Creating a minimal water level with sound water quality in De Oude Haven and 'T Sas in Zierikzee

An analysis of the consequences of a minimal water level in De Oude Haven and 'T Sas on the water quality

Report

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Client: Municipality of Schouwen Duiveland

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Acknowledgement

As a student of Aquatic ecotechnology and Civil engineering at the HZ University of Applied Science my time as a student here comes to an end. The final assignment or thesis project is officially the last step in the study program. I would like to thank my supervisors form the HZ Peter Hopmans and Bram Verkruysse for their advice and support during this thesis; and Marco de Bruine and Leo Kaan from the municipality of Schouwen-Duiveland for the pleasant cooperation, exchange of information and criticism.

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Iris Zijlstra

26th of February 2018

Vlissingen

Abstract

Introduction
In the harbor of Zierikzee there is a strong tidal influence. The difference between the water levels during high and low tide lies around the three meters. The harbors De Oude Haven and ‘T Sas fall dry during an extremely low tide. When these harbors fall dry, foundations will come in contact with oxygen, allowing them to rot. Furthermore, the sight of the harbors is not attractive during this situation.

According to the Municipality of Schouwen-Duiveland the area around De Oude Haven and ‘T Sas are <u>not sufficiently attractive.</u> Therefor the municipality of Schouwen Duiveland has plans to develop the area around De Oude Haven and ‘T Sas in order to make it more attractive.

The municipality of Schouwen Duiveland would like to realize a minimum water level in the harbor of Zierikzee by the use of a water retaining structure. This will prevent the foundations and the banks to be exposed during low water levels. This water retaining structure would be located under the bascule bridge. The retaining structure would “lock” the water in the harbors when the water on the Oosterschelde side of the structure has reached the desired maximum water level, likewise to the low tide. When the water level on the Oosterschelde side of the retaining structure lies within the allowed boundaries there will be a free connection to the Oosterschelde, the retaining structure is open.

The minimal water level would make more activities in De Oude Haven and ’t Sas possible and make the area more attractive by decreasing the tidal differences, preventing exposure of the deteriorated quay walls and banks.

Research problem
retaining structure and a reduction of the tidal influence influences the water in the harbors and this could have consequences for the water quality. This research is about analyzing whether water quality problems will arise when a minimal water level is implemented. Furthermore, solutions will be developed if the research points out that water quality problems will arise. In order to do this, the following main question will be answered in this report: *“What are the consequences on the water quality when a minimal water level of +0,80 mNAP is implemented in the projected separated harbor of Zierikzee?”.*

Method
By means of desk research, interviews and calculations the problems regarding the water quality were identified. Alternatives were developed, and the most suitable alternatives were chosen using a multi criteria analysis. The most suitable alternative was worked out into detail, calculations, drawings, implementation costs and an implementation strategy were developed.

Conclusion
The conclusion is split in two parts. Conclusions are made on the chemical water quality and the biological water quality.

Chemical water quality
By studying the water movement and refreshment on the water in the harbor a water quality problem has been identified when a minimal water level is implemented.

In the Oude haven the velocity of the water is reduced and the refreshment time is increased. In other words, there is a chance on stratification in this area. An increase in chloride will decrease the oxygen concentration by reducing the saturation ability (Bayley, 1972) and by

stratifying the water. The increase in N and P will increase algae growth. When the algae die, they will in turn decrease the oxygen concentration.

In order to safeguard the water quality in the Oude haven a turbine is suggested to be installed to mix the water in the harbor. The water in the harbor is mixed by means of turbulent flow produced by the turbine. This movement prevents stratification of the water.

Biological water quality

In the present situation the harbors have an open connection with the Oosterschelde and therefore are subjected to the tide. Fish migration is possible through a leaking pipe in pumping station ‘t Sas. When the minimal water level will be created with the sluice doors the fish will not be able to migrate any more. This problem was seen as most relevant to study due to the fact that this negatively influences the water quality.

The harbor is able to maintain the biological water quality considering the fish, by implementing a fish passage with a fish friendly pump. The fish will be able to migrate from the harbor to the polder and vice versa.

Inhoudsopgave

1 Introduction

1.1 Background information

According to the Municipality of Schouwen-Duiveland the area around De Oude Haven and 'T Sas is not sufficiently attractive. Therefore, the municipality of Schouwen Duiveland has plans to develop the area of De Oude Haven and 'T Sas to make it more attractive.

In Zierikzee there is a strong tidal influence due to the connection of the harbor with the Oosterschelde. The difference between the water levels during high and low tide is approximately three meters in the harbor. The harbors De Oude Haven and 'T Sas fall dry during an extremely low tide. When these harbors fall dry or have a low water level the decayed quay walls and banks are visible. This view is not attractive. Another aspect of the low water levels is that the foundations will come in contact with oxygen, allowing them to rot. (Gemeente Schouwen-Duiveland , 2015)

The municipality of Schouwen Duiveland would like to realize a minimal water level by implementing a water retaining structure. The minimal water level would make more attractive by decreasing the tidal differences, preventing exposure of the deteriorated quay walls and banks. This water retaining structure would be located near the bascule bridge. The retaining structure would "lock" the water in the harbors when the water on the Oosterschelde side of the structure has reached the desired maximum water level, likewise to the low tide. When the water level on the Oosterschelde side of the retaining structure lies within the allowed boundaries, the doors are open and there will be an exchange of water between the Oosterschelde and the harbor of Zierikzee. (Gemeente Schouwen-Duiveland , 2015)

The minimal water level would make more activities in De Oude Haven and 't Sas possible and the deteriorated quay walls and banks will not be visible any more.

Leo Kaan has designed a set of sluice doors that would be able to create a minimum water level of +0,80 m NAP in the harbor of Zierikzee. Leo Kaan functions is planner of civil construction for municipality of Schouwen-Duiveland.

1.2 Problem definition

A retaining structure and a reduction of the tidal influence influences the water in the harbors and this could have consequences for the water quality. The purpose of minimal water level is to create a more attractive area. When the water quality is bad, orders might arise, and the water might not give a fresh look, negatively influencing the environment. Furthermore, the water board is responsible for the water quality in the harbor of Zierikzee, the harbor must meet certain water quality standards. This research is about analyzing whether water quality problems will arise when a minimal water level is implemented. Furthermore, solutions will be developed if the research points out that water quality problems will arise.

1.2.1 Chemical water quality

One aspect of this thesis is the chemical water quality. A part of this thesis project is to do research how the chemical water quality in the harbors will be influenced by the minimal water level. This is research by studying the water movement and chloride concentration in the harbor.

1.2.2 Biological water quality

The other aspect that is studies is the biological water quality. A problem with the fish migration has been found. Because the obstruction of the migratory pathway has negative influences for the biological water quality, this subject is studied.

In the situation where the harbor of Zierikzee is connected to the Oosterschelde, the harbor is subjected to the tide. With the tidal influence fish migration is possible through a leaking pipe in pumping station ‘t Sas during low tide. When the minimal water level will be implemented with the sluice doors the fish will not be able to migrate anymore through the leaking pipe. The fish have no opportunity to overcome the 2,30 m to 3,70 m water level difference. The second part of this thesis project focuses on finding a solution to facilitate the fish migration from the harbor to the polder and vice versa. On Figure 1 the problem of the fish migration is visualized.

