



CIE4061-09

MULTIDISCIPLINARY
PROJECT



Coastal and Marine Engineering and
Management Master

Final Report

Xabier Arrieta

Ermano de Almeida

Renan da Silva

Hithaishi Hewageegana

Krasimir Marinov

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Executive Summary

The Hague Municipality, which is responsible for Scheveningen Harbour, is seeking solutions for two problems it is currently facing: reorganization/expansion of Scheveningen Harbour considering the shortage of marina places and the future demands; and connection of the north and south sides of the harbour, namely, bridging De Pijp.

CoMEM TU Delft students were retained to provide a solution to these problems, as part of the Multidisciplinary project (CT4061-09) course. This final report covers the full description of the problem and the solutions proposed – a reorganization of Scheveningen Harbour, focused mainly in the Yacht Harbour; the construction of a new marina harbour in De Kom, hereafter called as Scheveningen Fourth Harbour, that includes a new breakwater; and a taxi boat to fulfil the connection demand for the north and south sides of the harbour. On Annexes 1 to 6 it is presented the detailed drawings of the proposed solution.

The project approach to solve the current project followed the methodology developed from Roozenburg and Eekels (1995), in which basically alternatives for problems are proposed and multi-criteria analysis are used to help making decisions.

A profound study of Scheveningen Harbour was performed, including historical aspects that led to its current features. The Harbour division - in Eerste Haven (First Harbour), Tweede Haven (Second Harbour), Derde Haven (Third Harbour), and De Pijp - was also put into perspective as part of the problem description analysis.

It was verified that the current harbour configuration is complex and sub-optimal, and improvements could be proposed. These should take into account the demand for more mooring space for vessels like yachts and sailing boats. It was also concluded that a better rearrangement of facilities and capacities, including a proper division of zones to be incorporated within the harbour, should be implemented in order to achieve a clear division between industry and leisure. Regarding the connection over De Pijp, the evaluation of this need was made in a broader context, including urban planning aspects.

The project was divided in its two elements: a New Scheveningen Harbour and Bridging De Pijp. As for the former, the solution concept is to provide a reference in order to adapt the current infrastructure to the changes in the activities experienced by Scheveningen Harbour in the last years and decades and prepare the foundations for fulfilling the future development demands. Concerning the connection, numerous possibilities were considered and evaluated from a technical, operational and feasibility perspective. Both parts of the project were lately combined in a coherent complete solution for Scheveningen Harbour.

Regarding the New Scheveningen Harbour, the first step was to evaluate the possible locations where expansion could take place, and the preliminary feasibility assessment showed that a reorganization/improvement of the current infrastructure and expansion only within the current harbour basin need to be considered, as explicitly required by The Hague Municipality.

Three project alternatives were proposed, briefly presented below:

- Alternative 1 would only require the reorganization of the First, Second, Third Harbours, with concentration in the fishing activity in the First Harbour, optimization of the Second Harbour with priority to marina boats, and the Third Harbour being used by Rijkswaterstaat and other commercial boats;
- Alternative 2 would be equivalent to the previous one, but adding a permanent marina in De Kom (Fourth Harbour). This alternative would require the construction of a new inner breakwater; and

- Alternative 3 would also concentrate the fishing activity in the First Harbour and optimize the Second Harbour with priority to marina boats. A permanent marina (or commercial boats area) would be added to the current configuration (Fourth Harbour), and with the extension of the outer Southern breakwater a Fifth Harbour would be constructed in Buitenhaven, accommodating both Rijkswaterstaat, and marina/commercial boats. The Third Harbour would be used for marina and/or commercial boats.

A multi-criteria analysis was performed to choose which of these alternative was the most suitable for Scheveningen Harbour. Firstly, thirteen primary indicators were proposed, and then they were grouped and weighted in two general indicators, namely, the sustainability of the alternative (economic, social and environmental impacts) and effectiveness of the engineering solution (operational conditions and infrastructure). The conclusion was that Alternative 2 scores higher than the two alternatives for both categories, so it was developed in a more detailed level.

A more detailed study of Scheveningen Harbour showed that it has high potential for development and growth. The Yachtclub Scheveningen shows a very intense use, which does not allow the fulfilment of existing recommendations for marina layout and compromises the quality of the marina for users and the navigation safety. Regarding the design of new marina facilities in Second and Fourth Harbours, a few important considerations are listed below:

- With the proposed measures, Scheveningen Harbour will be able to offer to the permanent and seasonal users infrastructures and services for up to 475 vessels (375 in the Second Harbour and 100 in the Fourth Harbour).
- It followed the most recent guidelines in order to include the Yachtclub Scheveningen among the highest ranked marinas by criteria of sustainability and quality of infrastructures and services.
- The distribution of the berthing and navigation geometry considered recommendations and guidelines in order to ensure the highest safety and comfort for permanent and seasonal users.
- The design of the access to the marina such as gates, ramps (including for disabled persons), pontoons, fingers and moorings are in accordance with the recommendations and guidelines.
- The current availability of parking places in the area will be able to adequately fulfil this demand.

The First Harbour of Scheveningen is expected to maintain its current activities according to this project proposal. The optimization of the activities in this basin, improving the land facilities and logistics, should be performed, as the current use of the area shows that it is not optimal. The fishing activity in Scheveningen would also have an important opportunity with the redevelopment of the harbour, towards offering higher added value products and services.

As for the Third Harbour, the current facilities of Rijkswaterstaat will continue in the north-half area, while the south-half area will be dedicated to the future commercial uses related with the urban development which will take place in the old Norfolk terminal area. The detailed design of the redevelopment and adaptation of the area should take place according to the demand and characteristics of the vessels to be used.

The Fourth Harbour is intended to be a new marina, and as such it requires very strict operational conditions, namely, significant wave heights lower than 20 cm and wind magnitudes lower than 22 m/s. As it is located in a non sheltered location, a metocean study was conducted to verify the need of breakwater and to provide the wave design conditions. As no data were available inside Scheveningen Harbour, 23 years of offshore wave conditions were extracted from BMT Argoss database and propagated with numerical modelling to the nearshore zone, close to the outer breakwater tip. With a wave height transformation matrix based on Deltares study (2006), which used a wave agitation model appropriate for complex geometries as Scheveningen Harbour basin, the waves were obtained in the

Fourth Harbour. A downtime of 7% and 23% was calculated for seasonal and permanent marina uses, respectively, for the situation without an inner breakwater, thus a new breakwater is needed.

The first step of the breakwater design was to define the concept of the solution – vertical caisson, floating breakwater and composite breakwater - through a Multi-criteria analysis and it was concluded that a Caisson breakwater is the best option due to its less restrictive spatial constraints. The breakwater design was carried out for the solid wall and toe with return period of 100 years, and overtopping rates were checked both for operational and extreme conditions. The total length of the breakwater is approximately 130 m, and its presence resulted in a downtime of less than 1% for marina permanent use.

Regarding the connection over De Pijp, numerous possibilities for solving this connection problem were initially considered, such as a fixed or movable bridge, a non-constant connection (e.g. cable car or taxi boat), a tunnel and even a scenario without a connection was evaluated. The first analysis concluded that three alternatives should be detailed – a movable bridge, a tunnel and a taxi boat, mainly to spatial constraints and traffic conditions. A Multi-criteria analysis was performed for these three options with similar methodology as explained above, and it was concluded that the taxi boat is the best option as it requires the least initial investment and it is the most flexible alternative.

The shortcomings of a tunnel are related to the highest costs and to the lack of aesthetic aspects, combined with very strict spatial constraints. Concerning the movable bridge, its cost is not that high as the tunnel, but much higher than the taxi boat. With Monte Carlo simulations for simulating a boat queue around De Pijp, the maximum amount of time that the bridge remains lowered for which the marine traffic conditions were least compromised is ten minutes per hour, which means fifty minutes of waiting time for pedestrians and cyclists. Finally, it was verified that the provided usage scenario does not offer much convenience to pedestrians, and even less so to cyclists, and this had a major point in the conclusion that a taxi boat as the chosen solution.

A taxi boat service was proposed to improve the mobility of the visitors arriving at Scheveningen Harbour. Based on demand analysis, applicability of the route and the boat stands within the harbour and future development, several points within Scheveningen Harbour were selected to be connected by a shuttle service. A taxi boat route between the Second harbour (eastern land boundary of the port) and south beach side of the Scheveningen Harbour was proposed, with three intermediate stopping points: the first one at the Northern bank of De Pijp in the Second Harbour side, the second one at the southern bank of De Pijp in the Second Harbour side and the last one at the northern side of the harbour entrance. The total journey in one direction will take approximately 11 to 15 mins, a travel schedule can be proposed where the taxi boat is available every 15 mins from a given stop in Summer, every 30 mins for the rest of the year.

Even though the solutions provided for the identified problems were discussed separately, great care was taken to integrate the applications to provide a coherent solution for the harbour in the larger perspective – for example the project alternatives impact on marine traffic conditions, navigability and the mobility of visitors. The timeline and cost estimate were prepared considering the complete solution, and a capital cost of around 9 million euros was calculated, with construction time of 19 months.

The project team believes that the application of solutions provided within this report will generate a positive economic growth. This will ensure long term sustainability of Scheveningen Harbour becoming a key pillar of success of The Hague vision of becoming a global city by the sea.

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1. Introduction

The Hague Municipality – the client of the current project - is responsible for Scheveningen Harbour. An overview of Scheveningen Harbour is presented in Figure 1, while its nautical chart is shown in Figure 2.

The Hague Municipality has at this moment the practical problem to come up with a solution for two problems:

- Reorganization/expansion of Scheveningen Harbour considering the shortage of marina places and the future demands; and
- Connection of the north and south sides of the harbour, namely, bridging De Pijp.

CoMEM TU Delft students were retained to provide a solution to these problems, as part of the Multidisciplinary project (CT4061-09) course. Three reports were required in this project, briefly summarized below:

- Inception report - the initial conception of the project work, the methodology to address the problem, with a brief description of the problem and a conceptual approach to tackling the issues, were presented. The organization structure of the group, including the responsibilities of each member, were also defined in this report.
- Interim report – a profound analysis of the problem was presented through the study of data and maps collected and from information provided by ‘The Hague Municipality’ in the kick-off meeting (2016/03/01). Three alternatives to solve the problem were defined and the specific methodology to continue the design was elaborated.
- Final report – the final solution including both the complete system (Scheveningen Harbour as a whole, with a holistic approach) and subsystems (each of the Harbours and the connection over De Pijp, with more detailed aspects) are supposed to be provided.

This report is the final one, and its objective is to provide a full description of the problem and the solutions proposed, including aspects already covered in previous reports. This report was divided in the following chapters:

- Methodology –the method proposed to solve the current project is shown;
- Problem description – a profound analysis of the problem is presented;
- Towards the future – this chapter explains the general concept with which the solution was proposed;
- New Scheveningen – Alternatives – this part covers the alternatives for the shortage of marina places and future demands;
- New Scheveningen – Solution – the solution for the shortage of marina places and future demands is presented in detail;

- Bridging de Pijp – Alternatives and Solution – both the alternatives and the final solution for the connection over de Pijp are presented;
- Integration – this chapter presents the integration of the solution, whereas solutions for both Scheveningen Harbour and the connection over de Pijp are treated together; and
- Next steps – final recommendations for the next phases of the design are provided in this final chapter.



Figure 1: Overview of Scheveningen Harbour.



Figure 2: 18017B Nautical Chart Scheveningen Harbour 2011. (Dienst der Hydrografie)

2. Methodology

This section describes the methodology with which the problem was tackled, separated in Project Approach and Project Methodology.

2.1 Project approach

The approach to solve the current project followed the methodology developed from Roozenburg and Eekels (1995). Table 1 summarizes the steps and respective products for this approach.

Table 1: Steps performed and associated products for methodology (Roozenburg and Eekels, 1995).

Step	Products
Analysis	Inventory of the problem
	Problem formulation and objective
	List of disciplines and techniques
Synthesis	Preliminary design of alternatives
Simulation	Conceptual design with results of simulations
Evaluation	'Multi Criteria Evaluation' tables
Decision	Selection of best alternative

This project approach was followed both for the Scheveningen Harbour regarding the shortage of marina places and future demands (see Chapter 4) and for the connection over de Pijp (see Chapter 6). The breakwater design, a subsystem of the former problem, also followed this approach in a more detailed level.

2.2 Project methodology

The steps performed in the project are summarized in the fluxogram below (Figure 3) and this report comprises each of the items as follows:

- The problem description is presented in Chapter 3;
- Towards the future is described in Chapter 4;
- Scheveningen Harbour-future demands, proposal of alternatives and evaluation of alternatives, and decision are treated in Chapter 5;
- Alternative 2 – detailed solution including First Harbour, Second Harbour, Third Harbour, Fourth Harbour, Metocean conditions, Breakwater design and Marina layout are addressed in Chapter 6;
- Connection over de Pijp, Proposal of alternatives, Evaluation of alternatives and Water boat detailed solution are all described in Chapter 6; and
- Integration of the solution is covered in Chapter 7.

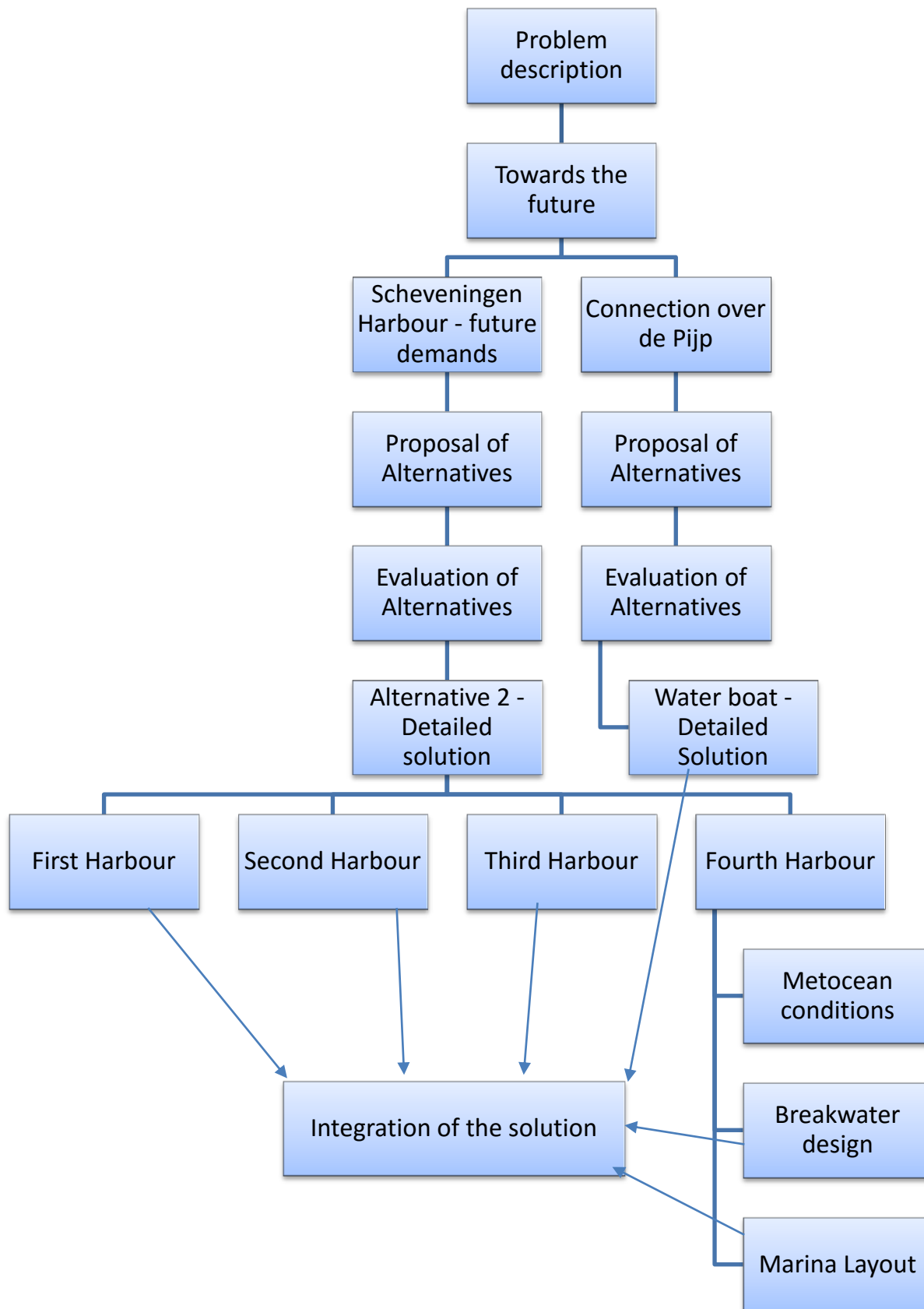


Figure 3. Steps of the project

3. Problem description

3.1 Introduction

This chapter illustrates the problem description for the Scheveningen Harbour project. The problem description is based on the meeting held with the client- The Hague municipality on the 1st of March and subsequent studies carried out. The section contains an outline to the background of the port, scope of the issues and project goals to be fulfilled.

3.2 Background

The different chapters in the history of the Scheveningen Harbour are briefly presented in this section. This is important for understanding how and why the harbour was developed over the years and how it reached its present day state. It is also essential to introduce a standardized division of the harbour in order to avoid confusion and to provide unification throughout the report.

3.2.1 History and development

The Scheveningen Harbour has been developed over the years from its conception as a pure fisheries harbour in 1904. Afterwards, the rudimentary harbour was expanded in 1931 to handle the growth of the fishing and related activities. This expansion was connected to the primary harbour (now the First Harbour) through De Pijp (“The Pipe”, see section 3.2.2, Figure 5).



Figure 4: Scheveningen Harbour in 1928 (Source: <http://www.scheveningentoenenu.nl>)

In 1970's came a new era for Scheveningen, the second expansion of the port became more dominant for use of recreational activities and for tourism purposes. With this influence in 1972 the marina of Scheveningen was declared open within the Second Harbour while the First Harbour was used for fishing (see section 3.2.2 for harbour division).

The third transformation came into Scheveningen with the entrance of the Norfolk Line. The now Third Harbour was commissioned and improvements to the breakwaters were carried out in order to accommodate this new section. After forty years of service, due to the size restrictions at the harbour, the Norfolk line moved out of Scheveningen.

The above brief timeline of the history of the Scheveningen Harbour was based on (Klein, 2015)

3.2.2 Harbour division

As elaborated in the previous sub-section, Scheveningen has been developed over a long period of time to cater to specific needs. As a result, the current harbour configuration is complex and sub-optimal. Referencing the current Zoning plan, Scheveningen accommodates a large variety of vessels e.g. private yachts, tourist boats, fishing vessels and other. Furthermore, a mixture of private and business oriented usage is present (Bestemmingsplan "Scheveningen Haven", 2013). The harbour's complex layout necessitates a logical division into smaller areas based on their geometry, facilities and purpose (see Figure 5). The below presented division is used throughout the report. In Chapter 5 new zones are included corresponding to the proposed alternatives of action, however, they are not included here. The below division is in accordance with the Zoning plan of The Hague (Bestemmingsplan "Scheveningen Haven", 2013).

Buitenhaven (Outer Harbour)

The outer most part of the harbour is outlined by two breakwaters on each side and provides the entrance to Scheveningen Harbour. It has a breakwater on each side of the entrance. Dimension wise, the entrance is around 120 m at its narrowest where the old and new breakwaters meet.

Voorhaven (Connecting Harbour)

The Voorhaven serves as a connection between the Outer, First and Third harbours. Situated within it is De Kom (the bowl), a small bay-like area housing a ramp. The latter provides access to the water for smaller boats (Bestemmingsplan "Scheveningen Haven", 2013).

Eerste Haven area (First Harbour)

This part of the port is predominantly used for fishing related activities, namely unloading of freshly caught fish on one side and supply and export of frozen fish on the other (Bestemmingsplan "Scheveningen Haven", 2013), (Figure 5, pos. 1 and 2, respectively). Additionally, the short end quay (Figure 5, pos. 3) is occasionally used by visiting naval ships (Bestemmingsplan "Scheveningen Haven", 2013). The shape of the port is rectangular, roughly 400 m by 140 m, with a depth of 8 m and entrance width of 35 m. A narrow channel, called De Pijp, connects the First and Second harbours.

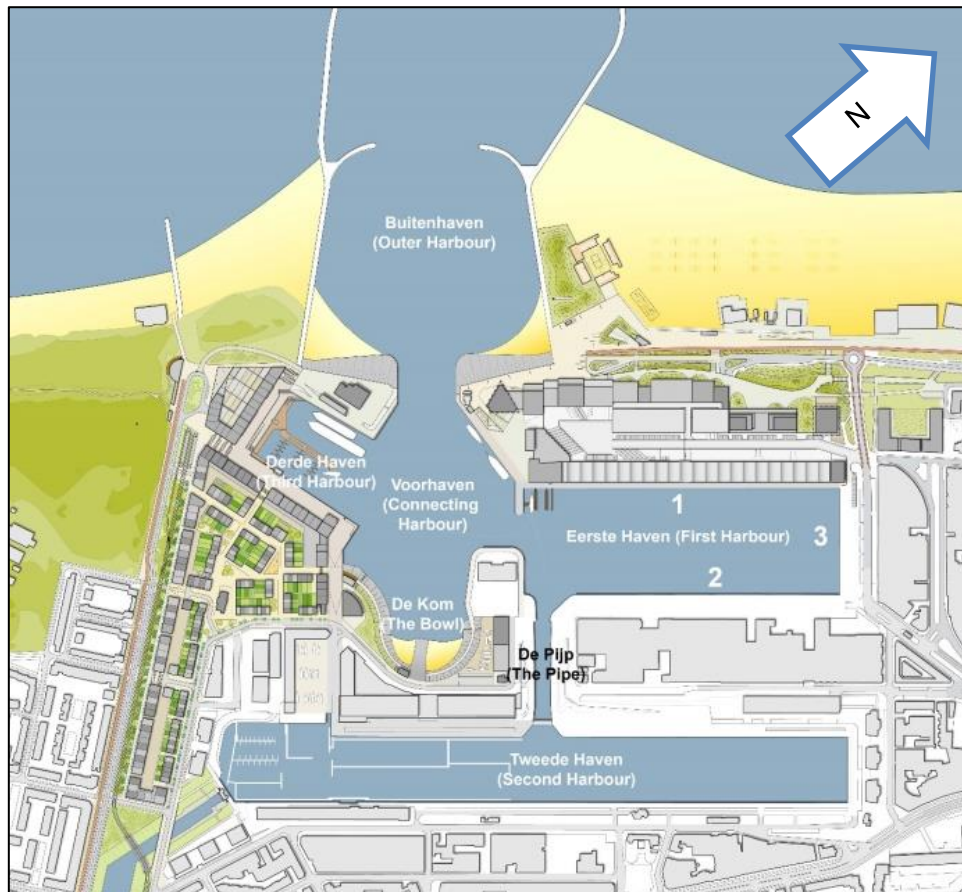


Figure 5: Scheveningen Harbour division (Underlay source: The Hague Municipality)

Tweede Haven area (Second Harbour)

The second part of the port, as divided by the zoning plan (Bestemmingsplan "Scheveningen Haven", 2013) is used for a wide range of activities. For convenience, this part can be subdivided into two relatively equal halves – southwestern and northeastern, with De Pijp as the division. The former houses a marina, whereas the latter is used by fishing vessels, inshore/coastal trawlers, boats offering recreational activities for tourists and other ships. An important note is that the Tweede Haven area accommodates ships seeking shelter during bad weather conditions (Bestemmingsplan "Scheveningen Haven", 2013). The southwestern half is connected through a channel and a lock to a drainage basin, part of the city's flood protection. The whole Tweede Haven area measures around 800 m by 80 m and is the largest in Scheveningen.

Derde Haven area (Third Harbour)

This third area used to house the Norfolk ferry line and terminal. However, currently the northern part of the quay is occupied by Rijkswaterstaat vessels (Bestemmingsplan "Scheveningen Haven", 2013). Derde Haven is an almost square area (100m by 120 m). The quay is constructed from steel sheet pile walls and are relatively high.

De Pijp (“The Pipe”)

As previously mentioned, De Pijp is a straight and narrow channel that connects First and Second Harbour subdivisions. The channel is a former lock (Bestemmingsplan "Scheveningen Haven", 2013), and as a result has limited dimensions. De Pijp is 17m wide and 180m long, where the depth is limited by the old concrete structure to -4 m NAP¹ (Bestemmingsplan "Scheveningen Haven", 2013).

3.3 Issues and goals

The scope of the project is the Scheveningen Harbour area, including on-land facilities related to the harbour's functioning. During the aforementioned meeting with the client (2016/03/01) an outline of current issues and future goals was presented to the team, forming the basis for the Multidisciplinary project. These can generally be divided into two categories, namely:

- Harbour optimisation
- Urban development and connection over the De Pijp.

Elaboration on the problem scope and client goals related to both categories is presented below.

Harbour optimization

As previously mentioned, Scheveningen houses a variety of vessels and sea related activities. It is the client's desire to better optimize the functioning of the harbour area in order for it to be up to date with current and future demand. This could be achieved through rearranging, reorganizing and reassigning current port areas and facilities, as well as expanding through e.g. construction of new capacities. These changes will include both the marina and fishing facilities. The identified problems within harbour optimization can be classified under the following heading.

- ***Insufficient capacity***

Scheveningen Harbour is running out of capacity for many types of vessels. As elaborated in Section 6.1, the demand for more mooring space for vessels like yachts and sailing boats is especially high. Nevertheless, these changes in capacities should avoid harming the fishing industry in Scheveningen, which introduces an important boundary condition.

- ***Reorganization of the harbour entities***

Due to the variety of vessels housed in Scheveningen it is paramount that a proper division of zones to be incorporated within the harbour. As an example currently, fishing boats are moored in the Second Harbour (Bestemmingsplan "Scheveningen Haven", 2013), which negatively affects the area's functioning as a touristic hotspot. The client is interested in implementing a better rearrangement of facilities and capacities in order to achieve a clear division between industry and leisure.

¹ 'Normaal Amsterdams Peil' also known as 'Amsterdam Ordnance Datum'

The following boundary conditions and scopes can be established which have to be satisfied in addressing the issue of harbour optimization.

- Providing a plausible and agreeable alternative to the stakeholders involved

The problem has to be viewed from the perspectives of the different stake holders and any changes to the current harbour layout should consider all parties involved and must have a least negative impact on the various stakeholder groups. One example is reassigning of areas for recreation, which should not negatively influence the fishing industry.

- Physical constraints imposed by sea vessels

Restrictions on physical conditions needed (e.g. draft of vessel, wave conditions, quay wall height) for the assigned ships for the different zones should be satisfied. Furthermore providing onshore facilities for the vessels should also be taken into account.

- Traffic condition and manoeuvrability within harbour

In solving the insufficient capacity of the harbour great care should be taken as this could lead to traffic and manoeuvrability issues within the harbour. An important traffic constraint is De Pijp, which is a particularly narrow, but important connecting channel. An increase in vessel traffic (due to rearranging and/or new capacities) could lead to a bottleneck effect along the channel, which is not desirable. Therefore, any changes should consider the possibility of such a negative effect occurring.

- Constraints in expanding inland of Scheveningen

From a legal aspect, land ownership and environmental constraints should be considered. Additionally, just outside Scheveningen Harbour one finds areas protected under Natura 2000 (see Figure 6). Any design changes should also not compromise the effectiveness and reliability of the existing flood defences.



Figure 6: N2000 - 98 Westduinpark & Wapendal. (Natuur in Nederland)

Urban development and bridging De Pijp

Any changes to the harbour's usage scenarios and layout, which will be implemented according to the aforementioned section of the problem description, will result in changes in the configuration on land. The client has expressed interest in optimizing the land-based operations related to the harbour (eg-mobility of visitors to the harbour)

Following an increase in marina capacity and rearrangement of industrial and recreational facilities, a distinction between a typical residential and leisure zone, and a fishing/business oriented zone will arise. Detailed (urban planning) designs on this part is not be considered as a main goal of this project. Nevertheless, evaluation of and elaboration on the issue will be provided.

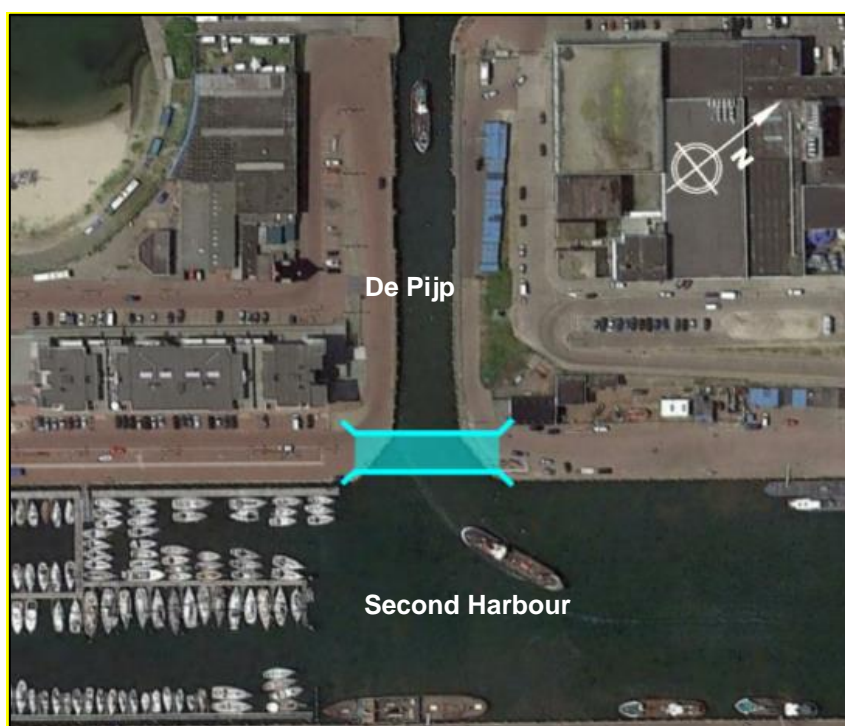


Figure 7: Possible point of connection across De Pijp (Google Earth)

It is within the client's goals for there to be space for urban growth of the Scheveningen area. Additionally, facilities that enable and encourage this course of development are necessary. One case of particular interest is a connection over De Pijp (Figure 7). This, the client specifies, will improve traffic in the Scheveningen area and further increase its pace of urban development. The possibilities for implementing a fixed or movable bridge, a non-constant connection (e.g. cable car or taxi boat) or a tunnel were all discussed and approved as possible solutions. The possibility to not provide a connection was also discussed.

4. Towards the Future

Considering the issues, demands and opportunities observed in the Scheveningen Harbour area, the different proposals are approached separately for the two differentiated project elements (see Figure 3): A New Scheveningen Harbour and Bridging De Pijp.

In the following sections, it will be briefly described how the two project elements are going to be addressed separately and lately combined in one complete proposal for the Scheveningen Harbour area.

4.1 A New Scheveningen Harbour

The current Scheveningen Harbour presents a number of very important opportunities for its development but at the same time very important limitations regarding the availability of high quality standards infrastructure for the various potential users. This project aims to provide a reference in order to adapt the current infrastructure to the changes in the activities experienced by Scheveningen Harbour in the last years and decades and prepare the foundations for fulfilling the future development demands.

In Chapter 5 it is presented and evaluated a series of alternatives in order to allow Scheveningen Harbour to fulfil the needs of expansion in a feasible, sustainable and quality-oriented development. In Chapter 6, it is described the details of the chosen proposal for the development of A New Scheveningen Harbour.

4.2 Bridging De Pijp

Currently, the Scheveningen Harbour represents an important barrier for the movement of pedestrians and bicycles in the north-south directions. The only connection between the north and south beaches and neighbourhoods is bordering the perimeter of the harbour (35 minutes for covering a gap of 150 meters along the harbour entrance or 30 minutes for covering a gap of 25 meters along de pijp).

Thus, in this proposal the existing needs of direct connection between the north and the south of the Scheveningen Harbour are going to be addressed in Chapter 7. For that purpose it is going to be presented and evaluated various possible alternatives from a technical, operational and feasibility perspective. The chosen proposal for the connection will be presented with further details.

4.3 Integration

Finally, Chapter 8 addresses the integration of the two project elements in one coherent proposal for the development of the Scheveningen Harbour area. This proposal aims to present a solid solution for the currently existing demands and at the same time allow the region to profit from the number of opportunities related to the waterfront activities in Scheveningen.

5. A New Scheveningen Harbour – Alternatives

In this chapter it is described the different alternatives for the development of the Scheveningen Harbour in order to secure its long-term capability of meeting the increasing demand of infrastructure and quality-oriented recreational services.

In Section 5.1 it is described the various alternatives possible, while in Section 5.2 the alternatives are evaluated through a multi-criteria analysis in order to select and develop the most suitable solution according to the local conditions and requirements.

5.1 Alternatives

In order to address the requirements of Scheveningen Harbour (see Chapter 3), a first analysis was made in order to evaluate the possible locations where the expansion of the Scheveningen could take place. According to a preliminary feasibility assessment and the considerations of The Hague Municipality, the alternatives for the development of the Scheveningen Harbour should be addressed based on the reorganization and improvement of the current infrastructure and considering an expansion within the harbour basin (see Figure 8). Thus, the expansion of the harbour towards the drainage channel or on an external development were discarded in the early stages of the project.



Figure 8: Expansion in the harbour basin

In addition to the expansion location within the harbour basin, The Hague Municipality remarked a series of constraints to be taken into account in the project, aligned with the problem description elaborated in Chapter 3.

1. Primary constraints:

- An extension towards the drainage or channel or on an external development is discarded
- In the old Norfolk terminal area, urban development will take place

2. Secondary constraints:

- Rijkswaterstaat building and mooring area will be maintained
- First Harbour: fishing activities and the storage building are going to be maintained

3. Additional constraints:

- Commercial activities in the Third Harbour might require specific mooring area

In the next sub-sections the three proposed alternatives are going to be described in detail. It is important to remark that these different alternatives have common elements such as the optimization of the currently existing infrastructure. Nevertheless, substantial differences are observed in the possibilities of expansion.

5.1.1 Alternative 1

This first alternative represents the necessary measures to be implemented in the Scheveningen Harbour with the least impact in the current harbour basin layout. It means that the current harbour basin will be optimized for allowing an increase in the demand of moorings for different uses, without including infrastructure expansion.

The justification of this alternative is the need of presenting a coherent alternative able to fulfil the existing demands without new investments in sheltering structures (such as breakwaters). The basic overview of Alternative 1 is shown in Figure 9.

First Harbour

In the First Harbour, the currently existing cargo and fishing activity is planned to be maintained. Nevertheless, the optimization of the moorings in this basin should be considered in order to concentrate as much fishing activity as possible, the aim being to liberate other harbour areas for other uses.

Second Harbour

The Second Harbour will be reorganized and optimized in order to allow an expansion of the existing marina moorings towards the northeast basin. Limiting these measures is the current use of this basin by fishing vessels. In the case that the First Harbour is not able to accommodate all the fishing vessels of the Scheveningen Harbour, the western quay of the northeast basin will maintain its fishing activity.

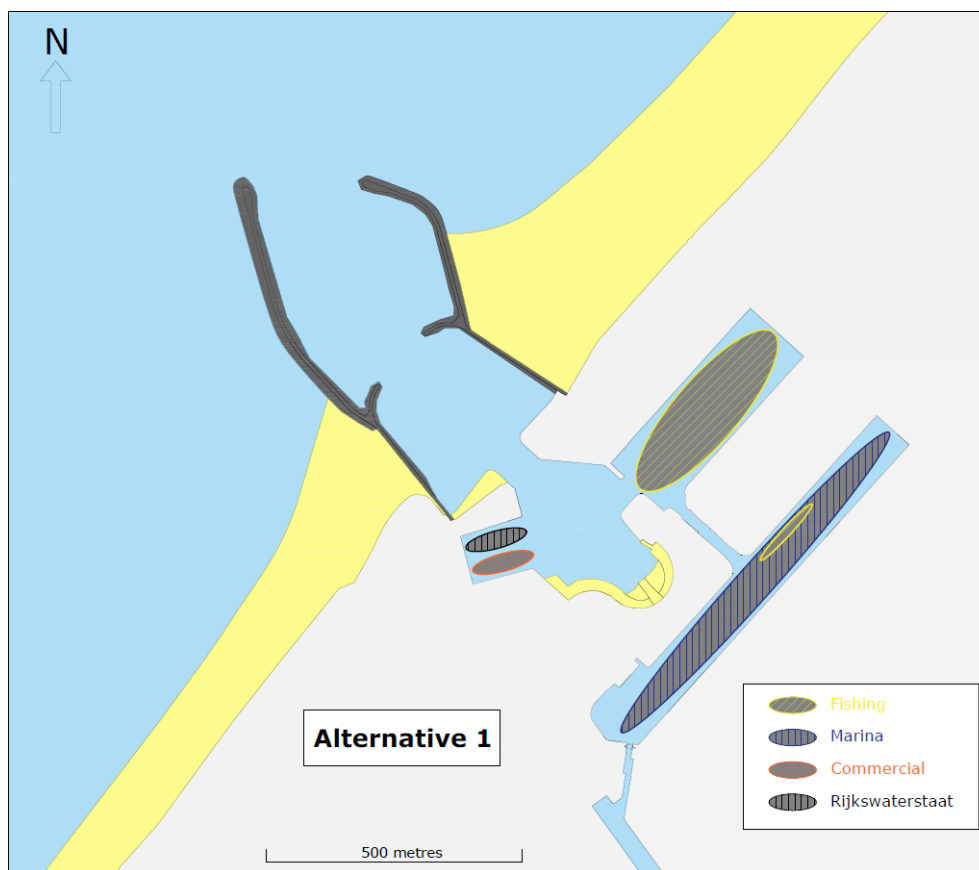


Figure 9: Alternative 1

Third Harbour

The north-western quay of the Third Harbour will continue to be used by the Rijkswaterstaat vessels as it is today. The south-eastern quay of the Third Harbour will accommodate the commercial vessels expected from the business development of the area.

5.1.2 Alternative 2

This second alternative addresses the requirements for the development of the Scheveningen Harbour with a permanent solution to the growing demand of mooring facilities throughout the whole year. It includes the optimization of all the harbour basins and a new marina to be known as the Fourth Harbour protected by a new inner breakwater (see Figure 10).

The justification of this alternative is the need of presenting a robust solution able to fulfil the existing and near-future demand in a permanent manner.

First Harbour

In the First Harbour, the currently existing cargo and fishing activity is planned to be maintained. Nevertheless, the optimization of the moorings in this basin should be considered in order to concentrate as much fishing activity as possible, the aim being to liberate other harbour areas for other uses.

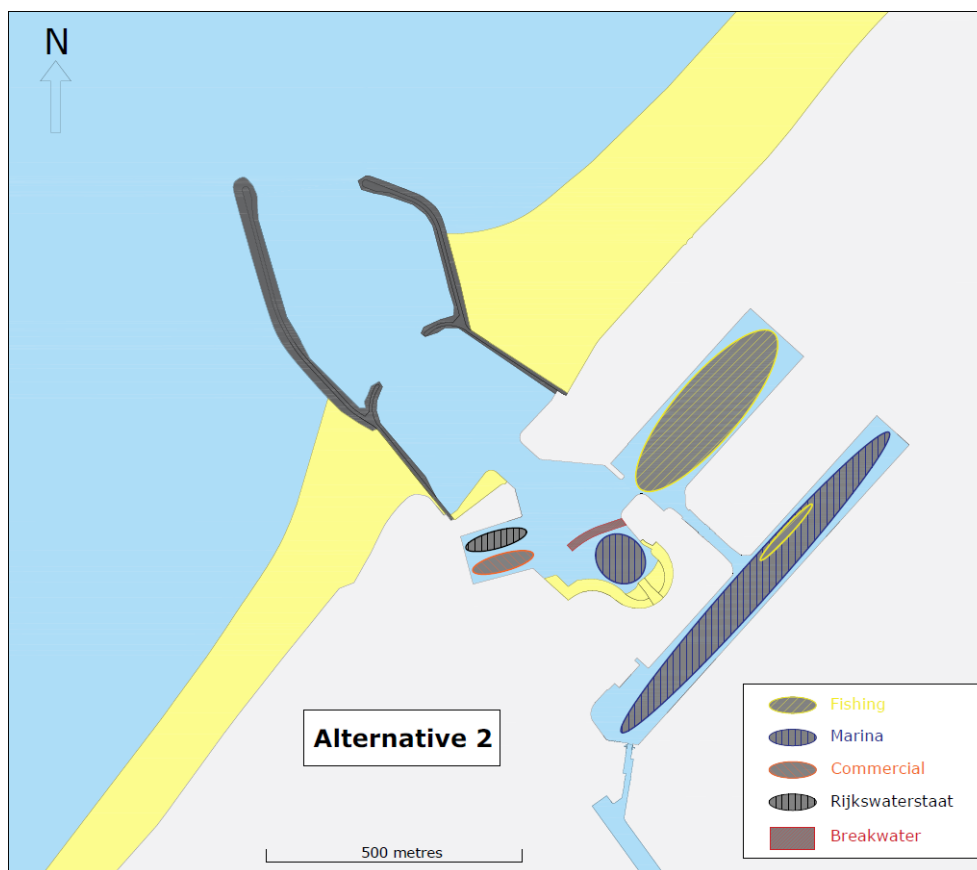


Figure 10: Alternative 2

Second Harbour

The Second Harbour will be reorganized and optimized in order to allow an expansion of the existing marina moorings towards the northeast basin. Limiting these measures is the current use of this basin by fishing vessels. In the case that the First Harbour is not able to accommodate all the fishing vessels of the Scheveningen Harbour, the western quay of the northeast basin will maintain its fishing activity.

Third Harbour

The north-western quay of the Third Harbour will continue to be used by the Rijkswaterstaat vessels as it is today. The south-eastern quay of the Third Harbour will accommodate the commercial vessels expected from the business development of the area.

Fourth Harbour (new)

In this alternative the new Fourth Harbour, located in De Kom, will allocate a new marina for addressing the growth in the demand of recreational mooring infrastructure. The necessary sheltering of this newly created harbour will require the construction of a breakwater as seen in Figure 10. This structure aims to reduce the wave agitation inside the Fourth Harbour, with a layout which does not enhance the wave reflection towards the navigation channels (see Section 6.4.1).

5.1.3 Alternative 3

The third alternative for the Scheveningen Harbour presents the actions to be taken in order to secure the development and growth of its activities in the long term (see Chapter 3). The extension of the western outer breakwater will provide additional protection to the harbour basins and allow the development of mooring facilities able to fulfil current and future needs of expansion. Included in this alternative are the necessary optimization of the current mooring infrastructure and the development of the Fourth Harbour and the Fifth Harbour.

The justification of this alternative is the need of presenting a definitive solution able to fulfil the long term demands in the Scheveningen Harbour. The general layout of Alternative 3 is shown in Figure 11. As can be seen, this alternative has the benefit of offering certain flexibility regarding the newly created two basins to accommodate all the demand of the marina and commercial moorings in the long term.

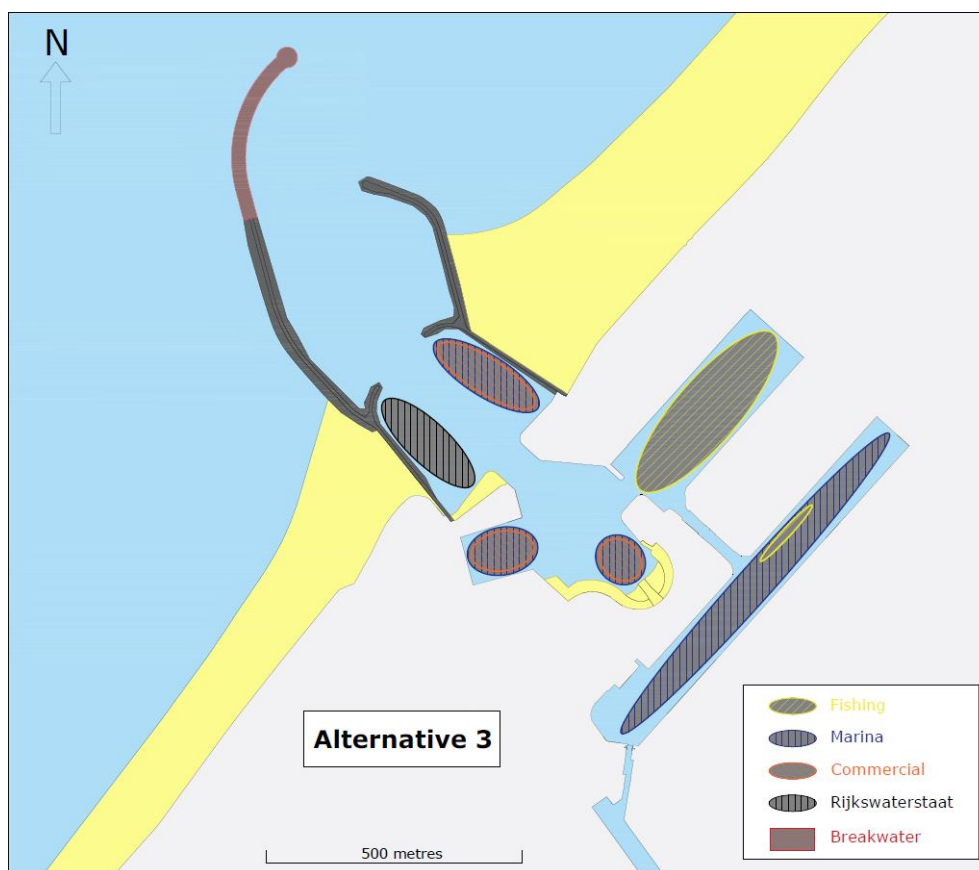


Figure 11: Alternative 3

First Harbour

In the First Harbour, the currently existing cargo and fishing activity is planned to be maintained. Nevertheless, the optimization of the moorings in this basin should be considered in order to concentrate as much fishing activity as possible, the aim being to liberate other harbour areas for other uses.

Second Harbour

The Second Harbour will be reorganized and optimized in order to allow an expansion of the existing marina moorings towards the northeast basin. Limiting these measures is the current use of this basin by fishing vessels. In the case that the First Harbour is not able to accommodate all the fishing vessels of the Scheveningen Harbour, the western quay of the northeast basin will retain its fishing activity.

Third Harbour

Since in this alternative the Rijkswaterstaat vessels are going to be relocated, the Third Harbour will provide enough space for the development of commercial and/or marina mooring infrastructure.

Fourth Harbour (new)

Similarly to Alternative 2, the Fourth Harbour will be used for fulfilling the demand of commercial and/or marina mooring infrastructure.

Fifth Harbour (new)

The new Fifth Harbour will be located in Buitenhaven. The newly created southern mooring area will be used to accommodate the Rijkswaterstaat vessels currently placed in the Third Harbour. The northern area will be made available for the development of commercial and/or marina mooring infrastructure.

5.1.4 Alternatives Summary

A summary of the most important characteristics of the three project alternatives is presented in Table 2 below.

Table 2: Project Alternatives

Harbour Area	Alternative 1	Alternative 2	Alternative 3
	Existing infrastructure	Inner breakwater	Outer breakwater
First Harbour	Concentrate fishing activity	Concentrate fishing activity	Concentrate fishing activity
Second Harbour	Optimization (Prioritize marina)	Optimization (Prioritize marina)	Optimization (Prioritize marina)
Third Harbour	Rijkswaterstaat and commercial	Rijkswaterstaat and commercial	Marina and/or Commercial
Fourth Harbour (New) – in De Kom	-	Permanent marina	Permanent marina and/or commercial
Fifth Harbour (New) – in Buitenhaven	-	-	Rijkswaterstaat and marina and/or commercial

5.2 Evaluation of Alternatives

The best alternative has to be chosen from the different alternatives proposed to solve the identified issues. The three alternatives considered fulfil the requirements in different levels. Thus a comprehensive analysis has to be performed to choose the best option. Three main methods can be identified in choosing between alternatives. Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA) and Multi Criteria Analysis (MCA).

The Cost Benefit analysis (CBA) tries to give monetary values to all advantages and disadvantages of the performing the project. The advantages are recognized as a benefit and disadvantages as a cost. Finally a balance sheet can be made between the costs and benefits for each alternative. Though this method is very straightforward, giving a “monetary” value for all the different aspects becomes difficult.

In Cost effective analysis (CEA) the weighing is done between the project cost and the advantages gained. If for example the project is to tackle one specific problem this method will lead to the least cost option. The problem encountered in this method is, since the cost of the project at the time of designing is very much an unknown, this ambiguous parameter of cost can lead to choosing the wrong option.

Multi Criteria Analysis (MCA) method enables the user combine the different indicators to the final outcome corresponding to its importance by weighing the various aspects relative to each other. If a proper method of assessing the indicators are established, the method is very straightforward.

5.2.1 Multi criteria analysis for alternatives evaluation

The main objective of the project is to develop the harbour to suit its future needs. Three alternatives were presented to obtaining this goal. In order to choose between the three alternatives, pertinent indicators concerning the project has to be defined and quantified.

5.2.2 Choosing of Indicators

In order to develop Scheveningen Harbour, the suggested alternatives are predominantly providing solutions to increase the harbour capacity to suit the future growth. Though this is one of the main objectives there are many other factors that has to be taken into account in arriving at the best alternative.

Indicators can be presented in a hierarchical order. The indicators at the top of the hierarchy is a combination of other primary indicators, these are defined such that, cumulatively they can capture the full scope of the project outcomes in different related areas. Thirteen primary indicators were identified for the project and they were then grouped to produce the hierarchical order. Figure 12 shows the hierarchical map which can be given to summarize the relationship between the indicators.

