding available for the maintenance and monitoring of the 4 projects. Generally, there is not enough evidence and funding available for full implementation of innovative NBS.
Participants	The environmental agency (EA) involved multiple actors from diverse sectors. Citizens were concerned about the effectiveness of NBS compared with hard infrastructure. They provided input for the construction phase rather than the NBS design.	Representative actors from the implementation arena: local and regional gov. authorities, private and citizens. Multiple sectors: flood safety, spatial planning, transport, nature.
Process design	The project was a collaborative process between public and civil actors. The EA acts as a boundary spanner.	First results are already available from the trial eco-blocks. These are useful to improve the monitoring of the actual eco-blocks. Even though first results are not ready for mainstreaming, the project was used as a policy instrument to learn about NBS and replicate them in other locations.
Project design	The time and spatial scales were sufficient to determine the suitability of the measures on an intertidal area.	First results seem promising. EA continues to monitor the blocks for the coming year at least.

In relation to the external success, mainstreaming of NBS was not yet started during SARCC (Table 3). Since the project was scaled down to an R&D project, the position of the project did not support mainstreaming. However, the Environmental Agency is monitoring the eco-blocks for the coming 1-2 years. The EA is planning to replicate the project outcomes in other locations of the coastline (horizontal mainstreaming) and adapt the local shoreline management plan (vertical mainstreaming). As a result, the EA is optimistic that the project outcomes will be mainstreamed in the near future. The EA acts as a boundary spanner by connecting actors from diverse sectors and administrative levels. This was supported by reaching out as a national authority to locals via public engagement events and showing responsiveness. This supports not only the internal success, but also the potential for mainstreaming of this NBS for coastal protection.

Vlissingen project, The Netherlands

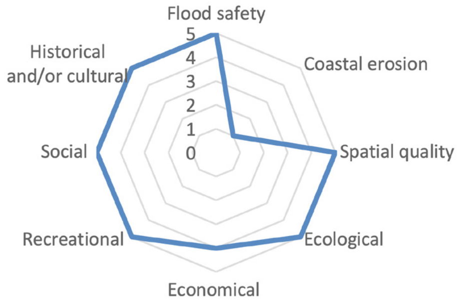
Benefits of NBS

The NBS measure implemented in Vlissingen city was to adapt spatial design at street level to direct overtopping water to a retention area (Spuikom). A major challenge was to get the support of citizens to accept water flowing on their street

Figure 61:

Scores for internal (blue) and external success (red) (Vlissingen project)

Figure 61 shows this measure has multiple benefits in the coastal city of Vlissingen: flood safety, more spatial quality (more green), ecological (more green, insects, birds) and recreational and social values while respecting the historical and cultural value of the city.



The internal and external success of the Vlissingen project

The project was internally successful because the design has been implemented and supported by the public. This was due to the combination of conditions in all project dimensions (Figure 62). Citizens were surprisingly positive about the idea of accepting water on their street and 'turning it into a river'. They support that the municipality acts upon flood risks. The municipality acted as a boundary spanner by taking initiative on urban coastal flood risk from their role in spatial planning (Table 4).

The project is considered externally successful because mainstreaming of NBS started during SARCC. As a result of the project, the involved citizens changed their mindset about NBS for coastal protection (Table 4). Traditionally in the Netherlands, flood protection was managed by building hard infrastructure to keep water out. Nowadays, actors have accepted the 'street river' concept, getting water over the dike in case of overtopping and storing it inland. The municipality of Vlissingen has developed two strategies to uptake the lessons learned from the Vlissingen project (Table 4).

Figure 62:

Scores for internal (blue) and external success (red), Vlissingen project

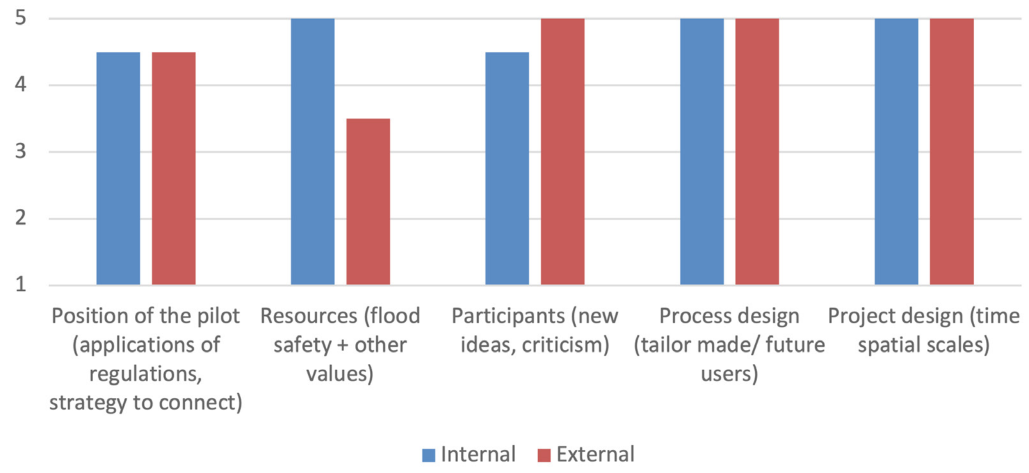


Table 4:

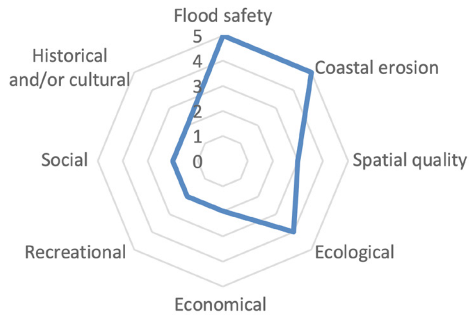
Empirical evidence of conditions for the internal and external success of the Vlissingen project

Project dimensions	**Internal project process**	**External project process**
Position of the project	Current policies provided the flexibility to experiment and learn about NBS	There are two strategies in place to connect project results with current coastal strategy: local flood safety plan for the boulevard and regional climate adaptation strategy (not formalized).
Resource distribution	Resources (knowledge, finance, human capacity, raw materials) were sufficient. No additional resources provided.	Current system does not provide enough finance for innovative solutions (NBS).
Participants	Actors (water board, citizens, business) were open to think out of the box. Municipality acted as a boundary spanner	Limited representativeness of actors from the implementation arena: local municipality departments, water board, private and citizens. Multiple sectors: water, spatial planning, tourism, transport.
Process design	The project was a tailor made collaborative process. Citizens and water board were consulted and their input improved the NBS design.	No results nor ready for mainstreaming yet. Monitoring will continue after SARCC. Results, once available, can be used to open the debate about NBS for coastal protection.
Project design	Spatial and time scales were enough during the project.	No outcomes available yet. More time needed to monitor during extreme weather conditions. Spatial scale is limited at the Dutch coast

Figure 63:

Scores for internal (blue) and external success (red), Gravelines project

Gravelines project, France



Benefits of NBS (vegetated dunes)

The project in Gravelines aimed to revegetate existing dunes via wooden faces and replantation. These combined NBS measures bring multiple benefits to the coastal city of Gravelines (Figure 63): more flood safety, less coastal erosion and more ecological value.

The internal and external success of the Gravelines project

The project was internally successful because the project reached its goal which was the revegetation of dunes and the implementation of wooden fences. The most supporting condition that enabled internal success was the process design. According to empirical evidence (Table 5), the NBS design integrated the needs of flood protection, nature and tourism sectors. The most difficult conditions were in resource distribution because of delays in raw materials, changes or lack of staff to monitor the development of the dunes.

In relation to the external success of the project, mainstreaming of the NBS was not achieved during SARCC. The least favourable conditions for NBS mainstreaming were in resources and project design (Figure 64). Based on evidence (Table 5) the municipality did not have sufficient resources such as personnel with knowledge of NBS, to implement and monitor the NBS measures beyond the project duration. Even though the NBS design integrated the local needs, the project manager (municipality) considered that the project outcomes were not representative enough for larger regions. Likewise, the dunes need more time to develop naturally and become more stable.