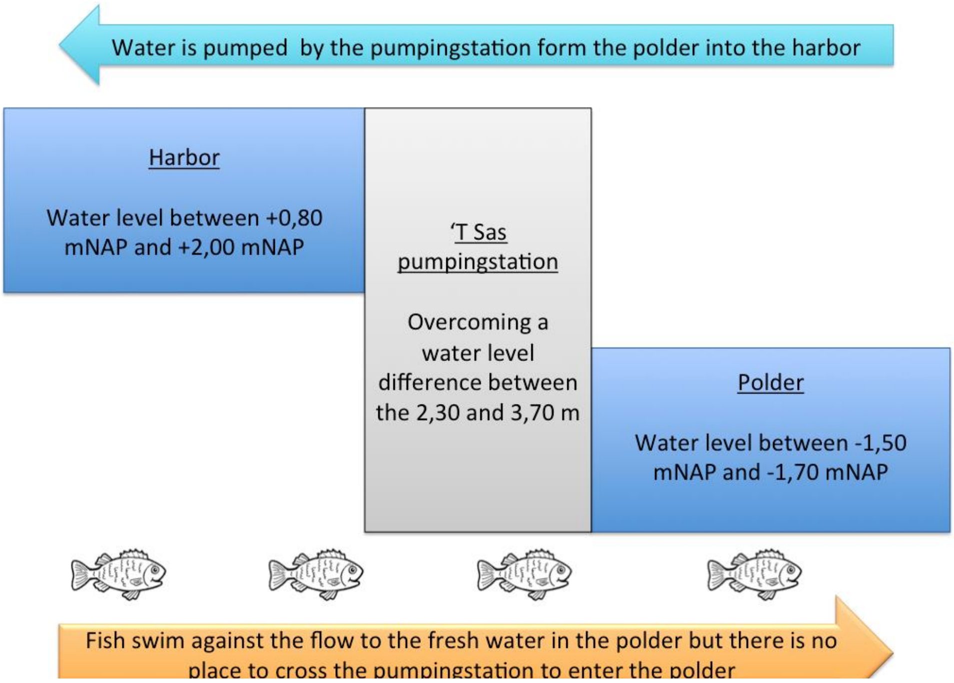

Figure 1 Schematisation fish migration problem

1.3 Objective and scope

The objective of this research is to analyze whether water quality problems are likely to arise when a minimal water level of +0,80mNAP is created; and to develop measures that contribute to the water quality requirements stated by the EWFD (European Water Framework Directive).

Leo Kaan has performed prior research about what the minimal water level is the most suitable be in the harbors De Oude Haven and ‘T Sas and how to realize this. The research Leo Kaan has performed has been used as a starting point for this research. The situation in the harbors behind the retaining structure will be studied. The ecological quality and the chemical quality of the water in the harbors will be considered.

This report is written for the studies Aquatic Ecotechnology and Civil Engineering. Therefore, this research consists of both technical and more biological aspects. For the competences of civil engineering calculations are made about the most important aspects of the constructions.

1.4 Research question

In order to find solutions for the problems that have been clarified and to achieve the objective, a main-question has been made. The main question is supported by the sub-questions.

1.4.1 Main question

What are the consequences on the water quality when a minimal water level of +0,80 mNAP is implemented in the projected separated harbor of Zierikzee?

1.4.2 Sub-questions

To properly answer the main question sub-questions have been made. Each sub-question has been translated into activities to execute the research.

1. What are the requirements for the water quality?
    - What are the requirements for the oxygen concentration in the water?
    - What are the requirements for salt and brackish water according the European Water Framework Directive?
    - What are the requirements for fish migration from the harbor to the polder?

2. What would be a suitable future image of the harbor?

3. What are the consequences of a minimal water level of +0,80 m NAP in relation to the water quality?
    - How will the saline gradient and dynamics influence the ecology during the different seasons?
    - How will the water movement in the harbor have an influence on the water quality in the harbor?
    - How could the migrating fish be facilitated from the harbor to the polder?

1.5 Thesis outline

This thesis report starts with providing a theoretical framework that acts as the foundation for this project. The second subject of discussion is the method. The method is about how this research is conducted. Next on, the results are discussed. The results start with the program of requirements and a vision. Furthermore, the chloride concentrations in the harbor, the fish migration and the chemical water quality are discussed. The discussion, conclusion and recommendations follow this. And finally, the appendixes containing the additional information about the project.

In this thesis is often spoken of “the harbor of Zierikzee” with this both the Oude haven and ‘t Sas are meant.

2 Theoretical Framework

The theoretical framework consists of information that is relevant as support for the research. First the European Water Framework Directive (EWFD) will be discussed, followed by the characteristics of brackish water. Potential water quality problems are identified along with alternatives how to improve the water quality This is followed by the residence time. Next, fish migration is discussed. The final subject considers formulas to calculate open channel flow.

2.1 European water framework directive (EWFD)

In the year 2000 the European Water Framework Directive has been launched. The goal of the EWFD is to reach sufficiently clean water bodies in all European countries by 2027 (Rijkswaterstaat, sd). The EWFD is relevant to this project because the water in the harbor must meet these goals regarding water quality. In order to be able to use this and establish a plan on how these goals could be met, it is necessary to understand where this policy comes from and what is entails.

To evaluate the ecological status of a water body objectively first the water type must be determined. In total there are 42 different water types. Each water type has a description of the ecological composition. De description notes in detail the different species in that water type as a reference. The purpose of the reference of each water type is to guide. The status of the water body is classified by means of the reference guide. In the Netherlands there are natural and strongly modified waters, both have a different classification in ecological classification. In Figure 2 the classification of the ecological status is shown. (STOWA, 2005)

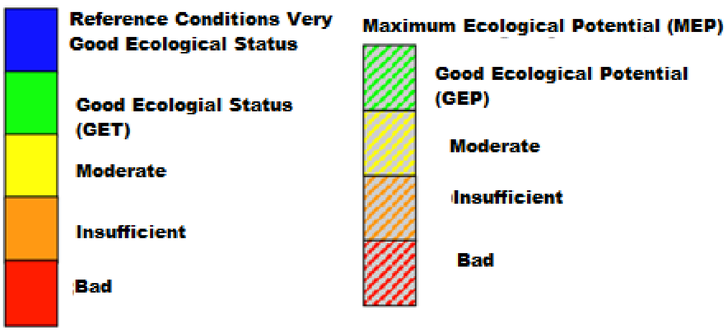

Figure 2 The five classes of the ecological status for natural water types (left) and the four classes of the strongly modified and changing waters (right) with the corresponding colour coding. (STOWA, 2005)

The waterboard has determined the ecological water quality in the harbor of Zierikzee. Therefore, the reference can be made to the EWFD degree of ecological water quality.

2.1.1 Indicator ecological water quality

For the different types of water bodies indicators are used to determine the ecological water quality. Per water type there is a list with positive and negative indicators. The important aspects of the ecological water quality are the phytoplankton, the macrophytes, macro fauna and the fish. The ecological status is only confirmed when all the quality indicators have been identified, this is called the “One-out-all-out-principle”. (STOWA, 2005)

Fish

Because a problem will arise for the fish migration when a minimal water level, the fish are evaluated. Furthermore, information was available on the fish population in the harbor of Zierikzee.

The relation in abundance between the fish species is a good indicator for water quality (Molen, 2014). A good ecological status due to fish is described as: “The age structure of the fish community shows signs of disruptions due to anthropogenic effects on the physical-chemical or morphological quality elements and points in some cases to a disruption in the reproduction or development of certain species of which some age classes are not present” (STOWA, 2005)

2.2 Brackish water

The harbor of Zierikzee has brackish water (Waterschap Scheldestromen, 2017). Brackish water has different characteristics compared to fresh water. To be able to analyze and evaluates the situation in the harbor of Zierikzee the goals for, and characteristics of the brackish water are considered in this project.

A brackish waterbody has a chloride concentration higher than 300 mg/L. Brackish waterbodies are mainly found along the coast, where seawater influences the fresh water however having no direct connection to the sea. The salt water flows through the soil to the fresh inland water. (Dam, Brakke wateren, 2014)

2.2.1 Classification brackish waters

The salt content of the water is the most important character that influences the organisms living in the water and in what abundance. The average chloride concentration over the years has been used as a basis for classifying the brackish waters into four groups. These groups and their chloride concentration range are shown in Table 1. This classification is mainly based on the discontinuousness of the spread of macro fauna along the chloride gradient, also for the other organisms this classification is suited. Aside from the average chloride content the fluctuations are important too, because they affect the ecology in the water. (Dam, Brakke wateren, 2014)

Table 1 Classification of brackish waters (Dam, Brakke wateren, 2014)

Classification brackish water	Chloride concertation [mg/L]
Weak brackish to fresh water	300 to 1.000 mg/L Cl
Weak brackish	1.000 to 3.000 mg/L Cl
Moderately brackish	3.000 to 10.000 mg/L Cl
Strongly brackish	> 10.000 mg/L Cl

The classification based on chloride concentration can be further divided based on the morphology of the waterbody.