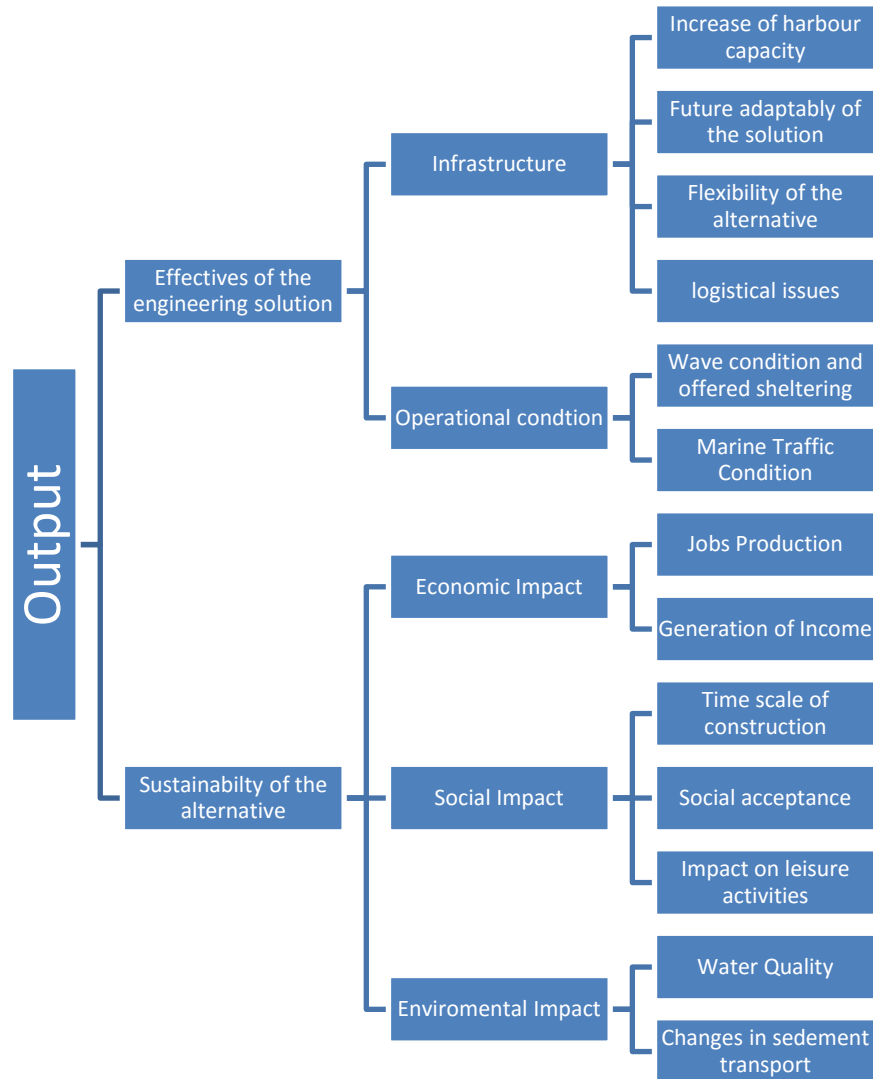


Figure 12: Grouping of indicators

A comprehensive description of the indicators are performed in the Annex 7

5.2.3 Evaluation of indicators

The next step of the multi criteria analysis is the measuring of the indicators for each alternative. The multi criteria analysis performed for this project is predominantly a qualitative investigation. Upon justification, a score varying between 0-10 is given for each indicator (0 being the worst case and 10 being the best).

The detailed evaluation of the alternatives are given in Annex 7

The Table 3 summaries the final scores given for each of the indicators.

Table 3: Indicators scores

Indicator	Alternative 1	Alternative 2	Alternative 3
Increase of harbour capacity	3	7	10
Future adaptability of the solution	10	8	3
Flexibility of alternative	2	3	9
Logistical issue	8	4	1
Wave condition and offered sheltering	0	8	7
Marine traffic condition	5	8	4
Jobs production	0	6	9
Generation of income	0	7	9
Time scale of construction	10	4	1
Social acceptance	5	9	3
Impact on leisure activities	10	5	4
Water quality	9	8	2
Changes in sediment transport	10	10	4

5.2.4 Calculation of the output indicator

For calculation of the final output indicator, weight factors have to be assigned for the indicators and indicator classes to reflect the comparative importance of them to the final output.

Allocation of weight factors

Weight factors are given from 1 to 3 depending on the relative importance. First, the weight factors were given for primary indicators for the calculation of the corresponding secondary indicator.

The weightages proposed for primary indicators in calculating the secondary indicators can be tabulated in the Table 4 as follows.

Table 4: Weight factors for secondary indicators

Secondary Indicator	Primary Indicator	Weight factor allocated
Operational condition	Wave condition and offered sheltering	3.0
	Marine traffic condition	1.5
Infrastructure	Increase of harbour capacity	3.0
	Logistical issues	1.0
	flexibility of the alternatives	1.0
	Future adaptability of the solution	2.0
Economic Impact	Jobs production	2.0
	Generation of income	3.0
Social impact	Time scale of construction	1.0
	Impact on leisure activities	1.0
	Social acceptance	2.0
Environmental Impact	changes in sediment transport	2.0
	water quality	1.5

The weight factors given for the secondary and the tier two indicators can be given as follows. The complete assessment done in choosing the weight factors are given in Annex 7

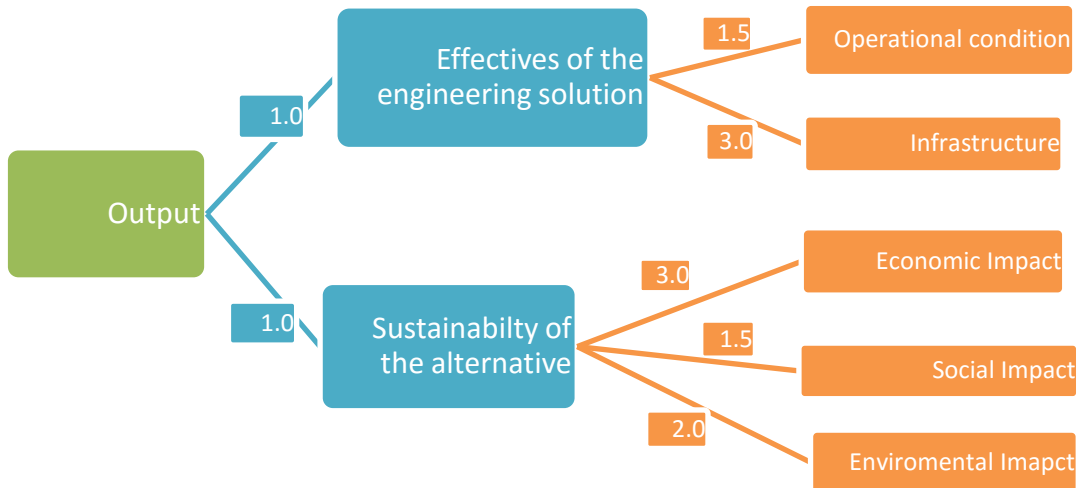


Figure 13: Weight factors for tier two

Following the analysis, the data assembled was input to spreadsheet based program JESEW (Joint Ecological and Socio-economic Evaluation of Water resources development) to calculate the viability of each alternative depending on their indicator score and relative weight factors. The output can be presented as a graph drawn between the two tier one indicators, sustainably of the alternative and effectiveness of the engineering solution. The ideal alternative will have the measurement point on the top right side of the graph (i.e. scoring in both the categories at a maximum). The graph derived for the three alternatives considered are provided in Figure 14

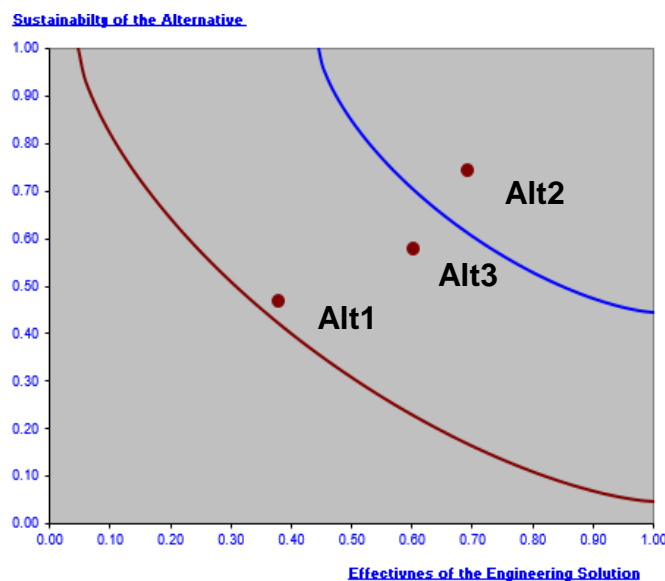


Figure 14: Alternatives output score

5.2.5 Conclusion

From the graph it is visible that the Alternative 2 scores higher than the other two alternatives in both tier one categories mentioned. Alternative 3 can be considered to be the next best option with Alternative 1 lagging far behind both the options.

Though the performed analysis is chiefly qualitative, the indicator scores can be taken as good representation of the areas considered and will only slightly differ with a change in perspective. However the weighting factors are more open to scrutiny as they can vary from the users' viewpoint. The problem arises between Alternative 2 and Alternative 3 as they are much closer in scores. With changes to the weight factors, a higher score can be transferred to the other alternative. Thus identifying the best alternative 2 and 3 without bias will not be possible.

An important factor which was not considered up to now in the selection process is the cost. Multi criteria analysis was chosen to circumvent the use of cost of the project which is largely an unknown at this level. However judging by the amount of civil works to be carried out in the alternatives it is prudent to assume that Alternative 3 will cost much more than Alternative 2.

Using the cost aspect of the project and considering the benefits gained in relation to the cost, it can very well be justified that Alternative 2 will be the most viable option to implement at the Scheveningen Harbour.

6. New Scheveningen – Solution

The chosen solution for the development of the Scheveningen Harbour is presented in the following sections. Detailed drawings are shown in Annexes 1 to 5. A fundamental aspect of this proposal is the expansion of the infrastructures dedicated to the mooring of recreational vessels with a focus on providing high quality infrastructure and services for permanent and seasonal users.

In Section 6.1 it is described the justification for the proposed development plan for the Scheveningen Harbour, while Section 6.2 addresses the marina development plan (comprising Second and Fourth harbours).

Furthermore, the details of the different measures and infrastructure development in the various harbour areas are presented as follows: redevelopment of the Second Harbour (Section 6.3) and construction of a new marina to be known as the Fourth Harbour (Section 6.4). On Section 6.5 it is described the planned uses of the First Harbour while on Section 6.6 the Third Harbour development is treated.

6.1 Justification

The Scheveningen Harbour has a direct connection to the open sea. There are only a few other ports within the Netherlands for which this is true. In addition, Scheveningen is attractive to sailors because of the different possibilities in the field of leisure.

- Scheveningen Harbour can be incorporated as an anchor point for (tourist) yachts and ships passing along the North Sea coast with deeper drafts, as well as for small ships and tall ships heading for the major events like Sail Amsterdam or Hafengeburtstag Hamburg.
- Scheveningen could play the role of a stopover harbour for world leading ocean races. (e.g. the Volvo Ocean Race in spring of 2015 used Scheveningen as stopover point).
- Major events such as the annual Delta Lloyd North Sea Regatta.
- The Hague municipality in collaboration with the Water Sports Association in the development of the Topzeilcentrum (NTC), transforming The Hague as a Sports City by the Sea – currently the InnoSportLab is also operating improving water sports. Both these entities will have a positive influence on Scheveningen Harbour.

It is apparent that Scheveningen Harbour has high potential for development and growth. It is also visible that the spectrum of ocean going vessels requiring the services of the harbour is wide.

The current Yachtclub Scheveningen is located in the southern half of the Second Harbour. According to its harbourmaster, the capacity of the marina is for 280 vessels plus 100 berths for seasonal use in summer. Furthermore, there is a waiting list of 40 vessels for permanent use only.

In addition, through observation of the marina during the month of July of 2013 (see Figure 15) the southern half of the Second Harbour showed the occupation shown on Table 5. The details of the

estimation of the current capacity of the Yachtclub Scheveningen can be found in Annex 11. Furthermore, approximately 50 small vessels in the northern half of the Second Harbour outside the Yachtclub Scheveningen were observed.

Table 5: Current use of the Yachtclub Scheveningen

Class	Observed vessels	Free berths	Total Existing
I	68	8	76
II	48	5	53
III	40	-	40
IV	80	5	85
V	38	-	38
VI	18	1	19
VII	2	-	2
TOTAL	294	19	313

According to the data presented in Table 5, the Yachtclub Scheveningen shows a very intense use of 95m²/vessel not allowing the fulfilment of existing recommendations for marina layout. This very intense use of the Yachtclub Scheveningen heavily compromises the quality of the marina for users and the navigation safety.

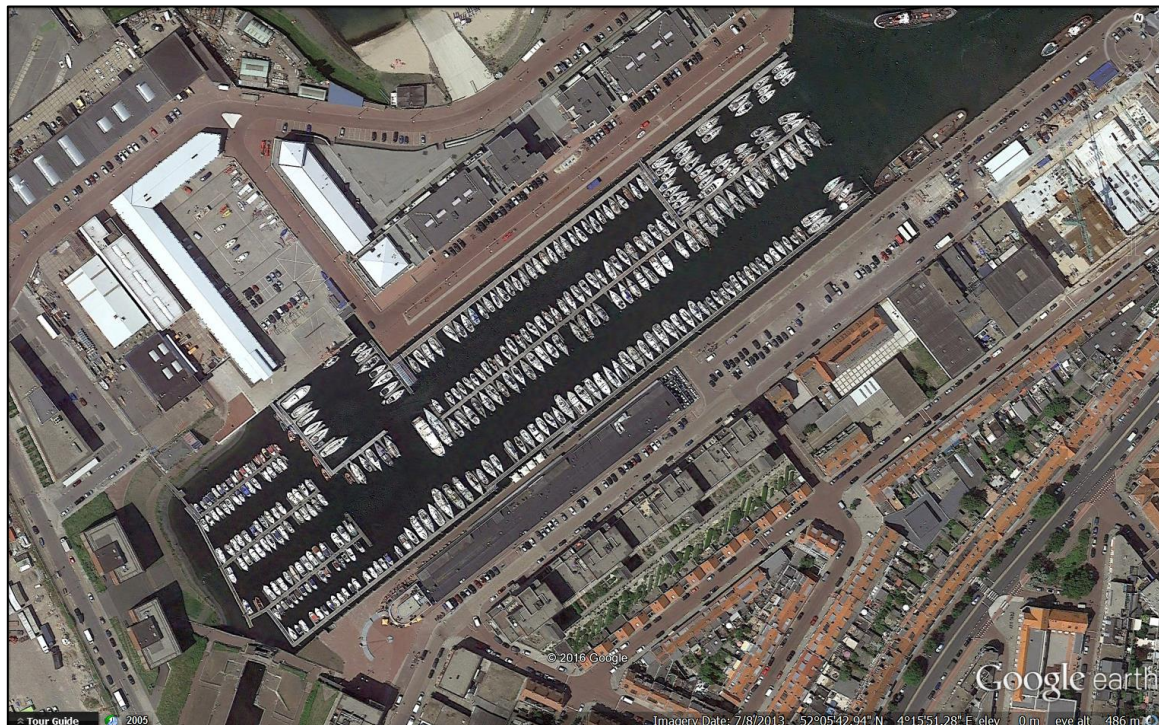


Figure 15: Yachtclub Scheveningen

Thus, the design of the new marina facilities proposed in this project (see Chapter 6) followed the most recent guidelines in order to include the Yachtclub Scheveningen among the highest ranked marinas by criteria of sustainability and quality of infrastructures and services.

6.2 Marina development

The current use of the Scheveningen Harbour by recreational vessels includes 280 permanent users with a waiting list of 40 and 100 seasonal users according to data provided by the Yachtclub Scheveningen on May 2016.

Direct measurement of the occupation of the Yachtclub Scheveningen from aerial view in 2013 showed the results presented in Table 6.

Table 6: Existing mooring facilities

Class	Existing	% Existing
I	76	24%
II	53	17%
III	40	13%
IV	85	27%
V	38	12%
VI	19	6%
VII	2	1%
TOTAL	313	-

With the proposed measures, Scheveningen Harbour will be able to offer the permanent and seasonal users infrastructures and services up to 475 vessels (375 in the Second Harbour and 100 in the Fourth Harbour) according to the latest guidelines and recommendations, see Table 7.

Table 7: Planned mooring facilities

Class	Total Second H.	Total Fourth H.	Total New Marina	% Total New Marina
I	84	26	110	23%
II	72	6	78	16%
III	48	12	60	13%
IV	94	36	130	27%
V	40	20	60	13%
VI	31	0	31	7%
VII	6	0	6	1%
TOTAL	375	100	475	-

As it can be seen in Table 7 and Figure 16, the development of the berthing infrastructure considers the needs to accommodate the trend of increasing demand for bigger vessels. Thus, the share of smaller vessels classes are going to be reduced while the higher classes will increase its participation.

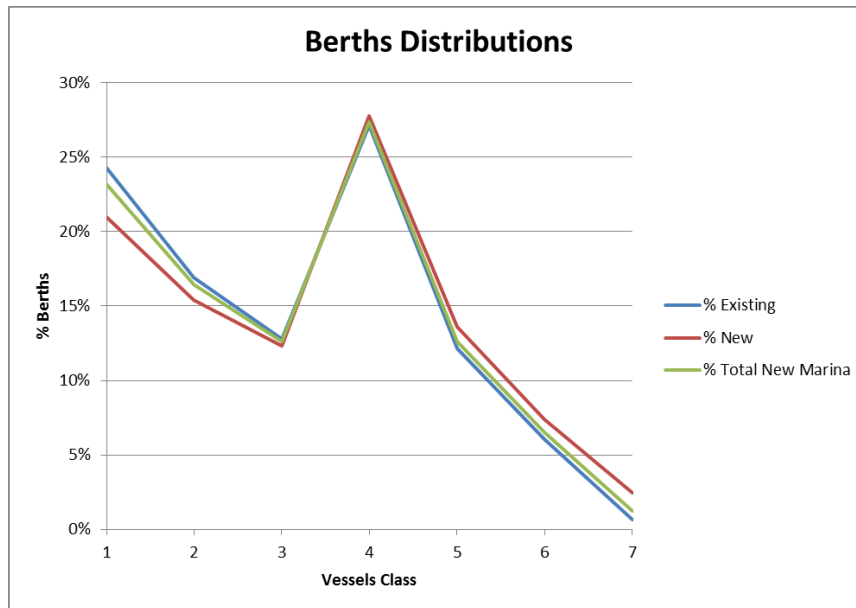


Figure 16: Share of vessels class berths

Regarding the distribution of the berthing and navigation geometry, all recommendations and guidelines (The Yacht Harbour Association Ltd., 2013) were applied in order to ensure the highest safety and comfort for permanent and seasonal users. Furthermore, the design of the access to the marina such as gates, ramps (including for disabled persons), pontoons, fingers and moorings are in accordance with the recommendations and guidelines (see Annex 12).

Besides the required expansion of the berthing infrastructure, a variety of criteria needs to be considered in order to establish in Scheveningen a marina with the highest quality recognition. This marina aims to be granted with international awards such as the “Gold Anchor Scheme” from “The Yacht Harbour Association” which recognises reference marina facilities around the world. An example of a complete list of elements to be considered in the development of a quality-oriented marina is shown in Annex 12.

A particular aspect to be taken into account in the planning of the marina is the availability of parking places. In Table 8 it can be seen the required distribution according to the guidelines. Thus, the current availability of parking places in the area will be able to adequately fulfil this demand.

Table 8: Parking places requirement

Class	Parking places per vessel	Total parking places
I	0.5	55
II	0.5	39
III	0.5	30
IV	0.5	65
V	0.5	30
VI	1	31
VII	1	6
Other uses	-	25
TOTAL	-	281

6.3 Second Harbour

The redevelopment of the Second Harbour proposes the use of the basin primarily for the mooring of recreational vessels. As it can be seen in Figure 17, the Second Harbour would provide the following infrastructure:

- 375 berths for recreational vessels up to Class VII size, distributed as shown in Table 7
- Maintenance of the current technical area for the repair of vessels up to Class V size
- The north-west quay would remain providing moorings for various purposes
- Two stations of taxi boat located at both sides of the entrance of De Pijp
- Fuel station for vessels up to Class VII size
- 6 access ramps and gates, including 1 for disabled persons

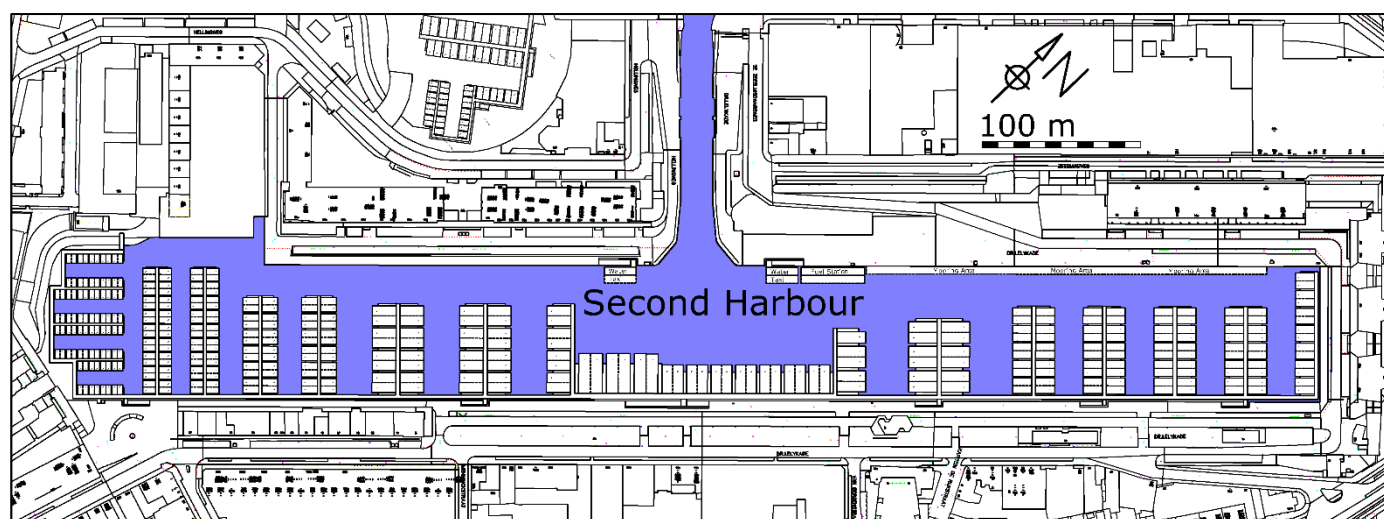


Figure 17: Second Harbour layout

All the previously elements were considered according to the most recent guidelines in marina design. In Annex 12 a wider description of the design of the marina is presented. In Annex 3 it is shown the detailed layout of the Second Harbour.

6.4 Fourth Harbour

The Fourth Harbour is going to be established in the currently existing area known as *De Kom* for the single use of recreational vessels mooring. As it can be seen in Figure 18, the Fourth Harbour would provide the following infrastructure:

- 100 berths for recreational vessels up to Class V size, distributed as shown in Table 7
- Ramp for the use of vessels up to Class V size
- Fuel station for vessels up to Class V size
- 3 assess ramps and gates, including 1 for disabled persons

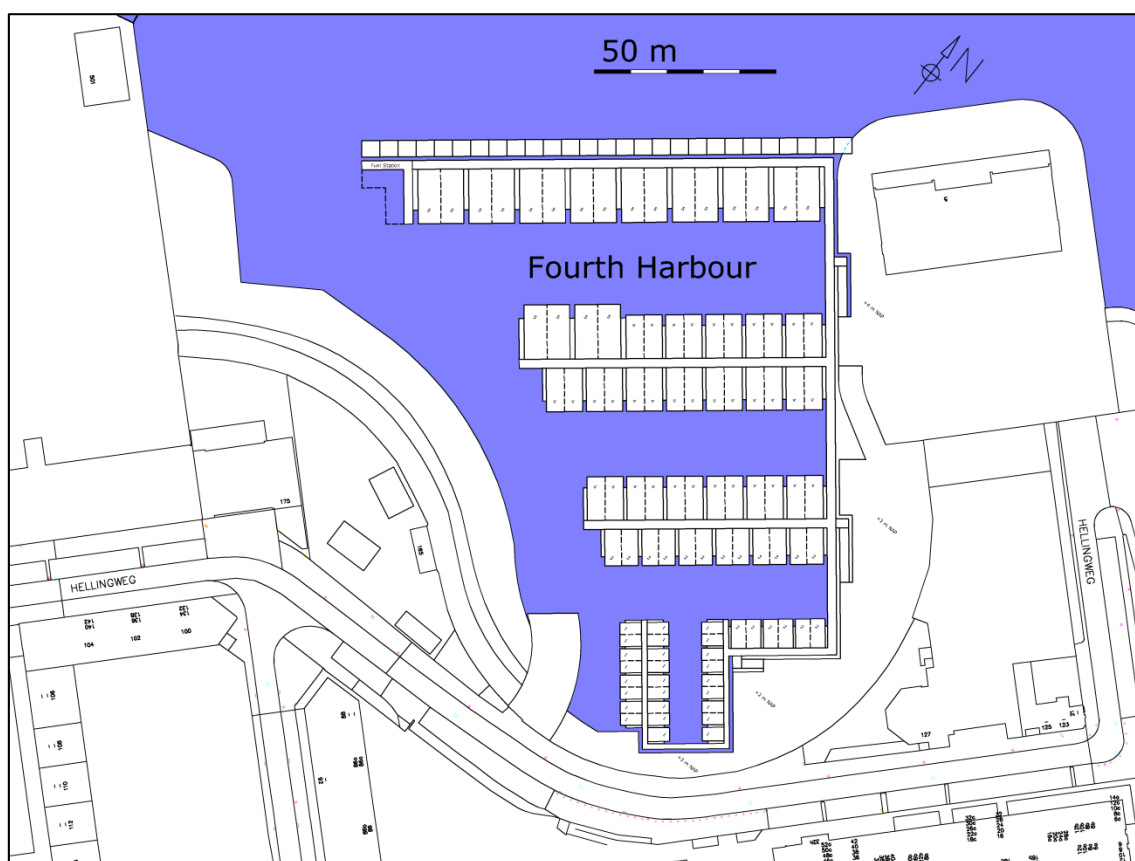


Figure 18: Fourth Harbour layout

All the previously elements are considered according to the most recent guidelines in marina design. In Annex 12 a wider description of the design of the marina is presented. In Annex 2 it is shown the detailed layout of the Fourth Harbour.

6.4.1 Metocean conditions

The metocean conditions of Scheveningen Harbour are described in Annex 8. The main aspects of this report are briefly summarized below.

6.4.1.1 Water level

Regarding the water level, the reference level adopted is NAP. The spring tide height varies from -72 cm to +125 cm NAP, with a range of approximately 2 m. The water level is higher than +245 cm NAP once per year. The water level for a return period of 100 years is +370 cm NAP, while the 10000 year water level is +515 cm NAP.

As Scheveningen is located in an excavated small tidal basin, the tide range inside the port area is practically the same than offshore. The extreme water levels are associated with storm surges. As a consequence of the Dutch coastline orientation, North-western storms are expected to be responsible for these events, whereas the water piles up due to wind and/or low pressure systems.

6.4.1.2 Waves

As no measured waves were available to the design wave analysis, offshore wave and wind data from BMT Argoss database were analysed and used as input a propagation wave model. Offshore wave conditions are characterized predominantly by waves from North-Northwest and West-Southwest. The highest wave heights and periods occur for waves coming from Northwest. Regarding the seasonality of offshore waves, the period from May to August presents the wave heights and wave periods with milder conditions than in the rest of the year.

As for the offshore wind conditions, the predominant wind comes from Southwest, while the highest wind speeds occur for winds coming from Southwest and North-Norhtwest. The mildest condition coincides with the period from May to August.

In order to obtain the design wave conditions at a point close to the Scheveningen Harbour entrance, SWAN (“Simulating Waves Nearshore”, TU Delft) was applied to propagate the waves from offshore (Argoss point) to nearshore. No calibration was carried out as no nearshore wave data was available. The whole time series of 23 years (1992-2014) was simulated and results were evaluated in the point with a depth of around -10 m NAP.

From SWAN results, it was observed that offshore waves from West-Southwest refracted and became from West, while offshore waves from North-Northwest turned and became mainly from Northwest. Higher wave heights and periods come from Northwest.

The entrance of the Scheveningen Harbour is protected by two breakwaters: the Southern breakwater with a length of 500 m and the Northern breakwater with a length of 350 m. The function of these breakwaters is related to the reduction of sediment transport towards the port basin, minimizing the siltation and the need of dredging. The approximate bulk longshore sediment transport rates are: 600 m³/y towards North, 400 m³/y towards South, with a net of 200 m³/y towards North. Therefore, the Southern breakwater extension is intended to accumulate sediments in its shadow zone. Due to the relatively small Northern breakwater extension, this breakwater is not capable of improving the ships navigation during storms.

As the waves enter in the inner port, complex processes such as diffraction, reflection and convergence occur simultaneously. Wave agitation models are used to properly estimate the wave properties in the inner area.

Deltares (2006) conducted a study of the wave conditions inside Scheveningen Harbour, and examined the wave behaviour for the existing wave conditions and for a few expansion options. Deltares results for the current situation (without any expansion) were considered in this project. The scenarios considered comprised the directions 360, 330 and 300°N, and wind speeds of 15, 20 and 25 m/s, and a fixed water level of +1.5 m NAP. The current situation and two expansion scenarios were simulated for all these

conditions. The output of this study is the significant wave height for every scenario and at all points inside Scheveningen First, Third and future Fourth harbours.

This study showed that:

- The outer significant wave height used as input with generation conditions with wind magnitudes up to 25 m/s varies between 3 and 5 m. This is comparable to the extreme nearshore waves (up to 4 m), which were derived at the same point with SWAN.
- A significant amount of energy dissipation is found mainly in the outer harbour (“Buitenhaven”).
- In the Scheveningen future 4th harbour, significant wave heights are hardly higher than 1 m.
- There is no clear evidence that the dissipative beach in the Scheveningen future 4th harbour really dissipates significant amounts of energy. The waves do not seem to always go towards this beach, but also refracts towards Scheveningen 1st harbour.

The current study obtained a time series of 23 years of wave data outside Scheveningen Harbour, in the same point as the one used by Deltares (at 52.11°N, 4.25° W). In order to derive the wave conditions in the new marina region, the significant wave height at this point was multiplied for every wave condition by the factors shown derived from Deltares study.

Regarding the wave statistics at Scheveningen Fourth Harbour, the average significant wave height is 15 cm for the whole year, while from May to September it reduces to 13 cm. The wavelength is in average approximately 52 m for the whole year, and while it is 48 m from May to September. The highest waves (0.6 – 0.8 m) have a peak wave period of between 10 and 15 s. the significant wave heights higher than 20 cm have a probability of occurrence lower than 20% from May to August.

The extreme waves at Scheveningen Fourth Harbour were evaluated through a POT (peak over threshold) analysis of storms – therefore a storm ranking was obtained by considering waves higher than 50 cm, and 6 hours as minimum distance between independent events. As for the extreme conditions, Goda (1988) method was applied by fitting the 40 highest significant wave height peaks, and a Weibull curve with $k = 2$ (Goda, 1988) was used after comparing 3 other curves.

The wave heights and periods for different return periods are presented in Table 9. The significant wave heights at Scheveningen Fourth Harbour for the return periods from of 1 year to 1000 years vary from 70 to 80 cm, approximately, with a range of only 10 cm. The associated wave periods range from 11 to 12 s. It is expected that these extreme wave heights will occur simultaneously with the extreme water levels as a result of storm surges, as both may be originated from Northwest wind systems. These results were used as reference to the breakwater design, as shown later in this report.

Table 9: Extreme wave analysis at Scheveningen Fourth Harbour

Weibull (2.0)		
Return period (y)	Hs (m)	Tp (s)
1	0.69	11.23
5	0.73	11.56
10	0.74	11.64
20	0.75	11.72
50	0.77	11.87
100	0.78	11.95
500	0.80	12.10
1000	0.81	12.18

Regarding the downtime in Scheveningen Fourth Harbour marina basin, two situations were evaluated: the first one without the presence of the breakwater and the second one with the new breakwater.

Two marina metocean criteria from ROM ('Recomendaciones de Obras Marítimas') were considered for the downtime analysis:

- Maximum significant wave height = 20 cm; and
- Maximum wind magnitude = 22 m/s.

As for the first situation (without breakwater), with the wave conditions obtained at Scheveningen Harbour Harbour, the downtime estimate due to waves and winds were calculated (see Table 10). This table shows that: a permanent marina in the Scheveningen Fourth Harbour without a new breakwater could operate only 75% of the time, mainly due to the wave conditions; and that a seasonal marina (from May to September) in the Scheveningen Fourth Harbour without a new breakwater could operate 93% of the time, only due to the wave conditions.

Table 10: Downtime calculation – for the situation without a new breakwater

Situation without new breakwater			
Criteria	Description	Downtime - whole year	Downtime - from May to September
1	Hs > 0.2 m	24.74%	7.23%
2	Wmag > 22 m/s	0.04%	0.00%
1 or 2	Hs > 0.2 m or Wmag > 22 m/s	24.74%	7.23%

By considering that 95% of the time is the desired operation time of a new marina, it can be concluded that a new breakwater is needed aiming to reduce the wave heights and guarantee sufficiently mild conditions to the marina.

Regarding the second situation (with breakwater), a quick calculation to estimate the wave height inside the marina basin was made of the wave attenuation (actual wave height over incoming wave height) with Wiegel (1962) diffraction diagrams. With the incoming waves as previously explained and with wave attenuation coefficients, the wave statistics and downtime were calculated.

With the breakwater, the average wave heights are lower than 10 cm are found throughout the whole year. The downtime estimate at Scheveningen Fourth Harbour with a new breakwater is presented in Table 11: as for 95% of the berths, a downtime due to waves of 0% was found both for summer and throughout the year, while for the remainder 5% (the 5 berths closest to the tip of the breakwater), a downtime of 0.26% (23 hours/year) throughout the year and 0.01% (1 hour/year) for summer were calculated. As it was shown, the breakwater reduces significantly the downtime due to waves.

Table 11: Downtime calculation – for the situation with a new breakwater

Situation with new breakwater - 95% of berths in New Marina			
Criteria	Description	Downtime - whole year	Downtime - from May to September
1	Hs > 0.2 m	0.00%	0.00%
2	Wmag > 22 m/s	0.04%	0.00%
1 or 2	Hs > 0.2 m or Wmag > 22 m/s	0.04%	0.00%
Situation with new breakwater - 5% of berths in New Marina			
Criteria	Description	Downtime - whole year	Downtime - from May to September
1	Hs > 0.2 m	0.26%	0.01%
2	Wmag > 22 m/s	0.04%	0.00%
1 or 2	Hs > 0.2 m or Wmag > 22 m/s	0.29%	0.01%

For the further phases of the project, it is strongly advised to perform a new hydrodynamics study, considering different set of conditions and the presence of breakwater, and measured data for calibration/verification. Especially the impacts of this new hard-structure (caisson breakwater) should be properly investigated, as both short/long waves may reflect and create standing wave patterns, and attention should be drawn to the enhancement of the potential of seiches.

6.4.2 Breakwater

6.4.2.1 Introduction and objective

In order to host a permanent marina at the Fourth Harbour a breakwater is required to protect the mooring area. The main performance of the breakwater will be to generate a sheltered area where the significant wave height has to be lower than 0.2 m. Moreover, the presence of a dissipative beach inside the harbour has not sense anymore. The dissipative beach was designed to dissipate the wave energy

at the access channel of the harbour during storm episodes, when the fishing boats used the harbour. Nowadays, the main activities of the harbour are related with leisure activities and a much lower use of the access channel during storm episodes is expected. Accordingly, the presence of the dissipative beach is obsolete and with the new Fourth Harbour it will be removed.

6.4.2.2 Multicriteria analysis

6.4.2.2.1 Alternatives description

Regarding the breakwater there are different options that are expected to accomplish the function of the structure. Thus, different alternatives are studied regarding and evaluating different criteria that the breakwater should accomplish. Those criteria will be analysed in a multicriteria analyse in order to decide the type of breakwater.

Three different breakwaters will be compared: vertical caisson, floating breakwater and composite breakwater.

6.4.2.2.1.1 Vertical caisson

A vertical caisson (see Figure 19) is a concrete solid structure that acts as protection for incoming waves by reflecting the energy. In addition, a vertical structure reduces the width of the structure allowing a higher mooring capacity. However, caissons have the disadvantage of the almost complete reflected wave. For the present situation, the reflection is an important factor to be considered. Some caissons include a chamber in front of it to reduce the reflection coefficient. Some experiments have shown reflection coefficients between 0.2 and 0.55 (Feys, 2009).

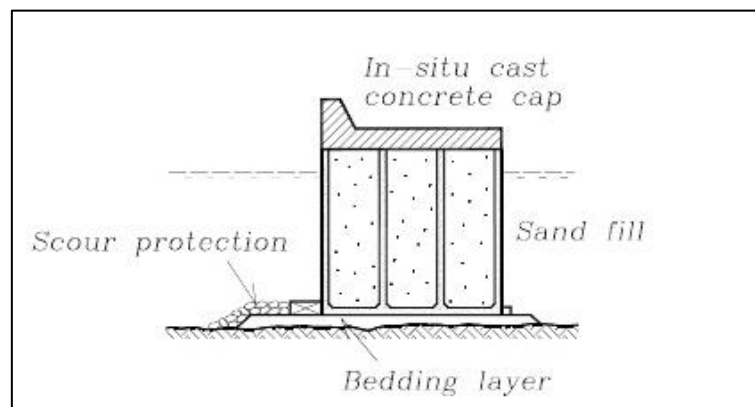


Figure 19: Vertical caisson

However, they have shown some disadvantages: they generate noise because of the air leaving the dissipative chamber and that the effectiveness of the energy dissipation is strongly related to the ratio between the wavelength of the incoming wave and the width of the chamber, making them very inflexible to wave states with wide spectrum. For those reasons, the dissipative caisson will not be considered like a feasible alternative.

6.4.2.2.1.2 Floating breakwater

A floating breakwater is a structure that is anchored to the sea bed but allows the flow under it. In the present case, a breakwater anchored with piles that allow the movement in the vertical direction will be considered. The main advantages of this structure are the easy transportability, the small visual impact and the multiple functions that it allows. By contrast, it provides less protection against waves, it is less effective for long waves and the maintenance cost is higher than for fixed structures.

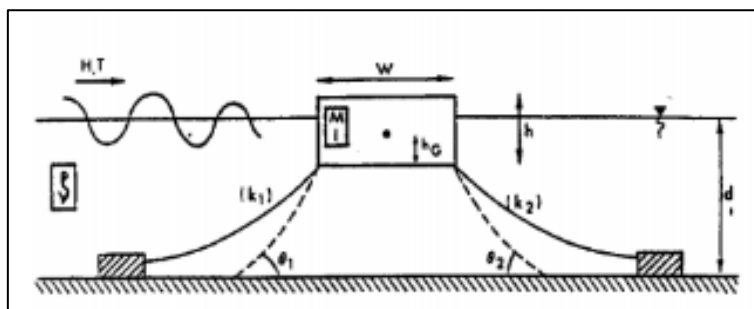


Figure 20: Floating breakwater

6.4.2.2.1.3 Composite breakwater

A composite breakwater is formed by the addition of a vertical wall or caisson with a rubble mound breakwater at the seaside, in order to dissipate energy and reduce the reflected wave. The main advantages are: a solid structure in order to reduce the transmitted wave, the reduction of overtopping for a wide range of waves and an increase of the energy dissipation. However, it needs a wider space and it has a higher visual impact.

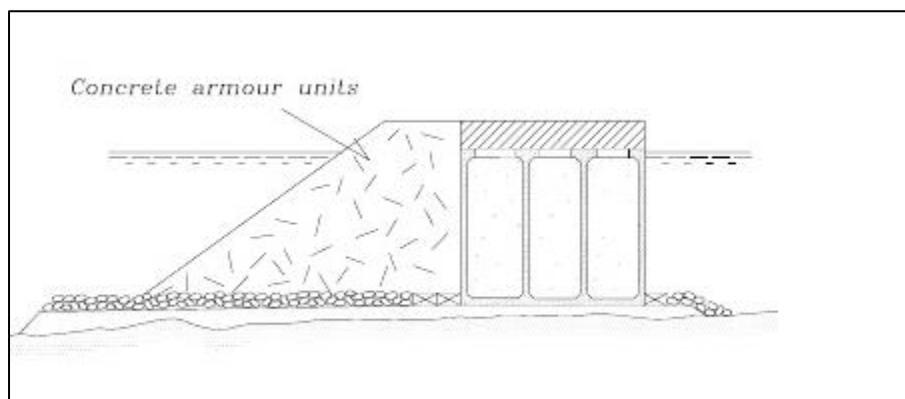


Figure 21: Composite breakwater

6.4.2.2.2 Alternatives analysis

The multicriteria analysis was based in three groups of criteria based in their importance for the project. For each criteria, all the alternatives was rated from 1 to 3. A detailed explanation of each of the categories and its corresponding grading can be consulted at Annex 9.

6.4.2.2.3 Results

The results of the alternative analysis are shown in Table 12 and Figure 22.

Table 12: Alternatives analysis results

Category (Weight)	Criteria	Vertical Caisson	Floating Breakwater	Composite Breakwater
Very important (3)	Transmitted wave	3	2	3
	Overtopping	3	1	3
	Visual impact	2	3	1
Important (2)	Reflected wave	1	2	3
	Size	2	3	1
	Flexibility	2	1	3
Considered (1)	Construction time	2	3	1
	Availability of material	2	3	2
	Maintenance costs	3	2	2

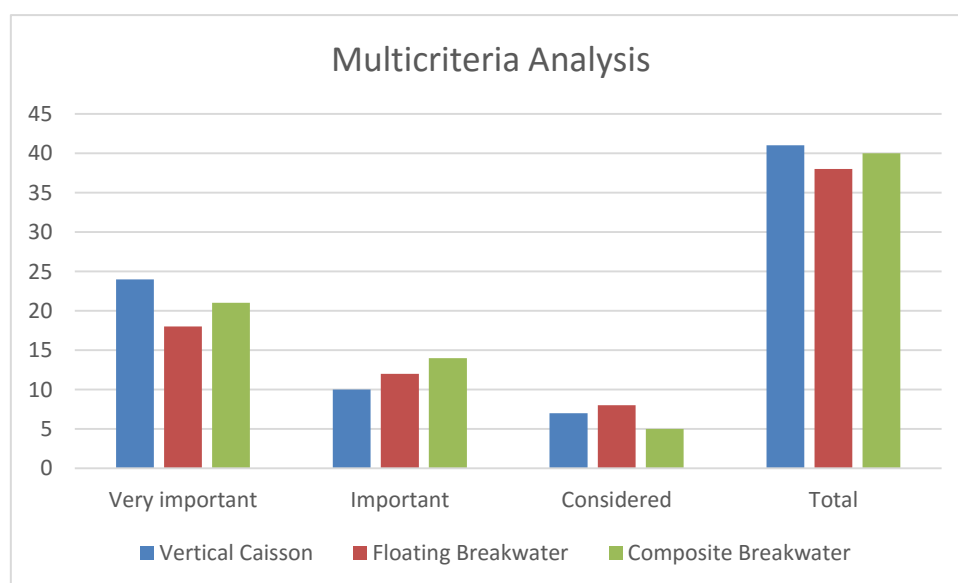


Figure 22: Alternatives analysis results

6.4.2.2.4 Results review

The multicriteria analysis shows very similar results for the vertical caisson and the composite breakwater. Thus, in order to make a reasonable decision a deeper research should be done at the effective reduction of the reflection coefficient of the composite breakwater.

Regarding the research, the reflection coefficient for the composite breakwater is computed in order to analyse the effectiveness of the rubble mound as dissipative structure. The graph shows the result for the analysis of wave data of more than 20 years. The computation of the reflection coefficient has been done according to Zanuttigh and Van der Meer (2006) as can be seen at the Annex 10.

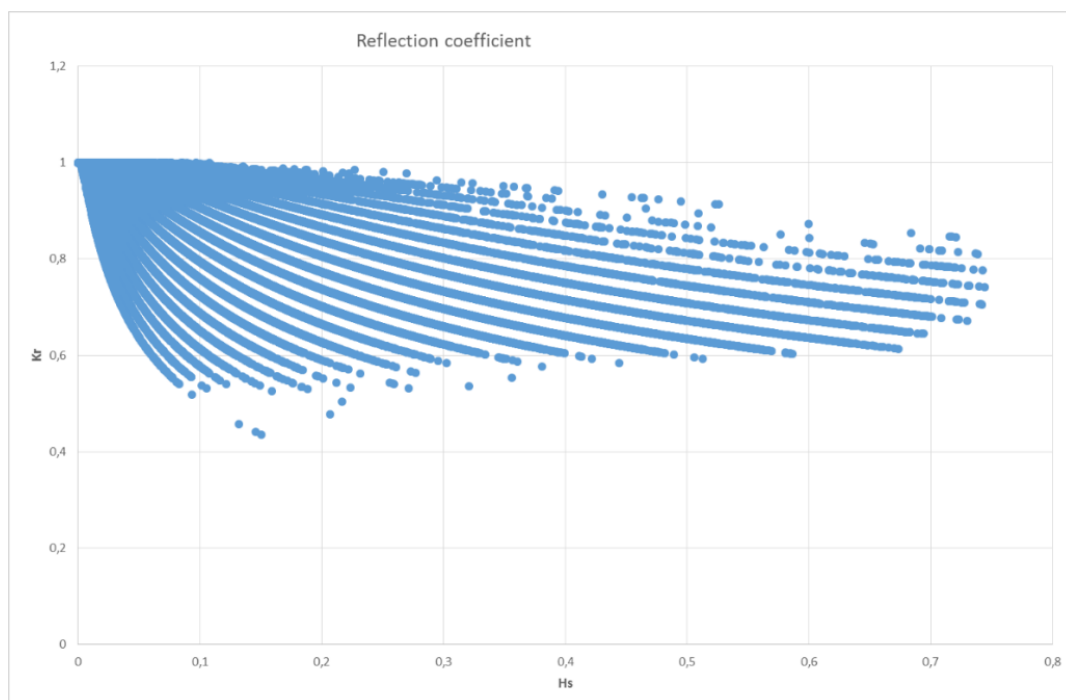


Figure 23: Composite breakwater reflection coefficient

6.4.2.2.5 Conclusions and chosen alternative

The study shows a very poor performance on reflection reduction by the composite breakwater. The average reduction of the wave height is lower than 10% and additionally it does not show a higher effectiveness for the highest wave heights, when the reflection reduction will be more important. The cost and construction time of the composite breakwater is higher and the poor results at the dissipation of energy do not justify the investment.

Thus, a vertical breakwater or Caisson will be built in order to generate a sheltered area at De Kom and create a new marina.

6.4.2.3 Design criteria

The various requirements considered in the design are shown in Table 13.

Table 13: Design criteria

Requirement	Return period	Type of design	Limit state	Verification method(s)	Design value	Calculated value
Vertical wall should not fail in extreme conditions sliding	100 years	Semi-probabilistic, PIANC (2001)	Ultimate limit state	Takahasi (1996)	SF = 1.5	2.4
Vertical wall should not fail in extreme conditions overturning	100 years	Semi-probabilistic, PIANC (2001)	Ultimate limit state	Takahasi (1996)	SF = 1.5	1.55
Toe should not fail in extreme conditions	100 years	Semi-probabilistic, PIANC (2001)	Ultimate limit state	Van der Meer et al (1995)	$N_{od} = 2$	0
Toe should not fail during lowest water level	100 years	Semi-probabilistic, PIANC (2001)	Ultimate limit state	Van der Meer et al (1995)	$N_{od} = 2$	0
No overtopping during working conditions	1 year	Deterministic (Eurotop manual)	Serviceability limit state	Pullen et al -2007	$q = 0$ l/s/m	0
Overtopping during extreme conditions	100 years	Deterministic (Eurotop manual)	Ultimate limit state	Pullen et al -2007	$q = 10$ l/s/m	0.13
Diffracted wave	1 h	Deterministic	Serviceability limit state	Wiegel -1962	Downtime < 5%	0.26%

6.4.2.4 Design calculations

As it has been seen at the multicriteria analysis a vertical breakwater is the best option to generate a marina at the fourth harbour. Next, the design will be carried out in order to find the proper dimensions for the structure.

The design follows various formulas to ensure the stability of the different parts of the breakwater; the toe protection and the solid wall. Moreover, the overtopping will be calculated to guarantee workability and safety for extreme conditions.

6.4.2.4.1 Caisson breakwater

For the stability of the concrete structure, the Takahasi equation (1996) for the modification of the Goda (1972) pressure distribution on a vertical wall has been chosen. For the design, a semi-probabilistic approach was followed according to the guidance of the PIANC (2001). The safety coefficients for failure by sliding and overturning were checked. Even that the semi-probabilistic approach considered some safety coefficients due to uncertainties at the loads and resistances are included, a safety factor of 1.5 is required in order to ensure the safety.

6.4.2.4.2 Toe stability

For the design of the toe, the PIANC stability formula proposed was applied (see Annex 10) following a semi-probabilistic approach (PIANC 2001) (see Annex 10). The input and results of this calculation are shown in Annex 10.

A low damage ($N_{od}=0$) is expected during the 100 y lifetime of the structure. If the design event is exceeded and the toe fails, the consequence for the overall stability of the breakwater will be the instability of the rock armour and could lead to the failure of the structure.

6.4.2.4.3 Overtopping

Two requirement conditions deal with the overtopping. During working conditions for the marina, no overtopping is allowed in order to ensure a safe path for pedestrians at the top of the wall and the safety of the yachts moored at the marina. Moreover, an overtopping maximum of 10 l/s/m is allowed in extreme conditions to protect the moored ships. Both situations have been checked with the formula of Pullen et al. (2007) for the maximum overtopping. The calculations are detailed at the Annex 10.

6.4.2.4.4 Reflection

The reflection coefficient has been calculated by using Zanuttigh and Van der Meer (2006) equation. For further studies, numerical modelling for results that are more accurate should be used. The best fitting numerical modelling is the IH-2VOF according to Van der Bos (2015).

6.4.2.4.5 Diffraction

The wave attenuation inside the new harbour should be studied in order to achieve the limitations of serviceability. A deep study of the influence of the breakwater is shown at Annex 8. The results of the study show that for 95% of the berths at the new harbour no downtime is expected during the whole year. For the more exposed 5% berths, those close to the tip of the breakwater, a downtime of 0.26% is expected, thus, only 23 hours per year.

6.4.2.4.6 Calculation results

The layout of the designed vertical breakwater is presented in Annex 4, while the typical cross-section of the vertical caisson is shown in Annex 5.

6.4.2.5 Construction Method

The main part of the construction is expected to be executed in situ. For the required space for the construction material and equipment storage, the Norfolk old terminal will be used. This is the optimum place because nowadays it is only used as a car parking and is close to the placement of the breakwater. The breakwater will be built in three different phases, explained below.

During the first phase, the fascine mattress will be placed at the seabed in order to avoid the erosion of the soil and at the same time it acts as a stable base for the structure. Due to the protected area where the mattress is placed, no operational downtime is expected.

The second phase will cover the construction of the concrete structure. Some special equipment have been developed to build caissons. However, due to the small size of the caisson it does not seem to be an economical option. In this case, a construction of the caisson by parts of approximately 5 meters long will be performed at the site. With a weight of 125 t each, after the curing period they can be placed at water by a crane. Once at the water, the floating line will be around half of the structure and can be carried to the correct place. As in the first phase, very short operational downtime is expected. The sinking of the structure will be done by filling it with gravel and sand by a floating crane.