Figure 64:

Scores for internal (blue) and external success (red), Gravelines project

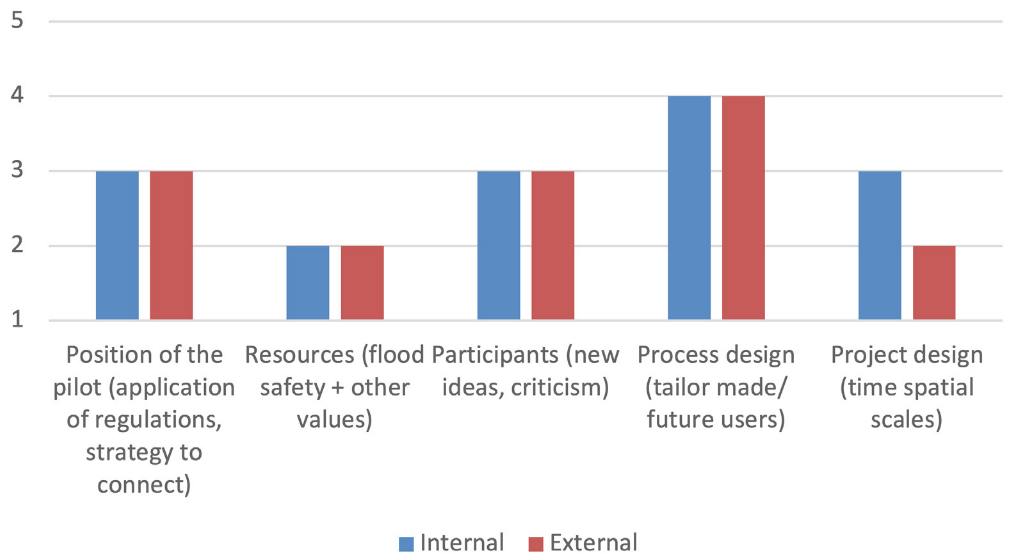


Table 5:

Empirical evidence of conditions for the internal and external success of the Gravelines project

Project dimensions	Internal project process	External project process
Position of the project	Current policies were flexible to experiment / learn about technical effectiveness of NBS	There is no strategy in place yet.
Resource distribution	Resources (finance, knowledge, raw materials) were sufficient but also faced some challenges: delays in raw materials, changes in staff or enough staff to monitor the dunes.	In the current policies, there are not enough resources (knowledge and funding) to implement NBS in France.
Participants	NBS are not considered new solutions. The feedback of beach users was considered in the process. Citizens were not involved due to Covid.	Limited representativeness of actors from the implementation arena: local municipality departments and beach users (sand yacht). Multiple sectors: tourism, flood safety, spatial planning.
Process design	The project was a collaborative process mainly internally. Local conditions and needs of future users (beach users) were included into the NBS design.	There are no results yet and not ready for mainstreaming.
Project design	Spatial scale was sufficient. More time was needed to monitor and validate the solutions	Not sufficient outcomes yet to consider them representative for larger areas. Dunes need more time (4-5 years) to become more stable

Ecosystem services of Nature Based Solutions

The analysis of Ecosystem Services of Nature Based Solutions are important to understand the added benefits over gray infrastructure. This section presents the results for the Belgian pilots.

Ecosystem services (ESS) were calculated for the three Belgium pilots: Dune-for dike in Ostend, Green dike in Middelkerke and enlarging the existing dune in Blankenberge. As dune scenarios can score on a broad range of ESS, the scope of the research was limited to the following ESS:

1. Regulating: coastal defence, air quality and health
2. Cultural: tourism, recreation
3. Supporting: biodiversity
4. Other: sand-capturing ability

Targeted data was collected so that all the tools could be completed as much as possible. Different ecosystem services or themes are calculated by both tools.

Oostende project

The municipality will save in cleaning costs of sand (11.273 € / y) because the marram grass captures enough sand. Surveys in the city of Oostende revealed that tourists are willing to pay a higher price for green infrastructure (5,3 euros/year) compared to residents (1,67 euros/year). Moreover, 58% of the surveyed people indicated that green infrastructure at the coast is more attractive and that they would come specifically for this. This has a result on the land & property values in the vicinity of the project. GI-Val expects an increase in land and property values of 2.3 million euros.
Marram grass only captures between 421 and 443 Mg $CO2$ ha^{-1} y^{-1}, depending on the anthropogenic disturbance level, therefore Carbon sequestration of the project is almost neglectable with a yearly carbon capture of around 5 gr $CO2$ ha^{-1}. However, the biodiversity of the project is expected to be increased by 2500 euros yearly. The reason behind this is that extra green infrastructure will give more possibilities and habitats for fauna and flora, thus increasing biodiversity.