- Small waters, to 1,5 m water depth
- Larger waters, to 1,5 m water depth
- Large deep waters, over 1,5 m water depth

(Dam, Brakke wateren, 2014)

This classification system has been used in order to determine what type of water the harbor of Zierikzee is.

2.2.2 Physical and chemical characteristics

Most of the brackish waters are naturally eutrophic because of the seepage. Concentrations of phosphate being higher than 1 mg/l are normal. In strongly brackish water the nitrogen-phosphate relationship is often low, lower than 6. This shows that the nitrogen is the limiting factor in the primary production. Brackish water is often shallow water where the wind creates turbidity by re-suspending small particles. The turbidity in the water represses the growth of phytoplankton and aquatic plants. Water and bank plants are important to create structures for the aquatic organisms. The water level in brackish water fluctuates during the year, but most waters do not fall dry. It is not favorable to the small shellfish if the waterbody falls dry for long periods. (Dam, Brakke wateren, 2014)

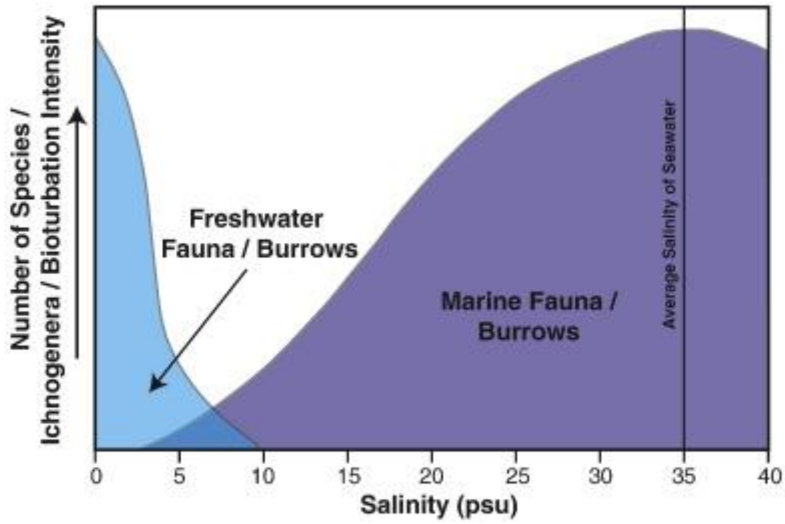

Figure 3 Relative amount of species in fresh, brackish and salt water (La Croix, 2015)

The brackish water is an extreme environment for organisms. Only a few species are fit to cope with the large fluctuations in salt over the year, however there is a large group of characteristic algae species that are suited for this environment. (Dam, Brakke wateren, 2014)

The composition of the specie community is strongly dependent on the chloride concentration. The most characteristic brackish water organisms live in moderately brackish circumstances with a salt content between the 3.000 mg/L and 10.000 mg/L. Many of these species are rare and only live in brackish waters. Many fresh water species are sensitive to salt and disappear at a chloride concentration above 150 mg/L. Because fresh and brackish water species are not suited to live there, waters with a chloride content between 150 and 3.000 mg/L are known to contain only a small amount of species. (Dam, Brakke wateren, 2014)

2.2.3 Ecological target

Two of the 42 water types are discussed below. The reason for only these two water types is that the harbor is brackish water that is subjected to tidal water and polder water.

Ecological target: “Estuary with moderate tidal influence, O2”

The key process in an estuary is the tidal movement from the sea opposite of the fresh water supply from the river. There are mud sand soil and the rich clay bottoms along the edges. Some silt in the ground that surfaces at places. Erosion and sedimentation processes shape the area with stream gullies, sand plates and wetlands. Differences in biology arrive from the flows, turbidity, oxygen concentration, type of sediment, water depth and the dry periods. (STOWA, 2005)

In the estuary there are fish species that live their total life cycles in the estuary; and species that use the estuary as a temporally living place in their life cycle. (STOWA, 2005)

There are two challenges that form a risk for the system: eutrophication and turbidity.

The eutrophication changes the composition of the community due to the boost in phytoplankton growth, causing an anoxic situation. The turbidity lows the growth of phytoplankton due to the lack of light. (STOWA, 2005)

Ecological target "Shielded coastal water, K2"
The key process is the tide from the sea with an average water level difference between the one and four meters. The bottom is muddy sand, clay and locally some hard substrate in the form of stones. The sedimentation and erosion process are constantly active. The factors that influences the biological composition in the water are the flow streams, the turbidity, temperature, oxygen, sediment and water depth. (STOWA, 2005)

Like the previous water type there are two challenges that form a risk for the system: eutrophication and turbidity. The eutrophication changes the composition of the community due to the boost in phytoplankton growth, causing an anoxic situation. The turbidity lows the growth of phytoplankton due to the lack of light. (STOWA, 2005)

2.2.4 Chemical target

The target for the brackish water bodies is explained in Table 2. The target has been divided into 5 subjects: Salt content, nutrients, oxygen balance, design and management and the natural values.

Table 2 Chemical target (Dam, 2002)

Subject	Target
Salt content	• In the summer the maximum salt content is not allowed to be more than three times the minimum winter salt content. • In the summer the salt content must be higher than the salt content during the winter. • The composition of the flora and fauna must be a reflected by the salt content in the water.
Nutrients	• A P concentration lower than 1 mg/L, when clear water is wanted. • A NH4-N concentration of 1 mg/L
Oxygen balance	• The oxygen saturation percentage between 70 % and 120%. • A BOD of 6 mg/L
Design and management	• As much nature friendly banks as possible • A minimal water transparency of 0,7 m to stimulate plant growth. • A naturally fluctuating water level. • No periods longer than a few days per year that the water body falls dry.
Natural value	• The largest amount of characteristic species present. • A large productivity of benthic organisms.

Nitrogen is along with transparency the most limiting factor. A high nitrogen concentration results in a high chlorophyll concentration. (Dam, Brakke wateren, 2014)

2.3 Potential water quality problems

The water quality can be reduced by a variety of influences. A reduction is water quality could have large consequences on the environment and the species in the water. Therefore, the possible water quality problems that might occur in the harbor of Zierikzee are discussed.

2.3.1 Climate change effects

Climate changes falls out of the scope of this thesis. However, this aspect should not be forgotten. Therefore, the influences of future climate change are shortly discussed.

Predictions of climate change suggest more frequent drought periods and heavy rainfall. This will lead to uncontrolled discharges into the water system. Alien species will highly likely invade the systems. Just as the migration of species that need to adapt to the changes of the habitat, the flow regime and temperatures will change. A reduction in flow velocity and higher water will reduce the dissolved oxygen content and enhance the possibilities for algae blooms. Upstream the system could experience and increase in dissolved oxygen, resulting in the requirement of water treatment in order to prevent toxic by-products entering the drink water supply. Nutrients will be flushed to the urban and rural areas or acidic pulses will be produced by storms that terminate drought periods. (Whitehead, 2008)

When the tolerance thresholds of the ecosystem have been exceeded due to a change in conditions like storms, snow, and drought the water quality is decreasing. Water quality changes will be likely first to appear during climate-induced stress if changes in available moisture occur and an increase in temperature. In other ecosystems the water quality in sensitive to climate variability. An increase in climate stress would increase the times the thresholds are crossed. The consequence of this is a chronic change in water quality. (Murdoch, 2000)

2.3.2 Salinity variability

The salt content of the water is the most important character that influences the organisms living in the water and in what abundance. Aside from the average chloride content the fluctuations are important too, because they affect the ecology in the water. (Dam, Brakke wateren, 2014) The brackish water is an extreme environment for organisms. Only a few species are fit to cope with the large fluctuations in salt over the year, however there is a large group of characteristic algae species that are suited for this environment. (Dam, Brakke wateren, 2014)

Generally, the biodiversity decreases along with the increase in salinity. The is due to the tolerance levels of species is exceeded. The tolerance for salt could in fact be the tolerance of O2. With increasing levels of salt the solubility of O2 decreases (Bayley, 1972).