The last phase of the construction will be the construction of the toe protection. The placement of the rocks will be done by a floating crane with a first part of bulk placement and a second part of fitting the geometry of the protection.

The construction time is expected to be 5 months in order to disturb as less as possible the activity of the harbour, see Annex 10 for a detailed construction schedule.

6.4.2.6 Further studies

Some important studies that were outside the scope of this project are recommended for the further phases of the breakwater design.

The reflection has been assumed not to be a main issue during the workability of the harbour. However, the placement of the breakwater in front of the navigation channel that gives access to the facilities make a deep study of the development of the reflected wave at the basin recommended. This study can be done by using hydrodynamic computational models.

If the results of the model simulation show a high influence at the navigation, some alternatives can be considered. The high reflection of the composite breakwater is mainly related to the steep slope of the structure. The lack of space for the breakwater make impossible to add a milder slope for the rubble mound. However, some studies have been done with a mixed breakwater composed by a vertical wall between mean sea level and the seabed and a rubble mound on top of it. This reduction of rubble height allows constructing much milder slopes with the same total width of the structure. For a slope of 1:4 for example, an average reflection coefficient of 0.5 can be achieved with values of 0.4 for highest waves, see Annex 10.

However, this alternative is more expensive than the caisson (approximately 2 or 3 times more), thus a deeper study of the influence the reflected wave should be done to be able to take a decision.

Additionally, the bearing capacity of the soil has not been studied. The most likely failure mechanism of the structure will be a soil failure at the rear toe of the breakwater. No information regarding this aspect

was available for the development of this project. Besides, in further investigations of this project the solid capacity should be studied. The preliminary pressure distribution of the caisson shows a maximum of 350 KPa, that the solid should resist. Typical capacity for sand soils are around 300 KPa.

However, if the solid capacity is not enough some measures can be considered. The presence of a rock structure on the base of the vertical caisson will reduce the pressure over the soil and on the other hand, some techniques are available to increase the capacity of the existing soil.

6.5 First Harbour

The First Harbour of Scheveningen (see Figure 24) is expected to maintain its current activities according to this project proposal. The fishing activity is not only a traditional aspect of Scheveningen but still important in economic and employment terms. Thus, maintaining the current use of this basin focused on fishing activity is compatible with the redevelopment of the other areas towards recreational and leisure purposes.

It is also recommended the optimization of the activities in this basin, improving the land facilities and logistics in order to increase the capacity of the First Harbour. Recently, The Hague Municipality signed the Vispact between it and the fishing industry with the goal of “Improving the competitiveness and market position of the fishing industry in Scheveningen”, (Den Haag Municipality, 2009). With a basin with 55000 m² of surface, the current use of the area is not proving to be optimal. The more intense utilization of this basin would increase the economical feasibility of its users and allow to liberate all other basin areas from fishing activities.

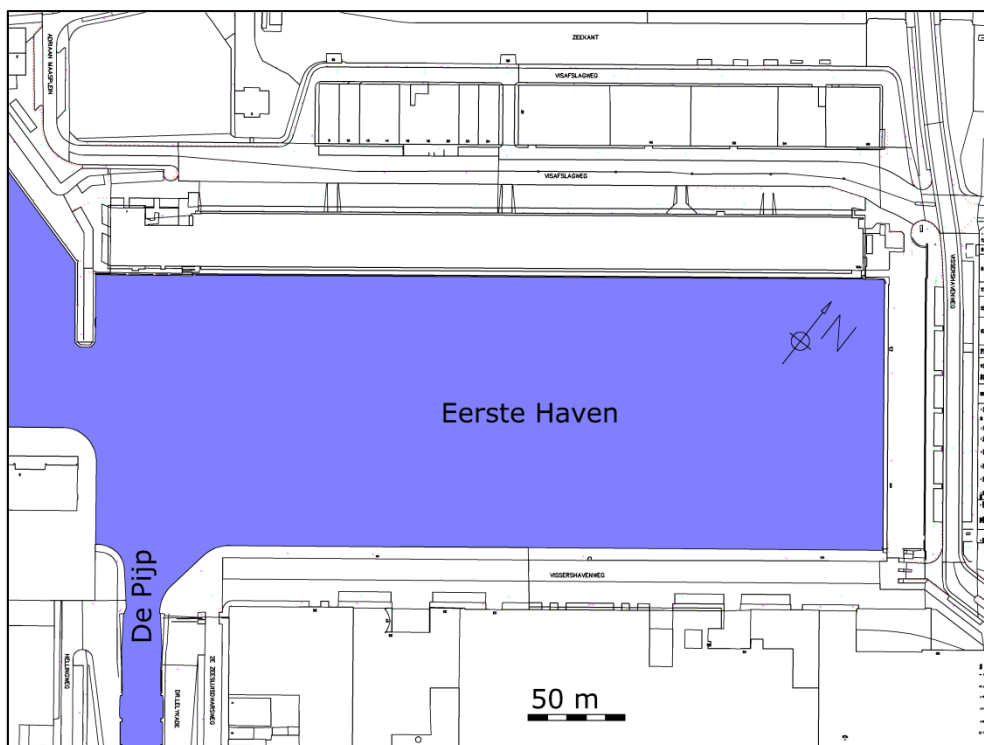


Figure 24: First Harbour layout

The fishing activity in Scheveningen would also have an important opportunity with the redevelopment of the harbour, towards offering higher added value products and services. In this sense, permanent and seasonal users of the recreational facilities would not only demand high quality locally fished products but also be willing to know the local history and to participate in traditional fishing activities. Locals and visitors could see the history of Scheveningen bound to the sea as an additional and attractive reason to use the recreational facilities in the Second and Fourth harbours.

6.6 Third Harbour

The proposed uses of the Third Harbour (see Figure 25) can be divided in two: Rijkswaterstaat and commercial use.

Rijkswaterstaat:

The north-half area will continue to be used and a mooring facility for the Rijkswaterstaat, adjacent to its permanent facilities at the entrance of the Scheveningen Harbour.

Commercial use:

The south-half will be dedicated to the future commercial uses related with the urban development which will take place in the old Norfolk terminal area. The detailed design of the redevelopment and adaptation of the area should take place according to the demand and characteristics of the vessels to be used, not yet defined by The Hague Municipality.

Among others, possible users are:

- Research and Educational institutions
Many different cooperations and research bodies are currently willing to settle in the harbour of Scheveningen. The entities who have shown an interest in this matter vary from educational institutions to private coastal consultancy groups. Following is a non-exhaustive list of some of these groups.
 - Valorisation Programme Delta Technology & Water (VPdelta) at TU Delft has signed an agreement with The Hague Municipality to set up a 'testing ground' surrounding a theme in the field of coastal and water management in Scheveningen Harbour. (Mulder, 2016)
 - Shore Monitoring and Research, Wave Droid and Elemental Water Markers are some other companies who have shown interest.
 - Wageningen University and Research Centre (WUR) and affiliated research bodies like the strategic and applied marine ecological research (IMARES - Institute for Marine Resources & Ecosystem Studies) have shown interest using the harbour as a port for their research work in the oceans (e.g. : Survey Mackerel and Horse mackerel egg 6 May - 21 June 2013). They have also expressed their keenness in having a foothold in Scheveningen.

- Cooperations and Companies
 - Use of offshore wind farms has seen a dramatic increase through the years. In the Netherlands, the goal being to reach 6000 MW by 2020 (Eggink, 2013). As for the current situation there are two wind farms operating just offshore of Scheveningen in West Rijn Scheveningen Buiten from 2011 onwards generating 584 MW (European Wind Energy Association, 2009) . Furthermore there are tests being carried out (The “Slow Mil”) in offshore of Scheveningen to generate power using the wave energy (Ministry of Infrastructure and Environment, 2014). With this expected growth in energy generation in the North Sea, Scheveningen port offers great advantage with its proximity to the sites as a potential hub for operation for the maintenance vessels of these wind farms and other related facilities.
 - There is a demand towards the harbour from region-based companies that are active in the sea (e.g. Siemens, APM Terminals, Fugro).

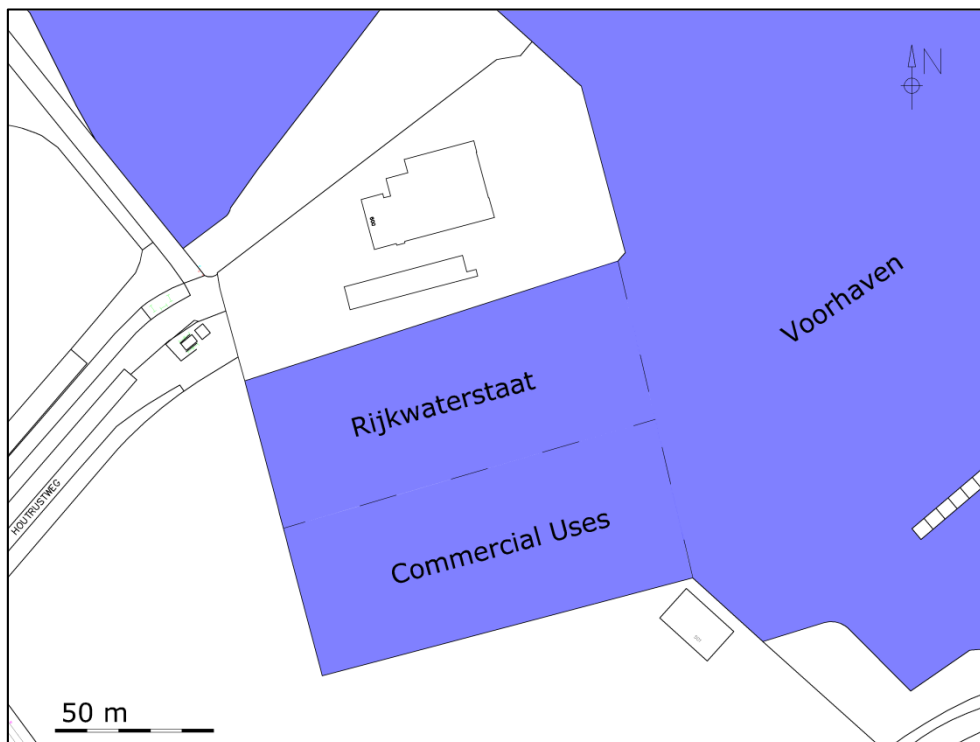


Figure 25: Third Harbour layout

7. Bridging De Pijp – Alternatives

A secondary objective of the project as defined by the client is exploring alternatives for a connection across De Pijp. Boundary conditions were not explicitly set by the client, therefore, these are regarded in this section. Further, a brief analysis of multiple solutions is presented, followed by detailed elaboration on the three best suited alternatives and a multi-criteria analysis of those. Finally, one alternative is chosen and further developed.

A connection between the southern and northern sides of Scheveningen has been considered before (see Figure 26). The locations of the connection vary, but are usually considered to be at the (southeastern) end of De Pijp, as specified by the client, and across the Buitenhaven (Outer Harbour). This section focuses on the former (Figure 26, green circle).

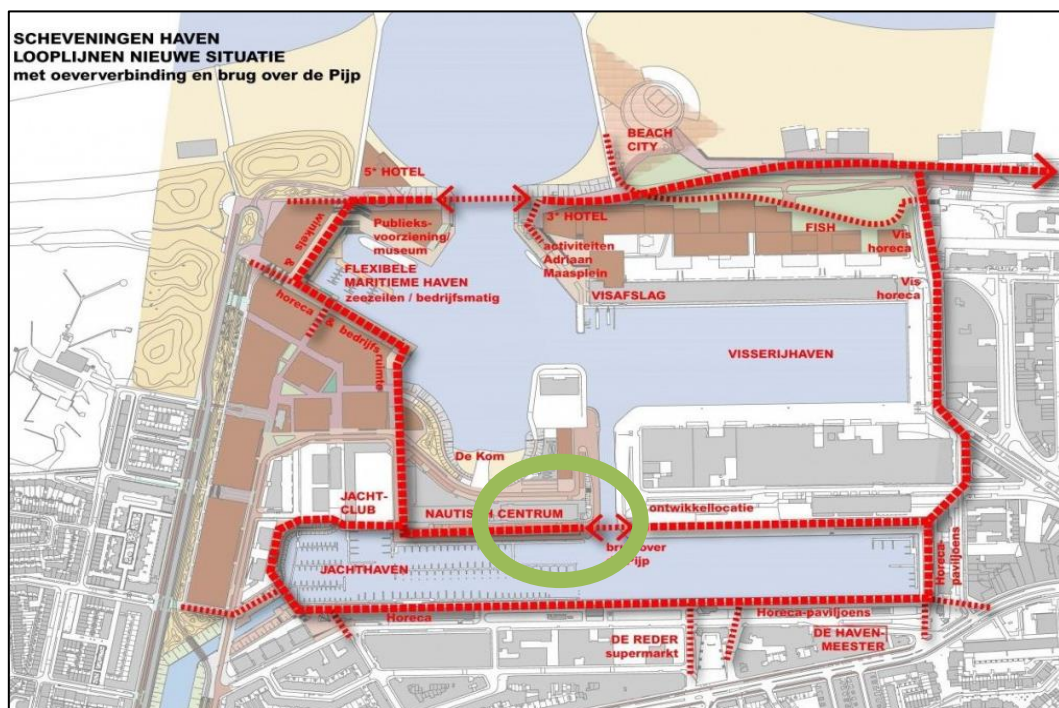


Figure 26: Popular connection points between the two sides of Scheveningen; Source image: <https://denhaag.pvda.nl/2014/01/er-komt-een-oeververbinding-maar-wat-voor-een/>; (Jong, 2014)

7.1 Boundary conditions

Five basic boundary conditions regarding the connection were identified, as listed below:

- Low disturbance – must not hamper marine traffic
- Efficiency – must enable on-land traffic efficiently
- Attractiveness – choose an alternative society will approve of
- Limited negative impact – keep negative impact as low as possible
- Cost – keep as low as possible

An additional boundary condition was determined to be the type of traffic that the connection will enable.

- Type of traffic – pedestrians, bicycles or motorized vehicles

It was decided that a pedestrian-oriented solution will be developed. A list of justifications why motorized vehicle traffic was dismissed can be found below.

Not in accordance with client's vision (Bestemmingsplan "Scheveningen Haven", 2013)

During the meeting with The Hague Municipality it was clear that a pedestrian and/or bicycle connection is preferred. The option for motorized traffic was not dismissed completely, but was not considered a viable alternative since it clashes with a number of goals that the client had set, mainly ensuring touristic appeal and quality leisure. Additionally, the current Zoning plan (Bestemmingsplan "Scheveningen Haven", 2013) does not include a vehicle-capable connection in the considered spot Figure 27.

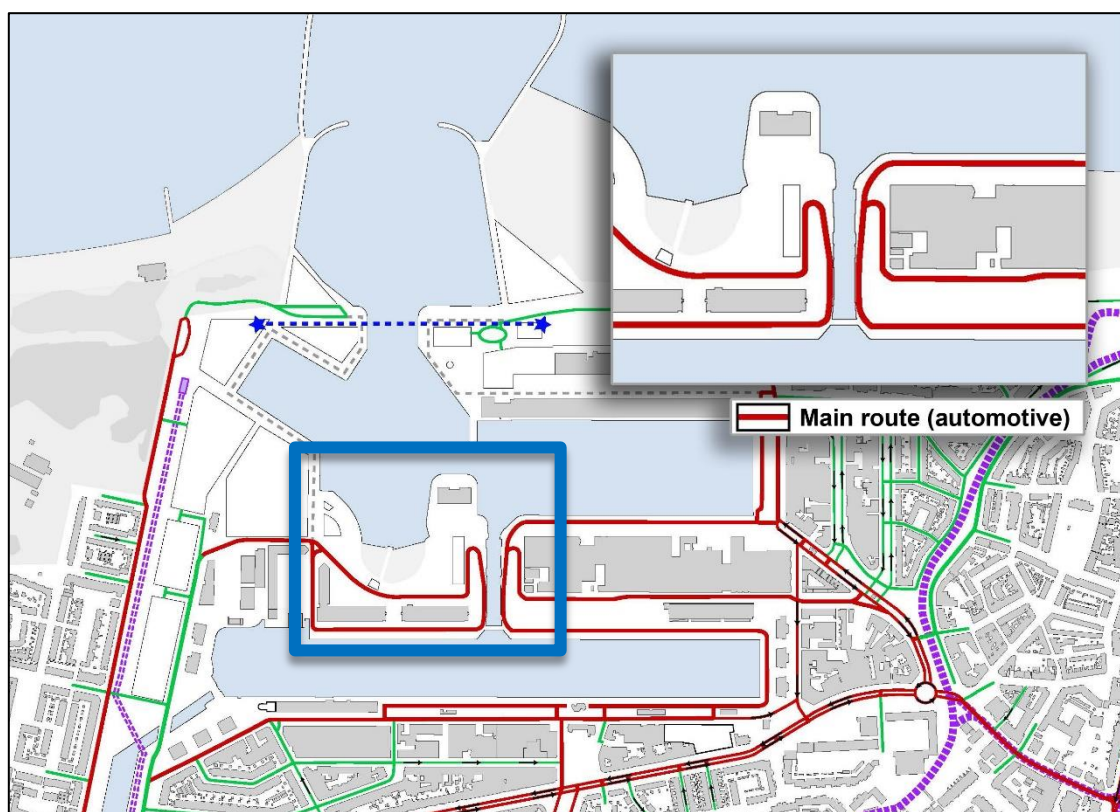


Figure 27: Plans for connection, but no continuation of vehicle paths. Red line indicates a main automotive route. Source image: Bestemmingsplan "Scheveningen Haven", 2013, p. 40

Air pollution, noise and vibrations

While according to the current Zoning plan vehicles are allowed in the Scheveningen area, and therefore already cause pollution, allowing motorized traffic to cross De Pijp will lead to an increase in traffic and thus lead to a decrease in air quality and a generally noisier environment. Additionally, depending in the implemented engineering solution, vibrations might also become an issue. Such a scenario will have a negative effect both on residents and visitors of the Scheveningen Harbour area.

Larger, architecturally unattractive structures

Depending on the proposed engineering solution, issues might arise from the dimensions of e.g. a bridge. Motorized traffic leads to increased live loads on the structure (Eurocode 1: Belastingen op constructies – Deel 2: Verkeersbelasting op bruggen. NEN-EN 1991-2+C1:2011 nl, 2011), which in turn leads to larger load bearing elements. Minimum allowed dimensions regarding e.g. bridges for vehicles are much higher than those for pedestrian and/or cyclists (e.g. (Berg, 2015); (European Committee for Standardization (CEN), 1992)), thus more space will be taken up by the structure itself. Lastly, the possibility to achieve an attractive architectural design is questionable.

Higher construction and maintenance costs

Naturally, a larger dimension-wise structure will cost more to construct. Additionally, more valuable real-estate will be taken up by the oversized structure. Lastly, the higher loads exerted on it will require high maintenance costs such as e.g. road surface and flexible joints repairs on a typical bridge or tunnel, movable mechanisms and mechanical part servicing on a movable bridge etc.

7.2 Considered alternatives

There is a wide range of possible solutions regarding the connection across De Pijp. A brief overview of pros-and-cons is outlined in Table 14.

Table 14: Pros and cons of possible solutions for a connection over De Pijp

Alternative	Positive aspects	Negative aspects
Fixed bridge structure	<ul style="list-style-type: none"> Land based traffic and vessel traffic are independent of each other 	<ul style="list-style-type: none"> Underbridge clearance – sailing boats need to be able to enter/exit the Second Harbour Considerable height compared to existing surrounding buildings and structures The need for large clearance leads to incline limitations that dictate the minimum length of the bridge High construction and maintenance costs High initial investment
Movable bridge	<ul style="list-style-type: none"> Considerable reduction in structure height and length when compared to a fixed bridge solution 	<ul style="list-style-type: none"> Considerable downtimes may restrict vessel and/or land-based traffic; traffic dependency High construction and maintenance costs High initial investment

Cable car	<ul style="list-style-type: none"> • Could be considered a tourist attraction 	<ul style="list-style-type: none"> • Considerable downtimes may restrict vessel and/or land-based traffic; traffic dependency • High limitations in operation conditions e.g. wind speed • High construction and maintenance costs • High initial investment
Tunnel	<ul style="list-style-type: none"> • Does not change the landscape of the harbour • Land based traffic and vessel traffic are independent of one another 	<ul style="list-style-type: none"> • A complex and difficult construction process that may result in the temporary blocking of the entrance to the Second Harbour during construction • High construction costs • Does not contribute to the touristic appeal of the area • Very high initial investment
Taxi boat	<ul style="list-style-type: none"> • Could be considered a tourist attraction • Lowered traffic dependency compared to other alternatives • Low initial investment • High degree of seasonal and long term flexibility 	<ul style="list-style-type: none"> • High long term maintenance costs • Possibility for congestion • Access for disabled people needs to be addressed • Higher long term environmental impact
No connection (zero alternative)	<ul style="list-style-type: none"> • No negative effect on vessel traffic 	<ul style="list-style-type: none"> • Limits land-based traffic in the area • Possible negative influences on the Second Harbour area's urban development

Based on these and other considerations, three alternatives were selected for further evaluation through a detailed multi-criteria analysis:

- Alternative 1 – Movable bridge
- Alternative 2 – Tunnel
- Alternative 3 – Taxi boat

A zero alternative was not considered as it is not in line with the project goal of modifying and improving the Scheveningen area. A more comprehensive elaboration on the 3 alternatives is presented in the following section.

7.3 Analysis of evaluated alternatives

7.3.1 Movable bridge

For the creation of this part, a consultancy meeting was set with ir. J. Smits from the Architectural faculty of TU Delft. The meeting took place on 12/05/2016 from 9:30 until 10:30. The team presented to the consultant, Mr. Jorid Smits a short overview of the area and issues to be addressed, and received valuable feedback that formed the basis for the evaluated design.

There are 6 types of draw bridges commonly applied in the Netherlands (Royal HaskoningDHV, 2016):

- Table bridge
- Draw bridge
- Tail bridge
- Bascule bridge
- Swing bridge
- Retractable bridge

Considering the situation and usage scenario in Scheveningen, constructing a draw bridge is recommended based on spatial, operational and architectural considerations. An example of a draw bridge in a similar setting can be seen in Figure 28.

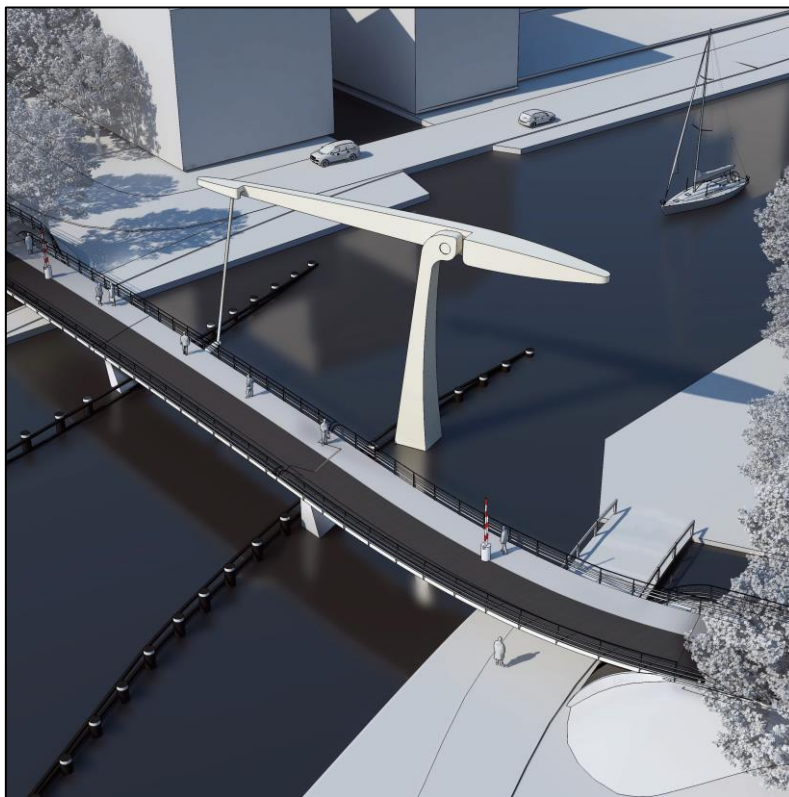


Figure 28: Katwijk Bridge project, courtesy of Royal Haskoning Dhv. A pedestrian and cyclist bridge with a fibre reinforced polymer (FRP) deck and 25 m span (Royal HaskoningDHV, 2016, pp. 34-36)

A more suitable location for the chosen structure type is proposed (Figure 29). This was done due to the following considerations:

- Reduced structure length (narrowest point chosen; avoiding tapered parts)
- Improved navigational conditions (wider turning radius at entrance to Second Harbour is kept; no obstruction of visibility)
- Spatial considerations

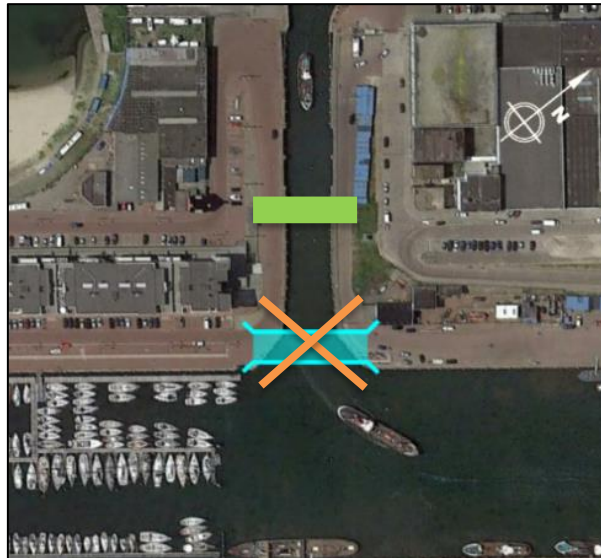


Figure 29: Proposed new connection point (green) and old connection point (cyan, crossed out)

In order to reduce the weight of the deck, the use of fibre reinforced polymer (FRP) is recommended. Steel should be used for all other weight-bearing elements, and the foundation will utilize piles. To avoid considerable downtime due to restricted access to the Second Harbour, the use of prefabricated elements is advised. The expected downtime during installation of the deck would be in the order of 1 to 2 weeks, according to the expert consultant.

A combined two way pedestrian and cyclist traffic is assumed. In order to keep the deck width and weight low, there will be no designated biking and pedestrian lanes, but those would be combined. Hence, a recommended rail-to-rail width of 5 m should be sufficient.

The cost for similar projects varies widely from case to case. Estimated cost, according to the consulting expert, will be in the range of 2 to 3 million euro. However, these figures are not exact and should be further studied, provided a movable bridge is the selected alternative.

The expected time of construction is roughly 6 months. Critically, restriction to the access to the Second Harbour is expected to taking no more than 2 weeks, as previously mentioned. Once again, more detailed project planning is required if the project is to be.

7.3.1.1 Operational scenarios and traffic analysis

An important constituent is to determine whether the aforementioned traffic dependence will cause considerable congestion for marine traffic going along De Pijp. Further, the bridge should go down frequently enough so that it does not cause inconvenience to pedestrians and cyclists. Through stochastic modelling, two scenarios were evaluated. This section elaborates on the results of that study, which can be found in Annex 14.

The study simulated worst case conditions that might be expected during the summer months, where, the harbour area is at its busiest. Thus, full correlation between peak on-land and marine traffic has been assumed.

The results indicate that, in the simulated conditions, it is reasonable to assume that a movable bridge will be able to operate according to a once-per-hour basis, that is, the bridge is lowered 10 minutes² every hour, and upright the next 50 minutes. This allows for on average 4.28 boats in the queue waiting 7 minutes 34 seconds. Thus, this is the operational scenario assumed in the multi-criteria evaluation.

It should be noted that this scenario provides adequate marine traffic conditions at the cost of land-based traffic. The waiting time of 50 minutes for pedestrians and cyclists was compared with the estimated time to go around without using the bridge across De Pijp. An average path was assumed, as seen in Figure 30.



Figure 30: Assumed average path for people wanting to go around rather than across De Pijp (1230 m)

² A full 10 minute cycle time includes a total of 2 minutes to lower/raise the bridge, and 8 minutes of usability

Depending on the average velocity, which for bicycles in a busy setting can be assumed to be 6 km/h, and for sightseeing groups of tourists around 2.5 km/h, times to go around vary around 12 and 30 minutes respectively (also see Table 15).

Table 15: Calculating the average time to go around rather than across De Pijp

Type of traffic	Distance	Average velocity	Time to go around
	km	km/h	minutes
Pedestrian	1.23	2 - 5	15 - 37
Cycling		4 - 10	7 - 18

It could be concluded that the provided usage scenario does not offer much convenience to pedestrians, and even less so to cyclists. With regard to the multi-criteria analysis, this has been taken into account and the movable bridge alternative has been marked down accordingly in the concerned fields.

7.3.2 Tunnel

Once again, ir. J. Smits provided valuable information regarding this alternative. Mr. Smits pointed out several disadvantages to this alternative that were taken into consideration during the multi-criteria analysis. Firstly, the tunnel is relatively deep compared to its length, which means that the access ramps will be of considerable length. Besides taking up valuable real-estate, this is an inconvenience for pedestrians and cyclists. Further, the security of the people crossing has to be additionally insured through e.g. cameras and/or frequent police patrols.

With regard to tourism, the dark and confined space of a tunnel is generally much less attractive than, for example, a movable bridge.

The construction timeline of such a structure will be considerable and involve relatively complex engineering solutions, such as ensuring a waterproof environment for construction through e.g. sheet-piling. Critically, access to the Second Harbour will be cut off during construction, which causes managerial and organizational issues and possible social backlash. Lastly, estimated construction costs would be roughly 10 times higher than constructing a movable bridge.

7.3.3 Taxi boat

As a third alternative, a water based transport (taxi boat) between the two points is considered. For the purpose of the multi-criteria analysis, only aspects regarding the connection between the two sides of De Pijp is considered. In reality, a longer route connecting more points within the Scheveningen Harbour could be applied, and should be evaluated, provided this alternative is chosen. Furthermore, it is assumed that the connection between the two sides of De Pijp will be free of charge, the boats will

provide space for cyclists and disabled people, and the time between journeys will be sufficiently short to justify use (less than 30 minutes).

The biggest drawback to this alternative is the continuous maintenance costs for servicing the fleet and keeping staff on-hand. However, this alternative enables seasonal application and could easily be changed to reflect current trends in demand.

7.4 Multi criteria analysis

In accordance with the project's secondary objective, to explore alternatives for providing a connection across De Pijp, a multi-criteria analysis has been done. As previously elaborated, this connection will be only for pedestrians and/or bicyclists, excluding any motorized vehicles (see Section 3.3). The preliminary analysis revealed three most feasible alternatives (see Section 7.2), which are further evaluated in this section by applying the JESEW³ model. In order to apply the model, firstly a definition of relevant indicators has been performed. Then, these factors are quantified, their importance evaluated by applying weight factors and grouped into multi-level tiers. Results of this analysis are presented further in this section.

7.4.1 Indicators

When choosing indicators, a multitude of factors have to be considered in order to ensure a comprehensive analysis of the individual alternatives. With regard to the connection across De Pijp, most important is finding a balance between land-based and marine traffic, ensuring optimal operation of both. Nevertheless, additional indicators covering e.g. construction time, social and touristic impact, are considered. In total, twelve primary indicators were identified, which were then grouped into consecutive tiers (see Figure 31). For the sake of consistency, weight factors were chosen on a qualitative basis since nearly all indicators are (nearly) impossible to measure quantitatively. Monetary values are not included within the multi-criteria analysis itself, but rather considered with regard to the results of the analysis.

7.4.1.1 Tier one

Two tier one indicators were selected.

- Effectiveness of the engineering solution.
- Sustainability of the alternative.

Effectiveness of the engineering solution is the competency of the proposed alternative from an engineering point of view, and represents the vertical axis in the final evaluation graph (see Figure 32).

Sustainability of the alternative measures the effects of the proposed solution, and thus sustainability of each alternative. Results are plotted on the horizontal axis (see Figure 32)

³ JESEW stands for Joint Ecological and Socio-economic Evaluation of Water resources development

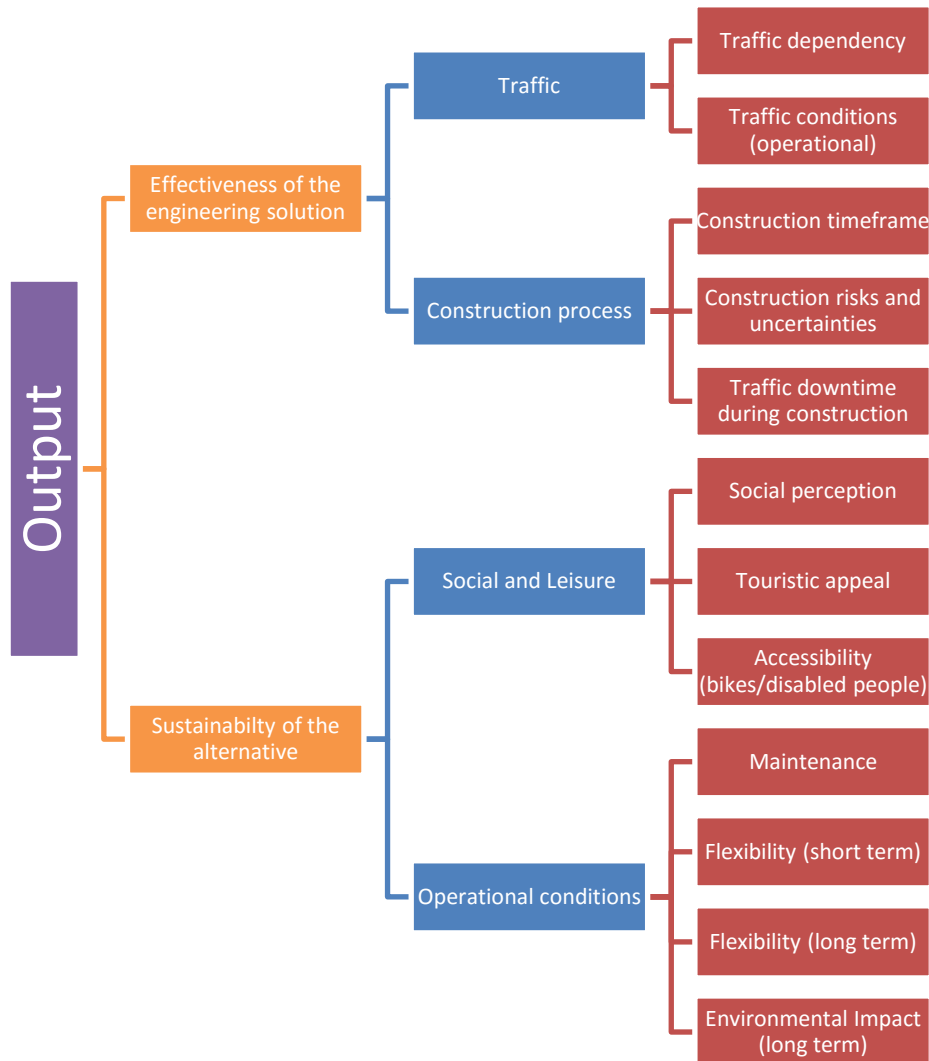


Figure 31: Hierarchy of indicators and tiers

7.4.1.2 Tier two

Each of the above tier one indicators includes two tier two groups.

Effectiveness of the engineering solution comprises:

- Traffic
- Construction process

Sustainability of the alternative comprises:

- Social and Leisure
- Operational conditions

Traffic conditions both on-land and in the harbour, and their interdependency, are grouped in this tier two indicator.

Construction process comprises relevant indicators with regard to the expected construction timeframe, complexity and resulting additional effects.

Social and Leisure groups indicators representing the societal outlook on the alternative and expected outcome for tourism.

Operational conditions regards short and long term aspects in hypothetically implementing each individual alternative.

7.4.1.3 Base indicators

An overview and description of all base indicators is presented in Table 16.

Table 16: Choice of base indicators

	Base indicators	Indicator represents
1	Traffic dependency	The interdependence of marine and on-land traffic along/across De Pijp
2	Traffic conditions (operational)	The quality of traffic conditions both along De Pijp and on land during use; expected probability and severity of congestion, if any
3	Social perception	The expected reaction of the public to the proposed solution; how (un)attractive society finds each alternative
4	Touristic appeal	A measure of architectural and/or recreational value; does a solution possess value as a touristic landmark or attraction
5	Accessibility (bikes/disabled people)	The accessibility that each solution provides, both for bikes and for disabled people; complicated or expensive solutions for providing accessibility are marked down
6	Construction timeframe	Length of construction process; expected schedule from start to finish
7	Construction risks and uncertainties	A measure of the complexity of each alternative; probability of unexpected complications, costs and delays
8	Traffic downtime during construction	Downtimes, traffic complications and congestion caused during construction
9	Maintenance	Maintenance frequency and cost; long term maintenance for engineering structures is considered but not marked down considerably; unforeseen complications excluded for all alternatives; frequent maintenance marked down; high maintenance frequency in the short term marked down

10	Flexibility (short term)	A measure of each alternative's adaptability to changing conditions and demand; daily and seasonal variations
11	Flexibility (long term)	A measure of each alternative's adaptability to changing conditions and demand; yearly and decadal variations
12	Environmental Impact (long term)	The long term environmental impact of each solution; a multitude of environmental constituents considered and clustered into one indicator

JESEW requires that each base indicator is assigned a value. A qualitative, rather than quantitative approach was chosen, applying abstract values to each indicator. It was found that this does not hinder the outcome of the model, as ranking of the considered alternatives remains the same (see Annex 13). This leads the team to believe that this approach presents an accurate enough overview of the characteristic qualities and effects each alternative for bridging De Pijp.

Nevertheless, such shortcomings should be taken into account, provided the project leaves the preliminary design phase. It is suggested that a more comprehensive and exhaustive research is conducted, and a more sophisticated model applied. Additionally, it is advisable to use up-to-date, accurate data acquired by research and/or on-site investigations considering diurnal, seasonal, and other variations in order to obtain a credible and realistic output.

A qualitative scoring system was applied, as seen in Table 17. Each alternative was evaluated within this scoring framework and assigned a corresponding value. Note that it is not a requirement to always have a best and worst alternative (i.e. a 0 and a 2 grade). It might be the case that e.g. all alternatives perform unsatisfactory with regard to a specific indicator, and therefore none will get a “good” score, and vice versa (see e.g. *Maintenance* indicator in Annex 13 Assigned grades and their justification).

Table 17: Scoring system

Interpretation	Bad/Worst	Average/Neutral	Good/Best
Assigned value	0	1	2

Assigning the “grades” in the scoring system varies for different constituents (also see Table 16 as it covers the considerations behind each constituent). For some (e.g. *construction time*, *traffic downtime during construction*) there is enough data to consider a qualitative value (e.g. obtained via consulting experts). Nevertheless, for continuity’s sake, this data has been converted to grades (see Table 18). Other indicators like e.g. *Social perception* and *Touristic appeal* are impossible to measure accurately, but rather easy to evaluate in a qualitative way.

Table 18: Example of conversion of actual values (weeks) to grades

Indicator	Value/grade	Range		Alternatives		
		Worst	Ideal	Bridge	Tunnel	Taxi boat
Construction timeframe	Actual value	72	2	26	72	2
	Assigned grade	0	2	1	0	2

A full list of assigned grades can be seen in Annex 13 Assigned grades and their justification.

7.4.2 Weight factors

JESEW offers the possibility to assign weight factors to indicators of all tiers. These weight factors are used to indicate the varying importance of constituents. A scale from 1 (least weight) to 5 (most weight) was chosen. Different weight factors were applied only to base level indicators, since it was concluded that all *tier one* and *tier two* indicators should be weighted equally.

Traffic conditions (operational) and *Touristic appeal* were given the highest weight factors since they are directly in line with the client’s goals. Other indicators that were considered important but not deciding constituents were given a lower value. A full list can be seen in Annex 13 Weight factors and their justification.

7.4.3 Result and conclusions

The model, set up as previously elaborated, yielded the results in Figure 32. The better an alternative is, the closer it will be to the top right corner (closer to values of 1.00 on both axes). The blue and red lines help distinguish between the ranking of alternatives.

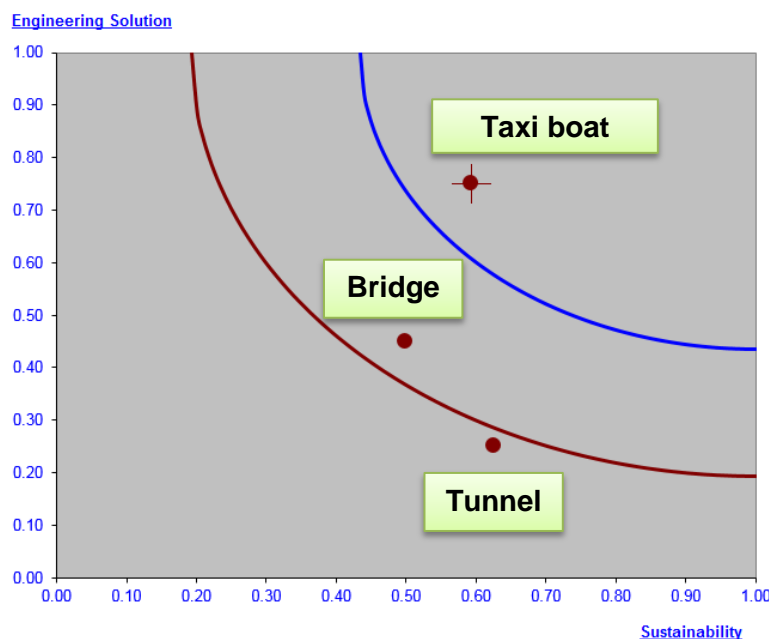


Figure 32: Results from multi-criteria analysis – bridging De Pijp. Ranking of alternatives

As can be seen, the multi-criteria analysis ranks *taxi boat* as the best alternative, and there is a considerable gap between it and the *bridge* and *tunnel* alternatives. This can be understood since the taxi boat is an appealing, yet very flexible solution. Both other alternatives include a sizeable impact on the Scheveningen area during construction, but also are simply not as flexible in keeping up with changes in demand, amongst other shortcomings.

One should note that additional considerations might not have been taken into account, such as e.g. personal preferences of the client, technological developments and improving construction techniques, changing boundary conditions etc. That being said, the output of the multi-criteria analysis gives a concise overview of the current conditions, and as such is considered sufficiently comprehensive for the task at hand. Hence, the *taxi boat* alternative will be further developed in the report.

8. Bridging De Pijp – Solution

Due to the waterbody of Scheveningen Harbour, direct paths between certain locations are cut off. A taxi boat service is proposed to improve the mobility of the visitors arriving at Scheveningen Harbour. The primary objective of this chapter is to find which points within Scheveningen Harbour have to be connected by a shuttle service. Several factors has to be considered in selecting the boat routes. One of the important factors is identifying at which locations the demand to cross the harbour is most prominent. A secondary aspect to be considered is the applicability of the route and the boat stands within the harbour.

The demand for connection between points can be analyzed under two main sections.

- Demand generated within the surrounding of the harbour
- Demand generated from external traffic arriving at the harbour

Demand generated within the surrounding of the harbour

The harbour waterbody divides the Scheveningen area into North and South regions. Usage of the two regions are different, thus attracting dissimilar masses of visitors. The Figure 33 shows the important public places that are of interest for the visitors to the area.



Figure 33: Locations of interest for visitors

As it can be observed most of the activities occur towards the northern side of the harbour area. The northern beach (Scheveningen beach) is one of the most visited beach stretches in the Netherlands and thus contain a many restaurants, leisure activities to cater for the people. The south side of the harbour

is relatively quieter, containing dune areas which are included in the Natura 2000. The dune area is used as a popular hiking and a bike trail. The southern beach side is also home to an annual pop music festival (Scholtenpop) which attracts many music fans.

It can be concluded that most of the activities are delimited towards the sea side border of the harbour. As there will be many visitors in this area there is a high possibility that the people may want to cross between the southern and northern ends.

Demand generated from external traffic arriving at the harbour

The traffic arriving at Scheveningen Harbour area is from the three main modes of, public transport, private transport (cars) and by foot from which the first two are the most prominent. The main public transport methods are the bus and the tram.

The influx locations of visitors to the Scheveningen area through public transport can be assessed by the bus and tram halts near to the harbour area. The entry points of private transport passengers can be assessed by the car parks around the area.

Three tram routes and a bus route serving the vicinity of the Scheveningen Harbour can be found. The Figure 34 shows the stops of these transport routes.



Figure 34: Public transportation links

The Car parks around Scheveningen is shown in Figure 35. There are three car lots dedicated for parking as shown. The highlighted roads are also frequently used as street parking lots.



Figure 35: Car parking locations

It can be observed that almost all the public transport access points are restricted towards the eastern land boundary of the harbour. The car parks are more spread through the area with a marginally higher density towards the northern end of the harbour.

It can be thus assumed that a higher number of the visitors arriving at the harbour will enter through the eastern and northern boundary. Furthermore, from analysis of the activities around Scheveningen, it is prudent to assume that most of the visitors may want to travel towards the seaside boundary of the port as many of the activities happen in this area.

Future developments

To provide a sustainable solution, the future scenarios should also be taken into account. The Hague Municipality has proposed an urban plan for the harbour of Scheveningen and zones are demarcated for the proposed types of constructions and developments that are to be carried out. The urban plan can be used to estimate the future growth of the area.

An apartment building complex is proposed in the southern end of the port where the Norfolk line used to operate. On the southern end towards the sea side, it is dedicated to social spaces and a hotel building which is to be constructed as a landmark building.

On the north side, another hotel is proposed towards the entrance of the port. The fisheries and the beach sports are bolstered even further by constructing new infrastructure in the respective areas.

Figure 36 is generated by overlaying all the above-mentioned elements of activities, traffic, and future developments.



Figure 36: Overlay of transportation demands

Based on the above analysis, the following inferences are drawn:

- Many of the activities and attractions for visitors in the Scheveningen Harbour area occurs on the sea boarder of the port. The proposed future developments of the urban plan further bolster this assertion. Thus considerable traffic demand is generated between the either sides of the breakwater of the harbour.
- Public transport gateways for the visitors are predominantly limited to the eastern land boundary of the harbour. Traffic demand is generated between public the transport portals on the eastern side of the port to the more populous area of the harbour in the eastern end.
- Private parking areas are more dispersed. As the eastern end of the harbour is identified as the probable destination for many of the visitors, demand for mobility from people using private transport will arise from the furthest parking areas to the eastern end of the port. The furthest parking areas are situated towards the eastern and north-eastern borders of the port.
- Furthermore for better connectivity throughout the harbour area, the two sides of De Pijp is also to be connected using a taxi boat.

Taking the above findings into consideration, a taxi boat route between the Second Harbour (eastern land boundary of the port)(S1) and south beach (S2) side of the Scheveningen Harbour can be proposed. The route contains three intermediate stopping points. From the previous analysis of the traffic demand and request from the client the intermediate stopping points to be used are:

- Northern bank of De Pijp in the second harbour side (S3).
- Southern bank of De Pijp in the second harbour side (S4).
- Northern side of the harbour entrance (S5).

The proposed route is given in Figure 37.

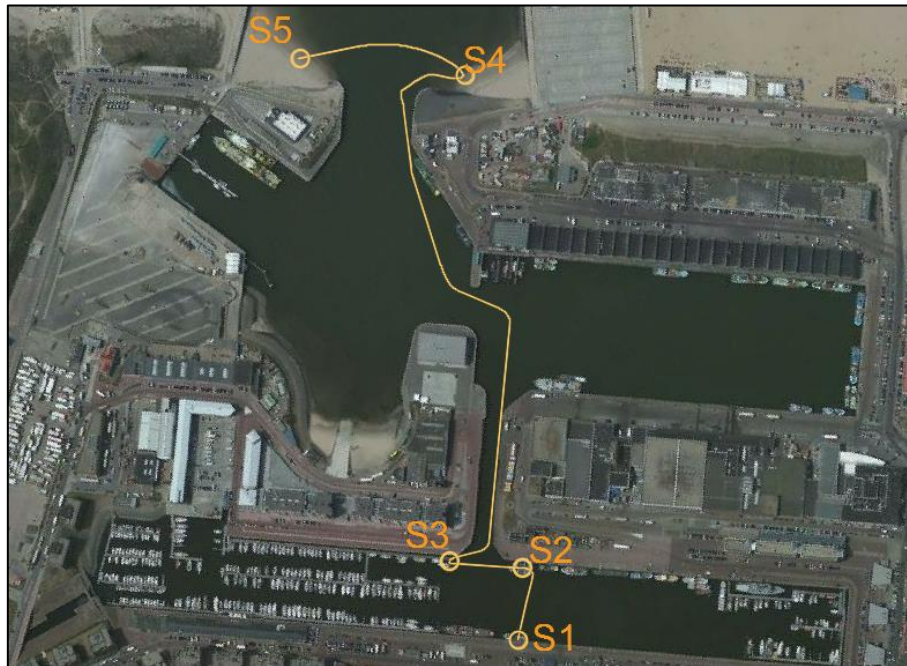


Figure 37: Propose taxi boat routes

The proposed boat route is about 800 m long. The taxi boat should be able to keep an average velocity of (including stopping time at the intermediary halts) 1.2m/s. Thus, the total journey in one direction will take approximately 11 mins. Adjusting for traffic and unforeseeable circumstances the travel time can be taken as 15mins.

The number of visitors to the Scheveningen area varies throughout the year with a maximum number of visitors expected during summer. The need for the taxi boat will also vary accordingly.

To minimize the maintenance and running costs of the service two levels of service depending on the demand can be proposed.

During summer, when the higher demand can be expected, a higher level of service can be provided. This can be archived using two taxi boats running on opposite directions. Thus the boat service will be available every 15mins from a given stop.

When the number of visitors are low, the service can be reduced to one boat. During this period, the service frequency will be 30 min for a given stop.

It can be proposed special schedules with a higher frequency of taxi boats on specific days such as when festivals are held in the Scheveningen Beach.

In Annex 6 it is presented a plant of the taxi boat in the Second Harbour.

9. Integration

In the pursuit of The Hague Municipality vision to become a global city by the sea, Scheveningen Harbour plays an integral part. The development of the port and the surrounding area is thus essential. The application of the harbour project will transcend Scheveningen port to the next level. As for the identified demand opportunities, addition of the new marina and the rearranging of the harbour will help put Scheveningen on the map as an important maritime destination.

Providing solutions to the mobility issue for the visitors to the port will make the Scheveningen port a well visited location, reaping the maximum benefits of neighboring one of the most popular beaches in the Netherlands. Thus, by the application of the solutions both the maritime and tourist sectors will complement each other resulting in a steady growth of economy and reputation of Scheveningen Harbour.