Amenity (reflection of the increased attractiveness of the place) is expected to be increased by 6.88 million euros. As the project of Oostende is not expecting to encourage at least 3 hours of exercise per week, it's not possible to apply the reduced mortality tool. Therefore no monetized value can be put on health for this project.

Middelkerke project

The benefits of the project in the commune of Middelkerke were calculated based on the plan of integrating the dune for dike principle along several sections of the coast, covering a total area of 11,5 hectares from what 10,5 hectares will be planted with marram grass.
In terms of carbon sequestration, a total yearly carbon capture of around 4,4 gr CO_2 ha^{-1} of the entire project is expected.
As previously mentioned in the project of Ostend, 58% of the surveyed people indicated that green infrastructure at the coast is more attractive and that they would come specifically for this. The Green Infrastructure validation tool expects an increase in land and property value of 9,5 million euros. As the project of Middelkerke might be capable of encouraging at least 3 hours of exercise per week, it's possible to apply the reduced mortality tool. The calculated reduced mortality benefit is 167.000 euro/year, resulting in a net present value (NPV, the value in present terms, accounting for all the net benefits the project will bring over their lifetime) of 1.12 million euros over 10 years.
The benefit estimation tool expects amenities to increase by 17 million euros, based on the number of visitors to the project, the average amount of spending per tourist and the real estate pricing and amount of flats in the vicinity of the projects. With amenities, the attractiveness and desirability of the area are meant.
Biodiversity is seen as a supporting ecosystem service and is expected to be increased by 17.677 euros over the entire project.
The avoided cost for sand cleaning due to the planted marram grass results in a yearly avoided cost of 384.618 euros.

Blankenberge project

The Blankenberge project also shows the highest increase in land & property values, similar to the other 2 Belgium projects, with a total increase expected of 5.96 million euros.
As the Blankenberge project is the only project where tree planting is involved, it has the highest value concerning carbon sequestration. In total 351 tonnes of carbon will be sequestrated in the following 10 years, resulting in a monetary value of 24.800 euros.
The biodiversity and ecology factor of the newly planted trees is expected to have a value of 1668 euros.
Because the Blankenberge project does not interfere with extra sand capture, the avoided cost for sand cleaning is not calculated. As the project of Blankenberge is not expecting to encourage at least 3 hours of exercise per week, it's not possible to apply the reduced mortality tool. Therefore no monetized value can be put on health for this project.

4

Learning from SARCC

Recommendation 1

Take into account the local conditions (risks, uncertainties, expert knowledge, local actors knowledge) in the urban development processes to better align the visions and needs of actors with current policies.

Recommendation 2

Allocate and share sufficient resources (human capacity, finance, instruments, knowledge) between urban authorities to develop/support urban coastal zones.

Recommendation 3

Urban authorities take the role of boundary spanners for inter- and intra-organizational collaboration to apply an integrated and transdisciplinary approach using NBS in urban development projects

Recommendation 4

NBS should challenge the status quo by assessing and evaluating current regimes & policies in climate adaptation of coastal urban cities

Recommendation 5

Performing cost benefit analysis on infrastructure in the initial stages of development

Recommendation 6

Using NBS approach and perspective to integrate and connect urban, environmental and socio-economic challenges in the project design

Recommendation 7

Share knowledge and information about NBS within the urban authority and other sectors involved (flood risk authorities, nature conservation authorities and other sector involved)

Recommendation 8

Understanding the value and layers of Longue Durée, at the beginning or prior to initiating the project – to ensure application during the project duration.

Recommendation 9

Consideration of ecosystem services through all stages of the development project such as initiation, design, implementation and maintenance.

Recommendation 10

Interdisciplinary design: ensuring iterative development between design, engineering and evaluation to create more long-lasting change.