2.3.3 Enrichment of the water system

As stated before, most of the brackish waters are naturally eutrophic (Dam, Brakke wateren, 2014). According to (Stumm, 1972) “one of the most important problems in the pollution of inland waters is the progressive enrichment with nutrients concomitant, with mass production of algae, increased water productivity and other undesirable biotic changes”.

Predictable increases in the biomass of algae in lake, reservoirs, rivers, wetlands and coastal marine ecosystems are causes by eutrophication. A change in nutrient load can have a large impact in lakes to suspended algae. (Smith, 2003)

An increase in trophic material is caused by an increase in the availability of limiting nutrients (Mihelcic, 2010).

The decomposition of organic matter consumes oxygen. The production of organic matter is stimulated by the nutrients that are able to limit growth, resulting in algae and macro phyte growth. When the organisms die they sink to the bottom where they are decomposed. If the growth of algae and macro-phytes yield a large amount of organic matter an anoxic situation may occur. The depletion of oxygen is one of the most important and commonly observed water quality problems. (Mihelcic, 2010)

The nutrient enrichment results in an increase in algal production, this has direct and indirect implications. The algal cells cause a reduction in water transparency and scums. When the algal cells die the decomposition of the biomass can result in oxygen depletion, due to the decomposition chemicals are released to the system like magnesium and iron. A high production rate of the algae could increase the nutrient cycle, creating a temporarily sink that enhances the nutrient release from the sediment. (Lorenzo, 1977)

2.3.4 Stratification

The formation of layers in the water is known as stratification. Stratification is linked to a reduction in water quality. (Perks, 2006) During the periods of stratification little oxygen is transported down across the thermocline line, oxygen can be depleted (Lorenzo, 1977). In eutrophic lakes the thermal stratification with its anoxic hypolimnetic layer restrict organisms to shallow depths (Dendy, 1945). During warm periods, the warm top layer of the water reduces the livable habitat even more, to a narrow band in the thermocline. (Hile, 1936)

In lakes the wind and motorboat activities cause wave action. The waves contribute in the erosion of the shoreline and the mixing of the surface water. As the wind moves the surface water circulates The water is replaced by water from below. Langmuir circulation is used to refer to the circular patterns. The wind generates circular pattern in which the forward pushed water needs to be replaced. The water is upwelled and down welled. The movement of the water could cause nutrient rich water from the hypolimnion to reach the epilimnion. The mixing rate is larger compared to the molecular diffusion, this could have significant influence on the aquatic system. (Dodds, 2010)

There are three factors that contribute to the mixing of water: the molecular diffusion, eddy currents and non-uniform flow. The eddy currents and the non-uniform flow are functions of the turbulence of the water. (Kocamemi, 2017)

2.4 Improving water quality

Just like the influences on the water quality, there is large variety of ways to improve the water quality. Below alternatives are discussed that could improve the water quality in the harbors. The alternatives are divided in alternatives that tackle the nutrient enrichment; reduce nutrient availability; and by managing the consequences of nutrient enrichment.

2.4.1 Tackling the nutrient enrichment problem

Nutrient control of the input is a desirable long-term lake management technique. There is ambient data that relates the nutrient concentration to the production of algae (Sakamoto, 1966). Nutrient control can be achieved by waste-water treatment, treatment of inflow, product modification or modifying the land use. (Lorenzo, 1977) Literature notes that coastal marine ecosystems are likely to respond in a positive way to controlling the nutrient loads in the system (Smith, 2003).

2.4.2 Reduce nutrient availability

The reduction of the nutrient availability means reducing the level of nutrient without changing the loading rates. Dredging the sediment; chemical precipitations of dissolved nutrients; flushing the system with low nutrient water; harvesting algae and micro phytes; and sealing the sediment are possibilities to reduce the nutrient availability. (Lorenzo, 1977)

Floating green

In many projects floating green patches are used. The main purpose of the green patches is the improvement of the water quality by purification. The floating green patches also have the ability to enhance the ecological values. Floating water plants and floating plant systems have positive effects on the oxygen content of the water. (Reinsel, 2012) According to (Sportvisserij Nederland) a minimal oxygen concentration of 5 mg/l in the water is required to provide sufficient oxygen to the aquatic organisms.

The water column is a cooler environment due to the shadow that is caused by plants (Nahlik, 2006). Floating green could participate in the competition for nutrients, resulting in a repression of algal blooms (Chang, 2012).

The Biohaven Float lands project is a nice example of floating green. The Biohaven Float lands project took place in the Chicago River in the USA. Man-made floating wetlands were created, see Figure 4. Underneath the float lands significantly more fish were present compared to the open water under the docking piers that were close by the island. Multiple explanations were given for this:

- The woven synthetic material of the float lands has much more surface available for algal growth then on the docking pier. This could lead to a positive ecological effect due to an increase in food availability. This food availability increases directly (for grazers) as indirectly because of the increase in plankton and macro fauna.
- The roots underneath the flatlands create more structural variation and therefore more habitats compared to the docking pier. The roots create more space for plankton and provide hiding places and food for fish, zooplankton and macro fauna.
- The improvement of the water quality could lead to better circumstances for the fish. (Midwest Floating Island, sd)

There are three kinds of floating islands considering the structures. There are floating islands without underwater structures, floating islands with artificial underwater structures and floating islands with living root structures. Of these three the floating island with the living root structure has the most ecological benefits. The roots offer hiding places, habitat, feeding, breeding places and contribute to the oxygen production. (Didderen, 2015)

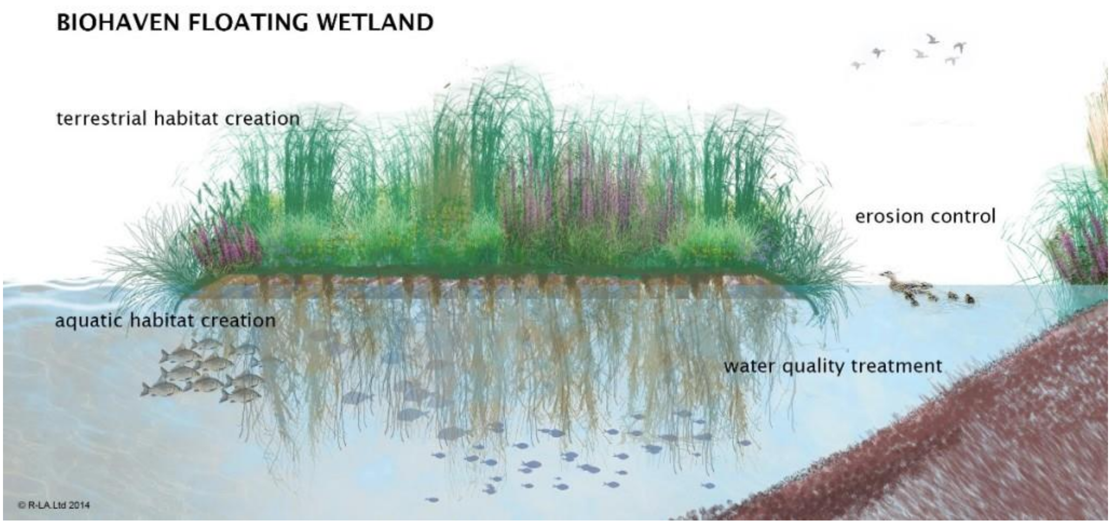

Figure 4 Biohaven floating wetland (Midwest Floating Island, sd)