Following section provides examples of incorporation between the solutions provided for a single issue and the holistic answer within the harbour project.

9.1 Incorporation of the solutions provided

The issues identified were categorized under two primary headings. Namely, the harbour optimization and the connection over De Pijp. Even though the solutions provided for the identified problems are discussed separately, great care was taken to integrate the applications to provide a coherent solutions for the harbour in a larger perspective.

The following points can be used to illustrate the integration of the solutions provided.

- Increasing mobility of visitors – Marine traffic condition

Scheveningen Harbour is facing an issue with reduced mobility of visitors to the area. To solve this problem initial plans proposed a movable bridge. Even though this solution would satisfy the mobility issue, analysis showed that the marine traffic across De Pijp will be adversely affected due to such an application. Thus a different solution (taxi boat service) is proposed to solve the issue effectively.

- Mobility of visitors – locations of interests

In order to solve the mobility issue of visitors to Scheveningen and to provide an optimal solution, a study of the possible destination and entry points of the visitors were performed. Through the study, integration between the locations of interests and transport links was possible.

- Increase in harbour capacity – rearrangement of the harbour

The Scheveningen Harbour operates at near capacity for certain vessels and increase of harbour capacity is needed. The increase is accommodated through new construction (Fourth Harbour) and by rearranging the harbour. The harbour rearrangement was not solely performed with the intension of

increasing the harbour capacity but taking other factors into consideration. Factors like marine traffic condition, standard code of practices and perception of the businesses and public of the moored vessels nearby were considered.

- Wave reflection of the internal breakwater – Impact on the vessels entering the harbour

In order to provide the needed wave environment within the new marina in the Fourth Harbour, a vertical caisson breakwater is to be constructed. The wave reflection due to the breakwater was considered to be an important factor in the selection of the breakwater. The reflection of the breakwater was kept to a minimum to reduce the impact on vessels entering the port.

- Future developments – current solutions

The solutions provided by the project was designed with the possible future developments in mind, where the current applications will not hinder the future plans. The rearranging of the harbour and the new marina was planned such that vessels of fishing and industrial origin will be based in the industrial section freeing space for recreational boats near the planned zone for apartment buildings. Moreover during the selection of the taxi boat route, future developments of the area was also taken into consideration.

Through proper integration it is able to provide a sustainable solution to Scheveningen Harbour in a holistic frame work.

9.2 Cost estimation and construction planning

It was carried out a cost estimation for the implementation of the measures included in this project for the Scheveningen Harbour. This cost estimate is shown in Table 19, divided in the following project elements.

- The breakwater for the establishment of the new marina in the Fourth Harbour
- All the marina development on the Second and Fourth harbours
- Taxi boat connection across De Pijp.

It is then estimated that the final cost to be considered for the tendering process carried out by the municipality if of around 9.2 Million Euros.

Furthermore, it is indicated in Figure 38 the construction timeline for the project, which aims to allow the correct execution of the different elements with the least vulnerability to meteorological constraints and minimum affection to the harbour uses.

As shown in Figure 38, the implementation is expect to last for 25 months, divided as follows:

- Phase 1 – 11 months: Breakwater and Fourth Harbour
- No activity during summer season

- Phase 2 – 8 months: Second Harbour and taxi boat

As boundaries conditions for the establishment of the construction plan, it was considered among others:

- Construction of the breakwater during the summer months, due to milder weather conditions. Furthermore, the use of the area of the former Norfolk terminal will minimize the affection to other activities and users during construction.
- The construction of the Fourth Harbour should precede the redevelopment of the Second Harbour, in order to provide enough capacity for temporarily reallocation of vessels.
- During summer, the least construction should take place in order to avoid higher affection to local and seasonal users.
- The construction of the Second Harbour will take place during winter due to the previously mentioned reduced affection to users and the limited interference due to adverse sea action.

The integration of the project for the Scheveningen Harbour and bridging De Pijp is shown in Annex 1. Further details about the project are presented in Annexes 2 to 6. A summary of the drawings presented in the annexes are:

- Annex 1 – Layout of the conceptual solution
- Annex 2 – Layout of Scheveningen Fourth Harbour
- Annex 3 – Layout of Scheveningen Second Harbour
- Annex 4 – Caisson breakwater – Plan view
- Annex 5 – Typical cross-section of new breakwater
- Annex 6 – Taxi-boat layout

Table 19: Cost estimation

Cost Estimation					
Element	Sub-element	Unit	Cost/Unit	Measurement	Total Cost
Breakwater					
Caisson	Concrete + filling	m ³	€ 90.00	7605.00	€ 684,450.00
Quarry stone	300 - 1000 kg	m ³	€ 30.00	2660.00	€ 79,800.00
Faccine mattress	Geotextile + structure + filling	m ²	€ 10.00	2743.00	€ 27,430.00
TOTAL Breakwater					€ 791,680.00
Marina					
Floating pontoon 2nd Harbour	1.5 m width	m ²	€ 450.00	166.05	€ 74,722.50
	2.0 m width	m ²	€ 450.00	570.00	€ 256,500.00
	2.5 m width	m ²	€ 450.00	3178.23	€ 1,430,201.25
	3.5 m width	m ²	€ 450.00	587.30	€ 264,285.00
Floating pontoon 4th Harbour	1.5 m width	m ²	€ 450.00	138.15	€ 62,167.50
	2.0 m width	m ²	€ 450.00	54.40	€ 24,480.00
	2.5 m width	m ²	€ 450.00	1004.50	€ 452,025.00
Fixing poles	Per 25 m length pontoon	-	€ 300.00	95	€ 28,500.00
Fingers	Class I	-	€ 541.13	67	€ 36,255.38
	Class II	-	€ 721.50	44	€ 31,746.00
	Class III	-	€ 1,462.50	35	€ 51,187.50
	Class IV	-	€ 1,755.00	76	€ 133,380.00
	Class V	-	€ 3,307.50	37	€ 122,377.50
	Class VI	-	€ 6,750.00	19	€ 128,250.00
	Class VII	-	€ 14,062.50	4	€ 56,250.00
Access ramp	6 x 2.5 m	-	€ 3,600.00	1	€ 3,600.00
	11 x 2.5 m	-	€ 6,600.00	1	€ 6,600.00
	14 x 2.5 m	-	€ 8,400.00	7	€ 58,800.00
	15 x 2.5 m	-	€ 9,000.00	1	€ 9,000.00
	35 x 3.5 m	-	€ 29,400.00	1	€ 29,400.00
Supply posts (Water/Electricity)	Class I-V	-	€ 500.00	259	€ 129,500.00
	Class VI-VII	-	€ 750.00	23	€ 17,250.00
Navigational aids	2nd and 4th harbours	-	€ 8,000.00	2	€ 16,000.00
Dredging	Dredging 4th Harbour	m ³	€ 8.00	2750	€ 22,000.00
Quay	Adaptation 2nd Harbour	m	€ 2,500.00	184	€ 460,000.00
	Adaptation 4th Harbour	m	€ 2,500.00	24.5	€ 61,250.00
	New quay 4th Harbour	m	€ 1,000.00	177.75	€ 177,750.00
Ramp	Concrete pavement (0.5 m)	m ³	€ 50.00	222.5	€ 11,125.00
	Pavement base (0.75 m)	m ³	€ 20.00	333.75	€ 6,675.00
	Base material (1.5 m)	m ³	€ 5.00	667.5	€ 3,337.50
Pavement 4th Harbour	Concrete blocks pavement	m ²	€ 15.00	2500	€ 37,500.00
	Pavement base (0.75 m)	m ³	€ 20.00	1875	€ 37,500.00
TOTAL Marina	-	-	-	-	€ 4,239,615.13
Taxi-boat					
Floating platforms	5 x 20 m	m ²	€ 450.00	200.00	€ 90,000.00
Fixing poles	4 per platform	-	€ 300.00	8	€ 2,400.00
Vessels	50 people capacity	-	€ 50,000.00	2	€ 100,000.00
Access ramp	20 x 3.5	-	€ 16,800.00	2	€ 33,600.00
Quay	Adaptation	m	€ 2,500.00	67.00	€ 167,500.00
TOTAL Marina	-	-	-	-	€ 393,500.00
Total cost estimation	-	-	-	-	€ 5,424,795.13
Unforeseen expenses (15%)	-	-	-	-	€ 813,719.27
Construction costs					€ 6,238,514.39
Detailed design (3%)					€ 187,155.43
General expenses (13%)	-	-	-	-	€ 811,006.87
Benefit (6%)	-	-	-	-	€ 374,310.86
Costs before taxes	-	-	-	-	€ 7,610,987.56
VAT (21%)	-	-	-	-	€ 1,598,307.39
Tender price	-	-	-	-	€ 9,209,294.95

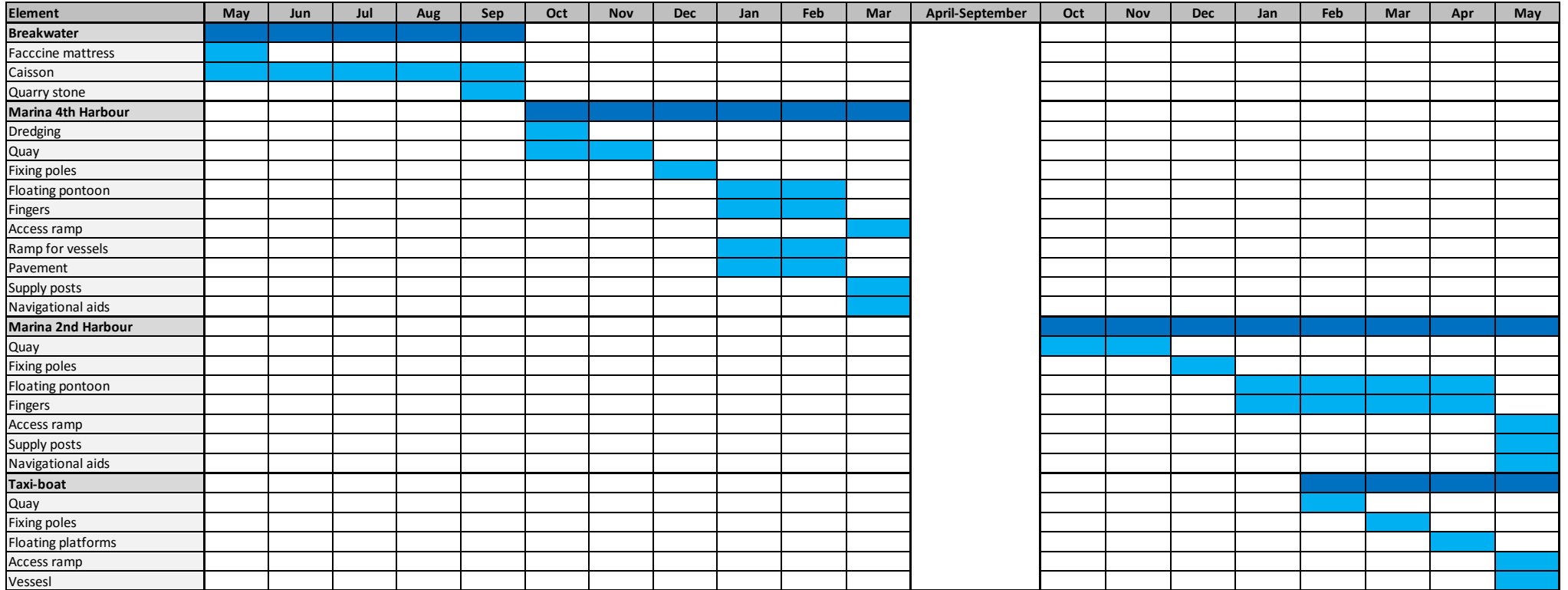


Figure 38: Construction timeline

10. Conclusion

The present report shows a conceptual design for the new Scheveningen, which give a global view for the development of the Scheveningen Harbour. In application of the proposed solutions the port will have a clear demarcation between the different activities (commercial fishing and leisure). Moreover, both quality and capacity of the port especially for recreational uses have been increased.

The new Scheveningen Harbour will also have better connectivity within the different areas improving the mobility of the visitors which leads to a better traffic strategy within and outside of the harbour.

The applied solutions were kept within the frame work of the urban master plan of the Scheveningen and due attention was directed to the current requirements of the different stake holders and their interests.

The project team believes that the application of solutions provided within this report will generate a positive economic growth. This will ensure long term sustainability of Scheveningen Harbour becoming a key pillar of success of The Hague vision of becoming a global city by the sea.

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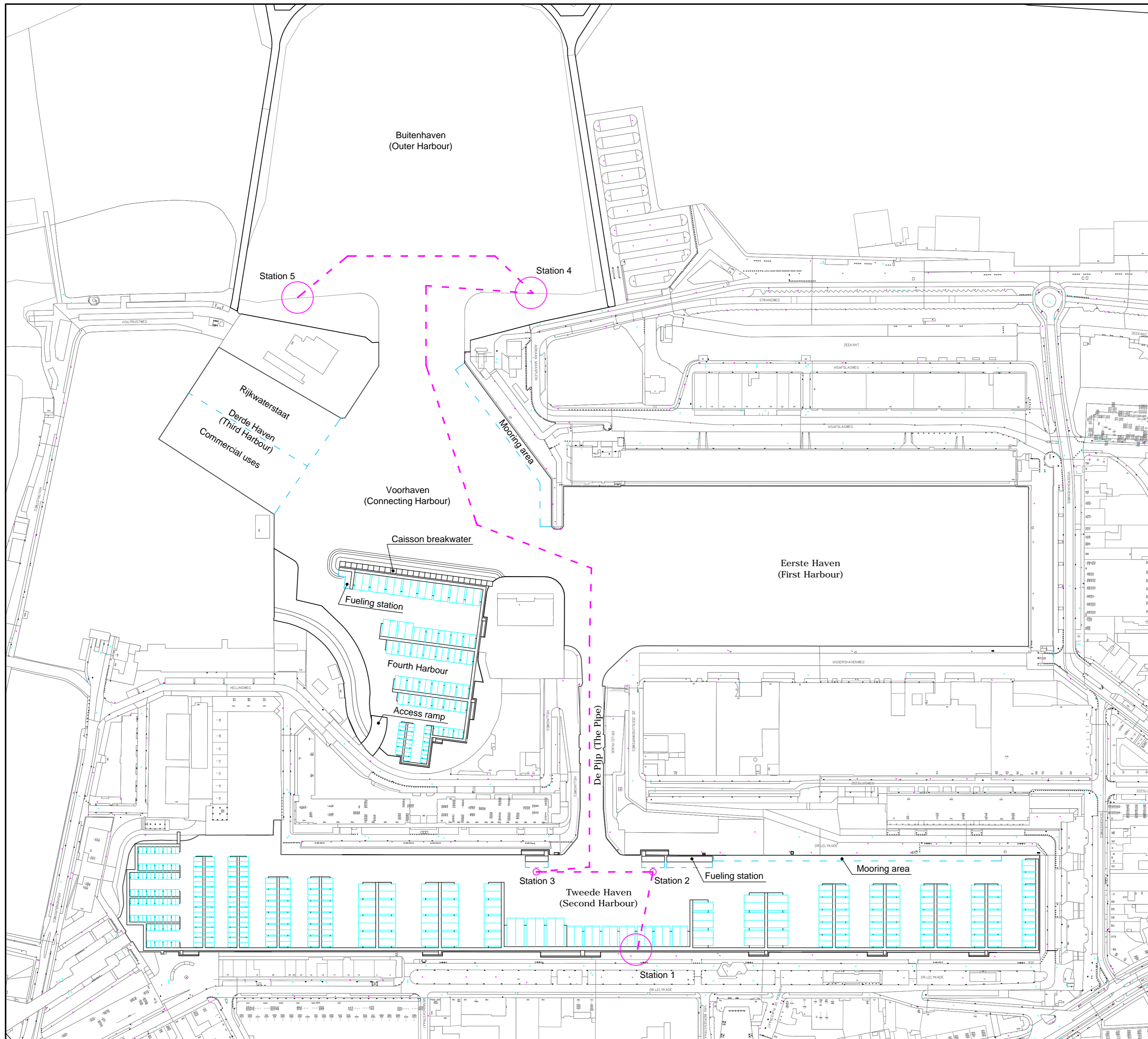
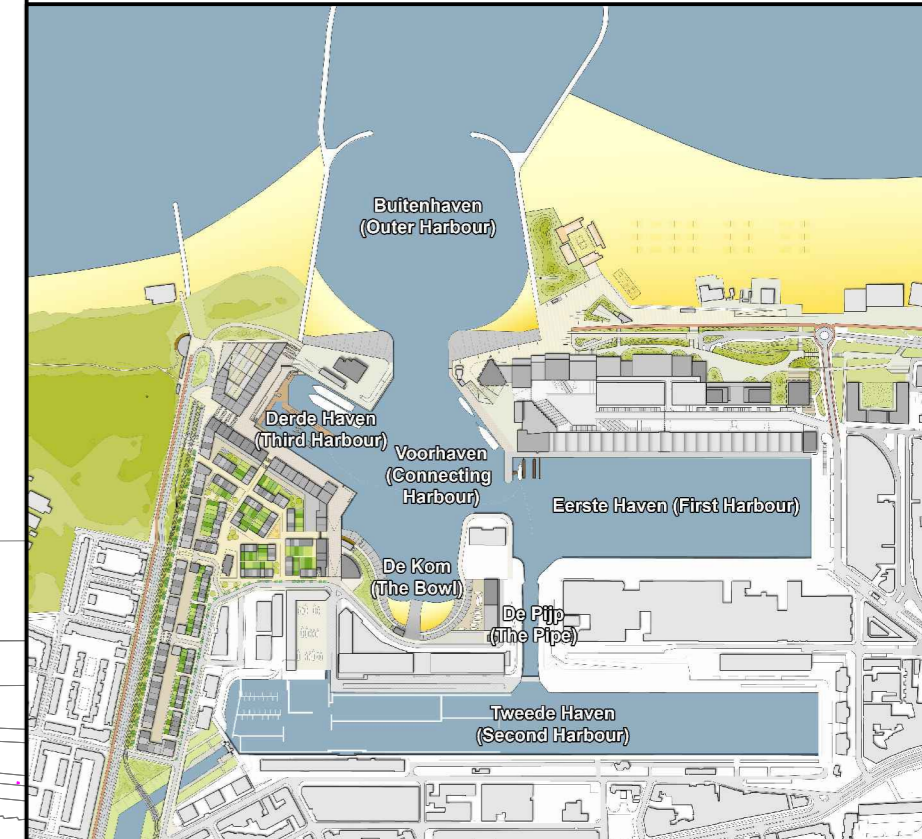
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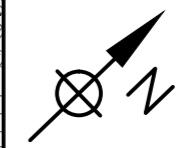
Annex 1 – Layout of the conceptual solution

See next page.

Scheveningen Harbour
Current Layout



Notes:
 1. All levels are according to the Dutch Level (NAP)
 2. Stations 1, 4 and 5 are optional and could be further optimized. Some additional changes in the harbour layout may be necessary.



100 m

Key	
	Taxi boat path
	Mooring area
	Individual mooring area (marina)
	Taxi boat station



Course:
Multidisciplinary Project

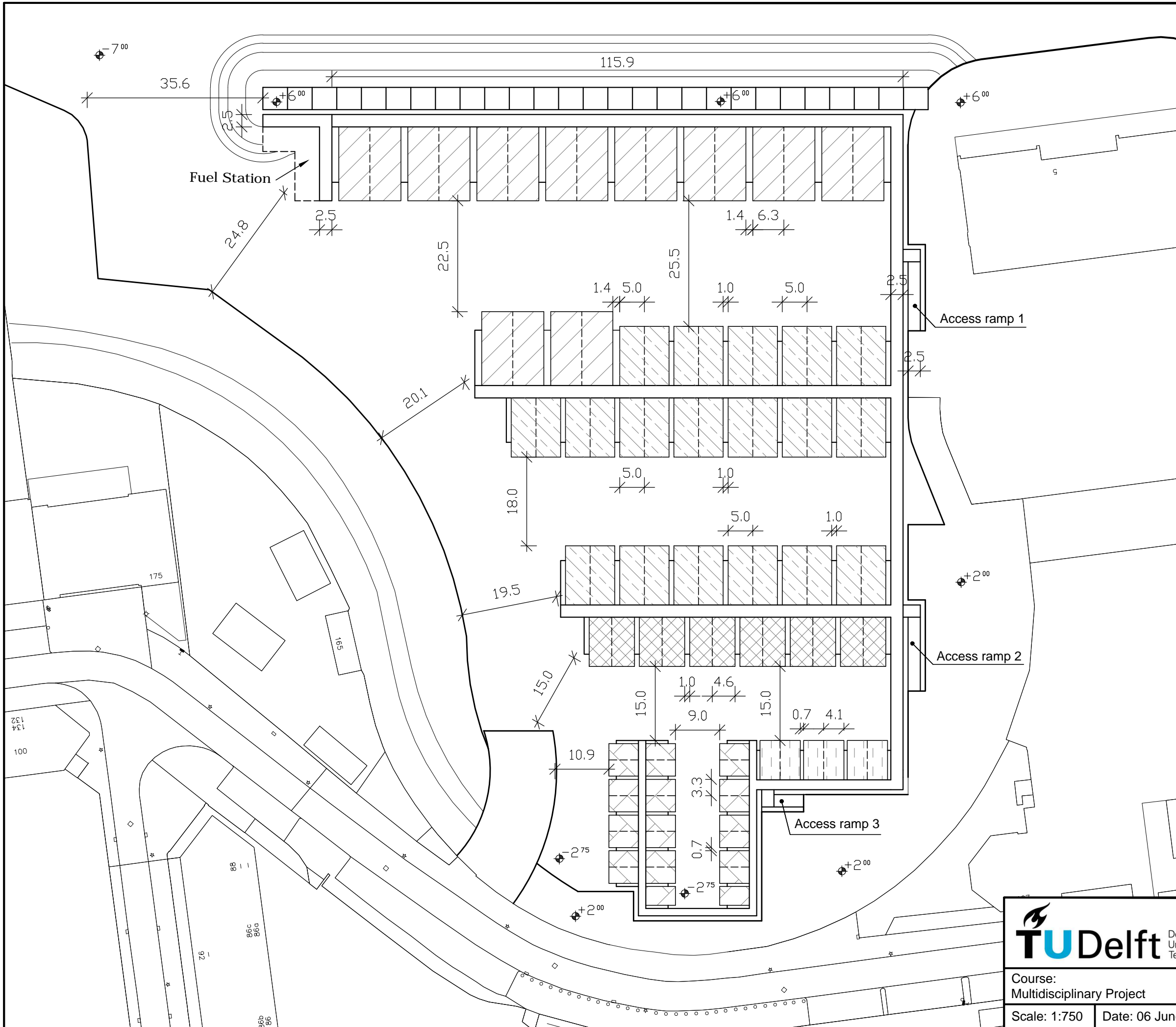
Scale: 1:2250 | Date: 06 June 2016

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 Ermano de Almeida
 Hithaishi Hewageegana
 Krasimir Marinov
 Renan da Silva
 Xabier Arrieta

Scheveningen Harbour Layout






Annex 2 – Layout of Scheveningen Fourth Harbour

See next page.




Vessels			
Class	Length	Width	Draft
I	6	2.3	1.5
II	8	3.1	1.8
III	10	3.6	2.0
IV	12	4.0	2.1
V	15	5.3	2.4
VI	18	5.7	2.7
VII	25	6.0	3.6

Boat Classes Key

-  Class 5
-  Class 4
-  Class 3
-  Class 2
-  Class 1

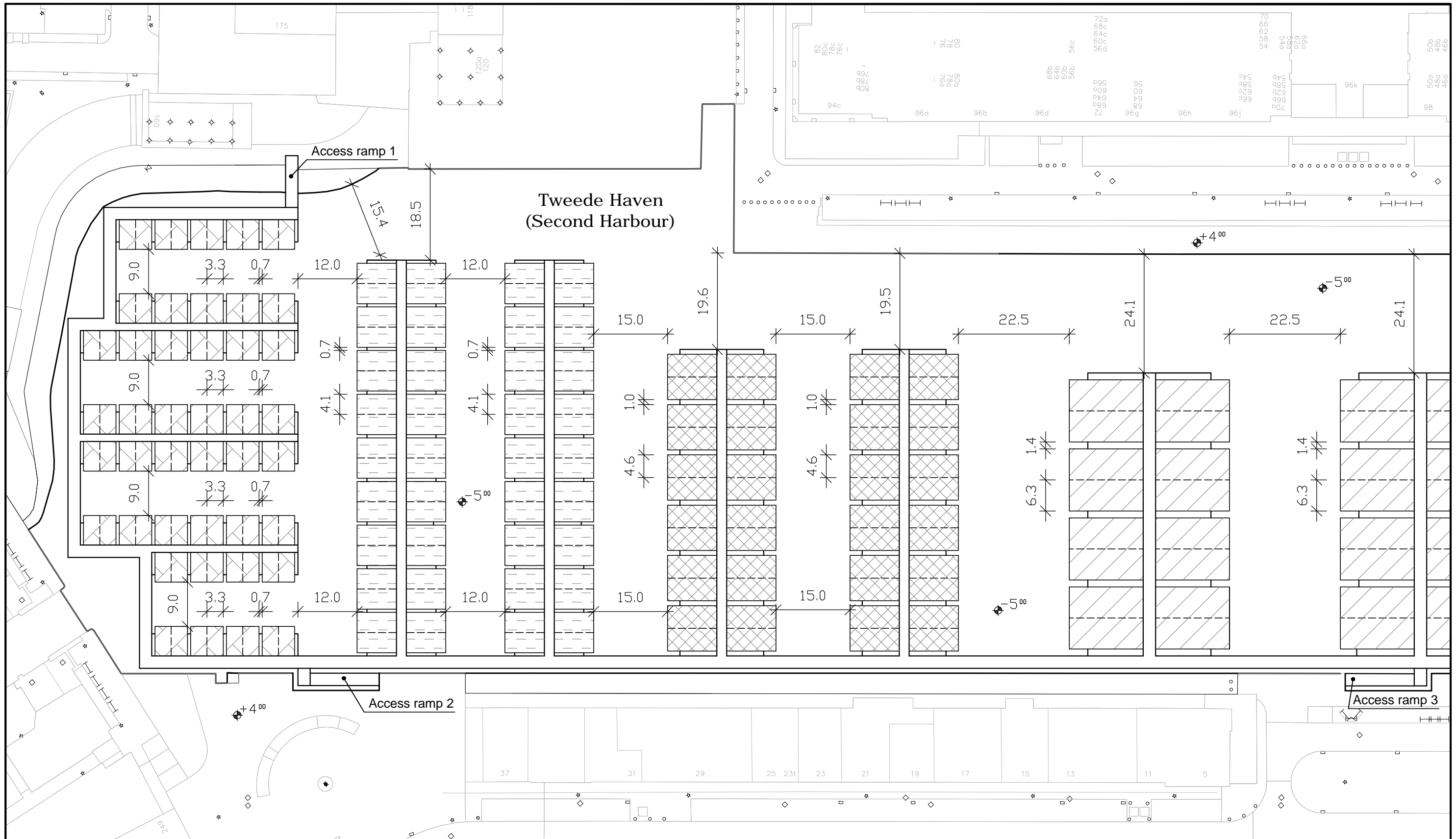
Notes:

- All levels are according to the Dutch Level (NAP) and dimensions in metres.
- The Fourth Harbour is located within the former De Kom.
- On-water pontoons are +0.5 m above the current water level.
- Slope of ramps:
 - Access ramp 1, 3: slope 1/4 -
 - Access ramp 2: slope 1/10 (access for disabled people)

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	Course: Multidisciplinary Project	Scale: 1:750
Date: 06 June 2016		Fourth Harbour; Marina Layout

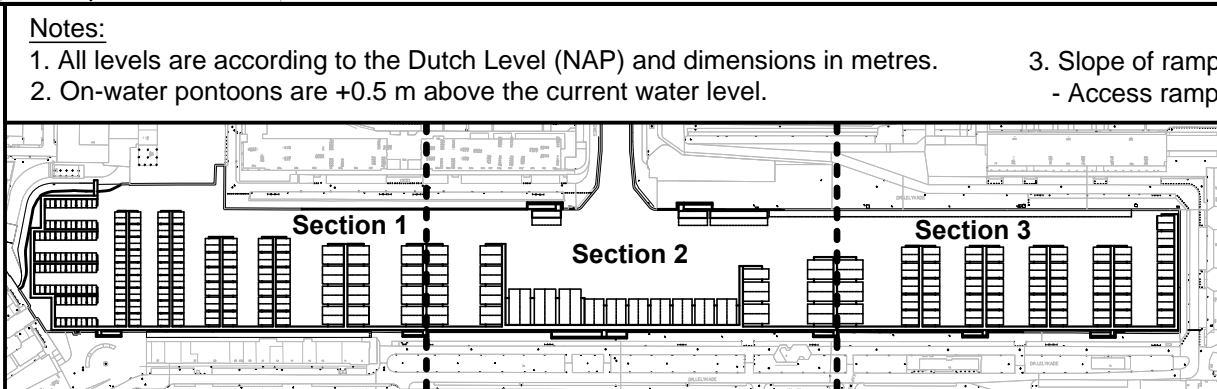
Annex 3 – Layout of Scheveningen Second Harbour

See next 3 pages.



Vessels			
Class	Length	Width	Draft
I	6	2.3	1.5
II	8	3.1	1.8
III	10	3.6	2.0
IV	12	4.0	2.1
V	15	5.3	2.4
VI	18	5.7	2.7
VII	25	6.0	3.6

Boat Classes Key	
	Class 7
	Class 6
	Class 5
	Class 4
	Class 3
	Class 2
	Class 1



TU Delft Delft University of Technology

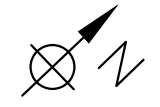
Course:
Multidisciplinary Project

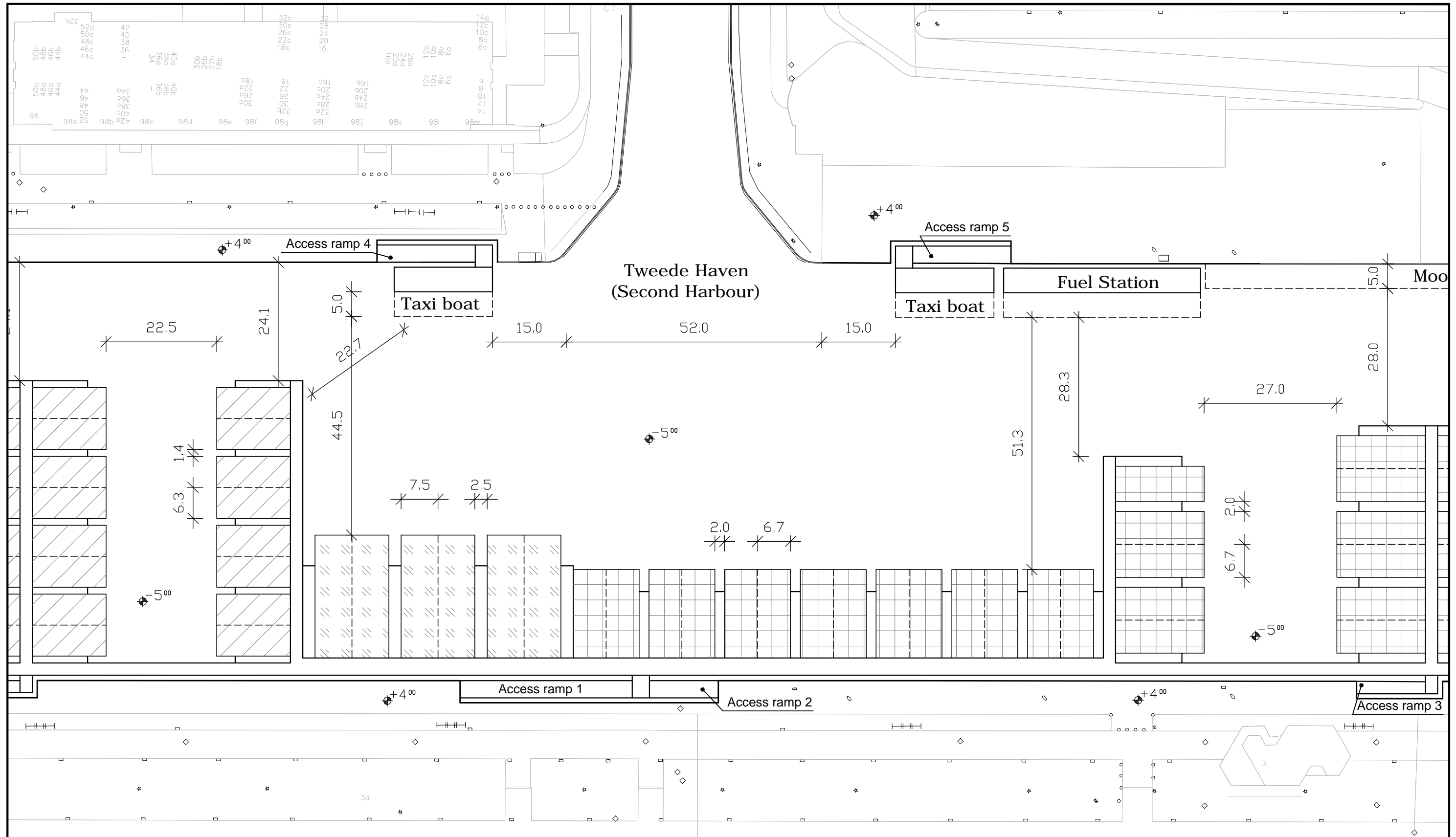
Scale: 1:750 | Date: 06 June 2016

Scheveningen Harbour Project

Ermano de Almeida
Hithaishi Hewageegana
Krasimir Marinov
Renan da Silva
Xabier Arrieta

Second Harbour; Marina Layout S.1

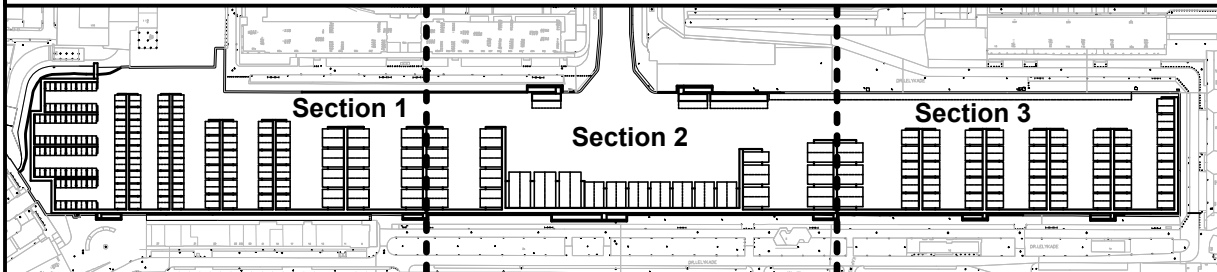





Vessels			
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II	8	3.1	1.8
III	10	3.6	2.0
IV	12	4.0	2.1
V	15	5.3	2.4
VI	18	5.7	2.7
VII	25	6.0	3.6

Boat Classes Key	
	Class 7
	Class 6
	Class 5
	Class 4
	Class 3
	Class 2
	Class 1

Notes:
 1. All levels are according to the Dutch Level (NAP) and dimensions in metres.
 2. On-water pontoons are +0.5 m above the current water level.
 3. Slope of ramps:
 - Access ramp 2, 3: slope 1/4
 - Access ramp 1, 4, 5: slope 1/10





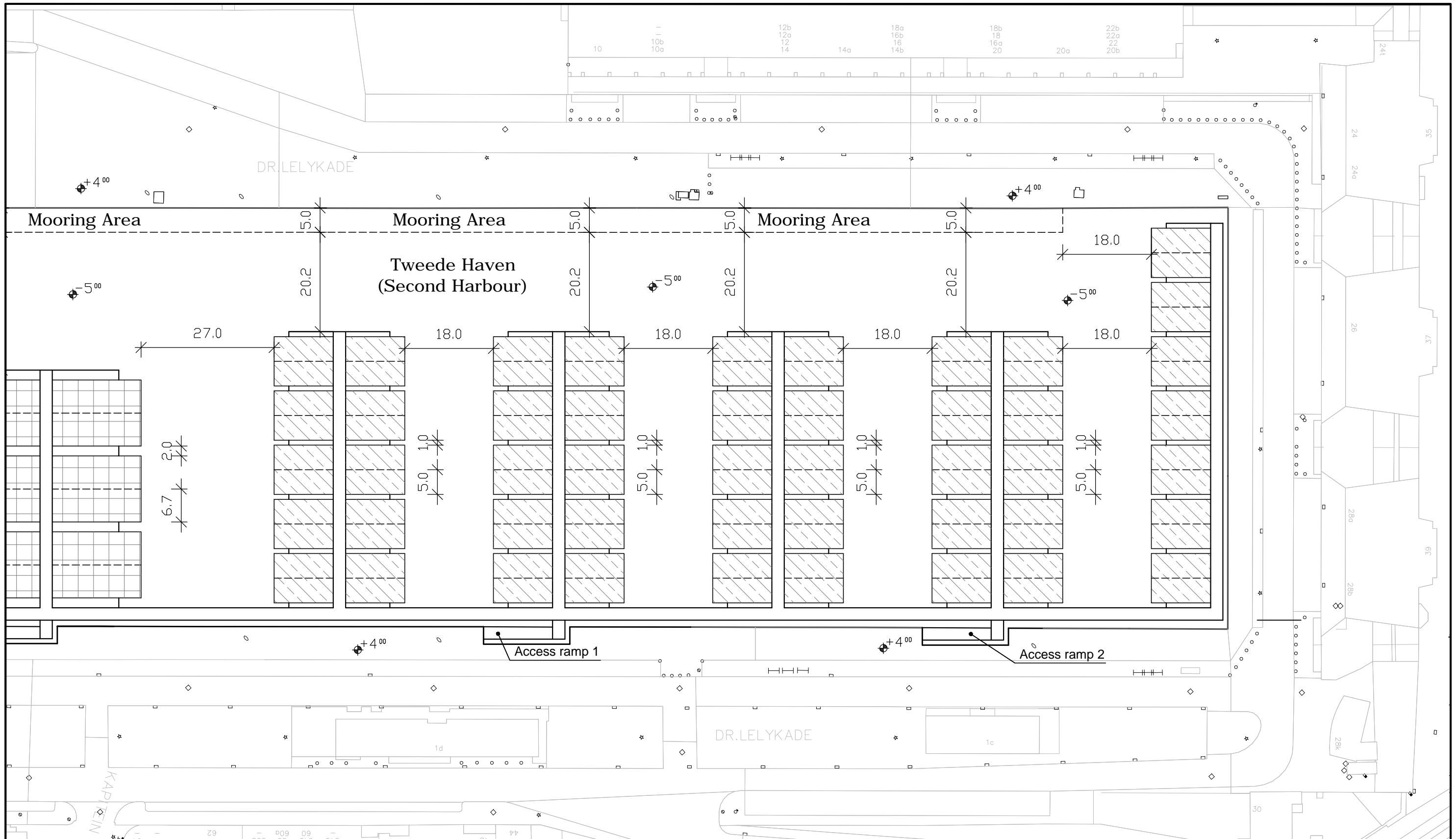
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 Hithaishi Hewageegana
 Krasimir Marinov
 Renan da Silva
 Xabier Arrieta

Course:
Multidisciplinary Project

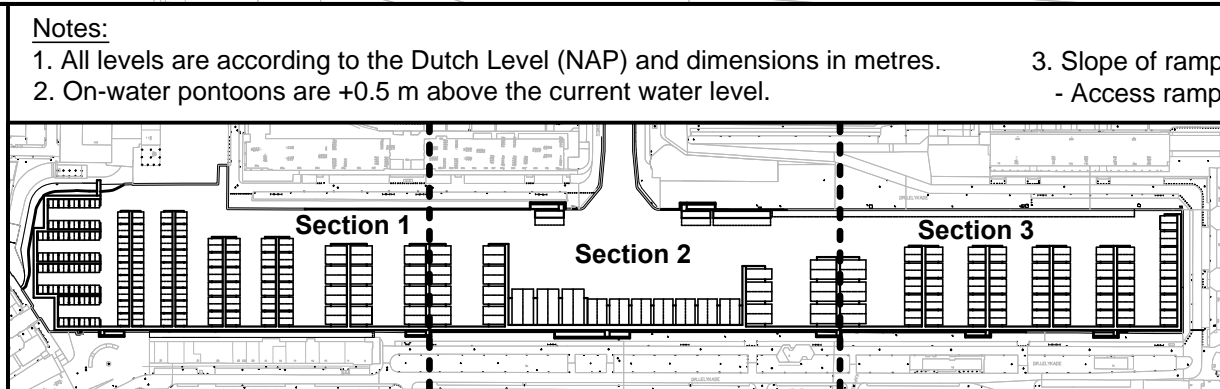
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Second Harbour; Marina Layout S.2



Vessels			
Class	Length	Width	Draft
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II	8	3.1	1.8
III	10	3.6	2.0
IV	12	4.0	2.1
V	15	5.3	2.4
VI	18	5.7	2.7
VII	25	6.0	3.6

Boat Classes Key	
	Class 7
	Class 6
	Class 5
	Class 4
	Class 3
	Class 2
	Class 1



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Course: Multidisciplinary Project

Scale: 1:750 | Date: 06 June 2016

Scheveningen Harbour Project

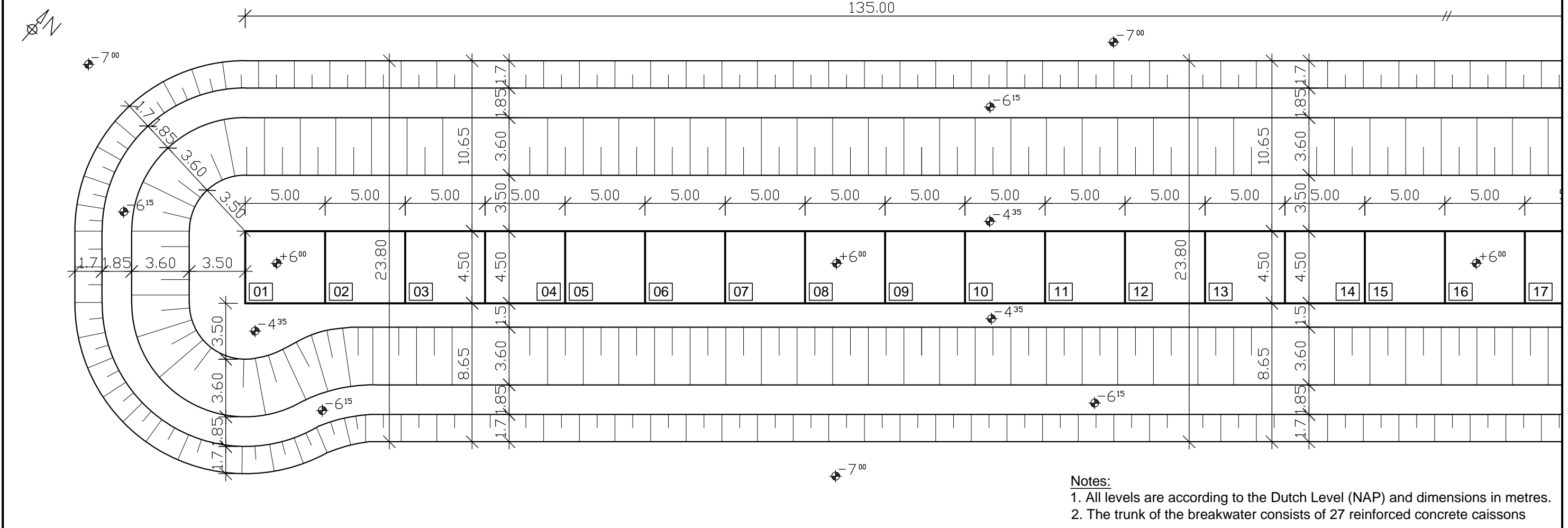
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Second Harbour; Marina Layout S.3

Annex 4 – Caisson breakwater – Plan view

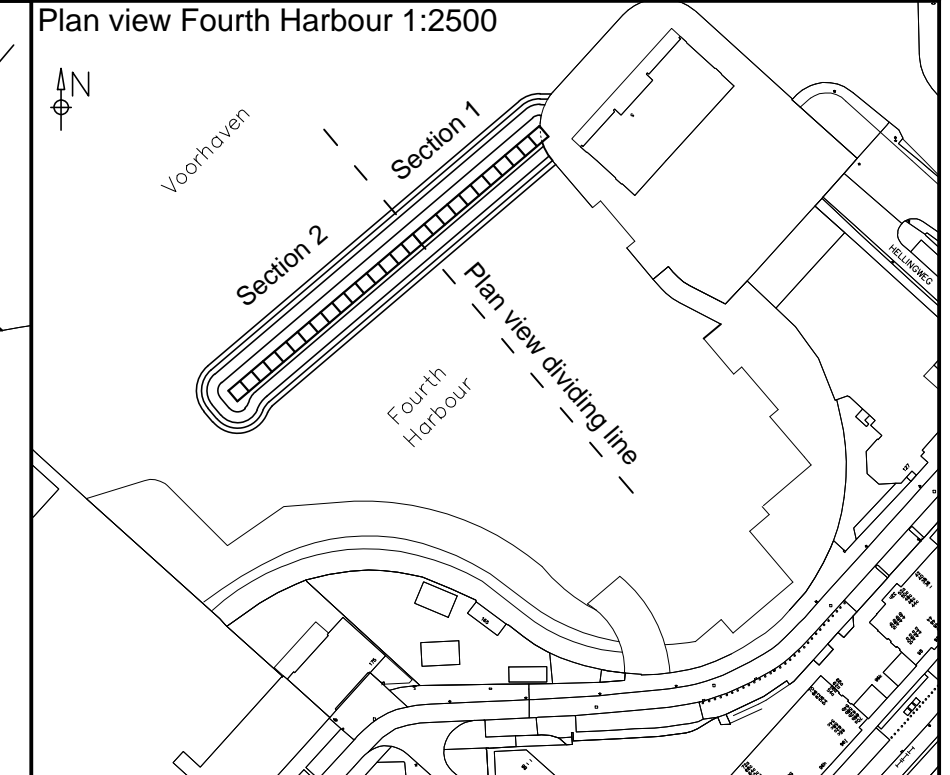
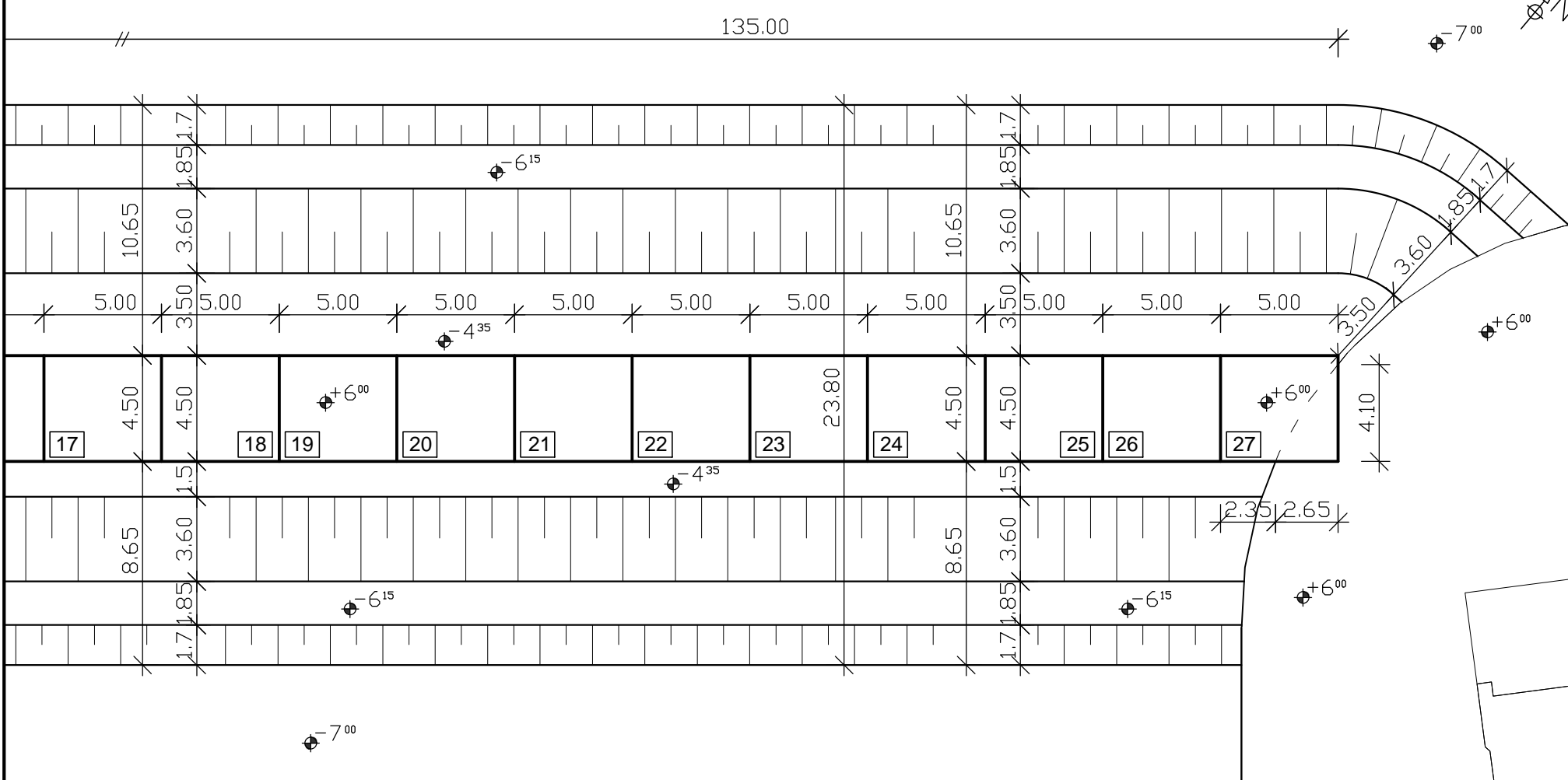
See next page.