Conclusions

The aim of the SARCC project was to create experience and evidence in prioritizing nature-based solutions in urban coastal areas. In this light, all projects were successful because they reached their goal to implement NBS measures in the urban coastal zone (internal success). However, based on the empirical evidence, not all pilot projects were successful in mainstreaming (external success).

Four key conditions necessary to mainstream NBS into coastal management were identified: project design, process design, participants involved and the position of the project with respect to policies.

Firstly, in the project design, sufficient time and physical space are needed to carry on all project activities: design, public engagement, implementation and monitoring. Especially the monitoring will create evidence and needs to be done over a longer time. The time to do this in the SARCC project was not enough to design, implement and monitor the effectiveness of most NBS measures and to upscale lessons learned.

Secondly, it is essential to involve a diversity of actors (public, private and civil), administrative levels (local, regional, national) and sectors (water, spatial planning, heritage, tourism, nature, transport) with different interests and competencies in urban coastal management. These actors need to be involved in the early stages of the project and take into account their needs in the process. Their input will improve the NBS design and the implementation procedure. A good collaboration between public and civil actors results in improved knowledge about NBS, more trust and stronger actors networks.

Thirdly, the attitude of the involved actors is also very important. A 'thinking out of the box' attitude and the willingness to experiment with innovative solutions foster empirical knowledge about NBS effectiveness. Among these actors, the presence of boundary spanners is particularly important for the implementation and mainstreaming of NBS. In SARCC we observed boundary-spanning activities across a multiplicity of contexts via initiating NBS beyond direct responsibilities, engaging inhabitants to support NBS and taking responsibility to monitor and share results about the effectiveness of NBS.

Fourth, the position (or distance) of the NBS project with respect to the coastal management policies is also very important to mainstream NBS. The current coastal management policies encourage the use of NBS but they are not clear on how to implement these innovative solutions in practice. In SARCC it was learned that there are ways to overcome policy gaps and obtain the support of decision-makers. For example, enhancing knowledge about NBS via site visits with policymakers to best practices in other countries, engaging local stakeholders, using historical evidence to produce engaging narratives that demonstrate the long-term and ongoing coastal processes, and adapting the project design to the needs of users (visitors, beach clubs) resulting in local support; adaptive management plans and temporary permits to enable monitoring of effectiveness, impact and benefits. These conditions can be enhanced via strategies to connect project results with urban coastal management policies. A strategy refers to an action plan showing how the project results will be employed to adjust and change current coastal management policies. Lastly, while resources (finance, knowledge, human capacity) were mostly sufficient during the project due to the support of SARCC, in daily practice there is a lack of finance and capacity to implement NBS.

The conclusion from the interdisciplinary design process are that NBS offers a shared state of mind and helps to mitigate barriers that are up when there is no consensus. The reductions of barriers are especially found in that that it enables engineering to participate in the urban development process and think with other approaches towards flood management that is not aimed at creating grey infrastructure but also needs their knowledge. This way design as proposition and engineering as creating evidence comes together in an integrated process in which NBS makes a flood management strategy over a longer time as part of urban development. NBS to manage flood risk will automatically be connected to other urban challenges like pluvial floods, heat stress and biodiversity increase and also scales of time and space become connected. The shared state of mind helps to smooth the coordination and communication of information of different nature owned by the different disciplines in the urban development process. The concept is a strong guidance with a strong ambition and clear goals.

The assessment of the pilot sites by reviewing historical data sets, as summarised above, has shown how past human influence along the coastline can cause detrimental long term impacts. In many cases, particularly in the deltaic low countries, it is impractical to reverse these actions. However, with wisdom from hindsight, similar mistakes can be avoided in comparable low lying regions where decisions have still to be made when managing the coastline.
This project has shown how an assessment of the Longue Durée provides an understanding of causal mechanisms that have shaped the coastline. Where these processes are identified as ongoing, this can inform coastal managers about the long-term forces acting on the coastline and contribute to a positive decision making process. They also provide historically derived baseline data that can be firmly integrated into the Project Design Development Framework.
Visual representations from historical documents and artworks can be a very valuable tool when telling the story of the transient nature of a coastline to the public.

The use of future scenarios is important because NBS, in contract to grey infrastructure, is accumulating over time. Thus flood defense strategies also become adaptive over time, tuning in with the contemporary societal needs and climate scenarios.