The Biohaven floating islands are made up of a matrix of non-woven PET plastic fibers derived from BPA free recycled plastic drinking bottles. This matrix is injected with marine grade foam to increase the buoyancy. The islands have a central anchor point and holes for vegetation. (Midwest Floating Island, sd)

The floating treatment wetland (FTW) from Biohaven has the ability to reduce the nutrients levels in the water. This ability would reduce the nitrogen and phosphorous concentration in the water. CH2M Hill has observed 20 ponds with FTWs, each pond contained about 5 million gallons of reclaimed water. The reclaimed water came from the Pasco County Master Reuse System (PCMRS), A wastewater transmission and distribution station where wastewater

effluent disposal for Pasco County and the City of New Port Richey is transmitted and distributed. All the FTWs were 2,5 by 3 meters, containing 154 plants.
(Floating Island International Inc., 2014)

The performance period of the FTW was the period after the plants were established on the island. The control phase was the period after the removal of the FTWs. The residence time for each pond was approximately 20 days. (Floating Island International Inc., 2014)

The FTWs have a positive effect on the total phosphor concentration (TP), the total nitrogen concentration (TN) and the pH. The result can be seen in Table 3. The bacterial and plant efficiency to remove nutrients was substantially enhanced during the performance period. In the control period the nutrients were still being removed, this was due to some bacterial activity and solids that were settling down. (Floating Island International Inc., 2014)

Table 3 Results FTW nutrient removal research (Floating Island International Inc., 2014)

	Performance period			Control period		
Parameter	**In**	**Out**	**Removal**	**In**	**Out**	**Removal**
Total N mg/L	6,10	2,04	67%	4,47	3,44	23%
Total P mg/L	1,96	0,63	68%	1,37	1,00	27%
pH	NA	9,96	NA	NA	11,25	NA

Ponton hula's and pole hula's in the Port of Rotterdam
Hula's are nylon rope structures that primarily have the purpose of facilitating substrate where organisms can attach to. This goes essentially for organisms that live on substrate like mussels, algae, barnacles, etcetera. When the substrate organisms have established on the hula, other organisms will follow.

Nylon was chosen as rope material because natural rope would degrade too fast. Therefore, nylon rope is considered the more sustainable material. (Herder J. P., 2009)
Experiments have shown that in salt water a rapid colonization of mussels takes place on the hula's. In fresh water the mussels tend to attach to similar structures (Building with nature in de stad, 2015)

Ponton hulas are floating frames made of PVC-sewers pipe. Within this frame hangs a nylon net, see Figure 5. At the knots of the net rope structures are attached. The floating structures improve the biological productivity in the water; especially the productivity of freshwater mussels could be increased greatly by the ponton hula's. (Paalvast P. d., 2010)

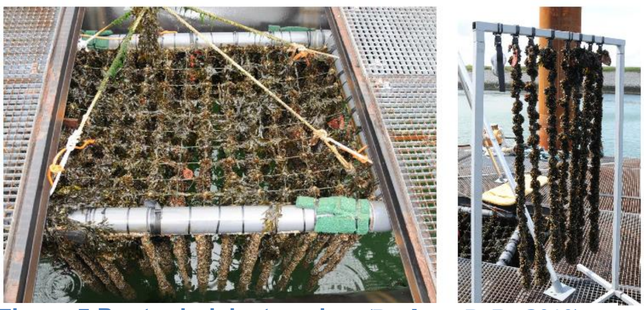

Figure 5 Pontonhula's top view (Paalvast P. B., 2010)

Pole hulas are nylon rope hanging around a pier pole submerged or temporarily submerged during the day, see Figure 6. (Herder J. P., 2009)

Figure 6 Polehula (www.visclublint.be)

The hulas have many ecosystem services.

- They contribute to filtering the water because of the mussels they attract. The mussels remove floating particles when filtering the water. The water transparency will increase and the amount of nutrients in the system will decrease.
- The hulas facilitate many species with a habitat and shelter, this increases the biodiversity. The Japanese oyster, an exotic species that threats the local mussels seems not to be able to attach to the hulas. This advantage provides the local mussel species with the opportunity to grow and reproduce.
- In the harbor the hulas decrease the reflective waves, this contributes to a stable water situation in the harbor.

(Building with nature in de stad, 2015)

The construction of the hulas is not a challenge, the position of the hulas however is an interesting subject. The pole hulas can be attached to the poles of the piers in the harbors. Another option is to secure pole hulas to the submerged parts of the quay walls in the harbor.

The ponton hulas can be placed underneath the piers and in the harbors in Zierikzee. They can be attached to the piers, which can fluctuate along with the water level. This allows the ponton hulas to constantly be submerged.

After nine months from the start of the experiment with the pole hulas, the wet biomass of the Blue mussel varied between the 9 kg and the 203 kg. The reference poles without hulas had an average wet biomass of Blue mussels of 100 kg. (Paalvast P. , 2015) On average the biomass on the pole hulas was 4,4 to 11,4 times larger than compared to the reference poles. The colonization on the ropes of the pontoon hulas was similar to that of the pole hulas. The density of the ropes related to the optimal biomass production was estimated at 4 to 8 ropes pet m2. (Paalvast, Wesenbeeck, Velde, & Vries, 2012)

Due to the experiments the conclusion could be made that the hulas enhance sessile biological production and biodiversity. This effect is likely to result in an increase in the water quality locally. (Paalvast P. , Application of string and rope structures, pole and pontoon hulas, to increase production and biodiversity in man-made hardsubstrate aquatic environments., 2015)

Other habitat structures

There are multiple other options next to the floating island and ponton hulas. Research has been performed on the effect of an addition of habitat structures on the ecological environment. Natural habitat structures are for example wood or stone, but also artificial structures like fake plants. The function for these habitat structures are growth possibilities, hiding places, reproduction substrate and indirectly food provisioning. There is a clear negative relation between the removal of habitat structures and the diversity and density of the fish community. (Smokorowski, 2006)

Oysters

Oysters are filter feeders, meaning they collect food by filtering the water. Oysters can filter up to 190 L per day, while filtering they gather algae and other suspended particles from the water column. The oysters indirectly remove nitrates from the water by feeding on algae who use nitrates to grow. Some of the nitrates end up in the tissue of the oyster of the shells, the rest is excreted by the oyster as feces. The oysters filter the water, improving the water quality and contribute to the natural population when spawning. (Kotz, 2015)

The phytoplankton productivity and the stocks of pelagic microbes, ctenophores, medusae, and particulate organic carbon would be decreased. The increase in oysters support the growth in benthic primary producers, mesozooplankton and fish stocks. Furthermore, the oysters have the potential to mitigate eutrophication by curtailment of nutrient inputs. (Ulanowicz, 1992)

As (Kotz, 2015) describes nitrate accumulates in the oysters. The nitrate is no longer available to the system as long as the oyster is alive, when the oyster dies the nitrate is retrieved back into the system. When the oysters are harvested the nitrate is removed from the system. The oysters can therefore be used as a temporarily storage for or as a way to remove the nitrate from the system.

On the Figure 7 below there are two tanks shown. Both tanks contain the same water, however one tank also contains oysters. After two hours the tanks are observed again. As can be seen the water in the tank containing the oysters is much less turbid than the tank without oysters. (Maryland Seafood, 2014)

When the water is clear, more sunlight is able to penetrate the water column. When more sunlight penetrates the water column, more water plants will grow, and indirectly more biodiversity because of the increase in habitats. (Maryland Seafood, 2014)

Figure 7 One tank with oysters and one tank without oysters (Maryland Seafood, 2014)

In order to be able to handle the many loose oysters they are put in cages (Figure 9) or bags (Figure 8). The size of the cages depends on the purpose and location of the oysters. The cages could be placed on the bottom or be hanged in the water column. The structure in which the oysters are has to be sufficiently open, so the oysters are in proper contact with the water.