Plan view - caisson breakwater; section 2; 1:250



- Notes:**
1. All levels are according to the Dutch Level (NAP) and dimensions in metres.
 2. The trunk of the breakwater consists of 27 reinforced concrete caissons

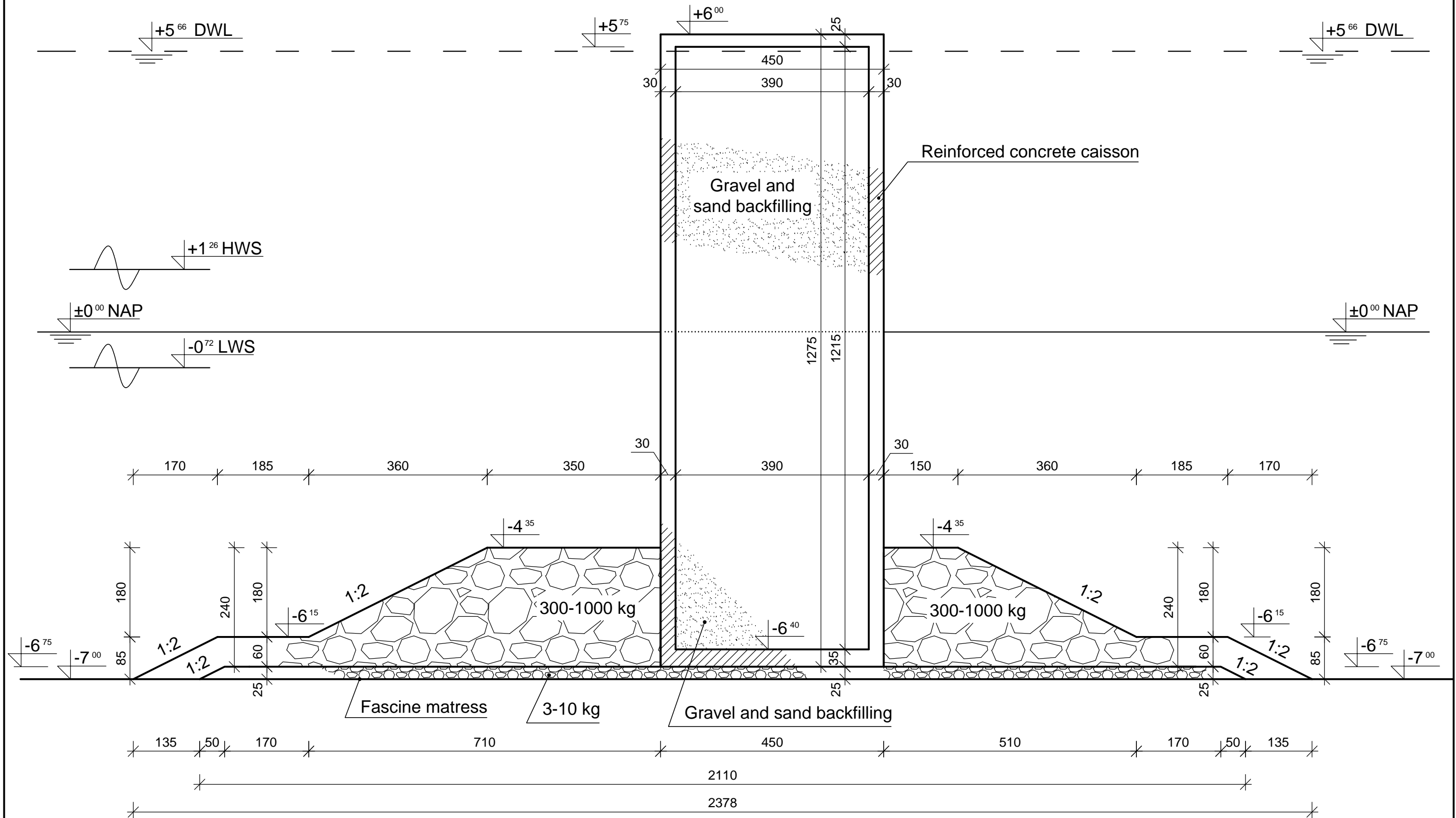
Plan view - caisson breakwater; section 1; 1:250



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	<p>Course: Multidisciplinary Project</p>	<p>06 June 2016</p>
	<p>Scale: 1:250; 1:2500 Caisson breakwater; Plan view</p>	

Annex 5 – Typical cross-section of new breakwater

See next page.



Fill material/rock gradings

Grading	D _{n50}	Application
	[cm]	
3-10 kg	12.8	Fascine mattress fill
300-1000 kg	60	Toe protection

List of Abbreviations:

NAP = Normaal Amsterdams Peil
 DWL = Design Water Level
 HWS = High Water Spring
 LWS = Low Water Spring

Notes:

1. All levels are according to the Dutch Level (NAP) and dimensions in metres.
 2. The caisson is filled with a gravel and sand mixture until +5.75 NAP



Course:
Multidisciplinary Project

Scale: 1:75

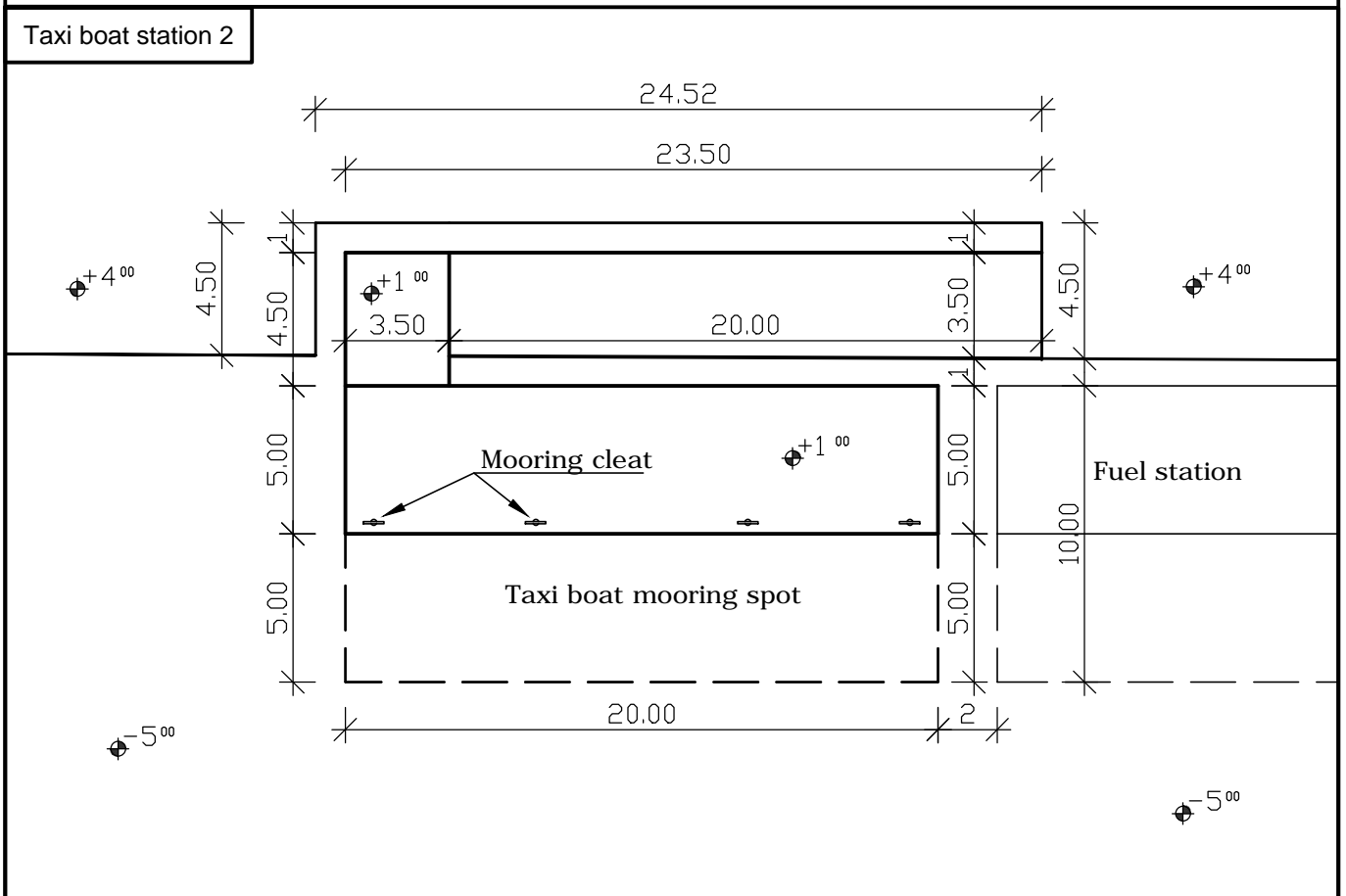
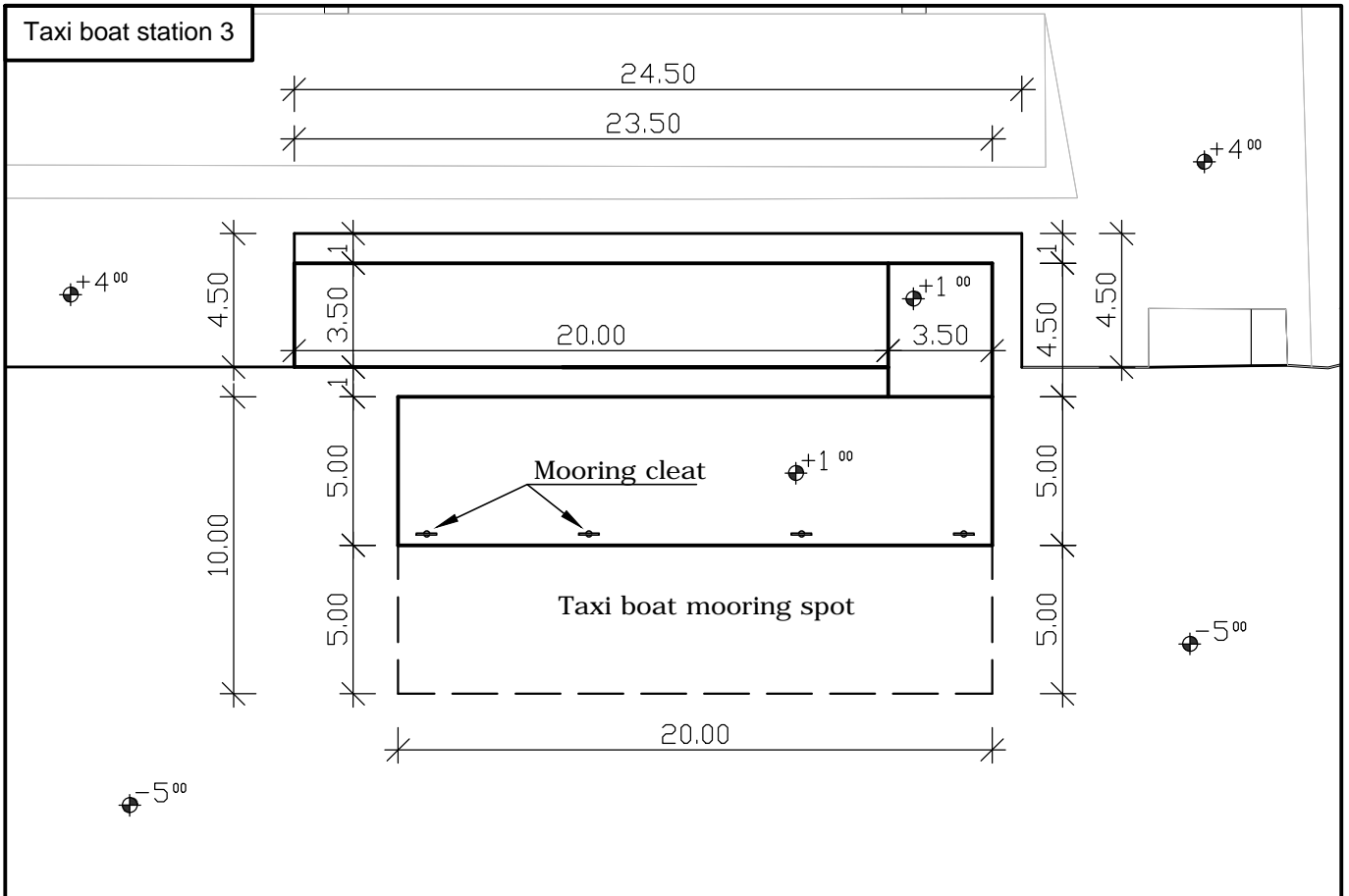
Date: 06 June 2016


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 Renan da Silva
 Xabier Arrieta

Caisson breakwater; Cross-section

Annex 6 – Taxi boat layout

See next page.



<p>Notes:</p> <ol style="list-style-type: none"> 1. Levels are according to the Dutch Level (NAP); dimensions in metres. 2. On-water pontoons are +1.0 m above the current water level. 3. Slope of access ramps: 1/10 4. Mooring cleats characteristics to be specified by the pontoon manufacturer 	 <p>Delft University of Technology</p>		<p>Scheveningen Harbour Project</p> <p>Ermano de Almeida Hithaishi Hewageegana Krasimir Marinov Renan da Silva Xabier Arrieta</p>
	<p>Course: Multidisciplinary Project</p>		
	<p>Scale: 1:250</p>	<p>Date: 06 June 2016</p>	<p>Taxi boat stations 2 and 3; Layout</p>

Annex 7 – Multi-criteria analysis for Scheveningen Harbour – future demands

Description of the indicators used

Tier one indicators

At the very top of the hierarchy, two tier one indicators are defined.

- Effectiveness of the engineering solution.
- Sustainability of the alternative.

Effectiveness of the engineering solution is established such that it can quantify the competency of the alternatives provided in solving the physical issue at hand. In order to measure this indicator, it is further sub divided into two more secondary indicators at the lower level.

Sustainability of the alternative is introduced to measure the factors that are effects of the proposed solution which ascertain the sustainability of the alternative. This is further disseminated into three secondary indicators.

Tier two indicators- secondary indicators

At the second level as mentioned above the two tier one indicators are quantified using secondary indicators.

Effectiveness of the engineering solution

Effectiveness of the engineering solution is measured using the following secondary indicators .

- Infrastructure.
- Operational conditions.

Infrastructure

This indicator is a combination of the following primary indicators, assessing the infrastructural scope of the project.

- Increase of harbour capacity
- Future adaptability of the solution
- Flexibility of the alternative
- Magnitude of the logistical issues needed to be addressed during construction.

Increase of harbour capacity

Considered one of the main objectives of the project. The alternatives varies in increasing the harbour capacity. As the port is used for different purposes, the harbour capacity is mainly comprised of capacity for commercial /fishing vessels and recreational vessels (marina).

- Future adaptability of the prospered solution

For a good solution, a development done at the current timeline should be easily incorporated in a future development as much as possible. This is an important requirement for a harbour like Scheveningen which has seen many developments during its life time.

- Flexibility of the alternative

Scheveningen Harbour is a multipurpose port, serving a wide range sea vessels. The solutions provided at present include for the expected growth of the different sectors. In case there is a change in the anticipated scenario for the future, the provided infrastructure solutions should be flexible enough to change its original designed use to another use as needed.

- Logistics issues during construction

During construction, each alternative poses different logistic issues. For example, if concrete breakwater elements are to be produced the finding a suitable casting yard, if a rubble breakwater is to be constructed the exporting of the needed rock and during construction and providing vessels at the harbour with alternative mooring areas which are disturbed by the construction work. Even though the issues are very short term, these types of various logistical issues of this nature has to be taken into consideration.

Operational Condition

The solutions provided in the alternatives will change the operational conditions of the current harbour. To assess the operational condition, two primary indicators have been used.

- Wave condition and offered sheltering
- Marine traffic condition

- Wave condition and offered sheltering

Different vessels require different levels of sheltering from waves. The alternatives considered will have a dissimilar effect in the wave condition changing their sheltering capacity. Thus in order to provide the required calmness for the considered vessels the wave condition inside the harbour has to be studied.

- Marine traffic condition

Application of the three alternatives will generate a different traffic condition within the harbour. The traffic condition is even currently an issue between the first and the second harbour. Thus any solution has to take into account the traffic condition generated for both safety of the vessels and for efficiency.

Sustainability of the alternative

The Other tier one indicator considered was, sustainability of the alternative. Within the tier two three secondary indicators are defined to value this indicator.

- Economic impact
- Social impact
- Environmental impact

Economic Impact

Economic impact is defined and quantified by the use of two primary indicators.

- Jobs production
- Generation of Income

These indicators should be able to give an idea of how the alternatives will vary in terms of providing to the economy of Scheveningen.

➤ Jobs production

The number of jobs produced can be quantified as jobs in the long term and short term. The short term jobs can be assumed to be generated due to the construction activities.

➤ Generation of income

With the increased capacity and facilities of the harbour, more vessels will be using Scheveningen port. This will directly related to the income of the harbour. Income generation varies from different type of vessels. As the alternatives considered will accommodate in different proportions of these vessel classes, the income generated will also vary.

Social Impact

Social impact due to the application of the solution are quantified using the following primary indicators.

- Time scale of construction
- Social acceptance
- Impact on leisure activities

The indicators can be used to assess the impact of the different social sectors dealing with the port of Scheveningen. The indicators can be described in the subsequent manner.

➤ Time scale of construction

The time taken for the implementation may have a significant impact on the users and nearby residents of the port as it can be an inconvenience. The noise, dust and other relevant issues will have to be taken into account. Though the problem is confined to a very small time period considering the total life time, if this is not taken into consideration, the project may come to a halt at the very beginning if large social displeasure is built up.

➤ Social acceptance

The indicator is more focused on the long term acceptance of the project by the society. As the harbour develops more ships and more people will be using the port. The greater influx of people may be seen differently by various sectors. Furthermore there may be reduced favorability for increase in certain

sectors like increase in fishing vessels due to the odor and more favorability for large yachts as they increase the value of the harbour.

➤ Impact on leisure activities

Due to the application of the projects there may be an impact on leisure activities. An important point is that these activities may be external of the harbour and due to the project these activities can get hampered.

Environmental impact

The environmental impact of the project is measured using two primary indicators.

- Water quality
- Changes in sediment transport

The indicators given should be able to capture and contrast between the alternatives in how well the solutions rank up against their environmental impact.

➤ Water quality

The water quality issues can be both in the long term and in short term. For example capital dredging will be needed for certain alternatives. If the plume created cannot be contained this can have an impact on the water quality around the harbour area. In more long term, fuel leakages and waste water generation of vessels can be provided. As the configuration of the harbour may change with the alternative, some solutions may have a higher chance of leaking fuel and other waste to the open ocean which will reduce the water quality.

➤ Changes in sediment transport

Sediment transport profile near the harbour is very important due to the fact that Scheveningen beach is a famous touristic attraction and due to the proximity to the sand engine. A change to the transport profile can be very unfavorable. For example a blocking of the longshore transport or a change in alignment or depth of the approach channel may lead to an issue.

Evaluation of the indicators

The three alternatives considered during this project which were described earlier are,

- Alternative 01 (Alt1): Rearranging of the harbour
- Alternative 02(Alt2): Rearranging of harbour + new marina at the fourth harbour
- Alternative 03(Alt3): Extending of outer breakwaters

Following description provides the analysis performed in scoring the indicators.

Effectiveness of the engineering solution

- Increase of harbour capacity

Due to rearranging of the harbor, the capacity of the harbour will slightly increase in Alt1 but in Alt2 and Alt3 due to addition of new area to the harbour the increase of capacity is much higher. Thus Alt1 scores a value of 3. Since different types of vessels will be catered the increase in quay length can be taken as a measurement for the increase in harbour capacity.

Alt 2 add a new quay length of approximately 560 m to the harbour while Alt3 adds a length of 270 m. Therefore Alt2 is given a score of 7 and Alt3 a 10.

- Future adaptability of the solution

In the masterplans prepared for Scheveningen Harbour the area used for the Alt2 marina is kept as the same as the present situation. However there are plans to use the quay walls in front of the proposed breakwater for the marina as berthing areas. Even though the breakwater is designed for minimal reflection, there can be a slight adverse effect. Considering these facts Alt2 is given a value of 8.

A hotel and a beach city is proposed near the northern side breakwater. If Alt3 is constructed the possibility of using this area for the proposed developments will be hindered to a certain level as there will be large sea vessels mostly of commercial origin near the hotel which is not appealing and furthermore due to the extending of breakwater the view of the ocean will be obstructed reducing the interest of an investor for these developments. Hence Alt3 can be given a value of 3.

Alt1 is a soft application which makes it very adaptable for future scenarios. A score of 10 is thus given to this alternative.

- Flexibility of alternative

Alt3 in general will reduce the wave penetration to the harbour due to the breakwater extension and is the alternative which gains the most capacity for the harbor these will be progressive facts for the future of the port. Alt2 is mainly focused on providing shelter for leisure boats only. Thus marina area will be hard to convert to cater to any other type of vessel (e.g. - deep draft commercial vessels). Since Alt1 will not add any new area to the harbour the flexibility for future scenarios become less. In view of these facts the Alt1, Alt2 and Alts3 scores 2, 3 and 9 respectively for this indicator.

- Logistical issue

The logistical issue during construction of each alternative varies greatly. For Alt1 during the reconfiguration of the harbour, mainly the existing marina, many boats will have to be moved to temporary berthing areas which will cause an inconvenience within the port. The construction of Alt2 will occur in an area which is not in use currently which will reduce construction based marine traffic in the harbor. However for Alt3 as the construction will occur at the entrance of the harbour the disturbance will be much higher. Furthermore the material needed for Alt3 is much larger than Alt2, thus Alt3 will require

more area for casting yards/stacking areas and more barges than Alt2 leading to complexities in logistics. Thus Alt1 is scored at 8 and Alt2 and Alt3 at 4 and 1

- Wave condition and offered sheltering

Alt1 will not provide any additional sheltering within the harbour scoring a zero for this indicator. Alt2 consists of an inner breakwater dedicated to reduce the waves for the marina. The wave attenuation provided for the marina will be very high. In Alt3, the outer breakwater will be extended. A certain amount of waves are yet expected to propagate to the harbour during the winter period. Hence only larger vessels will be able to utilize the proposed berthing areas of Alt3 around the year. In terms of providing the sheltering in the harbour throughout the year, Alt2 and Alt3 can be given values of 8 and 7.

- Marine traffic condition

Alt2 is situated in the straight line of the opening of the harbour which should have a minimal impact on the traffic of the harbour due to the ease of maneuvering. Moreover, the congestion in the marina of the second harbour will be reduced due to the new marina reducing the number of boats going to the second harbour through De Pijp, reducing this bottleneck point.

Alt3 will have quay walls along the entrance channel of the harbour. Due to area limitation, there can be a slight restriction to vessels arriving and existing the harbour. By rearranging of harbour area in Alt1, the traffic will be smoothed up to a certain level. These reasons give scores of 5, 8 and 4 for alternatives in order.

Sustainability of the alternative

- Jobs production

The number of jobs produced can be divided into two areas of short term and long term jobs. In Alt1, there does not consist of construction activities and moreover, it can be assumed no new jobs will be generated, thus the indicator value 0. Construction work in Alt3 is much greater and longer in duration than in Alt2, thus more short term jobs will be created in Alt3. The long term jobs will occur in different sectors like maintenance of sea vessels, service sectors, restaurants, security. Since Alt3 will incorporate more area to the harbour, it is prudent to assume the job creation will be higher than Alt2. Thus, the indicator can be scored at 6 and 9 for Alt2 and Alt3 respectively.

- Generation of income

The generation of income in this indicator is measuring the income generated by the different vessels using the harbour. The capacity increase in Alt1 will be very small, thus the additional income generated from the current situation will be less, giving a score of 0. For Alt2, incorporation of the new marina will attract many pleasure crafts to Scheveningen Harbour, a sector which is very affluent. Thus, income generated from the marina will be high. Alt3 will have new berthing areas for larger vessels. The vessels

can be of commercial and fishing in origin bringing in a varying income. Assuming this income will be higher than of Alt2, the indicator is scored at 9 for Alt3 and 7 for Alt2.

- Time scale of construction

Considering the disturbance to the surrounding, the time scale of construction is considered. As mentioned previously Alt3 will have the longest construction period followed by Alt2. Alt1 will not consist of construction work. Thus Alt1 will be the most desirable in this category scoring 10 while Alt2 scores 4 and Alt3 1.

- Social acceptance

Social acceptance for Alt1 will be more of a neutral stance as the change within the harbour will not be dramatic a score of 5 can be assigned to Alt1. Alt2 will bring more pleasure crafts to the harbour which will be seen as a value addition to the port and will be desirable to the public around the harbour. Alt3 will primarily bring larger vessels to the harbour. The new proposed quays for the Alt3 will also take some area of the beach from either side of the entrance. The increase of fishing vessels and commercial vessels will not increase the aesthetic appeal of the harbour and hence can be assumed to have a reduced acceptance from the public. Thus the indicator is scored at 9 for Alt2 and 3 for Alt3.

- Impact on leisure activities

The leisure activities around the harbour area mainly occurs at the Scheveningen beach. Alt1 will not change the current situation much scoring a 10. Alt2 will have a slight impact as to the increase in boats coming to the harbour, which may hinder activities like surfing. Alt3 will have larger boats anchored towards the entrance of the harbour. The beach area along the entrance may have to be allocated to the harbour which will have an impact on the leisure activities. Due to extending the breakwater leisure activities such as surfing can have an impact moreover the sea view may be hindered to some of the leisure goers due to the new breakwater. Hence the indicators for Alt2 and Alt3 can be given scores of 5 and 4.

- Water quality

The water quality for Alt1 will not change from the present case. For Alt2 dredging operations will have to be conducted but as it is much towards the inside of the harbour, the plume will be able to be contained. In the long term any waste water or fuel leakages happening at the marina will have a less likely chance of seeping to the outer sea. In Alt3 more dredging will have to be done and the dredging will occur at the entrance of the harbour increasing the chance of polluting outer sea. The vessels moored for Alt3 are much closer to the outer sea thus the chance of fuel leaking to the sea is much greater. Since the vessels in Alt3 are much larger and contain more fuel the risk is even greater than Alt2. The indicator can thus be given values of 9, 8 and 2 respectively for Alt1 Alt2 and Alt3.

- Changes in sediment transport

Alt1 and Alt2 are both done within the harbour which will not change the current sediment transport profile. Thus the indicator is scored at 10 for both the alternatives. Due to the extension of breakwater of Alt3 however there can be an impact on sediment transport rate. Furthermore the entrance channel will have to be changed for Alt3 changing the sediment dynamics around the entrance. The changes can be even direr due to the proximity of the sand engine. The actual impact will have to be found by performing complex analytical studies. At this point the alternative will be marked down for potential impact with a score of 4.

Evaluation of weight factors the indicators

Infrastructure

The most important indicator within infrastructure is the Increase of harbour capacity which is considered to be a primary goal of the project. Thus a weight of 3 is given for this indicator. Logistical issues and flexibility of the alternatives are measured less important because the logistical issues only occur during construction period and the flexibly of the alternative will be needed in a rare case where the projected growth levels of the different sectors have changed dramatically. Thus a weight factor of 1 is given for these two points.

Future adaptability of the solution is given a relative more importance with a weight factor of 2 as the harbour has seen many stages of development and very well see more phases of developments in the future and thus the development at the present should be well aligned with future plans.

Operational conditions

From the two indicators comprised in operational conditions, the wave environment and offered sheltering is given priority with a weight factor of 3 as the sheltering within the harbour is of utmost important. Marine traffic condition is given a value of 1.5 as it will not be a pressing issue.

Economic Impact

Both Production of jobs and generation of income are important economic segments. The income generated can be given a slight advantage above jobs as the final outcome is to bring more cash into the system. Thus weight factors of 2 and 3 are given respectively.

Social impact

From the three indicators calculating social impact, time scale of construction and impact on leisure activities is given a weight factor of 1 as they are less in relative importance. The time scale of construction is given a lower value because of its effect is only short term (during the construction

period) and impact on leisure activities is marked down because it is constrained to only to one section when compared with social acceptance indicator which is given a weight factor of 2.

Environmental impact

From the two indicators in assessing environmental impact, changes in sediment transport is given a higher weight (2) because any adverse effect will be almost irrevocable and chronic. While the impact on water quality will be more episodic and effort can be made to contain the spread of pollution which is given a weight factor of 1.5.

Weight factors for secondary and tier two indicators

The main objective of the project is to provide new infrastructure to Scheveningen Harbour and to boost the economy. Hence a higher weightage is given for the indicators measuring these two components which are Infrastructure indicator and the Economic impact indicator. A weight factor of 3 is allocated.

Social impact and operational conditions are given a weight factor of 1.5. The primary reason for the reduced weight factor is because, the impacts measures in these constituents are mostly short-term. Environment impact is given a higher weightage with a factor of 2 as it is an important requirement to be fulfilled in the project.

Finally the two tier two indicators, sustainability of alternative and effectiveness of the engineering solution both are given the same weight factor (1.0) as for a viable project both the elements have to be satisfied equally.

Annex 8 – Metocean conditions

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1. Introduction and objective

This document comprises the metocean conditions of Scheveningen Harbour, as part of the design conditions of the Multi-Disciplinary Project (CIE 4061-09). The Hague Municipality – the client of the current project - is responsible for Scheveningen Harbour. An overview of Scheveningen Harbour is presented in Figure 69, while its nautical chart is shown in Figure 40.

The multicriteria analysis indicated that the optimum design should include a permanent marina, sheltered by a new breakwater in De Kom, hereafter called as (new) Fourth Harbour.

The objective of this document is to present the metocean conditions around the Fourth Harbour, so as to provide the design conditions for both the breakwater and the new marina mooring structures.

The report was divided in the following chapters:

- Water level
- Offshore wave and wind climate;
- Propagation wave modelling
- Nearshore wave climate;
- Scheveningen Harbour wave climate;
- Downtime estimate; and
- Impact of the breakwater in the hydrodynamics of Scheveningen Harbour



Figure 39. Overview of Scheveningen Harbour.



Figure 40. 18017B Nautical Chart Scheveningen Harbour 2011. (Dienst der Hydrografie).

2. Water level

The Scheveningen Harbour is located in an excavated small tidal basin. As the water depths inside it are not that small and do not limit the tidal wave entrance, the tide range inside the port area is practically the same than offshore.

The water level data in the Scheveningen Harbour is summarized in Table 20. The following observations can be made:

- The tide height varies from -72 cm to +125 cm NAP, with a range of approximately 2 m;
- The water level is higher than +245 cm NAP once per year;
- The water level for a return period of 100 years is +370 cm NAP; and
- The 10000 year water level is +515 cm NAP.

The extreme water levels are associated with storm surges. As a consequence of the Dutch coastline orientation, North-western storms are expected to be responsible for these events, whereas the water piles up due to wind and/or low pressure systems.

Table 20. Water level data information in Scheveningen Harbour. Source: Deltares (2006)

Scheveningen	(Noordzee)		Slotgemiddelden 1991.0
<i>Gemiddelde waterstanden</i>			
type tij	HW-stand	LW-stand	tijverschil
	cm	cm	cm
	+ NAP	+ NAP	
gemiddeld tij	107	-71	178
springtij	126	-72	198
doodtij	84	-64	148
gem. waterstand		-1	
<i>Gemiddelde havengetallen</i>			
<i>waarden maansverloop</i>			
type tij cq grootheid	HW-tijd	tijd	LW-tijd
	u:min	u:min	u:min
gemiddeld tij	01:56		10:00
springtij	01:58		10:05
doodtij	01:54		09:52
duur rijzing		4:21	
duur daling		8:04	
<i>Gemiddelde over- en onderschrijdingsfrequentie per jaar</i>			
<i>overschrijding hoogwaterstanden</i>		<i>onderschrijding laagwaterstanden</i>	
	stand		stand
frequentie	cm	frequentie	cm
	+ NAP		+ NAP
1x per 10.000 jaar	515	1x per 100 jaar	
1x per 1.000 jaar	440	1x per 10 jaar	-195
1x per 100 jaar	370	1 x per jaar	-160
1x per 50 jaar	350		
1x per 20 jaar	325		
1x per 10 jaar	305		
1x per 5 jaar	290	LLWS 1985	-93
1x per 2 jaar (grenspeil)	270		
1x per jaar	245		
2x per jaar	230		
5x per jaar	210		
basispeil	515		
ontwerppeil	515		

3. Offshore wave and wind climate

As no measured waves were available to the design wave analysis, offshore wave data from BMT Argoss database were extracted at 52.17°N, 4.17°E (Figure 41). These data provided by BMT Argoss consist of hindcast numerical wavedata, calibrated with satellite data (see www.waveclimate.com), with a time step of 3 h.

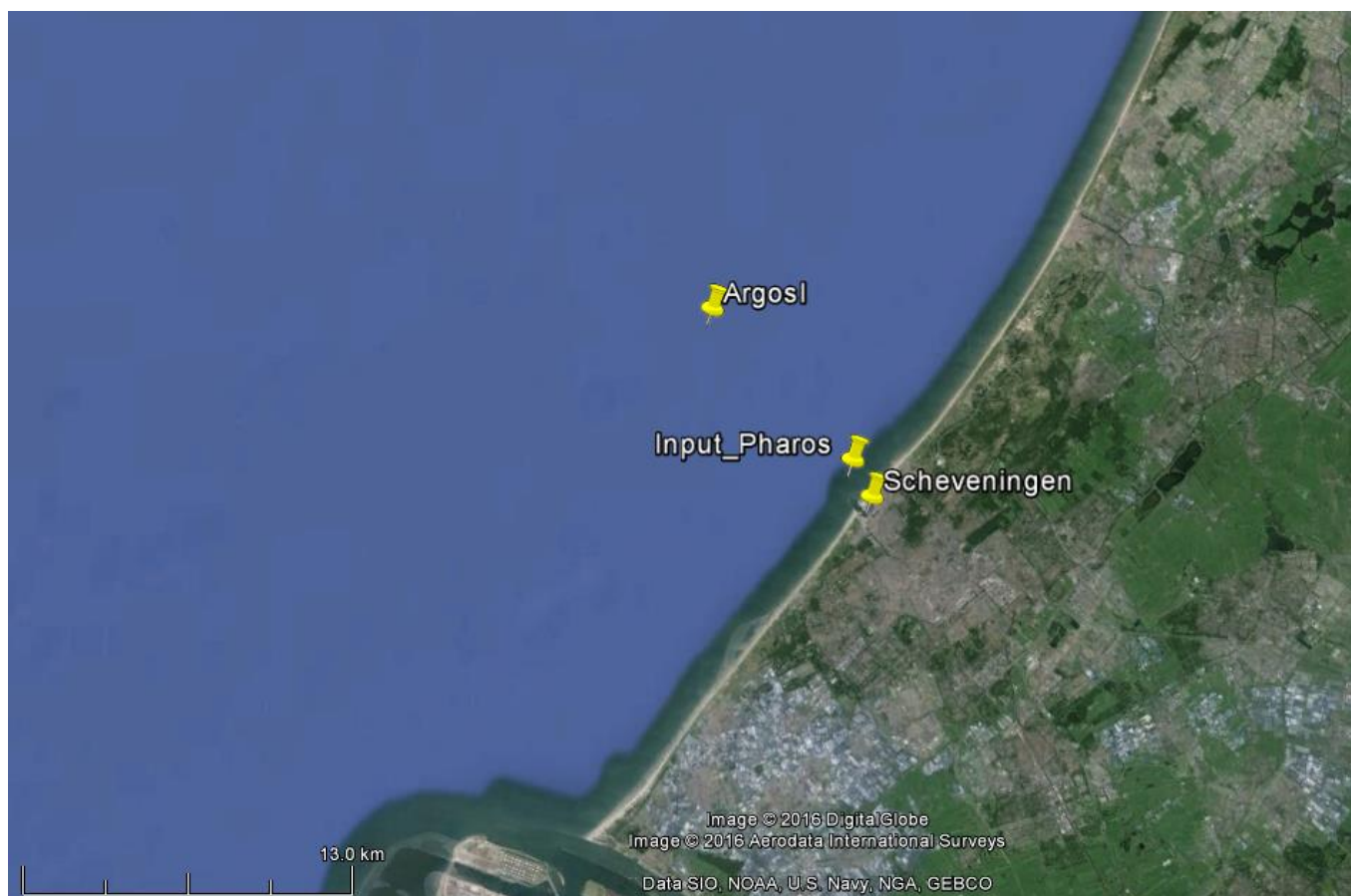


Figure 41. Argoss database extracted point and Deltares input for wave agitation study with Pharos.

The offshore wave climate is characterized predominantly by waves from South West, and Northwest. Offshore wave roses (Figure 42 and Figure 43) show that offshore wave climate presents mainly waves from North-Northwest and West-Southwest.

The highest wave heights and periods occur for waves coming from Northwest (Table 21 and Table 22). The highest significant wave heights have peak wave periods of 10 to 15 s (Table 23).

Regarding the seasonality of offshore waves, Figure 44 and Figure 45 show that from May to August the wave heights and wave periods are in general lower than in the rest of the year.

As for the offshore wind conditions, Figure 47 presents the wind rose. It shows that the predominant wind comes from Southwest, while the highest wind speeds occur for winds coming from Southwest and North-Norhtwest. The monthly wind histogram (Figure 46) indicates that from May to August more than 40% of the wind magnitudes are lower than 5 m/s.

As no measured wind data was available at Scheveningen Harbour, these offshore winds were used for the downtime analysis.

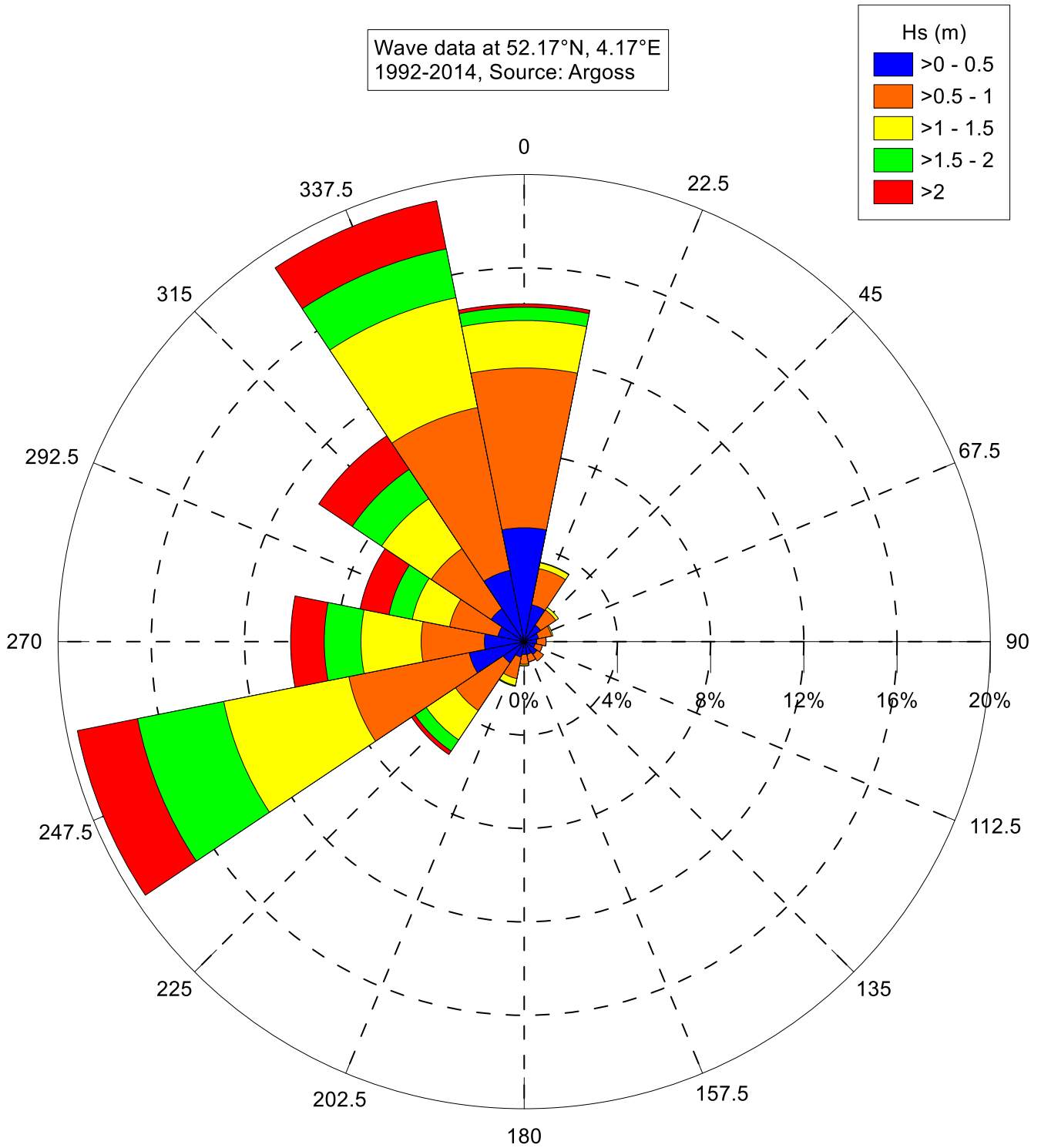


Figure 42. Offshore wave rose – significant wave height at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

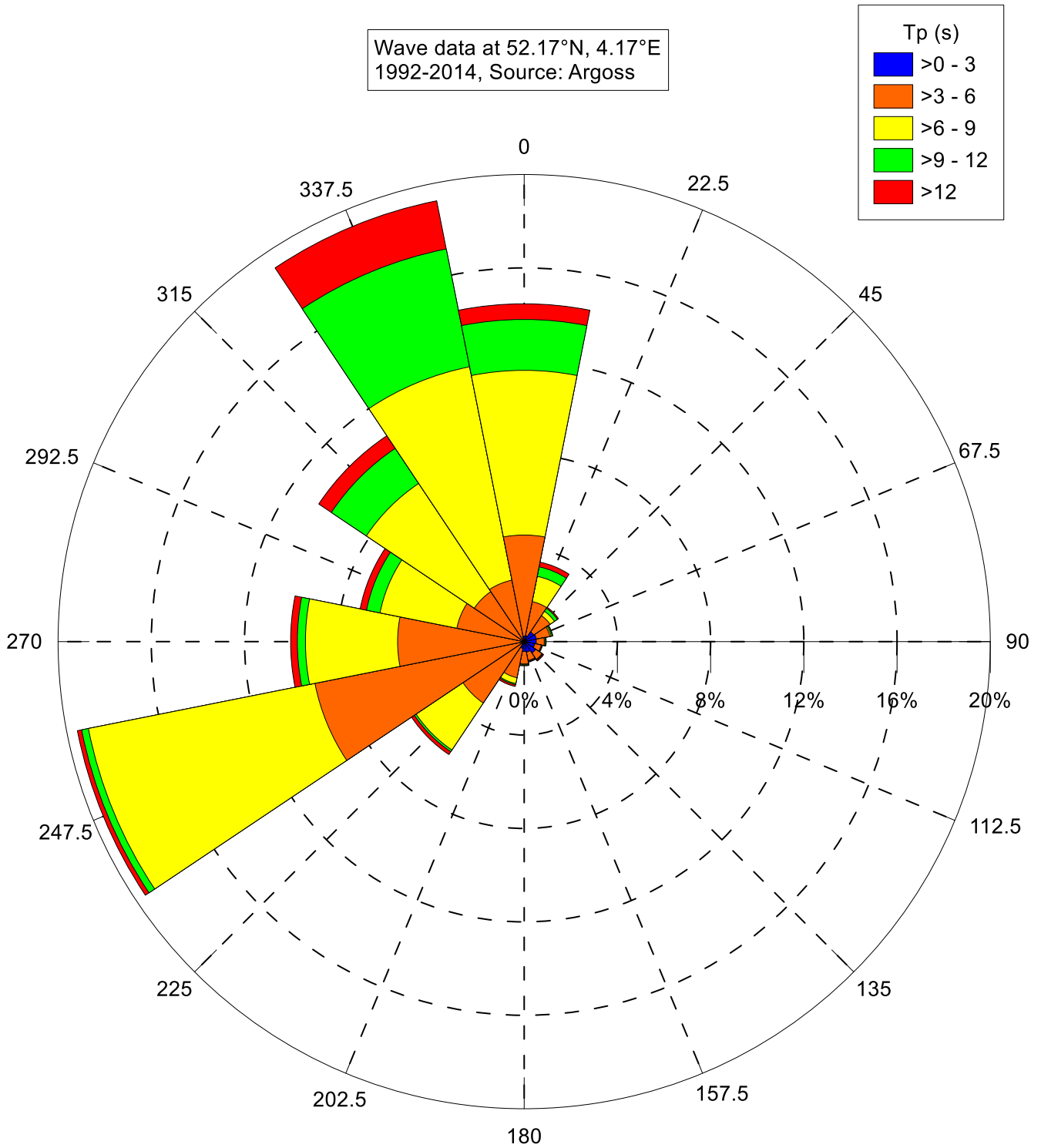


Figure 43. Offshore wave rose – peak wave period at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

Table 21. Significant wave height x mean wave direction at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

Scheveningen_offshore	Dp (°N)															
Hs (m)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0 - 1	11.72%	3.19%	1.63%	1.20%	0.93%	0.79%	1.00%	0.89%	0.97%	1.61%	3.55%	7.67%	4.42%	3.26%	4.79%	10.22%
1 - 2	2.60%	0.28%	0.14%	0.06%	0.01%	0.00%	0.00%	0.01%	0.07%	0.33%	2.09%	9.24%	4.15%	2.65%	4.08%	6.92%
2 - 3	0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.18%	2.44%	1.31%	1.01%	1.37%	1.70%
3 - 4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.13%	0.23%	0.33%	0.35%
4 - 5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.03%	0.04%
5 - 6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
Total	14.46%	3.47%	1.77%	1.25%	0.95%	0.80%	1.00%	0.90%	1.04%	1.96%	5.82%	19.55%	10.02%	7.18%	10.60%	19.24%

Table 22. Peak wave period x mean wave direction at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

Scheveningen_offshore	Dp (°N)															
Tp (s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0 - 5	2.64%	1.11%	1.21%	1.11%	0.86%	0.74%	0.92%	0.83%	0.93%	1.24%	1.56%	3.77%	2.52%	1.39%	1.14%	1.27%
5 - 10	10.07%	1.93%	0.40%	0.09%	0.05%	0.02%	0.02%	0.02%	0.05%	0.60%	4.05%	15.46%	6.99%	5.18%	7.88%	13.15%
10 - 15	1.60%	0.37%	0.14%	0.05%	0.04%	0.03%	0.05%	0.04%	0.04%	0.10%	0.17%	0.28%	0.46%	0.55%	1.45%	4.48%
15 - 20	0.14%	0.04%	0.01%	0.01%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.03%	0.03%	0.03%	0.04%	0.12%	0.32%
20 - 25	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.02%	0.01%	0.01%	0.02%
Total	14.46%	3.47%	1.77%	1.25%	0.95%	0.80%	1.00%	0.90%	1.04%	1.96%	5.82%	19.55%	10.02%	7.18%	10.60%	19.24%

Table 23. Significant wave height \times peak wave period at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

Scheveningen_offshore	Tp (s)					
	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	Total
Hs (m)						
0 - 1	22.22%	28.66%	6.17%	0.72%	0.09%	57.85%
1 - 2	1.02%	29.30%	2.24%	0.09%	0.00%	32.65%
2 - 3	0.00%	7.27%	0.88%	0.02%	0.00%	8.17%
3 - 4	0.00%	0.73%	0.49%	0.00%	0.00%	1.22%
4 - 5	0.00%	0.01%	0.08%	0.00%	0.00%	0.10%
5 - 6	0.00%	0.00%	0.02%	0.00%	0.00%	0.02%
Total	23.25%	65.96%	9.87%	0.83%	0.09%	100.00%

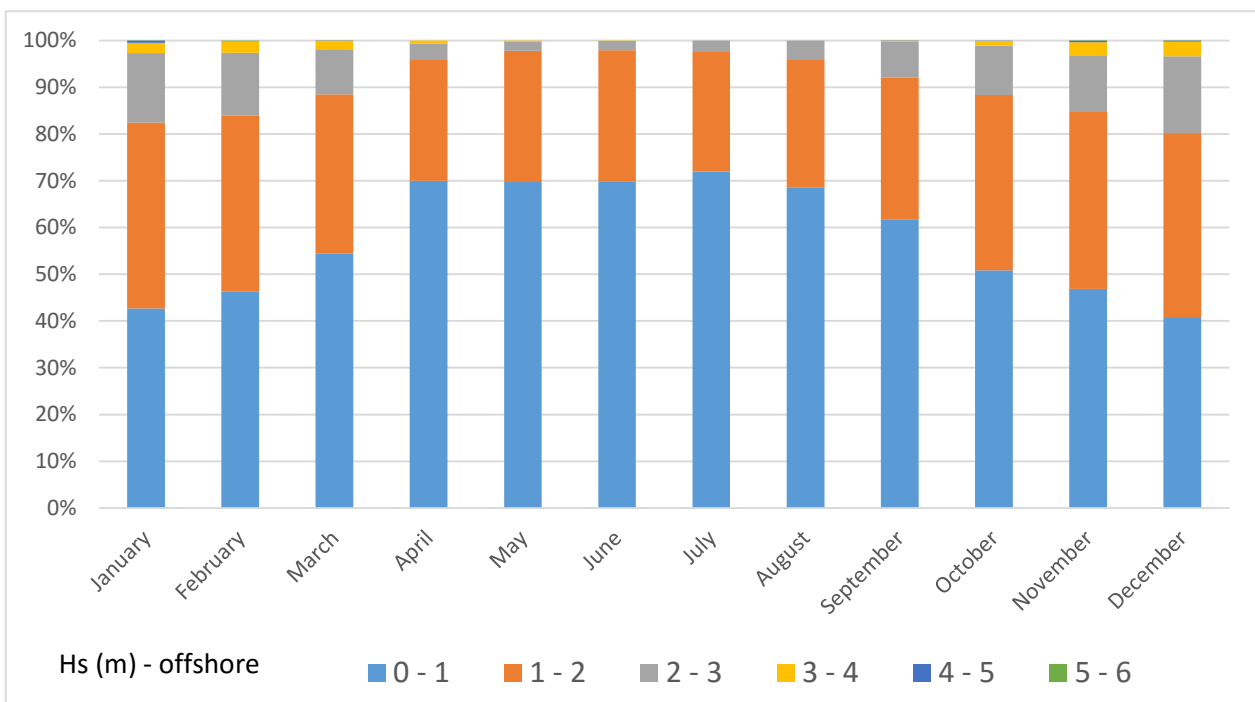


Figure 44. Monthly histogram – significant wave height at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