Recommendations

From the project, there is a series of overarching and key recommendations and benefits that act as a precursor to the NUM framework. The recommendations range from the topic of design and planning, monitoring and evaluation, analysis, and how you can change course with the consideration of concepts like the Longue Durée, Ecosystem Services, and Nature Based solutions.

Recommendation 1.
Take into account the local conditions (risks, uncertainties, expert knowledge, local actors knowledge) in the urban development processes to better align the visions and needs of actors with current policies.

Benefits:
• Increased capacity to adapt to change.
• Long-term impact and success.
• Make actors feel heard and part of the process.
• Alignment of the project with the current legal framework.
• Calibration of models.

Recommendation 2.
Allocate and share sufficient resources (human capacity, finance, instruments, knowledge) between urban authorities to develop/support urban coastal zones.

Benefits:
• Invest in organizational capacity for NBS.
• Increase the role of urban authority as prominent boundary spanner agent.

Recommendation 3.
Urban authorities take the role of boundary spanners for inter- and intra-organizational collaboration to apply an integrated and transdisciplinary approach using NBS in urban development projects

Benefits:
• Diversifying knowledge and collaborative actors' network.
• Increased roles of a diverse range of boundary spanners agents within governance, business, technical and societal sectors.
• Creation of the right knowledge & network.
• Willingness to collaborate, being open-minded for innovation.

Recommendation 4.
NBS should challenge the status quo by assessing and evaluating current regimes & policies in climate adaptation of coastal urban cities

Benefits:
- A form of empirical evidence to prove the additional benefits of NBS.
- Accept innovation and go beyond traditional (e.g. grey infrastructure) processes.
- Compare business as usual solutions and diverse NBS measures on interdisciplinary benefits.

Recommendation 5.
Performing cost benefit analysis on infrastructure in the initial stages of development

Benefits:
- Understand interdisciplinary values of various solutions and perspectives.
- Understand possible implications of durability and maintenance.

Recommendation 6.
Using NBS approach and perspective to integrate and connect urban, environmental and socio-economic challenges in the project design

Benefits:
- Prompting more diverse and integrated solutions and designs.
- Can use empirical evidence of projects to prove the benefits of NBS.
- Need for accepting innovation and going beyond traditional processes.
- Conducting a comparative analysis; current needs and NBS to show that current processes are not sufficient.

Recommendation 7.
Share knowledge and information about NBS within the urban authority and other sectors involved (flood risk authorities, nature conservation authorities and other sector involved)

Benefits:
- NBS can be included in flood management and larger urban development strategies as way of thinking.
- Empowers actors to utilise their expertise, like engineering to participate in the urban development process in a meaningful way that can lead to alternative solutions, beyond the status quo.
- Supports gathering of evidence about effectiveness of NBS beyond the project duration.

Recommendation 8.
Understanding the value and layers of Longue Durée, at the beginning or prior to initiating the project – to ensure application during the project duration.
Benefits:
- Helping to understand long-term patterns of change.
- Narrative building to justify and communicate to a wider audience.
- Recognition in value, in understanding the past change.
- Working with morphological and natural changes rather than against it.

Recommendation 9.
Consideration of ecosystem services through all stages of the development project such as initiation, design, implementation and maintenance.

Benefits:
- Maximise impact of project by broadening scope of service such as recreation, biodiversity enrichment and water purification.
- It strengthens the empirical evidence required to prove the effectiveness of NBS projects.

Recommendation 10.
Interdisciplinary design: ensuring iterative development between design, engineering and evaluation to create more long-lasting change.

Benefits:
- Information of different natures needs to be brought together, diverse perspectives.
- Enabling the use of scenario building as a way to test and simulate pathways
- Better informed decision making process, with increased understanding of impact, value and costs.
- Temporary solutions (e.g. permits) can support development of NBS with monitoring to gather evidence and adaptivity of NBS projects.

Interreg
EUROPEAN UNION
2 Seas Mers Zeeën
SARCC
European Regional Development Fund

Maritime Archaeology Trust · EXO Environmental · HZ University of Applied Sciences · Environment Agency · TU Delft Delft University of Technology · Department of Environment & Spatial Development · Flanders State of the Art

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