In the harbors in Zierikzee both cages and bags can be realized. They can be positioned underneath the piers. The number of oysters needed to sufficiently filter the water in the harbors is decisive on how the oysters will function and how efficient they will be.

Figure 9 Oyster cage (www.nanssanctuary.weebly.com)

Figure 8 Oyster bag (www.nanssanctuary.weebly.com)

2.4.3 Manage the consequence of nutrient enrichment

To control the undesirable conditions in enriched lakes chemical means are used like algaecides, herbicides and pesticides. Physical control mechanisms such as harvesting; deepening the lake; using fluctuating water levels; and circulation or aeration are used. The aeration and circulation techniques are suited to improve the water quality in a large range of uses. (M. Lorenzo, 1977)

Artificial destratification

The biomass, species and production rate of the algae are all influenced by the artificial aeration-circulation manners. The observed change is caused by the changes in pH, available light and nutrient status. (Lorenzo, 1977)

By artificially destratifing the Erdman lake in Washington the Silver Salmon survival rate increased 500 % (Mayhew, 1963).

Artificial destratification eliminates the chemical and the thermal barriers for fish and other organisms, increasing their habitat. During the periods of stratification little oxygen is transported down across the thermocline line, oxygen can be depleted. (Lorenzo, 1977)

Mixing

With a high energy system, the lake can be de-stratified to control algal blooms. The algae will be redistributed throughout the water column, this limits the amount of light available for photosynthesis with as a result a reduction in productivity of the algae. (Lorenzo, 1977)

There are three types of mixers. There are mechanical mixers, hydraulic mixers and pneumatic mixers. Mechanical mixers are propellers and turbines. Hydraulic mixers are dependent of the water flow. The degree of turbulence is measured in head loss. Examples of mechanical mixers are a venturi section, a hydraulic jump, parshall flume, and a weir. (Kocamemi, 2017)

By circulation, blending and mixing the water quality will improve. When the water is circulated over a long distance not only the water quality, but also the biodiversity increases, and odors are prevented. (Better World Solutions, 2017)

In six cat fish ponds tests were performed by mechanically circulating the water in the ponds during the day. Compared to the ponds without circulators the temperature and the dissolved oxygen concentration has little variation compared with the water depth. The circulators mixed the water effectively. The plankton abundance, the ammonia and nitrogen concentrations were not affected by the circulation. (Tucker, 1995)

Aeration
The aeration methods used when there is a lack of oxygen and to mix the water. Compressed air is released at the bottom of the lake. The oxygen that is required can be provided by mixing the lake, to eliminate the thermocline. (Lorenzo, 1977)

Mixing with water
An example of such a high energy mixing manner is a reservoir, the incoming water is being pumped through six jets. The inlets of the jets are horizontal or at an angle of 22,5 or 45 degrees to stir the water flow. (Lorenzo, 1977)

In a circular tank a study of the orientation of the water inlet and the water flow discharge through a bottom-center drain has been performed to research the water rotational velocities. (Davidson, 2004) concluded the following. “The water rotational velocity taken in a vertical plane bisecting the tank indicated that velocities were consistently higher at the tank’s perimeter and that these velocities increased nearly linearly with radial distance from the tank center. The results also show that higher rotational velocities were produced at larger bottom flow rates, i.e., a 12% bottom flow created higher rotational velocities than 6 or 0% bottom flows. Reorienting the direction of the water inlet nozzles also provided a simple method for adjusting rotational water velocities within the culture tank. For example, simply reversing the direction of one of the six 45° flow injection nozzles decreased the rotational velocity about the perimeter of the 10 m3 tank from 17.8 to 13.4 cm/s.” (Davidson, 2004)

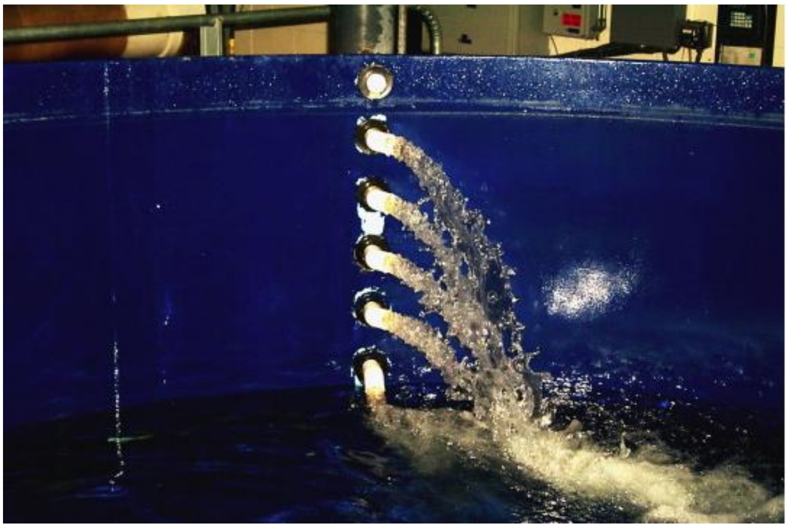

Figure 10 Bottom center drain in circular tank, the nozzles have different angles (Davidson, 2004)

Flushing
Amsterdam
In the past Amsterdam was directly connected to the Zuiderzee, the refreshment of the canals occurred naturally because of the tides. From the time the Oranjesluizen were made the refreshment had to be arranged differently because the canals were closed off. Parallel to the Nieuwe Vaart a discharge canal was constructed to improve the control of the water. In 1879 the pumping station Zeebrug was established six years after the construction of the Oranjesluizen. The Oranjesluizen were designed to facilitate the discharge of the water and to let the water from the Ijmeer into the canals to flush and refresh the water when there was a low oxygen concentration in the water. The water was redirected, instead of flowing from west to east the water was artificially made to flow from east to west. Via the Noordzeekanaal the water flows to the sea.

For the refreshment of the water, free discharge has been used. When the water level from the Ijmeer was 20 to 25 cm higher than that of the water level in the canals could be refreshed by means of a free flow, no pump was needed. During the refreshment of the water two sluices were closed, on Figure 11 the closed sluices are indicated red stripes. In the summer the canals were refreshed four times a week and in the winter two times a week. Since January 2010 the canals were only refreshed when the oxygen concentration (data collected by measurements) are too low. (Baaren, 2010)

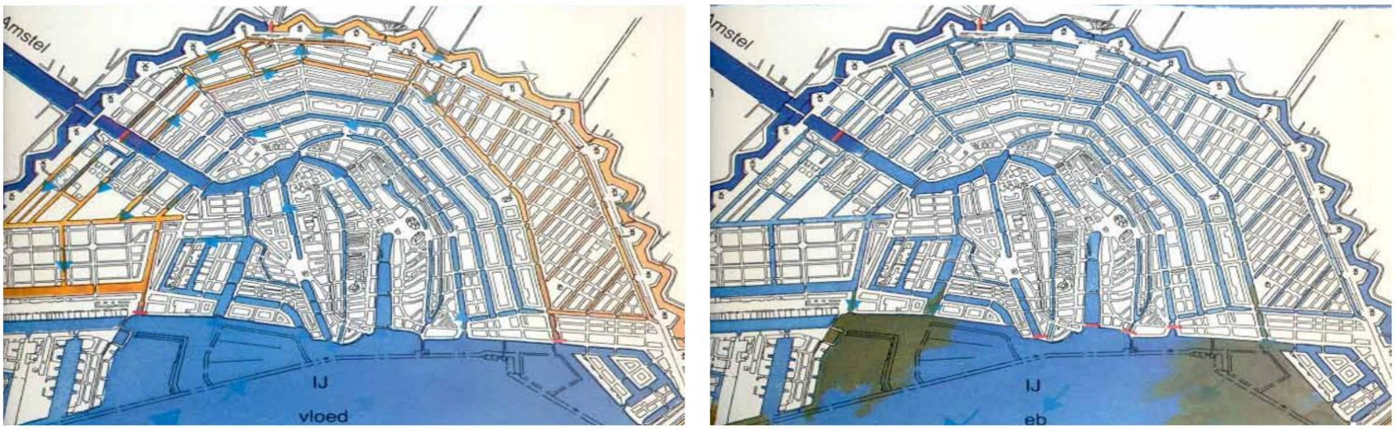

Figure 11 Amsterdam tidal canal refreshment (Baaren, 2010)