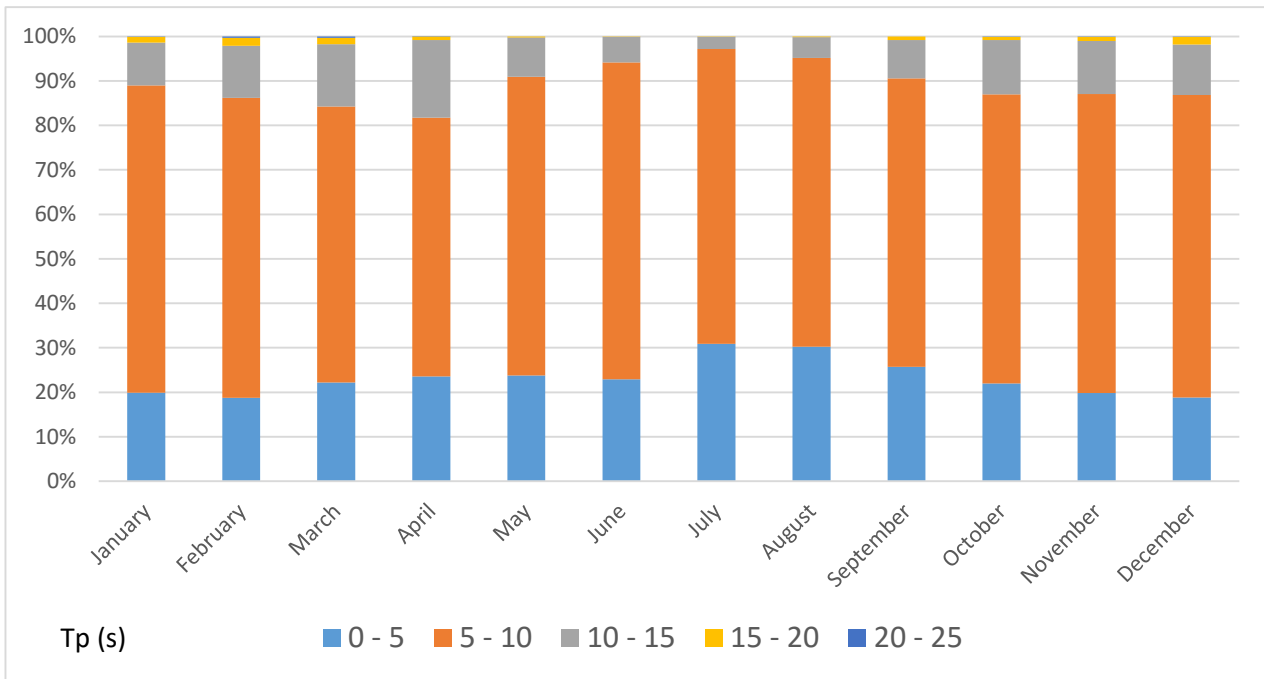


Figure 45. Monthly histogram – peak wave period at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

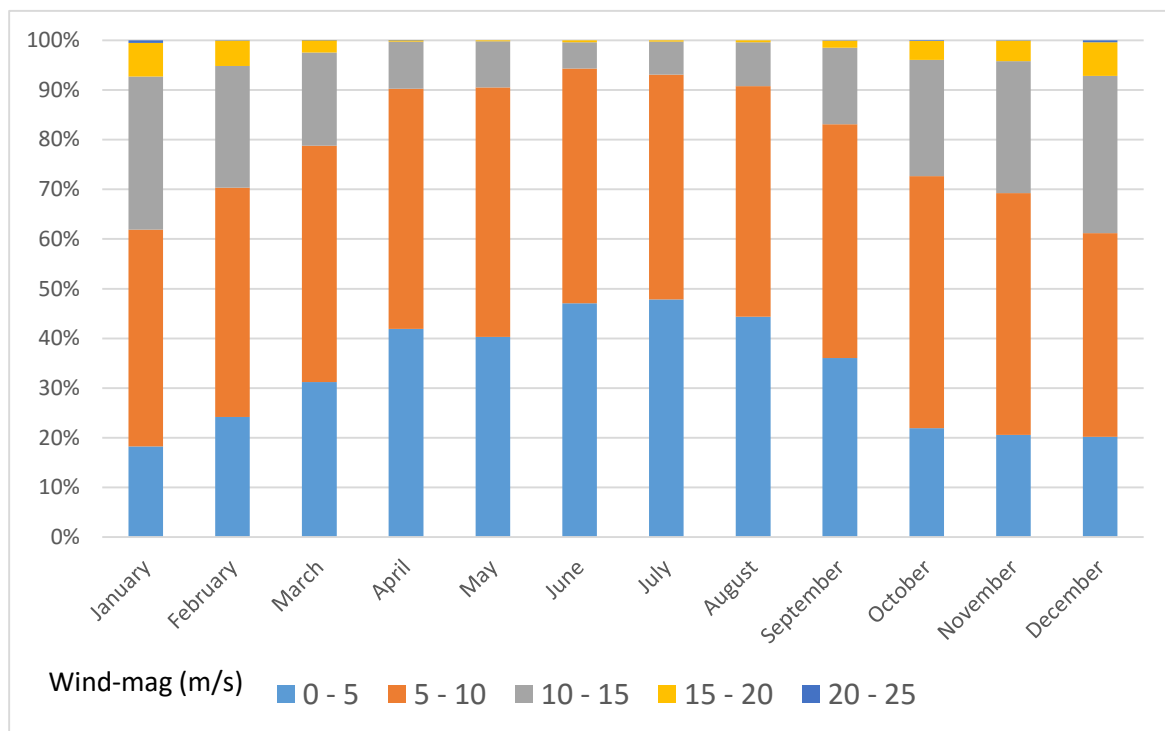


Figure 46. Monthly histogram – wind magnitude at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

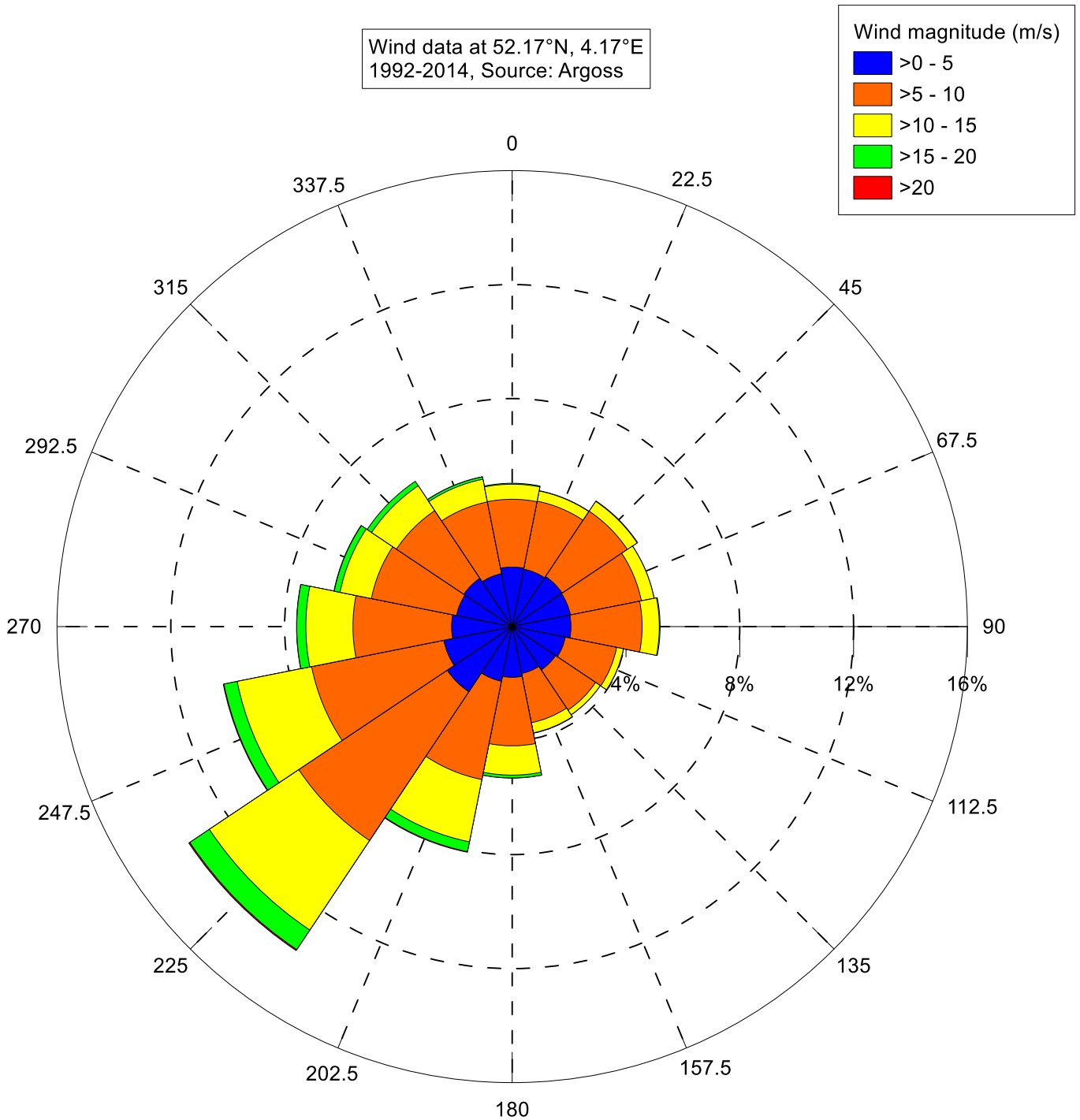


Figure 47. Offshore wind rose – peak wave period at 52.17°N, 4.17°E, from 1992 to 2014. Source: BMT Argoss.

4. Propagation wave modelling

In order to obtain the design wave conditions at a point close to the Scheveningen Harbour entrance, SWAN (“Simulating Waves Nearshore”, TU Delft) was applied to propagate the waves from offshore (Argoss point) to nearshore. SWAN is a numerical model that solves the balance of wave action along

the space, therefore a spectral model, including refraction, shoaling, friction, breaking, etc (see <http://www.swan.tudelft.nl/>).

In this study the one-dimensional (1D) version was applied – this means that alongshore depth contours were considered to be straight and parallel. The bathymetry (Figure 48) shows that the 10 m depth line close to Scheveningen is parallel to a line towards 38°N. Therefore, a typical Northeast-Southwest bottom profile from the extracted offshore point to the Scheveningen Harbour was used (Figure 49). The bathymetry used in the wave modelling was extracted from Navionics (<http://webapp.navionics.com/>).

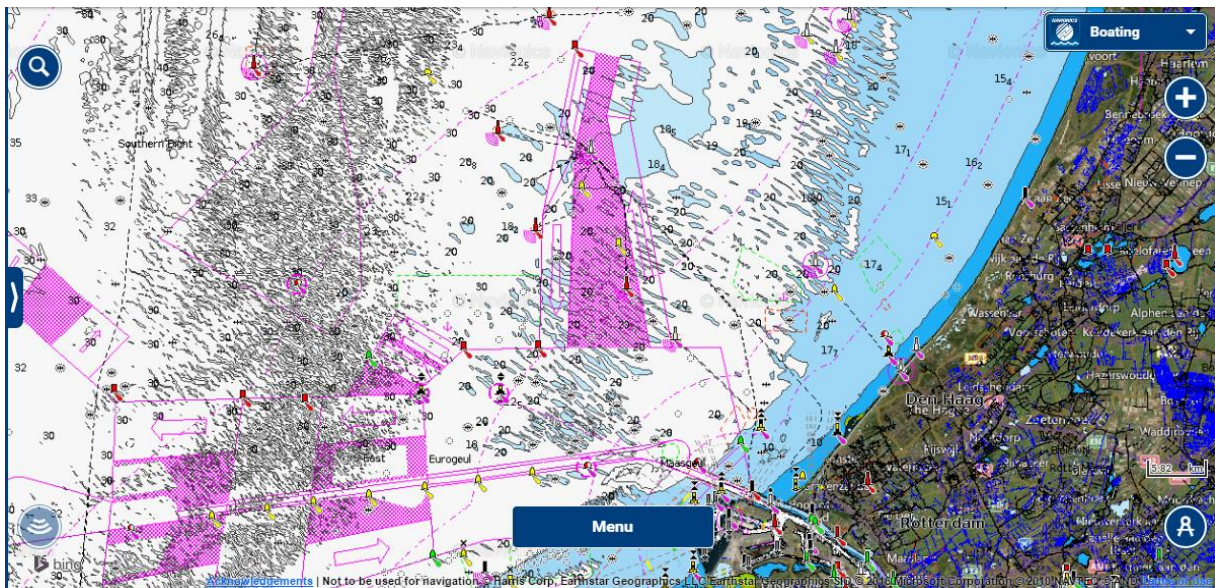


Figure 48. Bathymetry in the coastal area of Scheveningen. Source: Navionics.

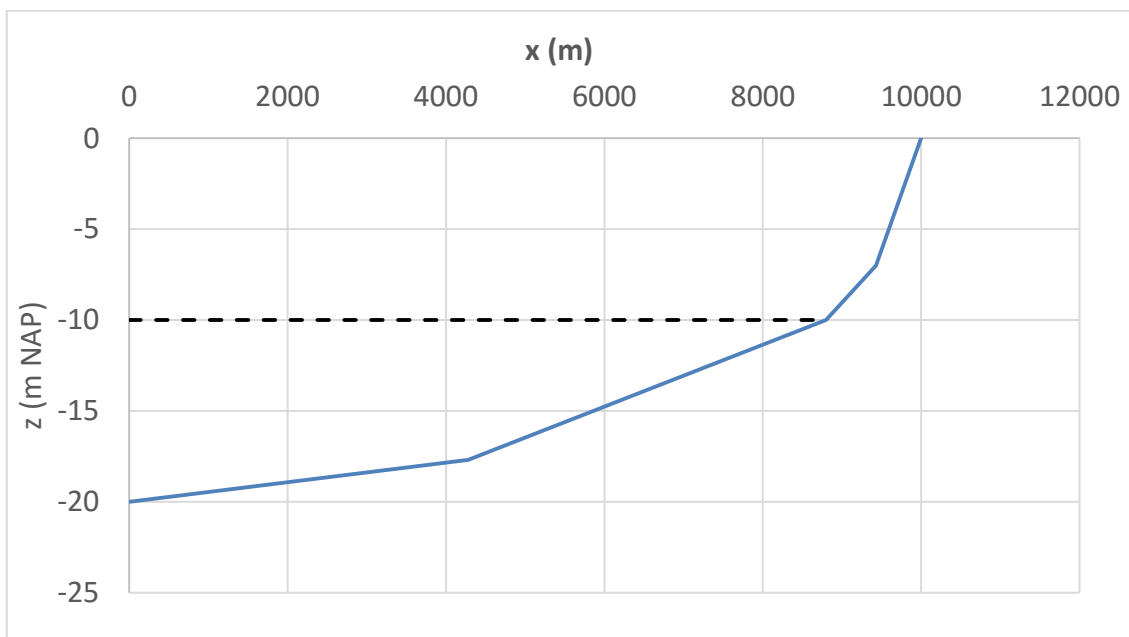


Figure 49. Bottom profile considered in SWAN (blue line) and the black dashed line represents SWAN output location.

Winds and friction were considered in the wave modeling, with stationary conditions. This means that SWAN solves a balance between energy sources (wind) and sinks (friction and breaking) and energy advective term, dependent upon the wave group velocity, as it assumed that there is not variation in time within the time scale of the input conditions (wave states of 3 h).

No calibration was carried out as no nearshore wave data was available.

A constant water level corresponding to the mean sea level was assumed in all simulations.

The whole time series of 23 years (1992-2014) was simulated and results were evaluated in the point shown in Figure 41 and Figure 49, with a depth of around -10 m NAP.

5. Nearshore wave climate

The wave climate at Scheveningen Harbour entrance was evaluated with SWAN results at a depth of -10 m NAP. Figure 12 and Figure 13 present the wave roses, where it can be seen that offshore waves from West-Southwest refracted and became from West, while offshore waves from North-Northwest turned and became mainly from Northwest. Both figures show that higher wave heights and periods come from Northwest.

Table 24 and Table 25 show the cross distribution between the significant wave height and peak wave period and the significant wave height and mean wave direction. These tables confirm that the highest wave heights come from Northwest and the associated wave periods range mainly from 5 to 15 s.

Regarding the seasonality of the nearshore waves (Figure 52), the lowest wave heights occur from April to August, while the highest wave heights happen during Winter.

6. Scheveningen Harbour wave climate

6.1. Wave conditions inside Scheveningen Harbour

The entrance of the Scheveningen Harbour is protected by two breakwaters: the Southern breakwater with a length of 500 m and the Northern breakwater with a length of 350 m. The function of these breakwaters is related to the reduction of sediment transport towards the port basin, minimizing the siltation and the need of dredging.

According to Marcel Stive (Coastal Dynamics lectures, 2016), the approximate bulk longshore sediment transport rates are: 600 m³/y towards North, 400 m³/y towards South, with a net of 200 m³/y towards North. Therefore, the Southern breakwater extension is intended to accumulate sediments in its shadow zone.

As it was studied in the previous chapters, the highest waves come from Northwest. Due to the relatively small Northern breakwater extension, this breakwater is not capable of sheltering the ships traffic during storms.

As the waves enter in the inner port, complex processes such as diffraction, reflection and convergence occur simultaneously. Wave agitation models are used to properly estimate the wave properties in the inner area. Typically, numerical phase-solver models – Boussinesq (example: TRITON/Deltares ou B2D/SMS) or elliptical mild-slope equation (PHAROS/Deltares) – could be used to obtain realistic estimates.

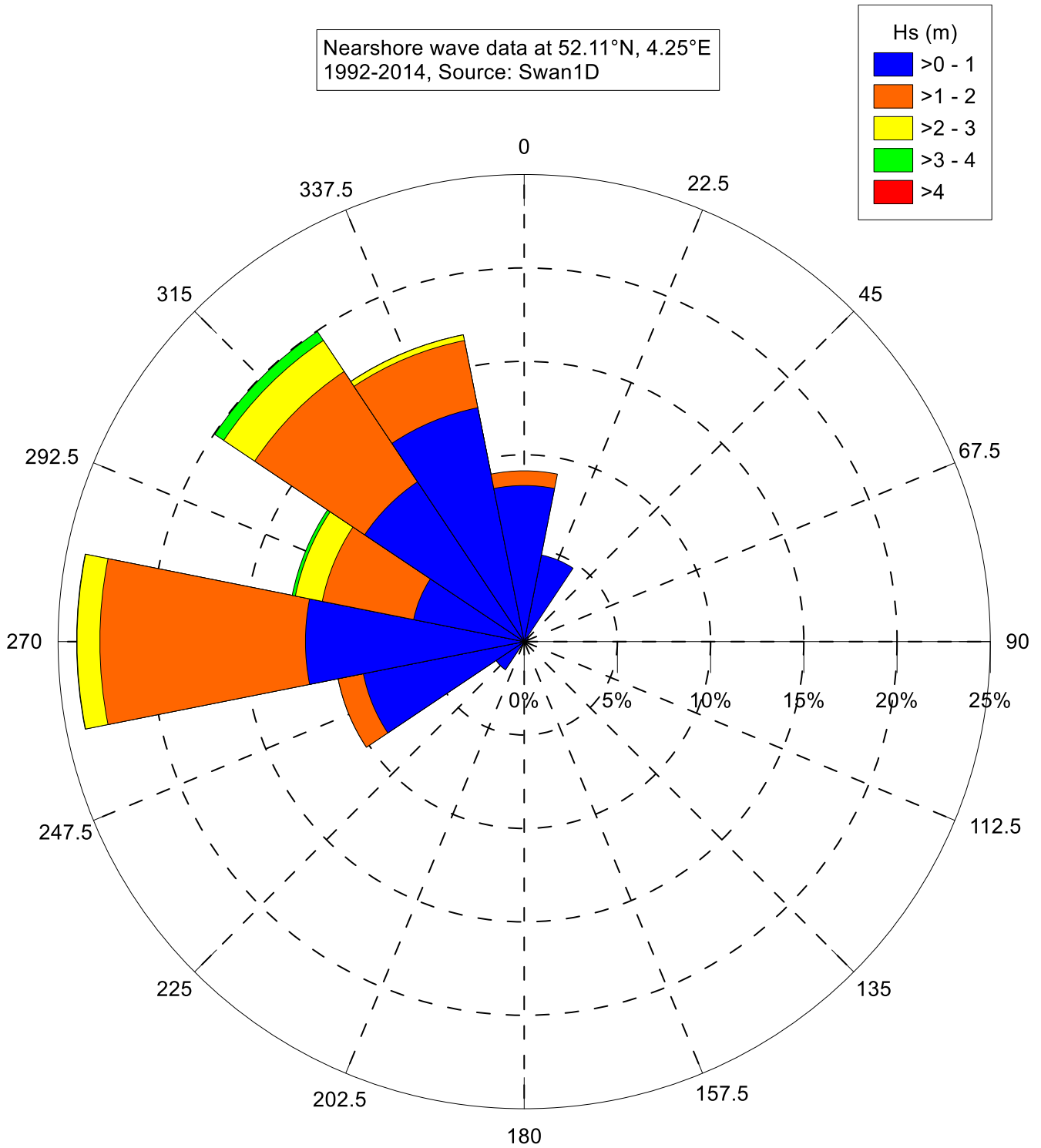


Figure 50. Nearshore wave rose – significant wave height at 52.11°N, 4.25°E, from 1992 to 2014 according to SWAN results.

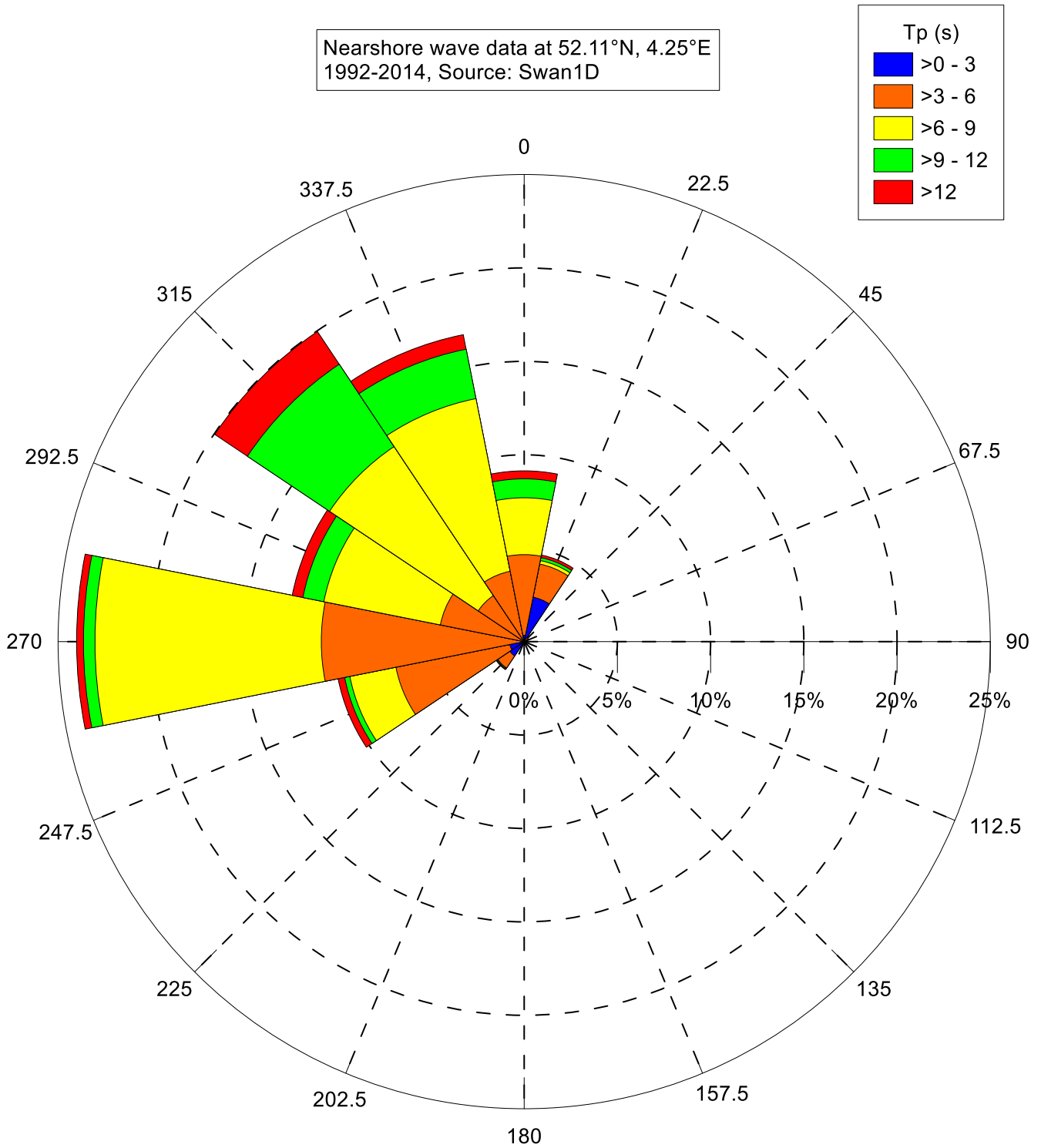


Figure 51. Nearshore wave rose – peak wave period at 52.11°N, 4.25°E, from 1992 to 2014 according to SWAN results.

Table 24. Significant wave height x peak wave period at 52.11°N, 4.25°E, from 1992 to 2014 according to SWAN results.

Scheveningen_nearshore	Tp (s)						
	Hs (m)	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	Total
0 - 1		22.82%	35.17%	6.46%	0.71%	0.09%	57.85%
1 - 2		0.42%	26.31%	2.13%	0.10%	0.00%	32.65%
2 - 3		0.00%	4.19%	0.81%	0.02%	0.00%	8.17%
3 - 4		0.00%	0.30%	0.48%	0.01%	0.00%	1.22%
Total		23.25%	65.96%	9.87%	0.83%	0.09%	100.00%

Table 25. Significant wave height x mean wave direction at 52.11°N, 4.25°E, from 1992 to 2014 according to SWAN results.

Scheveningen_nearshore	Dp (°N)																
	Hs (m)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0 - 1		8.35%	4.72%	0.26%	0.08%	0.05%	0.08%	0.11%	0.05%	0.05%	0.07%	1.81%	8.80%	11.73%	6.04%	10.29%	12.76%
1 - 2		0.79%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.38%	11.03%	5.00%	7.10%	3.67%
2 - 3		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.23%	1.47%	2.00%	0.31%
3 - 4		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.17%	0.58%	0.01%
Total		14.46%	3.47%	1.77%	1.25%	0.95%	0.80%	1.00%	0.90%	1.04%	1.96%	5.82%	19.55%	10.02%	7.18%	10.60%	19.24%

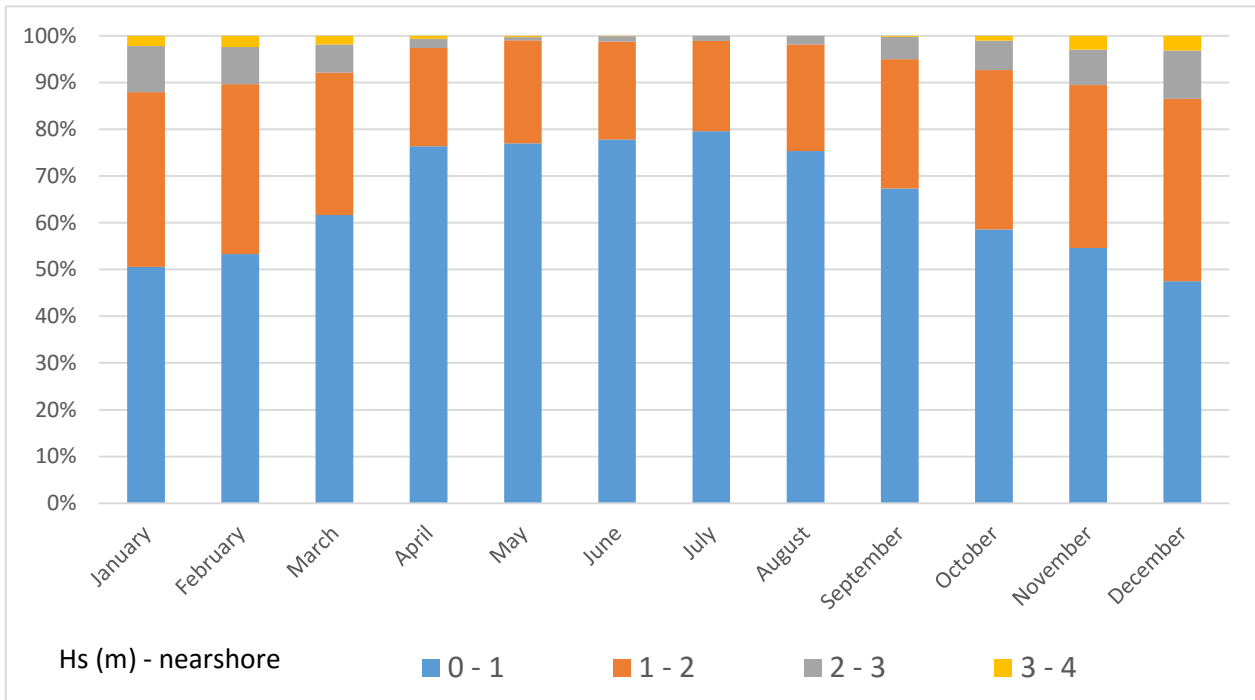


Figure 52. Monthly histogram – significant wave height at 52.11°N, 4.25°E, from 1992 to 2014 according to SWAN results.

Deltares (2006) conducted a study of the wave conditions in the Scheveningen Harbour, and examined the wave behaviour for the existing wave conditions and for a few expansion options. The methodology followed by Deltares is briefly summarized below:

- The model used to estimate the wave conditions inside the harbour was PHAROS, which uses the elliptical mild-slope equation and solves the wave phase, considering processes such as diffraction and reflection.
- The model grid includes both Scheveningen 1st, 3rd and future 4th harbours. Scheveningen 2nd harbour was not included in this study.
- The boundary conditions needed by PHAROS are the waves outside Scheveningen Harbour, close to breakwaters. In this study, the waves were obtained from a propagation wave study with SWAN done by Royal Haskoning and WL / Deltares in 2005. This study assumed 12 wind directions and wind speeds varying from 15 to 40 m/s and many water levels.
- Deltares used the results at the point 52.11°N, 4.25° W, with a depth of approximately -10 m NAP. The scenarios considered comprised the directions 360, 330 and 300°N, and wind speeds of 15, 20 and 25 m/s, and a fixed water level of +1.5 m NAP. The current situation and two expansion scenarios were simulated for all these conditions.
- The output of this study is the significant wave height for every scenario and at all points inside Scheveningen 1st, 3rd and future 4th harbours.

Table 26 summarizes the scenarios simulated by Deltares for the current scenario (without any expansion), including also the wave height outside the harbour, and in the Scheveningen future 4th harbour (Hs_{in}). A factor was also calculated, which is equal to the significant wave height inside divided

by the significant wave height outside. Plots of the results from Case 1 to Case 9 are presented from Figure 1 to Figure 9.

Firstly, it can be observed that the outer significant wave height used as input with generation conditions with wind magnitudes up to 25 m/s varies between 3 and 5 m. This is comparable to the extreme nearshore waves (up to 4 m), which were derived at the same point.

Table 26. Deltares study – Wave height factors.

Case	Wind-mag (m/s)	Wind-dir (°)	Hs_out (m)	Hs_in (m)	Factor
1	15	300	3	0.75	0.25
2	20	300	4.5	0.75	0.17
3	25	300	5	0.75	0.15
4	15	330	5	0.9	0.18
5	20	330	4.5	0.9	0.20
6	25	330	5	0.6	0.12
7	15	360	3	0.75	0.25
8	20	360	4.5	1.05	0.23
9	25	360	5	0.6	0.12

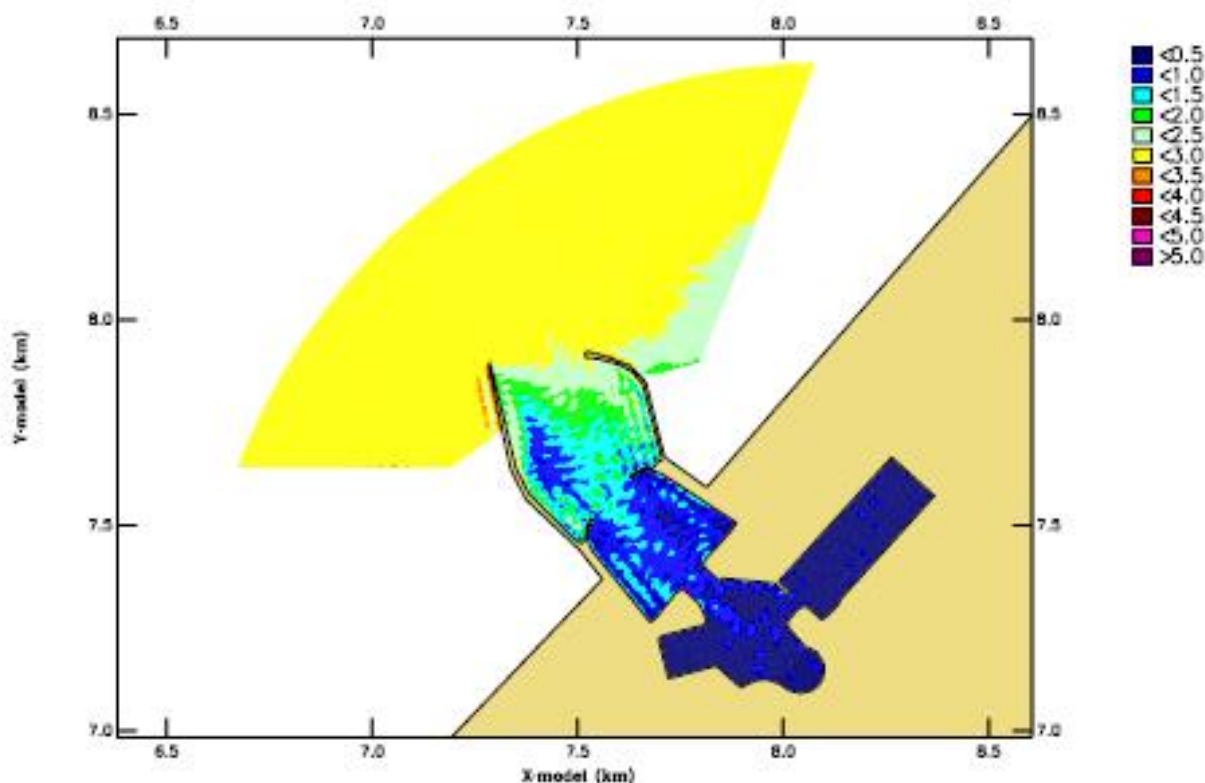


Figure 53. Significant wave height for Deltares Case 1. Source: Deltares, 2006.

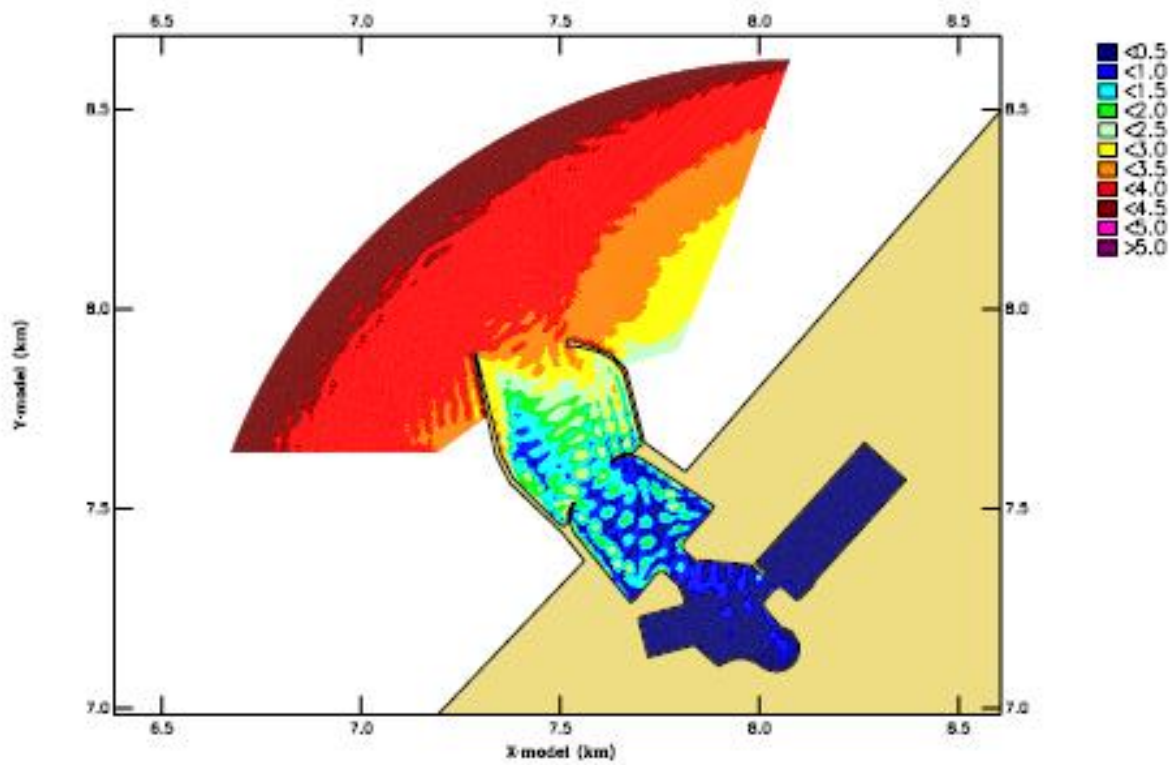


Figure 54. Significant wave height for Deltares Case 2. Source: Deltares, 2006.

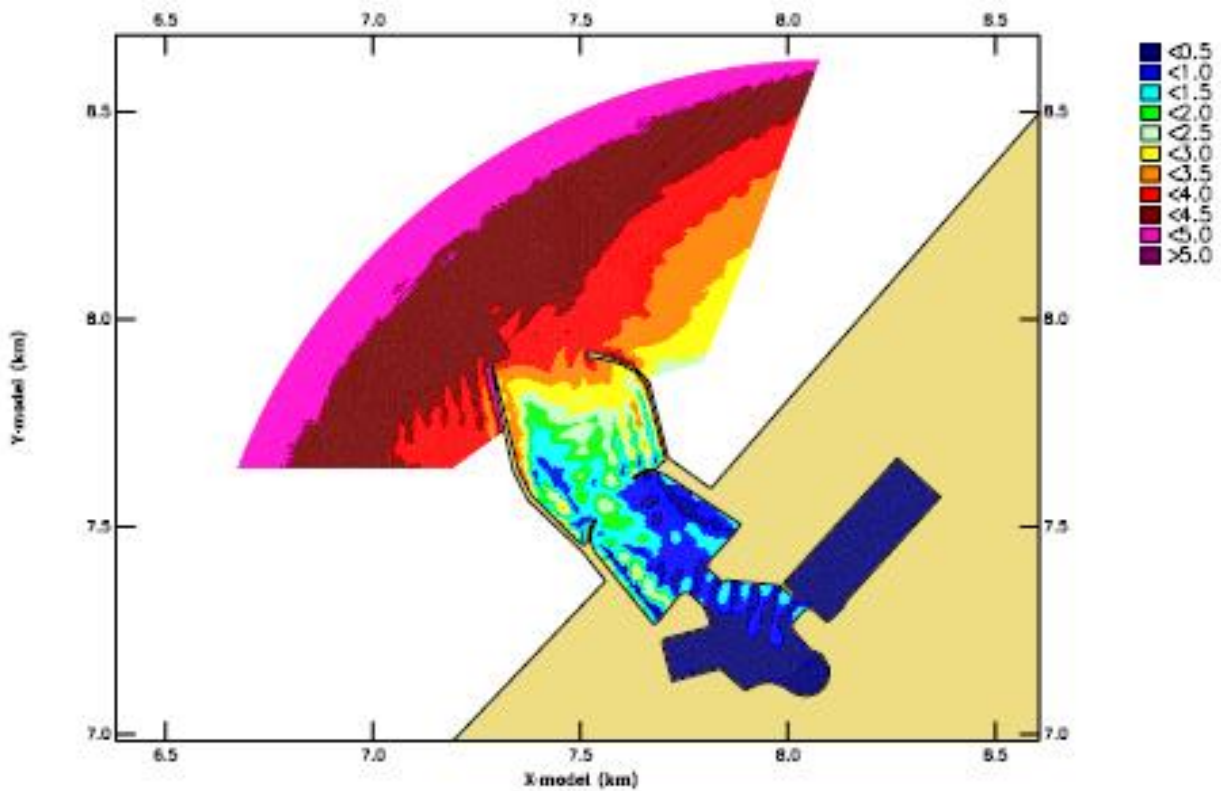


Figure 55. Significant wave height for Deltares Case 3. Source: Deltares, 2006.

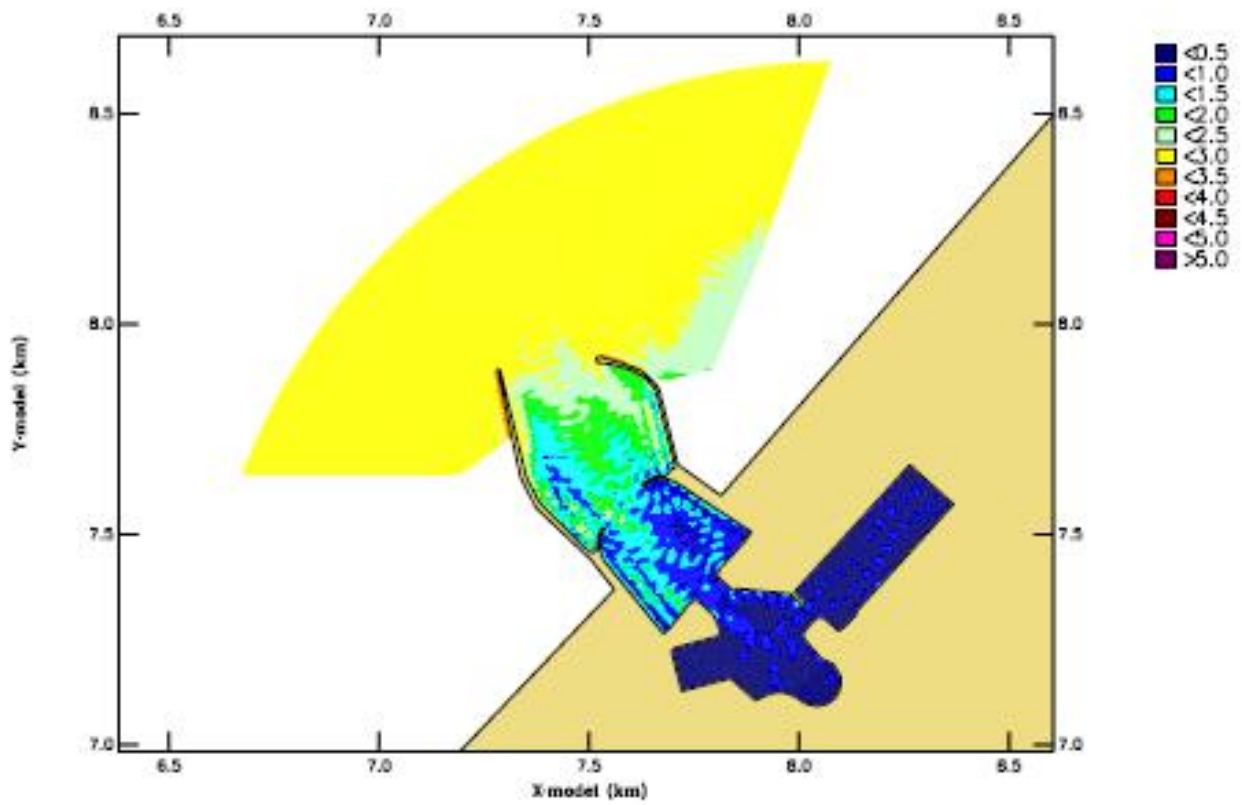


Figure 56. Significant wave height for Deltares Case 4. Source: Deltares, 2006.

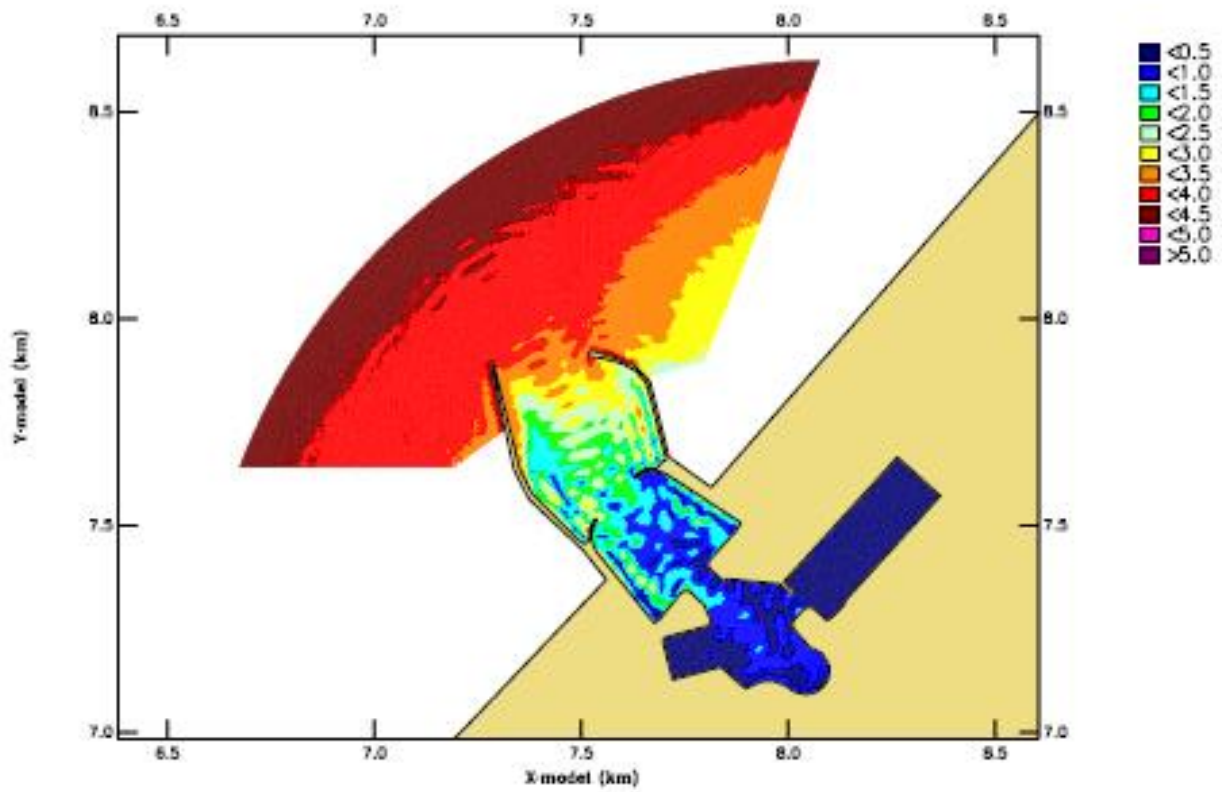


Figure 57. Significant wave height for Deltares Case 5. Source: Deltares, 2006.

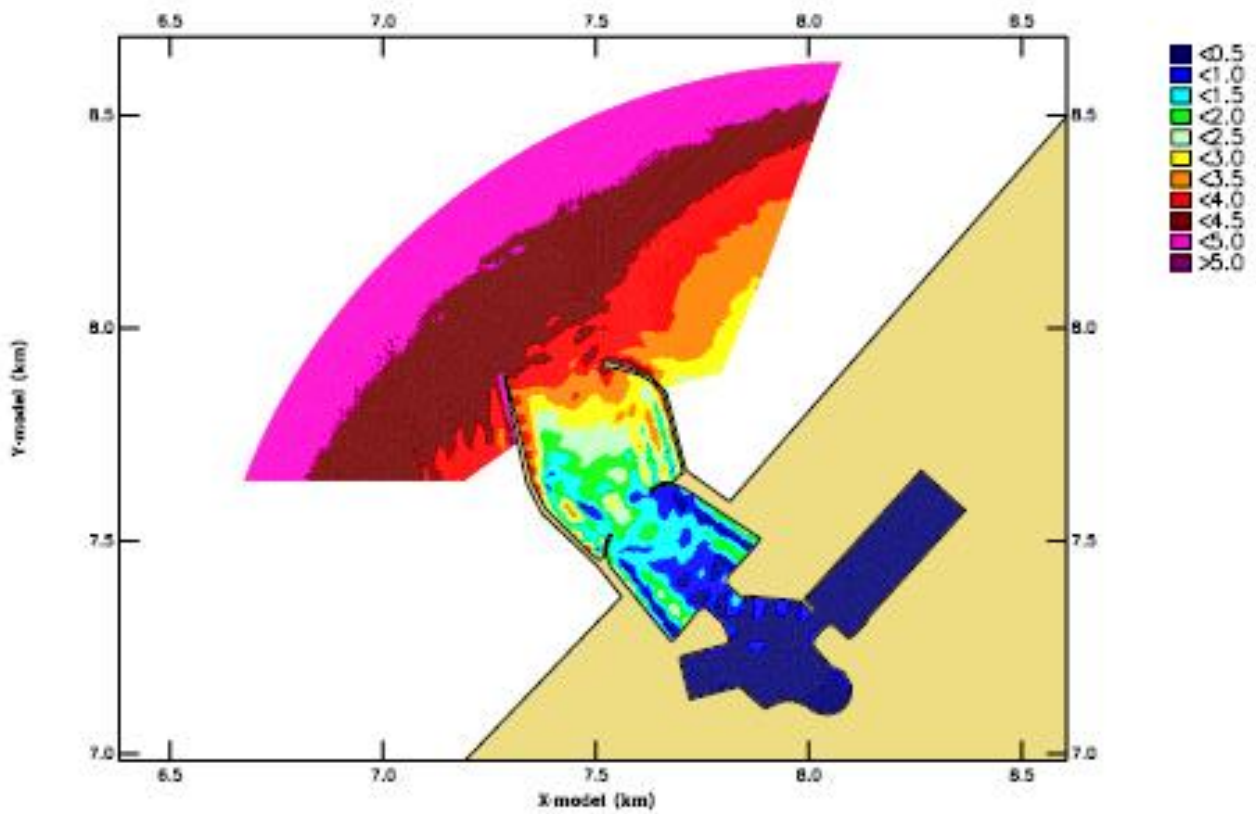


Figure 58. Significant wave height for Deltares Case 6. Source: Deltares, 2006.