New York

In New York the Gowanus Canal was a dumping place of all kinds of materials and chemicals., the canal was known as almost solid in 1910. In 1911 the brick-lined tunnel was constructed with a giant propeller. This structure was meant to flush dirty and toxic sludge from the Gowanus Canal, in the center of Brooklyn to the large Buttermilk Channel. The system to flush the brick-lined tunnel had mechanical problems and was not sufficiently effective. In 1960 the system did not function, and the city chose not to repair it. Forty years had passed and the area around the canal had changed immensely. Trucking had replaced the shipping and the factories were replaced with residential places. The bottom of the canal was described as “black mayonnaise”.

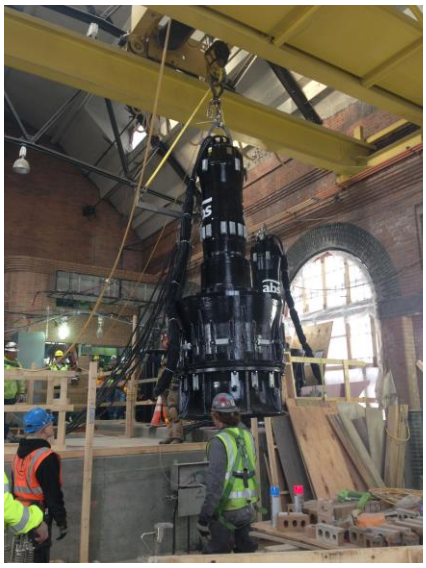

Figure 12 Turbine being installed (Flickr, 2017)

The New York City Department of Environmental Protection was focusing on the improvement of the canal flushing tunnel system to improve the water quality in the Gowanus Canal. The motor pit was reconstructed, and the old propellers were replaced by three vertical turbines. The water flow was reversed, pumping fresh water from the Buttermilk Channel into the Gowanus Canal.

The main purpose of the flushing was to bring oxygen rich water into the canal. The increase in oxygen will reduce the smell and make the canal more suitable for mollusks, fish and plants. (Manley, 2014)

2.5 Residence time

The residence time of the harbor of Zierikzee is influenced by the minimal water level. This change in residence time in turn influences the balance of the ecosystem. Therefore, the changes in residence time are studied in this thesis.

Two water systems can be similar in geographical region, climate and size. However, the difference between the systems are the features of the watershed and the residence times. A short residence time results in a more dynamic system compared to a longer residence time. There are pronounced temporal patterns that are related to the water column changes and the biomass of the phytoplankton. The water system with the longer water residence time is spatially more heterogeneous. The spatial zonation is more frequently seen in water systems with a short residence time. This is related to the availability of the light and nutrient sedimentation. (Soares, 2008)

2.5.1.1.1 Residence time

The residence time, also known as flushing time is the first order of transport. The residence time is a measure of water-mass retention within an area with clear boundaries. (Boyton, 1995). (Basu, 1996) found that the residence time should be the basis of the ecosystem-scale nutrient budget comparative analyses. In rivers the residence time is short, compared to the plankton population growth rate. This results in a low abundance of plankton in the rivers.

2.5.1.1.2 Calculating the flushing time

The description of the general exchange characteristics of a water body without identifying the physical processes, the spatial distribution or the importance of the processes is called the flushing time (Tf). The flushing time can be calculated with the formula Tf=V/Q or flushing time = Volume of the water * Volumetric flow rate. (Geyer, 2000)

When there are tides in a system the tidal prism method can be used to estimate the flushing time. This method is applied when only the basin geometry and the tidal range information is known. The tide is assumed the only element that flushes the system. (Dyer, 1973)

$$T_f = \frac{VT}{(1 - b)P}$$

Figure 13 Flushing time formula with tides (Dyer, 1973)

There is no substantial data available about the nutrient or chemicals in the water of the harbor of Zierikzee. Multiple measurements will have to be performed over a longer period to be able to include the nutrients and chemicals in the water. Therefore, the formula designed by (Dyer, 1973) has been used.

The domain volume between high and low tide is known as the tidal prism (P). The tidal prism can be estimated by multiplying the tidal range (R) by the surface area at the average water level. This means P=R*A average. The flow rate is found by dividing the tidal prism (P) by the tidal period (T) or P/T. V is the average volume water in the basin. The return flow factor (b) is the fraction of effluent water that returns to the main tide each flood. The return flow factor cannot be estimated from the geometry of the basin. It is a function of the effluent that leaves the domain. (Sanford, 1992) When b=1,0 all the water that existing the bay will return to the estuary. When b=0 no water from the bay will return to the estuary. (Shi, 2011)

The tidal prism method considers four assumptions: The system is well mixed; the tidal flow is large compared to the river flow; The receiving water is sufficient to dilute the water in the basin; and the system is at a steady state with sinusoidal tide signal. (Sanford, 1992)

The flushing time for the harbor is calculated in this thesis. The formula noted above it used for this calculation.

2.6 Fish migration

When a minimal water level is created the fish migration will be influenced. The current migration path will be obstructed. In order to meet the EWFD goals, fish migration needs to be facilitated.

In a natural landscape every river discharges into sea, at that place fresh and salt water mix. The salt-fresh water transitions have a crucial function in the reproduction cycle of fish species like the bream. The salt-fresh water transition zones are very limited by the introduction of construction that disrupt the natural watercourse. The reduction of the migratory fish species decreases the ecosystem quality of the Dutch waters. (Rijkswaterstaat, sd)

Because of the many structures in the waterway in order to control the water, the fish are being disrupted in their migratory path. On the regional migration routes lie many obstacles for the elvers and the three-thorned stickleback. (Philipsen, 2015)

Fish migration needs to be possible because fish need to be able to reach the essential habitats to complete their life cycle. It provides variety in the aquatic systems when waters are connected, enlarging the living environment and improving the water quality. The facilitation of fish migration is a large step forwards to recovering the communities. (Beeren, 2000)

Fish migration is the concept that fish move to find a suitable location to reproduce, find food or hide from predators. Fish migration can be divided into three categories: migration, movement and dispersion. Fish migration is the seasonal movement because it is necessary to change living environment. When discussing fish movement, the fish travels small distances, for example daily movement. In all living environments daily movements exists. Fish are looking for food, the distance between day and night stays and so on. The dispersion is the enlargement of the population by the exchange between subpopulations and free exchange between fish. The migration of fish species is shown in Figure 14. (Beeren, 2000)