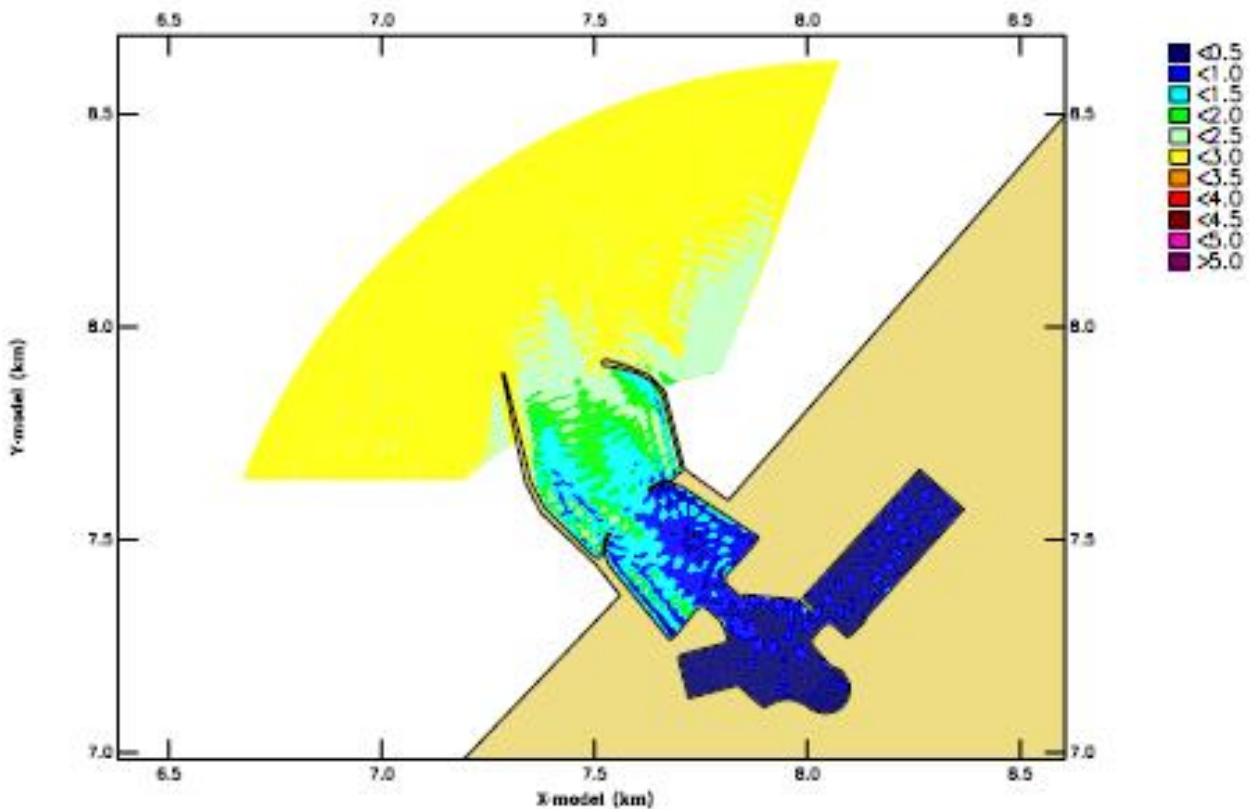


Figure 59. Significant wave height for Deltares Case 7. Source: Deltares, 2006.

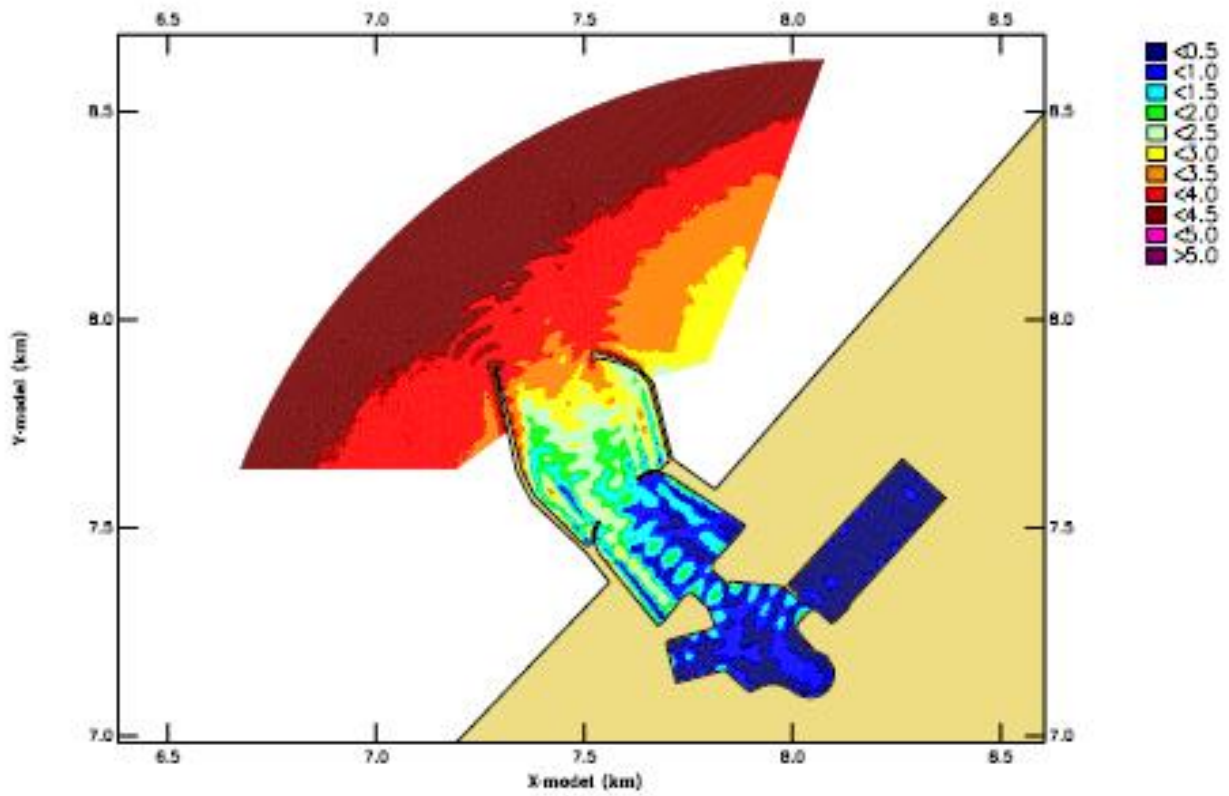


Figure 60. Significant wave height for Deltares Case 8. Source: Deltares, 2006.

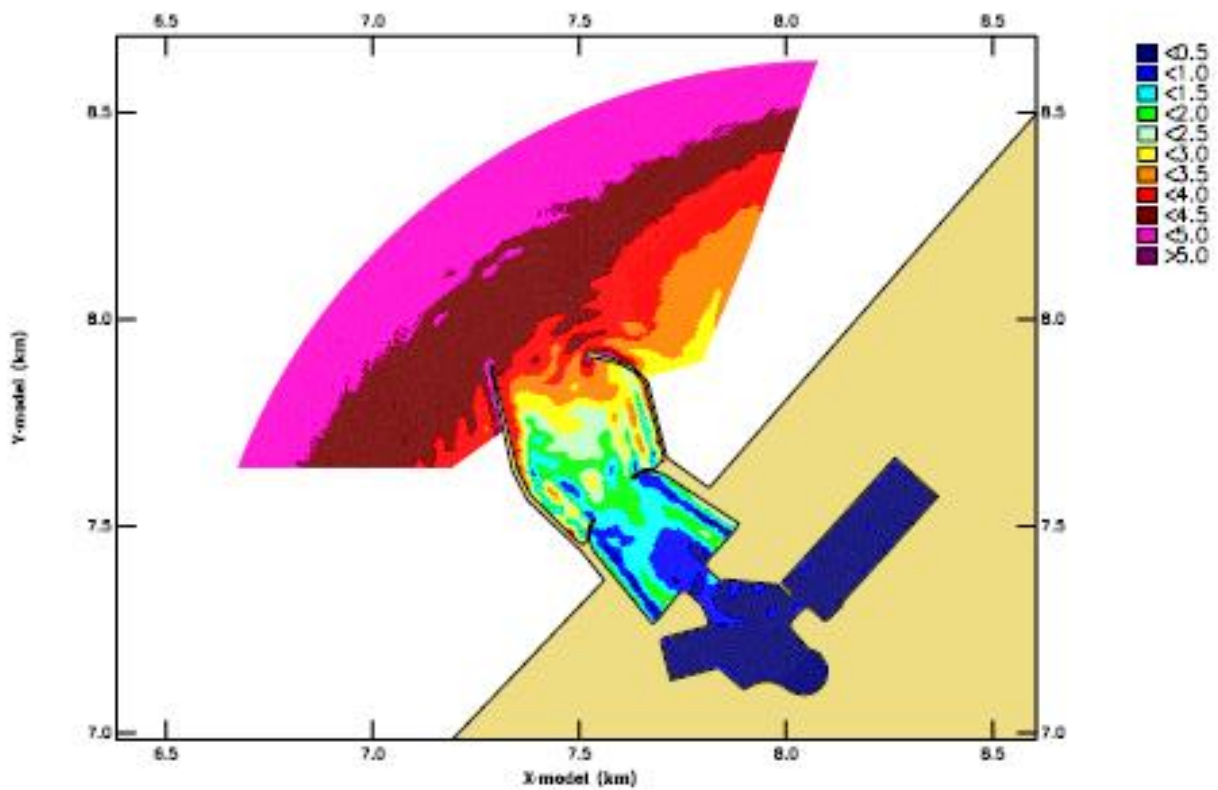


Figure 61. Significant wave height for Deltares Case 9. Source: Deltares, 2006.

The figures above show that:

- A significant amount of energy dissipation is found mainly in the outer harbour (“Buitenhaven”).
- In the Scheveningen future 4th harbour, significant wave heights are hardly higher than 1 m. For every scenario visual estimates of the significant wave height were taken both outside and in this new Scheveningen future 4th harbour, as shown in Table 26.
- There is no clear evidence that the dissipative beach in the Scheveningen future 4th harbour really dissipates significant amounts of energy. The waves do not seem to always go towards this beach, but also refracts towards Scheveningen 1st harbour.

As already explained, the current study obtained a time series of 23 years of wave data outside Scheveningen Harbour, in the same point as the one used by Deltares (at 52.11°N, 4.25° W). In order to derive the wave conditions in the new marina region, the significant wave height at this point was multiplied for every wave condition by the factors shown in Table 27, depending on the incoming wave direction. This table was elaborated by using Deltares results (see Table 26), and by assuming that the directions not simulated by Deltares would result in lower wave heights.

Table 27. Wave height factor as a function of incoming wave direction.

<i>Wave direction</i>		<i>Factor</i>
Dm (°N)_min	Dm (°N)_max	Hs_in/Hs_out
345	360	0.2
330	345	0.2
315	330	0.2
300	315	0.2
285	300	0.2
270	285	0.15
255	270	0.1
240	255	0.05
45	240	0
30	45	0.1
15	30	0.15
0	15	0.2

The peak wave period was assumed to be the same as outside Scheveningen Harbour and the wave directions were not derived.

This methodology to obtain the waves inside Scheveningen Harbour is limited, and thus a numerical wave modelling study is recommended for the further phases of this project, considering different combinations of wave heights, periods and direction, together with distinct water levels.

6.2. Operational wave climate

Table 28 shows the wave statistics at Scheveningen 4th harbour. The average significant wave height is 15 cm for the whole year, while from May to September it reduces to 13 cm. The wavelength (calculated with the peak wave period and the depth) is approximately 52 m for the whole year, and while it is 48 m from May to September.

Table 28. Wave statistics at Scheveningen 4th harbour.

Statistics - Scheveningen Harbour			
	Variable	Value	Unit
Whole year	μ_{Hs}	0.15	m
	μ_{Tp}	6.75	s
	μ_L	52.03	m
From May to September	μ_{Hs}	0.13	m
	μ_{Tp}	6.33	s
	μ_L	48.05	m

Table 10 presents the cross tables of significant wave height and peak wave period at Scheveningen 4th harbour. In general, the highest waves (0.6 – 0.8 m) have a peak wave period of between 10 and 15 s.

Table 29. Significant wave height x peak wave period at Scheveningen 4th harbour from 1992 to 2014 according to SWAN results and wave height factors.

Scheveningen_harbour	Tp (s)					
	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	Total
Hs (m)						
0 - 0.2	23.02%	44.90%	6.54%	0.72%	0.09%	75.26%
0.2 - 0.4	0.22%	17.90%	2.05%	0.10%	0.00%	20.27%
0.4 - 0.6	0.00%	2.89%	0.81%	0.02%	0.00%	3.72%
0.6 - 0.8	0.00%	0.27%	0.47%	0.01%	0.00%	0.74%
Total	23.25%	65.96%	9.87%	0.83%	0.09%	100.00%

Figure 24 shows the monthly histogram of the wave conditions at Scheveningen 4th Harbour. At it can be seen, the significant wave heights higher than 20 cm have a probability of occurrence lower than 20% from May to August.

6.3. Extreme wave climate

6.3.1. Extreme wave climate for the whole year

The extreme waves were evaluated through a POT (peak over threshold) analysis of storms – therefore a storm ranking was obtained by considering waves higher than 50 cm, and 6 hours as minimum distance between independent events (see Table 30– please notice that only 40 storms are presented, although 231 storms were obtained, giving an average of 10 storms per year).

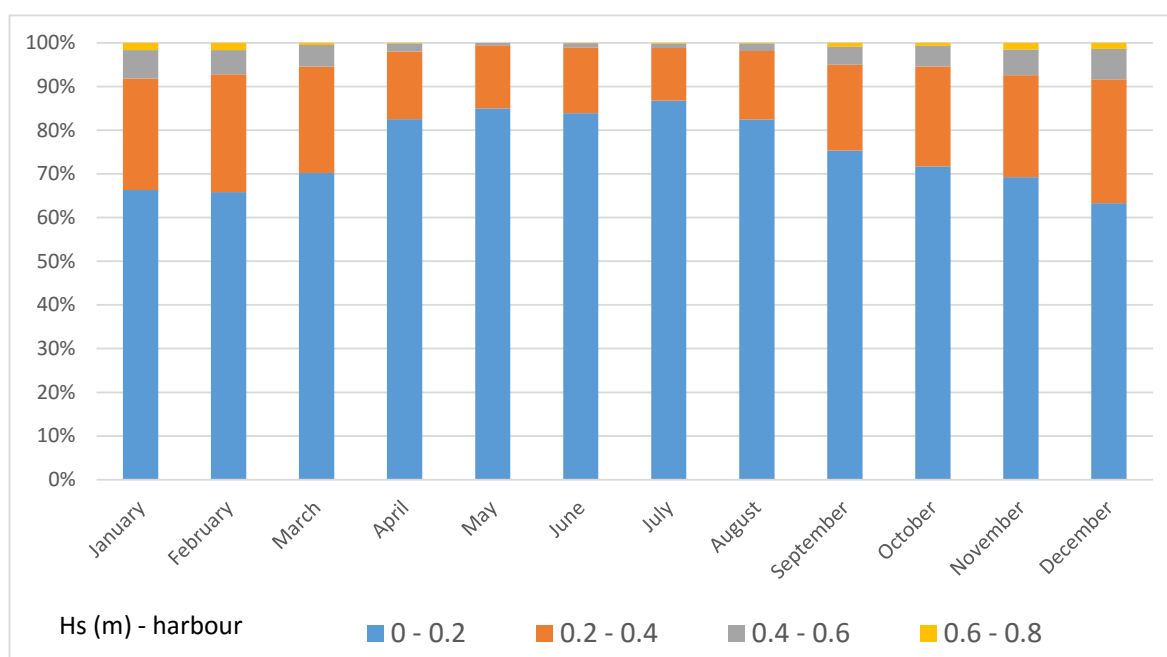


Figure 62. Monthly histogram – significant wave height at Scheveningen 4th harbour from 1992 to 2014 according to SWAN results and wave height factors.

Table 30. Scheveningen 4th harbour wave ranking according to SWAN results and wave height factors.

Storm Ranking - Hs > 0.5 m, From 1/4/1992 to 12/31/2014 9:00:00 PM - Scheveningen_50cm								
Ranking	Date start	Date end	Date peak	Hs (m)	Tp (s)	Wind-mag (m/s)	Wind-dir (°N)	Duration (h)
1	1/28/94 0:00	1/29/94 3:00	1/28/94 12:00	0.74	12.28	20.40	302.00	30
2	1/24/93 12:00	1/26/93 0:00	1/25/93 9:00	0.74	11.16	19.40	304.00	39
3	11/14/93 15:00	11/15/93 12:00	11/14/93 21:00	0.74	12.28	21.00	338.00	24
4	2/20/93 21:00	2/22/93 6:00	2/21/93 9:00	0.74	14.85	20.00	334.00	36
5	12/9/93 0:00	12/9/93 21:00	12/9/93 12:00	0.73	11.16	23.20	270.00	24
6	10/31/06 15:00	11/1/06 18:00	11/1/06 9:00	0.73	13.50	17.80	338.00	30
7	11/24/05 21:00	11/25/05 18:00	11/25/05 6:00	0.72	11.16	18.80	310.00	24
8	11/8/07 21:00	11/10/07 12:00	11/9/07 9:00	0.72	12.28	17.40	326.00	42
9	1/5/12 6:00	1/6/12 12:00	1/6/12 0:00	0.72	11.16	19.60	322.00	33

10	1/1/95 3:00	1/2/95 18:00	1/2/95 9:00	0.72	16.34	15.60	344.00	42
11	9/16/94 3:00	9/17/94 18:00	9/16/94 15:00	0.72	13.50	16.20	314.00	42
12	1/11/95 9:00	1/12/95 15:00	1/12/95 6:00	0.72	13.50	18.20	348.00	33
13	12/5/13 15:00	12/7/13 0:00	12/6/13 0:00	0.71	11.16	17.60	300.00	36
14	2/12/05 12:00	2/14/05 21:00	2/14/05 12:00	0.70	12.28	17.20	332.00	60
15	12/16/05 3:00	12/17/05 21:00	12/17/05 12:00	0.70	12.28	17.00	340.00	45
16	12/7/11 9:00	12/8/11 3:00	12/7/11 21:00	0.70	10.15	18.60	290.00	21
17	11/20/08 15:00	11/22/08 15:00	11/21/08 12:00	0.70	11.16	17.40	332.00	51
18	1/9/95 21:00	1/10/95 15:00	1/10/95 9:00	0.70	12.28	14.40	306.00	21
19	10/27/02 12:00	10/28/02 9:00	10/27/02 18:00	0.70	10.15	22.40	294.00	24
20	10/6/03 18:00	10/8/03 6:00	10/7/03 21:00	0.70	11.16	17.20	320.00	39
21	12/28/01 12:00	12/29/01 0:00	12/28/01 18:00	0.69	10.15	19.40	284.00	15
22	2/19/93 3:00	2/20/93 6:00	2/19/93 18:00	0.69	12.28	15.40	328.00	30
23	3/16/94 12:00	3/17/94 18:00	3/17/94 6:00	0.69	10.15	18.20	290.00	33
24	2/8/04 3:00	2/9/04 9:00	2/8/04 21:00	0.69	10.15	17.40	326.00	33
25	10/21/14 15:00	10/22/14 15:00	10/22/14 3:00	0.69	10.15	17.00	316.00	27
26	10/29/96 6:00	10/30/96 3:00	10/29/96 18:00	0.69	10.15	16.20	316.00	24
27	1/19/98 12:00	1/20/98 12:00	1/20/98 6:00	0.69	12.28	17.00	356.00	27
28	1/18/07 15:00	1/19/07 12:00	1/18/07 18:00	0.68	10.15	22.60	270.00	24
29	2/8/06 12:00	2/10/06 3:00	2/9/06 18:00	0.68	13.50	15.80	336.00	42
30	2/5/99 0:00	2/6/99 9:00	2/5/99 12:00	0.68	11.16	15.20	310.00	36
31	12/21/03 6:00	12/22/03 15:00	12/21/03 15:00	0.68	10.15	15.60	314.00	36
32	1/20/05 9:00	1/22/05 6:00	1/21/05 6:00	0.68	10.15	17.00	308.00	48
33	12/29/11 6:00	12/30/11 12:00	12/30/11 3:00	0.68	10.15	16.80	306.00	33
34	2/22/99 0:00	2/23/99 9:00	2/23/99 0:00	0.68	10.15	16.20	316.00	36
35	11/6/99 12:00	11/7/99 6:00	11/6/99 18:00	0.68	10.15	16.60	292.00	21
36	11/11/06 15:00	11/12/06 15:00	11/12/06 6:00	0.67	10.15	16.40	316.00	27
37	12/14/03 3:00	12/16/03 0:00	12/15/03 12:00	0.67	13.50	15.40	330.00	48
38	9/16/98 18:00	9/17/98 12:00	9/17/98 3:00	0.67	10.15	15.00	320.00	21
39	12/9/12 12:00	12/10/12 9:00	12/10/12 3:00	0.67	11.16	15.40	332.00	24
40	2/16/99 9:00	2/17/99 18:00	2/17/99 6:00	0.67	10.15	16.00	318.00	36

The storms show that:

- Most of the extreme conditions relate waves with a peak wave period higher than 10 s.
- The duration of the 40 most severe storms varies between 15 h and 60 h.
- The maximum significant wave height was found to be of 74 cm, and it occurred 4 times in 23 years.
- The wind magnitude during storm peaks varies between 15 and 23 m/s, while its direction ranges from 270 and 356°N. This means that the highest wave heights inside Scheveningen Harbour occurs simultaneously with strong winds from Northwest.

In order to obtain the extreme conditions, Goda (1988) method was applied by fitting the 40 highest significant wave height peaks (shown in Table 30) in 4 curves: FT-I distribution, and Weibull with 3

different coefficients. After comparing the results (Figure 63), the best fitting was obtained to the Weibull curve with $k = 2$ (Goda, 1988, equation 10), so these results were retained to the calculation (Figure 64).

The wave heights and periods for different return periods are presented in Table 31. The wave periods for the corresponding significant wave heights were determined through a scatter distribution between them (Figure 65), and an average condition between the offshore wave steepness of 0.002 and 0.005 was considered.

The significant wave heights at Scheveningen 4th harbour for the return periods from of 1 year to 1000 years vary from 70 to 80 cm, approximately, with a range of only 10 cm. The associated wave periods range from 11 to 12 s.

It is expected that these extreme wave heights will occur simultaneously with the extreme water levels as a result of storm surges, as both may be originated from Northwest wind systems.

It is important to remark that the rule of thumb (Goda, 1988) is to use at least one third of the desired return period to properly estimate the extreme wave height. However, only 23 y of wave data were used, so the degree of uncertainty of return periods higher than 70 y increases significantly.

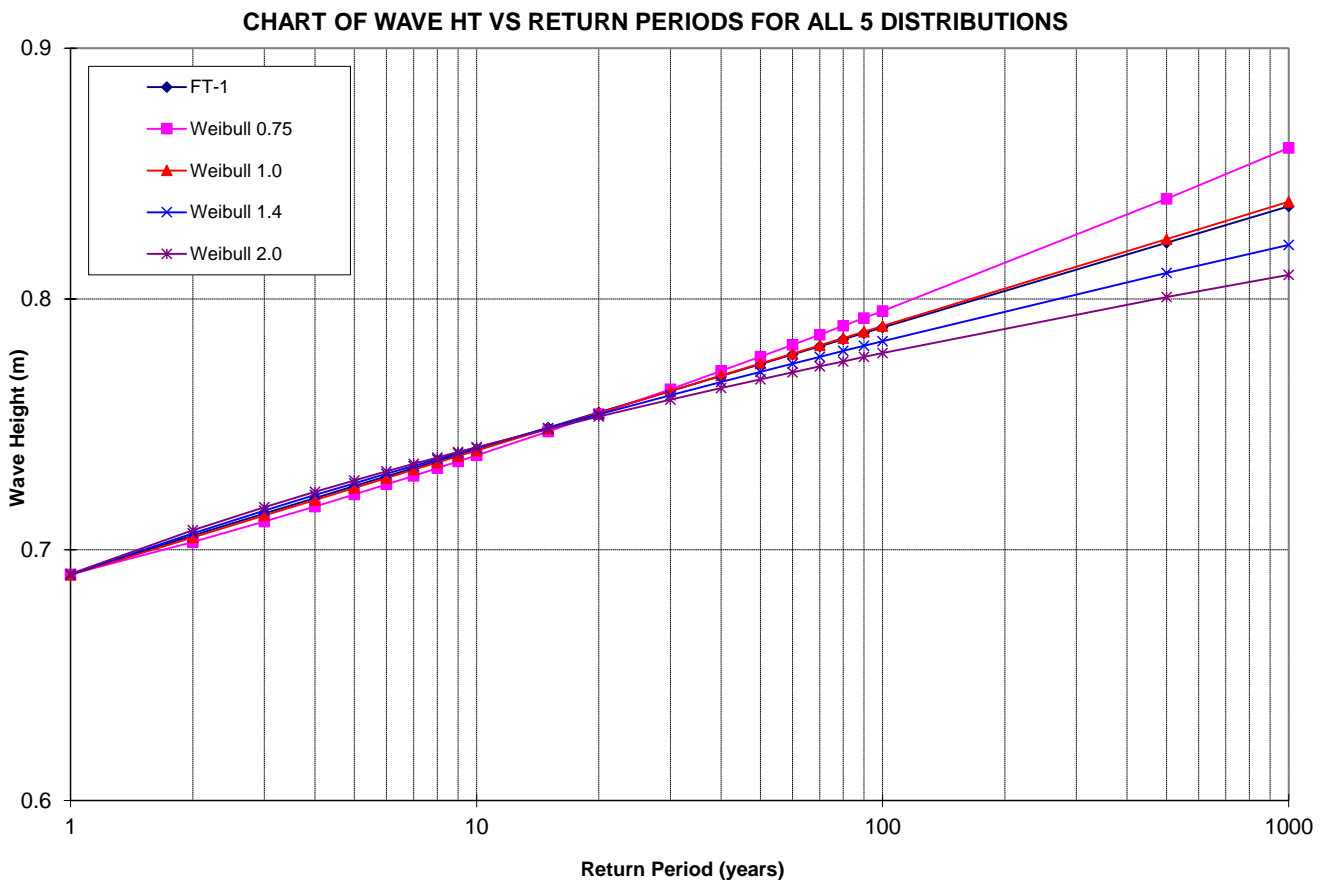


Figure 63. Chart of wave height versus return periods for all 5 distributions.

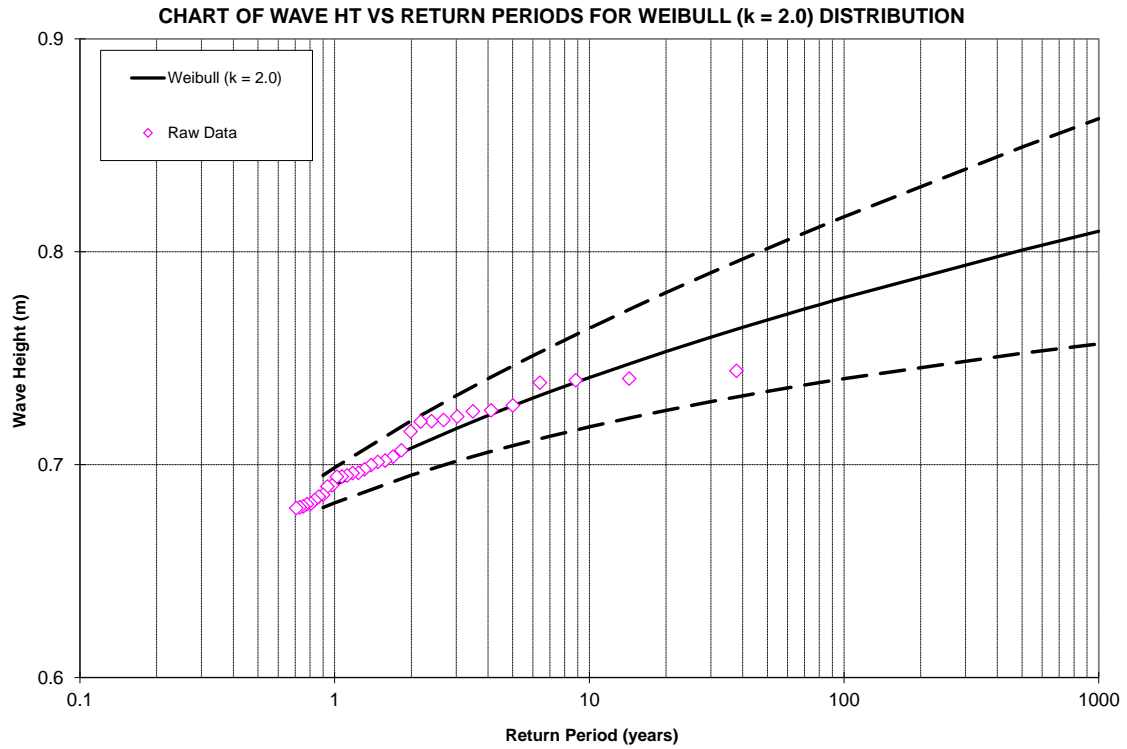


Figure 64. Chart of wave height versus return periods for Weibull ($k=2.0$) distribution.

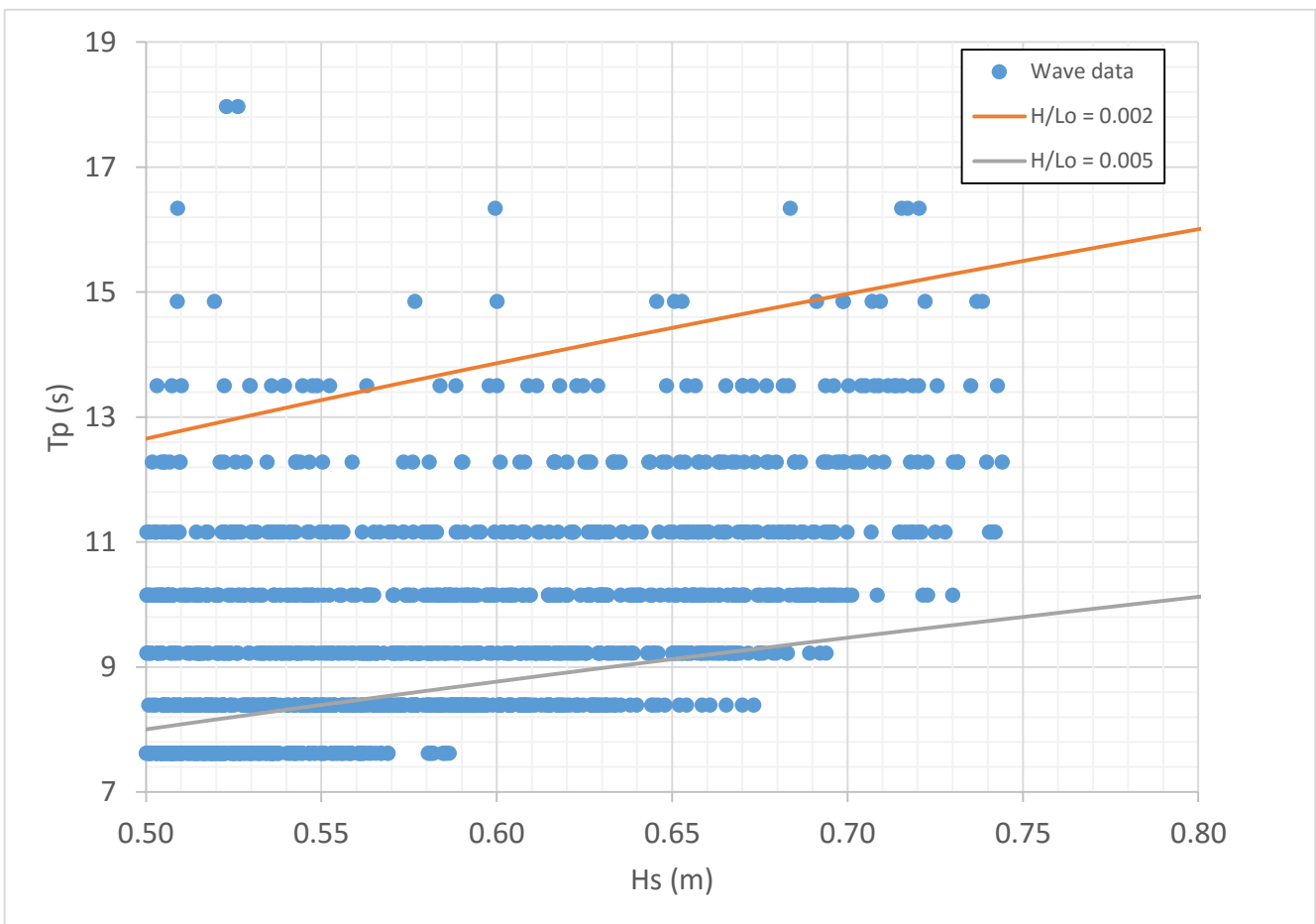


Figure 65. Distribution of significant wave height and peak wave period.

Table 31. Extreme wave analysis

Weibull (2.0)		
Return period (y)	Hs (m)	Tp (s)
1	0.69	11.23
5	0.73	11.56
10	0.74	11.64
20	0.75	11.72
50	0.77	11.87
100	0.78	11.95
500	0.80	12.10
1000	0.81	12.18

6.3.2. Extreme wave climate from May to September

Another extreme analysis was carried out for the period between May to September, as this time window can be considered for the breakwater construction. The previous storm definition was used, and the results are shown in Table 32.

Table 32. Scheveningen 4th harbour wave ranking from May to September according to SWAN results and wave height factors.

Storm Ranking - Hs > 0.5 m, From 5/1/1992 to 9/30/2014 9:00:00 PM - Scheveningen_50cm_summer								
Ranking	Date start	Date end	Date peak	Hs (m)	Tp (s)	Wind-mag (m/s)	Wind-dir (°N)	Duration (h)
1	9/16/94 3:00	9/17/94 18:00	9/16/94 15:00	0.72	13.50	16.20	314.00	42
2	9/16/98 18:00	9/17/98 12:00	9/17/98 3:00	0.67	10.15	15.00	320.00	21
3	7/21/08 3:00	7/21/08 18:00	7/21/08 12:00	0.67	11.16	16.60	312.00	18
4	9/8/01 0:00	9/10/01 21:00	9/9/01 6:00	0.66	10.15	16.00	324.00	72
5	9/14/98 9:00	9/15/98 9:00	9/15/98 0:00	0.66	10.15	16.00	312.00	27
6	8/29/10 18:00	8/30/10 12:00	8/30/10 0:00	0.66	9.22	17.40	340.00	21
7	7/23/11 18:00	7/24/11 18:00	7/24/11 6:00	0.66	11.16	17.20	296.00	27
8	9/12/96 15:00	9/13/96 18:00	9/12/96 21:00	0.65	11.16	14.40	344.00	30
9	7/14/11 9:00	7/15/11 0:00	7/14/11 18:00	0.65	10.15	17.20	312.00	18
10	9/4/01 15:00	9/5/01 3:00	9/4/01 18:00	0.64	10.15	15.20	332.00	15
11	6/26/07 9:00	6/27/07 3:00	6/26/07 15:00	0.64	10.15	15.00	302.00	21
12	8/6/93 0:00	8/6/93 9:00	8/6/93 3:00	0.63	9.22	16.20	292.00	12
13	9/27/95 18:00	9/28/95 9:00	9/28/95 3:00	0.63	10.15	13.60	308.00	18
14	9/10/13 18:00	9/11/13 0:00	9/10/13 21:00	0.62	9.22	14.20	334.00	9
15	8/28/95 0:00	8/28/95 21:00	8/28/95 6:00	0.62	10.15	14.60	358.00	24
16	9/21/04 0:00	9/22/04 9:00	9/21/04 9:00	0.62	8.39	16.00	282.00	36
17	6/2/01 18:00	6/3/01 15:00	6/3/01 6:00	0.61	10.15	14.00	328.00	24
18	9/26/93 9:00	9/26/93 21:00	9/26/93 18:00	0.61	10.15	14.40	320.00	15
19	9/23/04 18:00	9/24/04 21:00	9/24/04 6:00	0.60	10.15	13.80	322.00	30

20	9/4/09 18:00	9/5/09 3:00	9/4/09 21:00	0.59	8.39	15.20	286.00	12
21	9/10/07 18:00	9/11/07 3:00	9/11/07 0:00	0.58	10.15	13.00	342.00	12
22	7/11/00 6:00	7/11/00 18:00	7/11/00 9:00	0.58	9.22	13.00	324.00	15
23	8/12/94 9:00	8/12/94 15:00	8/12/94 12:00	0.56	9.22	14.00	292.00	9
24	8/31/12 6:00	8/31/12 12:00	8/31/12 9:00	0.54	8.39	14.40	352.00	9
25	7/9/14 15:00	7/10/14 0:00	7/9/14 18:00	0.54	8.39	14.40	340.00	12
26	9/4/09 0:00	9/4/09 0:00	9/4/09 0:00	0.54	8.39	15.80	262.00	3
27	7/25/96 0:00	7/25/96 3:00	7/25/96 0:00	0.54	8.39	13.00	312.00	6
28	9/25/10 15:00	9/25/10 21:00	9/25/10 18:00	0.53	12.28	11.60	338.00	9
29	9/7/00 0:00	9/7/00 0:00	9/7/00 0:00	0.53	8.39	13.60	304.00	3
30	6/19/10 18:00	6/20/10 0:00	6/19/10 21:00	0.53	12.28	12.40	342.00	9
31	7/24/07 9:00	7/24/07 9:00	7/24/07 9:00	0.52	8.39	13.80	332.00	3
32	8/18/94 6:00	8/18/94 6:00	8/18/94 6:00	0.52	7.62	14.60	304.00	3
33	6/9/95 0:00	6/9/95 6:00	6/9/95 3:00	0.51	10.15	11.80	284.00	9
34	9/15/10 18:00	9/15/10 18:00	9/15/10 18:00	0.51	7.62	14.60	274.00	3
35	8/9/11 15:00	8/9/11 15:00	8/9/11 15:00	0.50	10.15	11.80	314.00	3

Table 32 shows that:

- 35 storms were found with a peak of significant wave height of more than 50 cm. This is equivalent to an average of 1.5 storm per year.
- Most of these storms occur in September.
- Wind magnitudes vary from 11 to 17 m/s, while all the directions come from the Northwest quadrant
- Peak wave period from 7 to 14 s occur during the storm peaks.
- The duration of the storms varies between 3 and 40 h.
- In general, as expected, less stormy conditions occur from May to September.

7. Downtime estimate

7.1. Situation without new breakwater

Two metocean criteria from ROM ('Recomendaciones de Obras Marítimas') were considered for the downtime analysis:

- Maximum significant wave height = 20 cm; and
- Maximum wind magnitude = 22 m/s.

With the wave conditions obtained at Scheveningen 4th harbour, the downtime estimate due to waves and winds were calculated (see Table 32).

Table 33. Downtime calculation – for the situation without a new breakwater.

Situation without new breakwater			
Criteria	Description	Downtime - whole year	Downtime - from May to September
1	Hs > 0.2 m	24.74%	7.23%
2	Wmag > 22 m/s	0.04%	0.00%
1 or 2	Hs > 0.2 m or Wmag > 22 m/s	24.74%	7.23%

Table 33 shows that:

- A permanent marina in the Scheveningen 4th harbour without a new breakwater could operate only 75% of the time, mainly due to the wave conditions.
- A seasonal marina (from May to September) in the Scheveningen 4th harbour without a new breakwater could operate 93% of the time, only due to the wave conditions.

By considering that 95% of the time is the desired operation time of a new seasonal marina, it can be concluded that a new breakwater is needed aiming to reduce the wave heights and guarantee sufficiently mild conditions to the marina.

7.2. Situation with the new breakwater

A sketch of the breakwater and new marina layout is shown in Figure 66. In order to estimate the wave height inside the marina basin, a quick calculation was made of the wave attenuation (actual wave height over incoming wave height) with Wiegel (1962) diffraction diagrams with an average wavelength of 50 m, shown in Figure 67.

Three wave attenuation coefficients presented in Figure 67: 0.30, 0.20 and 0.13. This means the incoming wave times each of these coefficients provide the wave height inside the port basin. With the incoming waves presented in Chapter 6.2, the wave statistics and downtime were calculated.

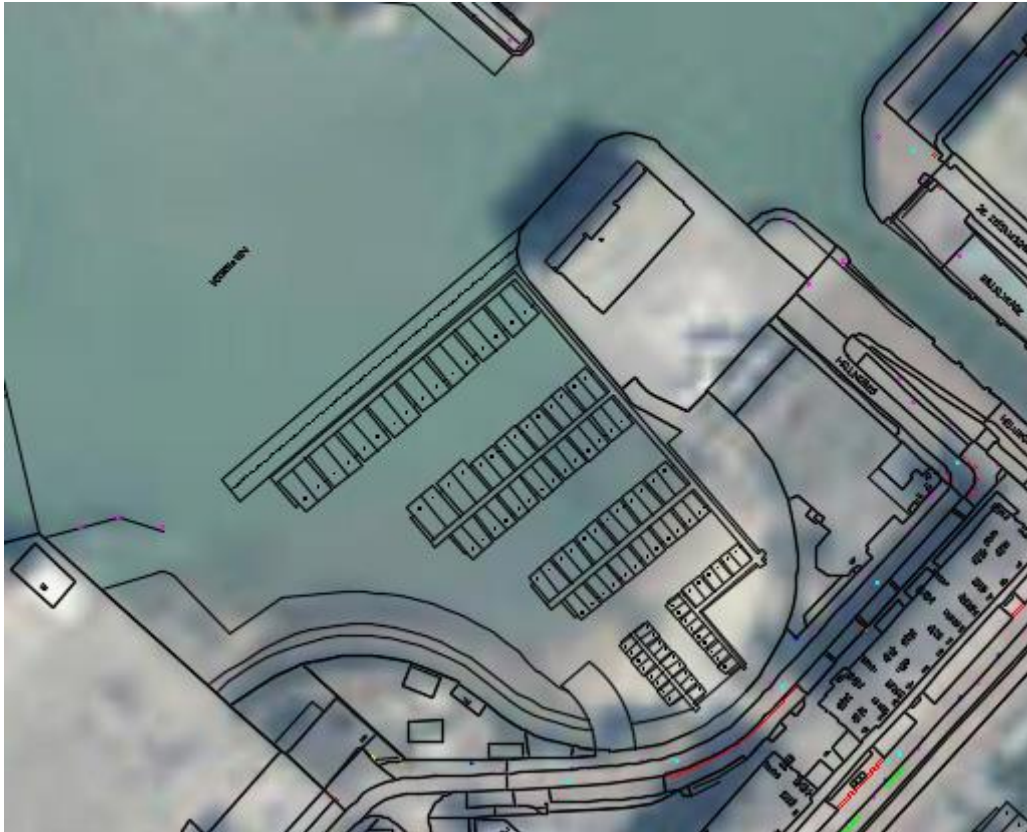


Figure 66. New marina and breakwater layout



Figure 67. Wave attenuation – Wiegel (1964) diagram for a wave with angle of 15° with perpendicular to breakwater. The red lines represent the wave attenuation coefficients, while the blue lines are the incoming wave crests and ray.

Table 34 and Table 35 summarize the wave statistics at Scheveningen 4th harbour with a new breakwater, assuming the two wave attenuation coefficients of 0.3 and 0.2, respectively. In average, waves lower than 10 cm are found throughout the year.

Table 34. Wave statistics at Scheveningen 4th harbour with a new breakwater (0.3 coefficient).

Statistics - Scheveningen Harbour with breakwater (0.3 coefficient)			
	Variable	Value	Unit
Whole year	μ_{Hs}	0.04	m
	μ_{Tp}	6.75	s
	μ_L	52.03	m
From May to September	μ_{Hs}	0.04	m
	μ_{Tp}	6.33	s
	μ_L	48.05	m

Table 35. Wave statistics at Scheveningen 4th harbour with a new breakwater (0.2 coefficient).

Statistics - Scheveningen Harbour with breakwater (0.2 coefficient)			
	Variable	Value	Unit
Whole year	μ_{Hs}	0.03	m
	μ_{Tp}	6.75	s
	μ_L	52.03	m
From May to September	μ_{Hs}	0.03	m
	μ_{Tp}	6.33	s
	μ_L	48.05	m

The downtime estimate at Scheveningen 4th harbour with a new breakwater is presented in Table 36 and Table 37. The former shows the downtime for 95% of the berths, namely, all berths situated in the wave attenuation coefficient of 0.20 or lower according to Figure 67, while Table 37 presents it for the remainder berths.

Table 36. Downtime calculation – for the situation with a new breakwater for 95% of the berths.

Situation with new breakwater - 95% of berths in New Marina			
Criteria	Description	Downtime - whole year	Downtime - from May to September
1	$H_s > 0.2$ m	0.00%	0.00%
2	$W_{mag} > 22$ m/s	0.04%	0.00%
1 or 2	$H_s > 0.2$ m or $W_{mag} > 22$ m/s	0.04%	0.00%

Table 37. Downtime calculation – for the situation with a new breakwater for 5% of the berths.

Situation with new breakwater - 5% of berths in New Marina			
Criteria	Description	Downtime - whole year	Downtime - from May to September
1	Hs > 0.2 m	0.26%	0.01%
2	Wmag > 22 m/s	0.04%	0.00%
1 or 2	Hs > 0.2 m or Wmag > 22 m/s	0.29%	0.01%

The breakwater reduces significantly the downtime due to waves. As for the 5 berths closest to the tip of breakwater, a downtime of 0.26% during the whole year was found, that is to say, 23 hours per year, while in the summer a downtime of only around 1 h per year was calculated. Regarding the remainder 95 berths, no downtime due to waves was estimated.

8. Impact of the breakwater in the hydrodynamics of Scheveningen Harbour

The breakwater presented in Figure 66 is a new hard-structure, with potential to influence the hydrodynamics inside Scheveningen Harbour.

Deltares (2006) studied the wave conditions with a numerical model, and it was shown that the dissipation of the incoming waves is concentrated in the outer harbour.

Although the energy dissipation in the new 4th Harbour does not look significant for the current conditions, it can be expected that the low incoming waves will reflect in the new breakwater, and standing wave patterns may be created, with potential to disturb the navigation. This is valid both for short waves and for longer waves, namely, the enhancement of conditions for the development of seiches can be a consequence of the new breakwater construction.

In order to properly estimate the effects of the breakwater in the local hydrodynamics, it is recommended that a new numerical wave modelling study to be performed, considering the presence of the breakwater and with different combinations of wave heights, periods, directions, and water levels. Also a hydrodynamics model should be run regarding the investigation of seiches for different wind conditions.

9. Limitations and recommendation for next studies

This metocean study was based on a few simplifying assumptions, which may impact on the degree of reliability of the calculated design conditions. The uncertainties/risk related to them are briefly treated below.

As no measured wave data were available inside Scheveningen Harbour, wave modelling was carried out to determine the nearshore wave conditions which resulted in the design conditions.

- Firstly, the offshore wave and data were assumed to be sufficiently calibrated, which not necessarily is true. No specific information about the calibration or comparison with measured offshore wave data was available.
- Besides, a onedimensional wave modelling method has been applied, which assumes straight and parallel depth contours. This means that two-dimensional effects were not considered, although the grid length is of only 10 km.
- A constant water level was assumed in SWAN. Higher and lower water level have the potential to change the results, although no relevant changes would be expected to a depth of -10 m NAP, where the model output is located.
- The simulated wave data were not calibrated with measured data in the nearshore zone. Deltares input data have approximately the same extreme wave heights for the same SWAN output location., but any comparison with any measured data was carried out.
- In order to propagate the nearshore data into Scheveningen Harbour, wave height factors depending on the direction were found based on Deltares study with a numerical wave agitation model. This is a simplified method, appropriate for this conceptual phase of the project, but it must be revisited in the next phases of the design.
- As for the wave conditions inside Scheveningen 4th Harbour, a diffraction diagram was used to estimate the waves inside the Marina basin with the new breakwater. This method is simplified with high degree of uncertainty.
- The extreme wave analysis was conducted with 23 years of wave data, which is enough for return periods of up to 70 years. In case higher return periods are desired, more years of wave data are needed.
- Finally, the water level and the wave data were not studied together, namely, the water level and wave heights were qualitatively assumed to be correlated, but no mathematical functions were defined. This is especially important for coastal structures design, such as breakwater, whose design depend upon the knowledge of the combination of water levels and wave heights.

For the further phases of the projects, the following recommendations should be performed:

- Calibration of offshore wave data, possibly with wave data from satellite images.
- The wave propagation modelling should be performed in a 2D mode to properly take into account the local bathymetry.
- Wave measurement in a depth of around 15-20 m is recommended for at least a winter season in order to calibrate the nearshore model for at least extreme events.

- In order to increase the number of years of wave data, hindcast wave modelling should be performed with offshore wave models, such as WaveWatch III or WAM, by using historic measured/simulated wind data.
- A wave agitation modelling using phase solving models should be carried out by considering different sets of wave heights, periods, direction and water levels. This would result in a more refined wave height transformation matrix to transfer the nearshore time series to the Scheveningen 4th Harbour.
- This wave agitation modelling should also include the presence of the new breakwater in order to properly obtain the wave conditions inside Scheveningen 4th Harbour.
- The correlation of water levels and waves could be investigated with a mathematical study of measured wave and water level data.

Annex 9 – Multi-criteria analysis for breakwater solution concept

- Very important criteria:
 - Transmitted wave: The main function of the breakwater is to generate a shallow area protected enough to allow a safe mooring of the ships.
 - Both Caisson breakwater and composite one will be rated with highest grade due because they are solid structures that will only allow transmitted wave by the entrance of the marina.
 - The floating breakwater will have a lower rate because it allows some transmitted wave bellow the structure.
 - Overtopping: The overtopping is a very important criteria for the safety of the users and the moored ships.
 - The overtopping at the solid structures will be relatively easy to control increasing the high and the roughness parameters of the structures.
 - The floating will not protect the overtopping in a really effective way for the highest incoming waves.
 - Visual impact: A marina placed in Scheveningen Harbour has to be integrated of the area and a lower visual impact is very important for the attractive of the area.
 - The floating breakwater will cause a minimal visual impact because the structure can be used as a floating platoon integrated in the area.
 - The caisson will cause a higher impact due to the presence of a high structure in front of the marina. However, a path can be included at the top of the structure for pedestrians.
 - The composite breakwater has similar characteristics as the caisson but a lower rate due to be presences of the rubble mound at the sea side.

- Important criteria:
 - Reflected wave: As has been explained before, for the situation of the forth harbour the reflected wave has to be considered as it will be reflected to the main navigation channel of the harbour.
 - The floating breakwater does not dissipate energy, thus all the energy that is not transmitted will be reflected.
 - The dissipative caisson will reduce the reflected wave comparing to a vertical wall but will still generate some.

- The composite breakwater will lead to the lowest reflected wave due to the dissipation at the permeable rubble layer.
 - Size: The mooring capacity and the integration of the breakwater will be related to a structure as small as possible.
 - The floating breakwater is the smallest structure and will lead to a higher mooring capacity.
 - The caisson is a bigger structure but narrower than the composite breakwater.
 - The composite breakwater is the widest structure and needs a higher space than the other structures.
 - Flexibility: Considering the wave climate of the area a wide range of waves are expected on the harbour. Thus, flexibility for different waves should be evaluated.
 - The performance of the floating breakwater is related to the ratio between the wave length and the width of the breakwater. Thus, it has a small flexibility for different incoming waves.
 - The dissipative rate of the caisson is almost null, for any range of wave. However, its performance is not really associated to a determinate wave climate
 - The composite breakwater reflection coefficient is also related to the wave characteristics, but it shows a smaller variability for different wave lengths.
- Considered criteria:
 - Construction time: Due to the importance and the popularity of Scheveningen Harbour a short construction time will be optimal.
 - The floating breakwater is a prefabricated structure with a short construction time at the site.
 - The caisson is also a prefabricated structure but it needs a higher site preparation than the floating one, leading to a higher construction time.
 - The composite breakwater is an in situ built structure and thus the construction time will be the highest one.
 - Material availability: In order to reduce the cost of the structure, the availability of the construction material should be considered.
 - The floating breakwater is made by construction materials available in the Netherlands.
 - The caisson is made by concrete but it needs some stones for the base of the structure.

- The composite breakwater is built using stones that are not available in the Netherlands. However, depending of the price, the option of using concrete block can be evaluated.
- Maintenance costs: The cost of the maintenance of the structure is always a criteria to take into account.
 - The dynamic structure of the floating breakwater requires a high rate of maintenance costs.
 - The caissons requires low maintenance costs because it is a solid structure.
 - The composite breakwater has also low maintenance costs, but the armour layer will need a periodical revision and maintenance.

Reflection Analysis

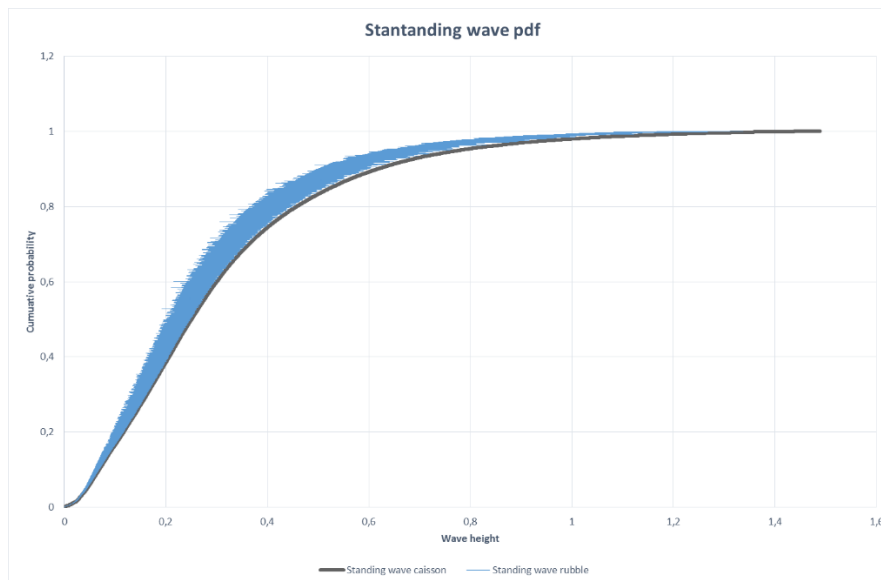


Figure 6.1: Reflected wave pdf

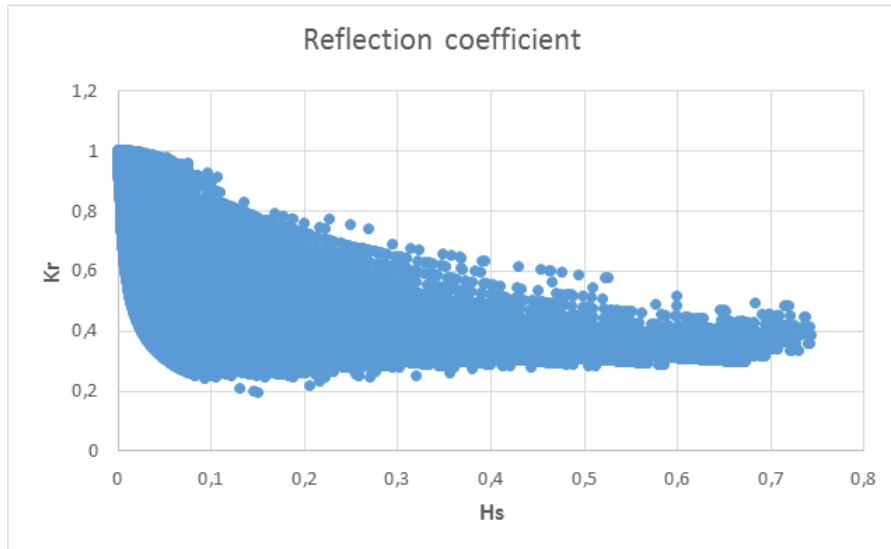


Figure 6.2: Reflection coefficient for 1:4

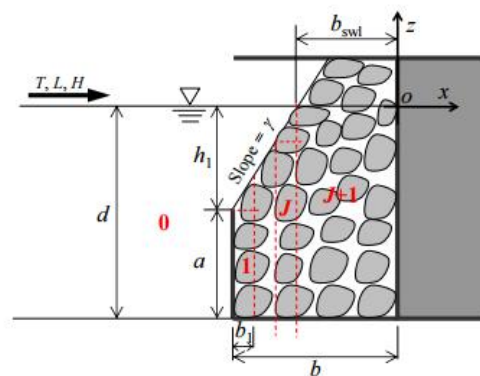


Figure 6.3: Caisson with internal rubble

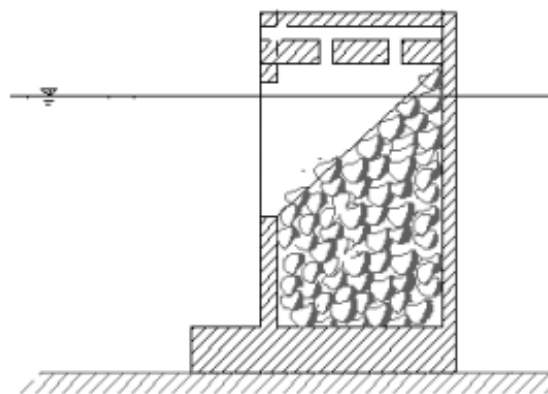


Figure 6.4: Caisson with internal rubble

Annex 10 – Breakwater design report

Design Formulas

Concrete structure

According to Takahasi (1996)

$$\alpha_1 = 0.6 + \frac{1}{2} \left[\frac{4\pi h/L}{\sinh(4\pi h/L)} \right]^2$$

$$\alpha_2 = \min \left\{ \left(\frac{h-d}{3h} \right) \cdot \left(\frac{H_D}{d} \right)^2 ; \frac{2d}{H_d} \right\}$$

$$\alpha_3 = 1 - \frac{h'}{h} \left[1 - \frac{1}{\cosh(2\pi h/2)} \right]$$

$$\lambda_1 = 1 \quad \text{for } H_D/h < 0.3$$

$$\lambda_1 = 1.2 - \frac{2}{3} \left(\frac{H}{h} \right) \quad \text{for } 0.3 < H_D/h < 0.6$$

$$\lambda_2 = 0$$

$$\lambda_1 = \lambda_3 = \begin{cases} 1 & \text{for } H_D/h < 0.3 \\ 1.2 - \frac{2}{3} \left(\frac{H}{h} \right) & \text{for } 0.3 < H_D/h < 0.6 \end{cases}$$

$$P_1 = 0.5(1 + \cos\beta) \cdot (\alpha_1\lambda_1 + \alpha_2\lambda_2 \cos\beta) \rho_w \cdot g \cdot H_D$$

$$P_3 = \alpha_3 P_1$$

$$P_U = 0.5(1 + \cos\beta) \alpha_1 \cdot \alpha_3 \cdot \lambda_3 \cdot g \cdot \lambda_1 \cdot \rho_w \cdot H_D$$

$$\eta^* = 0.75(1 + \cos\beta) \lambda_1 \cdot H_D$$

$$h_c = \min(\eta^*, R_c)$$

$$P_4 = \begin{cases} P_1 \left(1 - \frac{h_c}{\eta^*} \right) & \text{for } \eta^* > h_c \\ 0 & \text{for } \eta^* < h_c \end{cases}$$

$$P = \frac{1}{2}(P_1 + P_3)h' + \frac{1}{2}(2P_1 + P_4)h_c$$

$$U = \frac{1}{2}P_u \cdot B$$

$$M_p = \frac{1}{6}(P_1 + P_3)h'^2 + \frac{1}{2}(P_1 + P_4)h'h_c + \frac{1}{6}(P_1 + 2P_4)h_c^2$$

$$M_U = \frac{2}{3}U \cdot B$$

$$SF_{sliding} = \frac{\mu(M \cdot g - U)}{P}$$

$$SF_{overturning} = \frac{M \cdot g \cdot t - M_U}{M_p}$$

Where:

- L : Wavelength
- h : Water depth
- d : Toe depth
- h' : Structure height
- β : Approach wave angle
- B : Structure base width
- R_c : Freeboard
- H_D : Design wave height
- M : Structure effective mass
- μ : Friction angle between structure and base material

Overtopping

Franco et al. (1998)

$$\frac{q}{\sqrt{g H_s^3}} = 0.083e^{\left(-3\frac{R_c}{H_s}\right)}$$

Where:

- H_s : Significant wave height
- q : Dimensionless overtopping
- R_c : Freeboard

Reflection

According to Zanuttigh and Van der Meer (2006)

$$K_r = \tanh(0.12\xi_0^{0.87})$$

Where:

- ξ_0 : Iribarren number in deep water

Soil pressure

$$t_e = \frac{M_G - M_U - M_H}{F_G - F_U}$$

$$\begin{cases} q_1 = \frac{2(F_G - F_U)}{B} \cdot \left(2 - \frac{3t_e}{B}\right) \\ q_2 = \frac{3(F_G - F_U)}{B} \cdot \left(\frac{2t_e}{B} - 1\right) \end{cases} \quad \text{for } t_e > B/3$$

$$\begin{cases} q_1 = \frac{2(F_G - F_U)}{3t_e} \\ q_2 = 0 \end{cases} \quad \text{for } t_e < B/3$$

Where:

- M_G : Moment due to structure weight
- M_U : Moment due to under pressure
- M_H : Horizontal moment due to pressure distribution
- F_G : Structure weight
- F_U : Under pressure

Semi-probabilistic approach:

According to PIANC (1992)

$$\gamma_{H_s} = \frac{\hat{H}_s^{T P_f}}{\hat{H}_s^T} + \sigma'_{F_{H_s}} \left(1 + \left(\frac{\hat{H}_s^{3T}}{\hat{H}_s^T} - 1 \right) k_\beta P_f \right) + \frac{k_s}{\sqrt{P_f N}}$$

$$\gamma_z = 1 - k_\alpha \ln P_f$$

where

\hat{H}_s^T is the central estimate of the T -year return period value of H_s , where T is the structural lifetime ($T = 20, 50$ and 100 years were used for the code calibration). γ_{H_s} is applied to \hat{H}_s^T (the characteristic value of H_s , cf. the design equations).

\hat{H}_s^{3T} is the central estimate of the $3T$ -year return period value of H_s .

$\hat{H}_s^{T P_f}$ is the central estimate of H_s corresponding to an equivalent return period T_{P_f} , defined as the return period corresponding to a probability P_f that $\hat{H}_s^{T P_f}$ will be exceeded during the structural lifetime T . T_{P_f} is calculated from the encounter probability formula $T_{P_f} = \left(1 - (1 - P_f)^{\frac{1}{T}} \right)^{-1}$, cf. Fig. 2.1.

$\sigma'_{F_{H_s}}$ is the variational coefficient of a function F_{H_s} , modelled as a factor on H_s . F_{H_s} signifies the measurement errors and short term variability of H_s , and has the mean value 1.0. $\sigma'_{F_{H_s}}$ is equal to σ' for H_s in Table 2.1.

N is the number of H_s data, used for fitting the extreme distributions. The statistical uncertainty depends on this parameter.

k_α, k_β and k_s are coefficients which are determined by the optimization procedure, eqs. (8.23) - (8.24). $k_s \simeq 0.05$ for all failure modes. Examples of the k_α and the k_β values are given in Table 10.1.

Table 2.1. Typical variational coefficients $\sigma' = \sigma/\mu$ (standard deviation over mean value) for measured and calculated sea state parameters (Burcharth, 1989).

Parameter	Methods of determination	Estimated typical values		Comments
		σ'	Bias	
Significant wave height, OFFSHORE	Accelerometer buoy, pressure cell, vertical radar	0.05-0.1	~ 0	
	Horizontal radar	0.15	~ 0	
	Hindcast, num. models	0.1-0.2	0-0.1	Very dependent on quality of weather maps.
	Hindcast, SMB method	0.15-0.2	?	Valid only for storm conditions in restricted sea basins.
	Visual observations from ships	0.2	0.05	
Significant wave height NEARSHORE determined from offshore significant waveheight taking into account typical shallow water effects (refraction, diffraction, shoaling, ...)	Numerical models	0.1-0.20	0.1	σ' can be much larger in some cases
	Manual calculations	0.15-0.35		

Table 10.3. Hydraulic stability of rock toe berm.

Formula	Design equation	k_α	k_β
Van der Meer rock	$\frac{1}{\gamma_s} 8.7 \left(\frac{h_t}{h}\right)^{1.43} \Delta D_{n50} \geq \gamma_H H_s^T$ <p>Valid range $0.4 \leq \frac{h_t}{h} \leq 0.8$</p>	0.087	100

Design values

Input			
Parameter	Symbol	Value	Unit
Mean water level	MWL	7	m
Storm surge respect to MWL	Δ_h	4.4	m
Astronomical tidal range	Δ_{Ti}	1.98	m
Design water level	DWL	12.66	m
Wall height	h_w	13	m
Wall width	Bw	4.5	m
Significant wave height	H_s	0.77	m
Mean wave period	T_m	10.78	s
Peak wave period	T_p	11.86	s
-1,0 wave period	$T_{m-1,0}$	10.78	s
Wave length	L	56.87	m
Mean wave steepness	S_m	0.4	-
Storm duration	D	3	h
Number of waves	N	1500	-
Water density	ρ_w	1025	kg/m ³
Stone density	ρ_s	2650	kg/m ³
Gravity	g	9.81	m/s ²
Relative density	Δ	1.59	-

Input			
Parameter	Symbol	Value	Unit
Mean water level	MWL	7	m
Storm surge respect to MWL	Δ_h	4.4	m
Astronomical tidal range	Δ_{π}	1.98	m
Design water level	DWL	12.66	m
Wall height	h_w	13	m
Wall width	Bw	4.5	m
Significant wave height	H_s	0.77	m
Mean wave period	T_m	10.78	s
Peak wave period	T_p	11.86	s
-1,0 wave period	$T_{m-1,0}$	10.78	s
Wave length	L	56.87	m
Mean wave steepness	S_m	0.4	-
Storm duration	D	3	h
Number of waves	N	1500	-
Water density	ρ_w	1025	kg/m ³
Stone density	ρ_s	2650	kg/m ³
Gravity	g	9.81	m/s ²
Relative density	Δ	1.59	-

Table 7.38 Caisson input values

Toe			
Parameter	Symbol	Value	Unit
Toe depth (DWL)	$h_{t,DWL}$	10.24	m
Toe depth (LWS)	$h_{t,LWS}$	3.88	m
Stone diameter	$D_{n50,DWL}$	0.6	m
Displaced units (DWL)	N_{od}	0	-
Displaced units (LWS)	N_{od}	0	-
Stone mass	M_{n50}	240	Kg
Validity condition 1 (3-17.5) (DWL)	h_t/D_{n50}	17.1	-
Validity condition 2 (0.3-0.8) (DWL)	h_t/h	0.8	-
Validity condition 1 (3-25) (LWS)	h_t/D_{n50}	6.5	-
Validity condition 2 (0.3-0.8) (LWS)	h_t/h	0.31	-

Table 7.39 Toe design

Vertical Wall PIANC 2001			
Parameter	Symbol	Value	Unit
Coefficient 1	$\alpha 1$	0,67014064	-
Coefficient 2	$\alpha 2^*$	0,00138976	-
Coefficient 3	$\alpha 3$	0,59065851	-
Modification Coefficient 1	$\lambda 1$	1	-
Modification Coefficient 2	$\lambda 2$	1	-
Modification Coefficient 3	$\lambda 3$	1	-
Pressure at SWL	$P 1$	13,8896165	KN/m ²
Pressure at the toe of the wall	$P 3$	8,20402024	KN/m ²
Under pressure	$P u$	6,39899107	KN/m ²
Water height after impact	η^*	2,41161217	M
Pressure at the top of the wall	$P 4$	11,9313955	KN/m ²
Freeboard	$h c^*$	0,34	M
Pressure	P	117,729929	KN/m
Under pressure	U	14,3977299	KN/m
Under pressure moment	$M u$	43,1931897	KN
Pressure moment	$M p$	678,530884	KN
Vertical Wall mass	$m V$	49,6807382	tn
Sliding safety factor	Sliding	2,41045068	-
Overturning safe factor	Overturning	1,55244946	-

Table 7.3 Caisson design

Impulsive waves calculation	
δ_{11}	-0,092
δ_{22}	-0,391
δ_1	-1,839
δ_2	-1,916
α_{IB}	1,275
α_{IH}	0,148
α_I	0,189
α^*	0,189

Table 7.4 Impulsive wave study

PIANC Method (2001)			
Parameter	Symbol	Value	Unit
Probability of failure	P_f	0,2	-
Structure lifetime	T	100	y
Return period corresponding to probability P_f	T_{P_f}	500	y
Lifetime significant wave height (100y)	H_s^T	0,77	m
3 times lifetime significant wave height (300y)	H_s^{3T}	0,78	m
Return period significant wave height (500y)	$H_s^{T_{P_f}}$	0,8	m
Variational function of FHs	σ_{FHs}	0,2	-
Number of data used in extreme distributions	N	40	-
Coefficient depending on the failure mode	k_s	0,05	-
Coefficient depending on the failure mode	k_α	0,031	-
Coefficient depending on the failure mode	k_β	38	-
Coefficient depending on the failure mode - toe	k_α	0,087	-
Coefficient depending on the failure mode - toe	k_β	100	-
Safety factor for resistance	γ_r	1,04989258	-
Safety factor for load	γ_{H_s}	1,05663954	-
Safety factor for resistance - toe	γ_r	1,1400211	-
Safety factor for load - toe	γ_{H_s}	1,05663871	-

Table 7.5 Semi-probabilistic approach

Construction time

Phase 1

The fascine mattress placing will last 10 days. The whole mattress will be divided in 5 different sections; 4 of 25 meters long and a last one of 30 meters. Each section will required a day for the construction and placement.

Activity	Duration	Equipment
Construction of the mattress	8h	Manual labour
Placement in water	15 minutes	Crane
Sailing	30 minutes	Tugboats
Placing and sinking	3h	Tugboats/Floating Crane/ Barge
Levelling	4h	Floating Crane/ Barge

Table 7.6 Phase 1

Phase 2

The placement and construction of will last around 140 days. 260 sections of the caisson have to be placed with an estimation of two sections per day. However, do to the uncertainty of such a long construction a 10% of extra time has been add. The cycle of placement of each section will follow the next steps.

Activity	Duration	Equipment
Curing	21 days	Concrete/excavator
Placement in water	15 minutes	Crane
Sailing	30 minutes	Tugboats
Placing	30 minutes	Tugboats
Controlled sinking	1h	Tugboats/Floating Crane/ Barge
Bulk filling	2h	2 Floating cranes/Barge

Table 7.7 Phase 2

Phase 3

The construction of the toe protection will last approximately 9 days, 5 days for the sea side and 4 days for the rear side.

Activity	Duration	Equipment
Sea side		
Bulk placement	28h	Floating crane / Barge

Profiling	9h	Floating crane
Rear side		
Bulk placement	20h	Floating crane / Barge
Profiling	7.5h	Floating crane

Table 7.8 Phase 3

Productivity

Floating crane	
Activity	Production
Levelling	140 m ² /h
Bulk filling and placement	75 t/h
Profiling	125 m ² /h

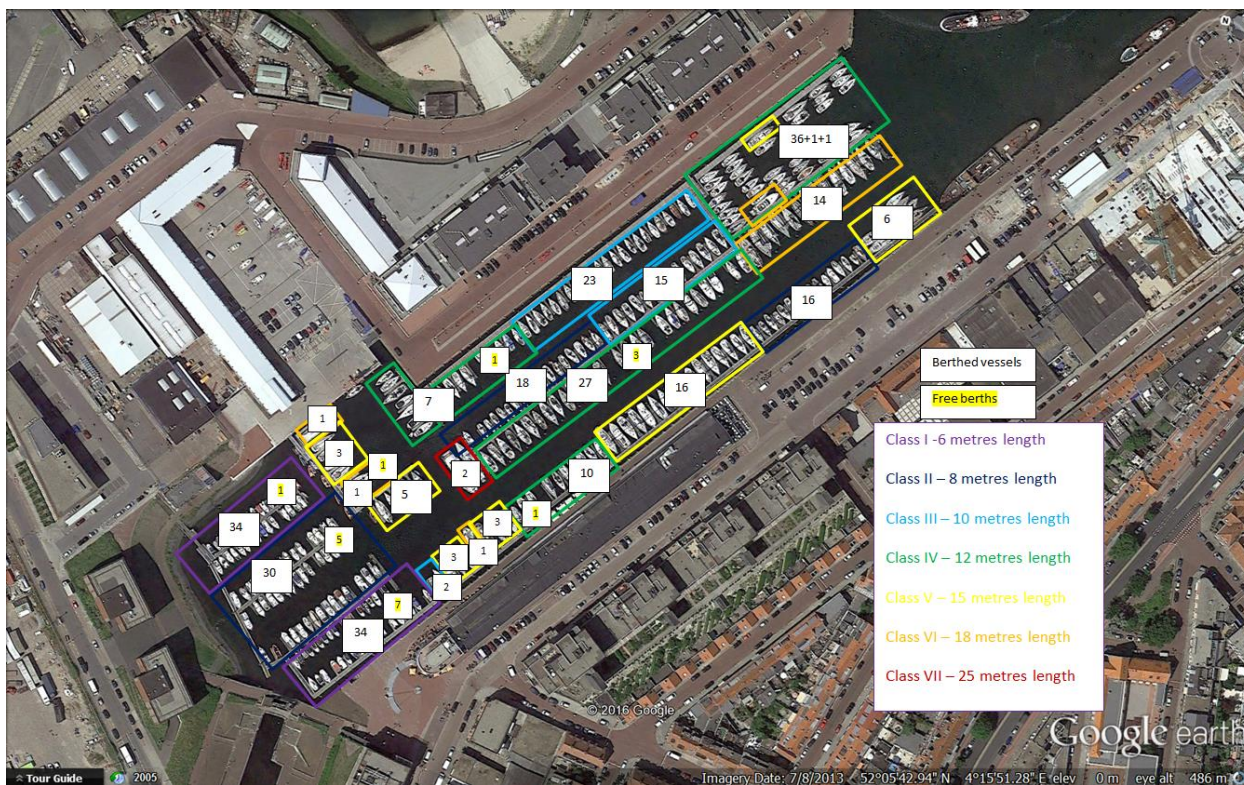
Table 7.9 Floating crane productivity

Barge		
Phase	Demand/day	Days
Phase 1	150 m ³	5
Phase 2	500 m ³	130
Phase 3	600 m ³	6

Table 7.10 Barge material demand

Annex 11 – Scheveningen Yachtclub current use

Besides the official occupation provided by the Yachtclub Scheveninge, it was estimated from an aerial view as follows:



Giving the following results:

Class	Observed vessels	Free berths	Total Existing
I	68	8	76
II	48	5	53
III	40	-	40
IV	80	5	85
V	38	-	38
VI	18	1	19
VII	2	-	2
TOTAL	294	19	313

Annex 12 – New marina design

The design of the Marina facilities in the Second and Fourth harbour were considering the British recommendations “A Code of Practice for the Design and Construction of Marinas and Yacht Harbours” (The Yacht Harbour Association Ltd., 2013).

The distribution of the boats was done according to the following vessel classes and associated dimensions: length, beam and draught.

Class	Length	Width	Draft
I	6	2.3	1.5
II	8	3.1	1.8
III	10	3.6	2.0
IV	12	4.0	2.1
V	15	5.3	2.4
VI	18	5.7	2.7
VII	25	6.0	3.6

For each of the different vessel classes, the required geometry of the navigation channels and berthing facilities are the following.

Class	Outer channel width	Inner channel width	Fairways	Berths		Walkways		Fingers	
				Single	Double	Main	Sec.	Length	Width
I	11.5	9	9	3.8	6.6	2.5	1.5	4.50	0.65
II	15.5	12	12	4.6	8.2	2.5	2	6.00	0.65
III	18	15	15	5.1	9.2	2.5	2	7.50	1.00
IV	20	18	18	5.5	10.0	2.5	-	9.00	1.00
V	26.5	22.5	22.5	6.8	12.6	2.5	-	11.25	1.40
VI	28.5	27	27	7.2	13.4	2.5	-	13.50	2.00
VII	30	37.5	37.5	8.0	15.0	3.5	-	18.75	2.50

The ramps connecting the pontoons to the quays in the Second and Fourth harbours are designed with a slope of 1:4. In the Second Harbour, it is also included access for disabled persons to all the berthing areas with a slope of 1:10.

Marina development criteria:

- Ambience and Administration
 - Walk ashore access to berths
 - Clearly identifiable marina office
 - Maintenance policy
 - Safety briefing and site safety plan
 - Suitable berthing contracts
 - New berth holder induction event
 - Clear and good signage for the marina
 - Policy for enforcing local rules
 - Customer feedback procedure
 - Up to date website
 - Information regarding access to river or canal (inland)
 - Help and information exchange for all customers
 - Daily weather forecasts and tidal information (coastal)
 - Documented emergency plan
 - Facilitate regular berth holder events
 - Wireless internet available for berth holders
 - New customer welcome service
 - Internal auditing procedure
 - Internet and photocopier available for berth holders
 - Tourist information available
 - 24/7 office or alternative solution
 - Staff uniform

- Environmental compliance
 - Waste properly managed
 - Fuels and oils properly stored
 - Prohibition of sewage discharge
 - Suitable oil spill kit available
 - Waste management plan / policy
 - Records of compliance to national environmental rules
 - Waste disposal facilities well signed
 - Waste recycling programme
 - Adequate number of spill kits for marina size
 - Management of flotsam and jetsam
 - Documented emergency (pollution) plans

- Environmental policy
- Customers advised on environmental best practices
- 3 year compulsory environmental audits
- Staff trained in environmental best practice
- Level indicator fitted to waste oil tanks
- Nominated environmental staff member
- Environmental initiatives (ISO 14001 or other)

- Regulations and directives
 - Electrical certificates for marina installations
 - Fire equipment and servicing record
 - Records of compliance of national safety rules
 - Compliance with statutory regulations
 - Suitable illumination to cover the site
 - First aid policy and an accident book
 - Plant lifting equipment inspection (if applicable)
 - Confirmation of adequate insurance
 - Procedure to ensure contractors are insured
 - Annual electrical certificates
 - Fire equipment & servicing record
 - Suitable illumination to cover the site

- Berth construction and services
 - Sufficient safety ladders
 - Drinking water available to berth holders
 - Fairways have sufficient width for safe navigation
 - Piers and floating walkways are robust and maintained
 - Floating structures are well secured
 - Safe berthing protected from waves and swell
 - Lifebuoys and / or floating heaving lines
 - Adequate mooring cleats or eyes
 - Clear navigation aides (where applicable)
 - Electricity available to berth holders where required
 - Clean and adequate toilets and showers
 - Convenient access to car parking
 - Fingers have adequate length and width
 - Clean & adequate toilets and showers
 - Trolleys available for berth holders

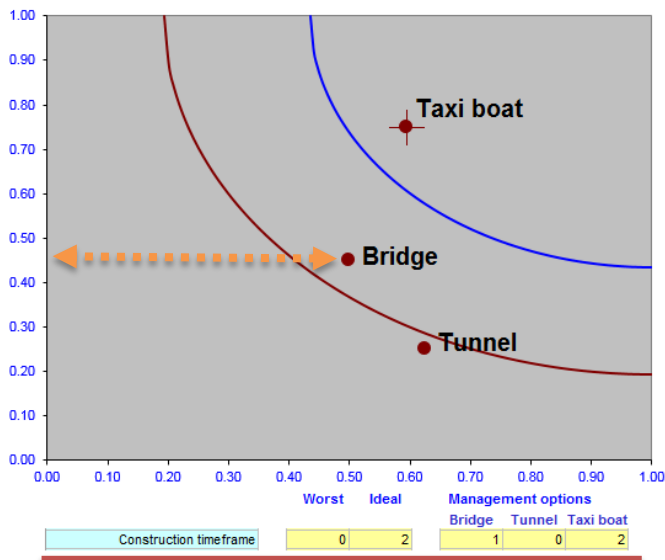
- Berths accessible at normal maximum water levels
- RYA training or alternative provided and encouraged
- Access to suitable laundry facility
- Access to fuel service (coastal)
- Suitably trained staff
- Reception / visitor berths available
- Berths accessible at minimum water levels
- Access to fuel service (inland)
- Trolleys for berth holders
- Fairways have sufficient width for safe navigation
- Piers and Walkways are robust and maintained
- Staff trained to industry requirements
- Suitable layout and design of pontoons (coastal)
- Life buoys and / or floating heaving lines
- Gated access to marina or a suitable alternative
- Clear navigation aids (coastal)
- Access to boat repair and services

Annex 13 – Multi-criteria analysis for bridging De Pijp

Assigned grades and their justification

Within the JESEW model, values for each base indicator have to be assigned. Obtaining accurate data within a limited timeframe was not possible. Therefore, a qualitative approach was chosen, applying abstract values to each indicator. This somewhat hinders the accuracy of the model, as can be seen in the below example (Figure 68). It should be noted that there is change in the position of the alternatives, but none to their overall ranking. Such accuracy can be considered sufficient for the task at hand.

1. Case with abstract values



2. Case with real values (weeks)

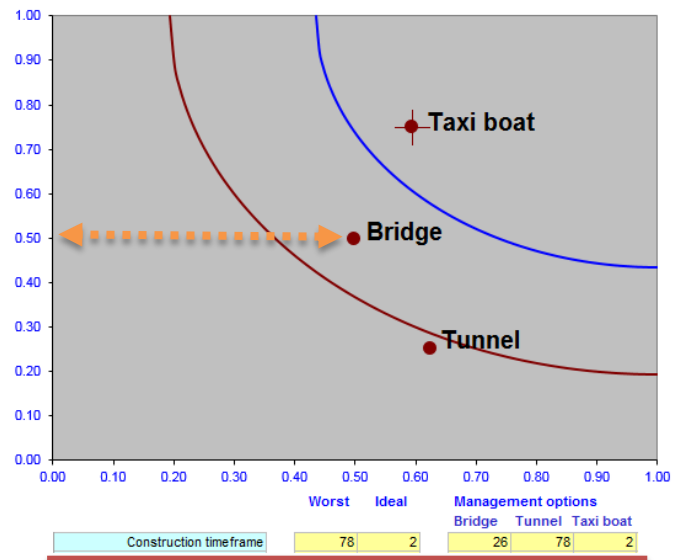


Figure 68: Example where one abstract value has been substituted for actual numbers (weeks). Note that alternatives 2) Tunnel and 3) Taxi boat do not change position. Alternative 2) Bridge

Weight factors and their justification

Base indicators		Assigned grade					
		Movable bridge		Tunnel		Taxi boat	
		Grade	Justification	Grade	Justification	Grade	Justification
Traffic							
1	Traffic dependency	0	High traffic interdependency	2	No traffic interdependency	1	Limited traffic interdependency
2	Traffic conditions (operational)	0	Expected congestion and/or relatively long waiting times	2	No congestion or waiting time	1	Expected minor congestion and relatively short waiting time
Social and Leisure							
3	Social perception	2	Common solution in the Netherlands; architecturally attractive design will be widely appreciated	1	Hidden from sight, hence does not evoke strong opposition; marked down for high costs; safety has to be ensured; psychologically unsettling, claustrophobic	1	Relatively inoffensive and cheap solution; marked down for noise and pollution
4	Touristic appeal	2	An attractive architectural design could turn such a bridge into a tourist attraction and the focal point of Scheveningen	0	Limited, if any	2	A free boat ride will appeal to the majority of tourists; choice and decoration of boats could turn them into a tourist attraction
5	Accessibility (bikes/disabled people)	2	No restrictions to access	1	Possible if designed accordingly; marked down for complexity and increased dimensions/required area	0	Possible if designed for accordingly e.g. ramp access points; some modifications to the boats might be required; marked down for complexity
Construction process							
6	Construction timeframe	1	Possibility for prefabrication of major elements and short assembly process; some elements e.g. foundations will require considerable time	0	Lengthy and complex construction sequence, especially compared to alternatives	2	Quick and easy construction of quay elements; no major construction work required

7	Construction risks and uncertainties	1	Risks involving installing the movable mechanisms; failure of propulsion system; possible geotechnical uncertainties	0	High risk and uncertainties related to geotechnical conditions, working within water and hydroisolation, working with concrete, removing of former concrete lock gate (currently De Pijp channel) and other	2	Virtually no risk or uncertainty
8	Traffic downtime during construction	1	Traffic will be blocked during assembly of prefabricated elements and testing of assembled bridge	0	Connection to Second Harbour will be cut off during construction	2	No downtime
Operational conditions							
9	Maintenance	0	Regular maintenance of moving parts and mechanisms required; high repair cost	1	General maintenance e.g. lighting, security; assumed quality execution of construction and no problems with e.g. hydroisolation	0	Regular maintenance of boats required; varying repair cost
10	Flexibility (short term)	1	Moderate flexibility and adaptability due to finetuning of operational scenarios, although still limited by the high traffic interdependence	1	No possibility for adaptation; no adaptation to traffic conditions needed due to no traffic interdependency	2	Very high flexibility and adaptability due to optimizations in work schedules and applied usage scenarios; relatively low investment further increases flexibility
11	Flexibility (long term)	0	Very limited possibility for adaptation in case of increasing traffic; cost/capacity increase ratio very high; marked down for being a permanent structure	0	No possibility for adaptation; no adaptation to marine traffic conditions needed due to no traffic interdependency, but no way to meet increasing demand of land based traffic; cost/capacity increase ratio very high; marked down for being a permanent structure	2	Relatively low investments needed to increase capacity considerably; no big loss in case of decreasing capacity

1 2	Environmental Impact (long term)	2	Limited to no long term environmental impact (environmental impact during construction not considered)	2	Limited to no long term environmental impact (environmental impact during construction not considered)	0	Noise, air and water pollution due to internal combustion powertrain; pollution during vessel maintenance; possibility for implementation of electric propulsion to reduce impact
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Sensitivity analysis of JESEW model – qualitative vs quantitative values

	Base indicators	Weight factor	Justification
Traffic			
1	Traffic dependency	3	It is best, but not critical, to avoid any traffic dependency
2	Traffic conditions (operational)	5	Marine traffic conditions are a major factor in creating an attractive marina and a safe harbour; on-land traffic conditions are an important factor for ensuring a better experience with regard to leisure and enabling the development of the Scheveningen area
Social and Leisure			
3	Social perception	3	Essentially tax payers are the funders of the project, so their opinion should be considered; Politicians would not approve a project that is not accepted in the eyes of the public
4	Touristic appeal	4	A major goal is to make Scheveningen more attractive with regard to leisure and tourism
5	Accessibility (bikes/disabled people)	1	Accessibility is possible for nearly any kind of solution, although costs and convenience may vary
Construction process			
6	Construction timeframe	2	Inconvenience (noise, pollution, restricted access etc.) to local residents and possibly leisure (if construction continues for too long)
7	Construction risks and uncertainties	1	These are usually related to high unpredicted costs and delays, however, the probability of occurrence is usually assessed and planned for accordingly
8	Traffic downtime during construction	1	Very inconvenient, but one has to consider that this will last only temporarily (during construction)
Operational conditions			
9	Maintenance	2	Maintenance costs are always highly important to governmental institutions
10	Flexibility (short term)	2	The ability of an alternative to adapt to daily/seasonal variations will improve its functional benefits and possibly reduce construction and maintenance costs
11	Flexibility (long term)	3	Unpredictability in demand (both decrease and increase) and changes in usage scenarios might render a solution inadequate; easy adaptability to these factors will lead to lowered long term costs; lack of adaptability is a considerable shortcoming
12	Environmental Impact (long term)	3	Long term environmental impact in a residential and touristic area is not desirable and is not in line with the primary goals of urban improvement

Annex 14 – Boats queue study

Introduction and objective

This document comprises the boats queue study at Scheveningen Harbour that could be generated in the case of the construction of a new moveable bridge bridging De Pijp.

Several options aiming to bridge De Pijp conditions are being evaluated – a tunnel, a movable bridge and a water taxi. As the moveable bridge would influence in the ships traffic across De Pijp, a study of is required in order to determine the feasibility of this solution. This document is part of the multi-criteria analysis of the connection problem of the Multi-Disciplinarity Project (CIE 4061-09).

The Hague Municipality – the client of the current project - is responsible for Scheveningen Harbour. An overview of Scheveningen Harbour is presented in Figure 69.

The objective of this document is to present the changes in the ships waiting time and queue through a stochastic modelling (Monte Carlo) of the arrival of ships.



Figure 69. Overview of Scheveningen Harbour.

Methodology

The simulation study assumed a few simplifying hypotheses, summarized below:

- The interval between arrivals/departures of boats across De Pijp is a stochastic variable and follows a Gaussian curve with average of 1 boat every 2.5 min (2.5 min/boat) and standard deviation of 0.5 minute/boat. This average was obtained with a calculation of 300 boats arrivals/departures every 12 h across De Pijp, and represent a peak estimate, that may happen in Summer.
- The time taken by a boat to cross De Pijp is also a stochastic variable that follows a Gaussian curve with average of 2 min/travel with standard deviation of 0.5 min/travel. This number was estimated with an average channel length of 150 m and a boat velocity of 2.4 kn (1.23 m/s).
- Only one boat is able to cross De Pijp at the same time.

Two scenarios were considered, briefly described below:

- Scenario 1: Moveable bridge closed 10 min/h in a fixed time, from **:00 to **:10 h, including the bridge opening and closing cycle time.
- Scenario 2: Moveable bridge closed 20 min/h in a fixed time, both from **:00 to **:10 h and **:30 to **:40 h, including the bridge opening and closing cycle time.

The mathematical model study considers boats arriving from 10:00 to 22:00, and comprises 1 month of simulation. The algorithm is explained below:

- Firstly, a random number is assigned to determine the boat arrival time. For every boat, this random number between 0 and 1 will be transformed into a date by taking the inverse cumulative distribution function of a Gaussian variable, with aforementioned average and standard deviations.
- Another random is assigned to calculate the boat travel time across De Pijp. For every boat, this random number between 0 and 1 will be transformed into a time by taking the inverse cumulative distribution function of a Gaussian variable, with aforementioned average and standard deviations.
- Two other variables are calculated for every boat: the departure start date, which is equivalent to the time in which the boat starts to enter in De Pijp, and the departure end time, which is equivalent to the time in which it finished its travel, and De Pijp is free again.
- In order to determine the departure start, another variable is assigned, the queue parameter. This variable is responsible for saying if the De Pijp is busy at the moment in which the boat arrives, and thus the boat goes to the queue. Three reasons could justify why a boat goes to the queue: firstly, if the moveable bridge is closed, therefore the boat has to wait until it opens again; secondly, if there is another boat using De Pijp that arrived earlier; and the third one is if the moveable bridge will close before the boat stops using De Pijp, calculated together the stochastic travel time.
- The departure start date is a complex function depending upon the presented variables. A queue is formed when the bridge is about to close or is closed or when another boat is using De Pijp. No priorities were assigned for this queue, so the first in will be first out.
- The departure end date is calculated with the sum of the departure start date and the stochastic travel time described above.
- The waiting time is calculated for every boat as the difference between its departure start date and its arrival date.

- The number of boats in queue is calculated for every time step, which is variable and depend upon the boats arrival interval, a stochastic variable.

Table 44 shows a visual impression of how the simulation works. Only 15 rows are shown, but more than 8000 boat arrivals were considered for each simulation.

Calculation results

Scenario 1

Table 40 presents the “waiting time” statistics, while Table 41 shows the number of boats in queue statistics for Scenario 1.

Table 40. Waiting time statistics for Scenario 1.

waiting time		
μ_y	7.57	min
σ_y	5.22	min

Table 41. Number of boats in queue statistics for Scenario 1.

queue		
μ_y	4.28	boats
<i>max</i>	13	boats

The cumulative distribution function of the waiting time is shown in Figure 70.

Scenario 2

Table 42 presents the “waiting time” statistics, while Table 43 shows the number of boats in queue statistics for Scenario 1.

Table 42. Waiting time statistics for Scenario 1.

waiting time		
μ_y	78.67	min
σ_y	44.98	min

Table 43. Number of boats in queue statistics for Scenario 1.

queue		
μ_y	32.88	boats
<i>max</i>	75	boats

The cumulative distribution function of the waiting time is shown in Figure 70.

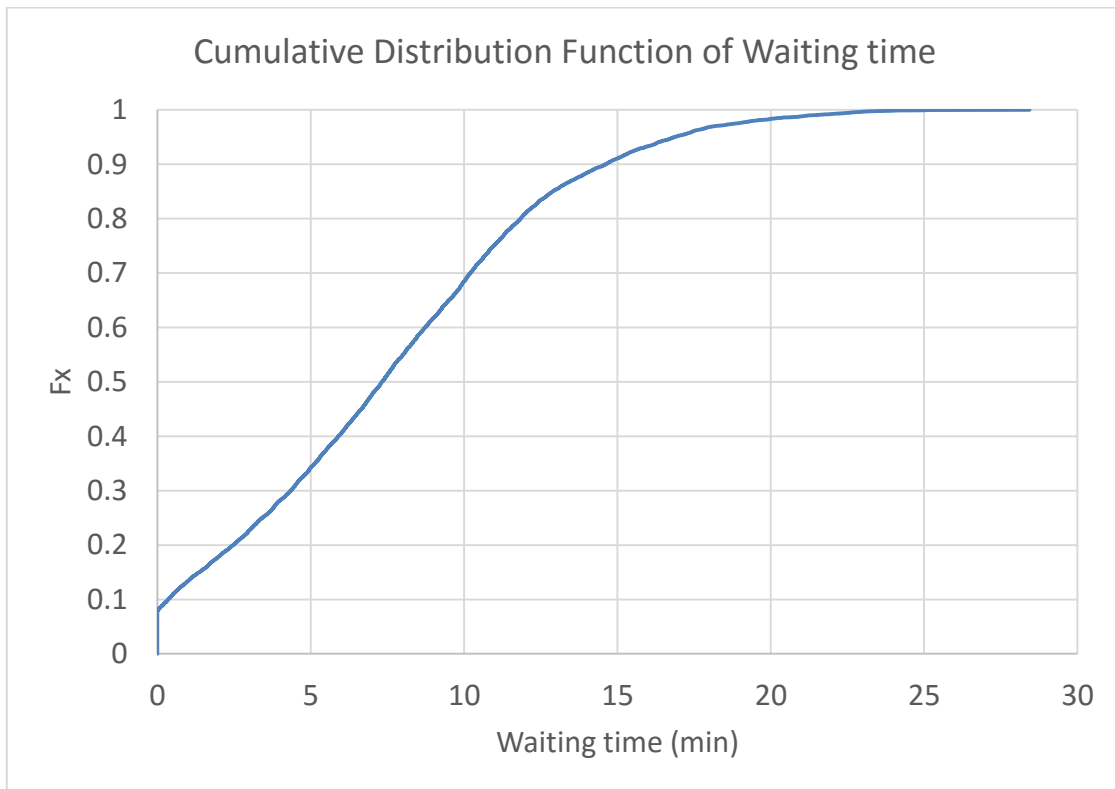


Figure 70. Cumulative distribution function of “waiting time” for Scenario 1.

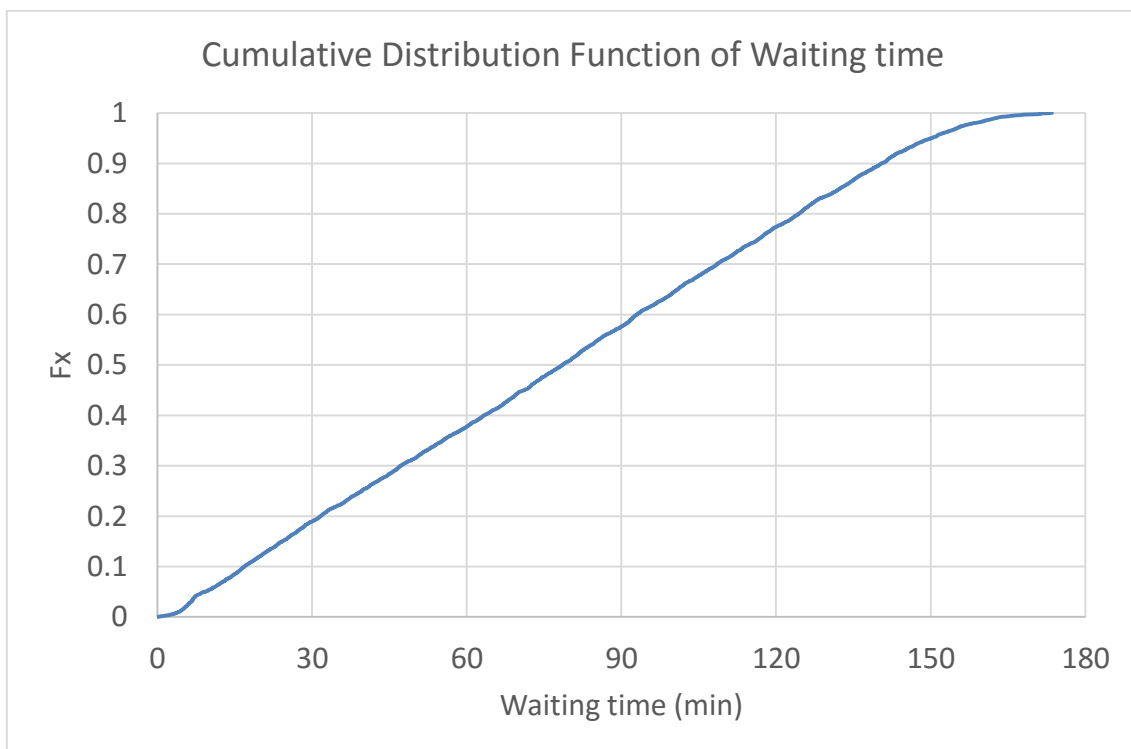


Figure 71. Cumulative distribution function of “waiting time” for Scenario 2.

Evaluation of results

The results shown in the previous paragraph show that:

- For Scenario 1 - with a moveable bridge closed 10 min per hour -, the average waiting time is of 8 min, while an average queue of 4 boats may be found, with a maximum number of boats in queue of 13. The waiting time during 90% of the time is lower than 15 minutes.
- For Scenario 2 - with a moveable bridge closed 20 min per hour in 2 turns -, the average waiting time is of 80 min, while an average queue of 33 boats may be found, with a maximum number of boats in queue of 75. The waiting time during 60% of the time is higher than 1 hour.
- Scenario 2 is completely unfeasible, as critical waiting times and number of boats in queues were calculated.
- Scenario 1 is not thoroughly satisfactory, as every boat has to wait for 8 minutes in average, and a maximum queue of 13 boats may be a problem for the Harbour authority.

Recommendations

The current study evaluated the changes in the boats queue as a consequence of the construction of a new moveable bridge with Monte Carlo simulations. Simplified assumptions were considered in this mathematical study.

These assumption could be verified and optimised with the participation of the Marina Yacht Club in order to refine the calculation results. Besides, the model could consider different types of boats, with different velocities, and also peak hours.

Table 44. Monte carlo simulation for Scenario 1.

Input												Output	
boat arrival				queue analysis				boat in De Pijp				queue	
Boat	Arrival date	random	interval for next arrival (min)	queue?	criteria 1 (bridge closed when boat arrives)	criteria 2 (boat arrives when another boat is still queueing or in the channel)	criteria 3 (bridge about to close when boat arrives)	departure_start	random	travel time (min)	departure_end	waiting time (min)	number of boats in queue
1	6/1/18 10:03	0.86	3.04	yes	yes	no	no	6/1/18 10:10	0.90	2.63	6/1/18 10:12	6.96	5
2	6/1/18 10:05	0.46	2.45	yes	yes	yes	no	6/1/18 10:12	0.03	1.08	6/1/18 10:13	7.13	4
3	6/1/18 10:07	0.07	1.77	yes	yes	yes	no	6/1/18 10:13	0.43	1.91	6/1/18 10:15	6.44	4
4	6/1/18 10:10	0.71	2.78	yes	no	yes	no	6/1/18 10:15	0.80	2.42	6/1/18 10:18	5.58	4
5	6/1/18 10:12	0.21	2.10	yes	no	yes	no	6/1/18 10:18	0.62	2.15	6/1/18 10:20	5.90	4
6	6/1/18 10:14	0.10	1.86	yes	no	yes	no	6/1/18 10:20	0.05	1.17	6/1/18 10:21	6.19	4
7	6/1/18 10:16	0.59	2.61	yes	no	yes	no	6/1/18 10:21	0.02	1.01	6/1/18 10:22	4.76	3
8	6/1/18 10:19	0.49	2.49	yes	no	yes	no	6/1/18 10:22	0.00	0.64	6/1/18 10:23	3.28	3
9	6/1/18 10:20	0.04	1.64	yes	no	yes	no	6/1/18 10:23	0.51	2.01	6/1/18 10:25	2.29	2
10	6/1/18 10:22	0.08	1.81	yes	no	yes	no	6/1/18 10:25	0.00	0.71	6/1/18 10:25	2.49	2
11	6/1/18 10:25	0.49	2.49	yes	no	yes	no	6/1/18 10:25	0.73	2.30	6/1/18 10:28	0.70	2
12	6/1/18 10:27	0.67	2.72	yes	no	yes	no	6/1/18 10:28	0.70	2.26	6/1/18 10:30	0.29	2
13	6/1/18 10:29	0.12	1.90	yes	no	yes	no	6/1/18 10:30	0.54	2.06	6/1/18 10:32	0.65	2
14	6/1/18 10:31	0.36	2.33	yes	no	yes	no	6/1/18 10:32	0.40	1.87	6/1/18 10:34	0.38	1
15	6/1/18 10:35	0.98	3.53	no	no	no	no	6/1/18 10:35	0.64	2.18	6/1/18 10:37	0.00	0