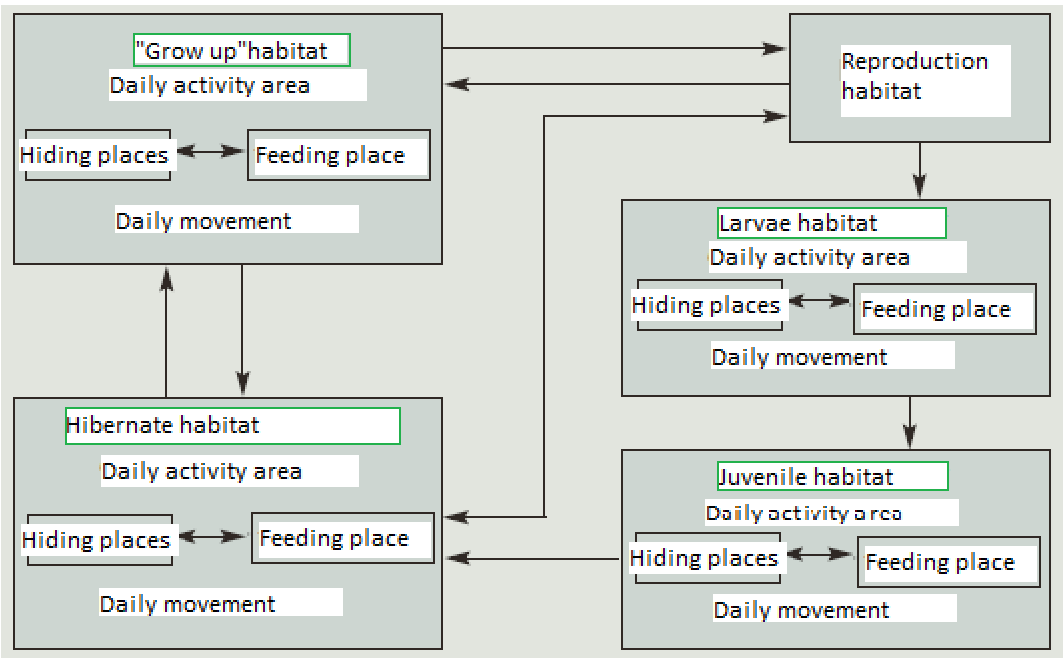

Figure 14 Migrating fish life cycle to habitats. The dispersion is not shown. (Beeren, 2000)

2.6.1 Fish passages

Fish passages are used to enable fish to migrate. This means helping the fish to overcome structures or obstacles to reach the polders. The migrating fish want to move upstream. (Hofma, 2014)

De Wit fish passage

De Wit fish passage consists of a box with separate rooms inside. The box can be made of concrete, steel or synthetic materials. Submerged windows connect the rooms, allowing fish to swim through. The windows are all equal in size, however the location of the window in each wall is different, reducing the water velocity in the rooms. See Figure 15 for the schematic overview of the fish passage. The water levels differ 5 cm from each other, resulting in a water velocity of 1,0 m/s in the windows. Fish can swim through the rooms, the little differences in water level make it possible to pass a weir.

The size of the De Wit fish passage can be adjusted to the situation and the requirements of the client. Characteristic for the De Wit fish passage is that the velocity in every window is equal, but this depends on the design and the water level differences per room. (Hofma, 2014) In Table 4 the pros and cons of the De Wit fish passage are noted.

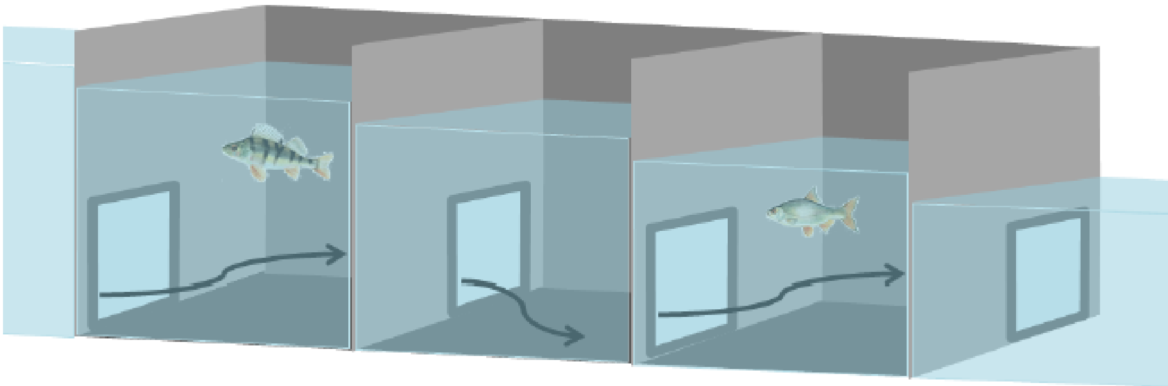

Figure 15 De Wit fish passage (Hofma, 2014)

Table 4 Pros and cons De Wit fish passage (Beeren, 2000)

Pros	Cons
Suited for a large fluctuation in discharge and water levels. The difference in water levels is being divided over the chambers.	Sensitive for the accumulation of floating debris outside of the construction.
During low discharge periods fish migration is still facilitated.	The construction becomes larges when the water level difference increases.
Simple implantation when prefab chambers are used.	Classical concrete or steel designs are ecologically not interesting.
Economical water use is the fish passage. The construction can be applied in flat or light angled areas or in areas with only little available water.	Less powerful attraction flow compared to the semi-natural fish passage or the V-shaped fish passage.
Not sensitive to the accumulation of floating debris within the construction due to the submerged entrance.	Not suited for fish that live close to the water surface and for fish that are larger than the opening of the chambers.

Basin fish passage

The basis fish passage is a by-pass divided into basins, separated by weirs. These weirs form steps in the waterway. Between the different steps there is a 5 to 10 cm water level difference. The weirs are shaped like a wide V, see Figure 16. The V creates high water velocities in the middle of the weir, reducing toward the sides. The fish can pass the weirs on the sides easily. The discharge also varies along the V shaped weir, without limiting the ability for fish to pass. The weirs are made in many forms, for example of wooden quay walls or stones that are deposited. (Hofma, 2014)

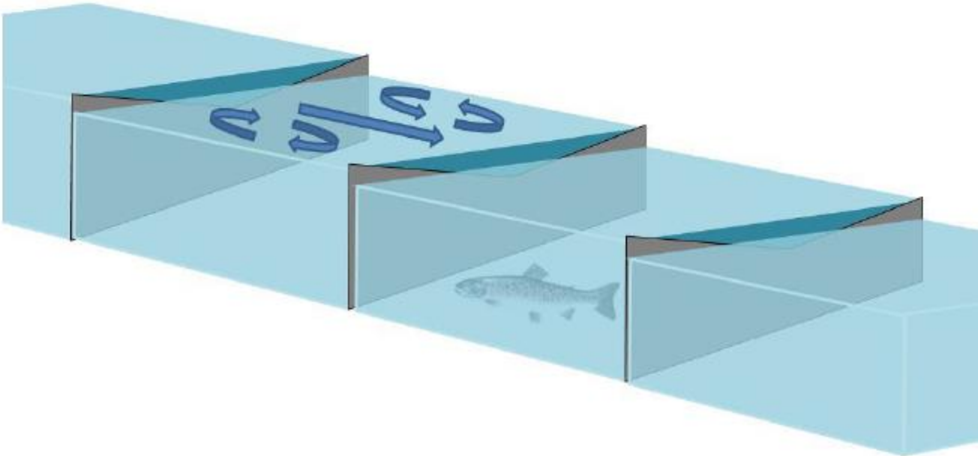

Figure 16 Basin fish passage (Hofma, 2014)

Polder sluice passage

The polder sluice is a compact fish passage. It is specially designed for situations with fluctuating discharges, limited available space and no electricity available. The polder sluice is a prefabricated box that is placed against the sheet pile of the weir. A hole is made in the sheet pile, the lowest part of the hole is at the minimal permitted water level. The water flows through the hole, into the fish passage. On the downstream side of the passage a submerged window is present through which the water can be discharge. The discharge of the water results in an attraction flow, luring the fish to the fish passage. When the fish swim through the window into the fish passage, a valve closes the window. The valve is closed using solar energy and water pressure. The fish passage is filled with water, when the passage is almost completely full an overflow maintains the attraction flow. When the fish passage is totally filled with water the water level is equal to the upstream water level. The equality in water levels allows the fish to swim out of the passage upstream. How many times the cycle takes places during a day is adaptable. (Hofma, 2014) On Figure 17 the polder fish passage is shown.

Figure 17 Fish sluice passage (Hofma, 2014)

The sluice fish passage is independent of the discharge, compact and easy to implement, solar energy is used, and it is independent of the height of the weir. The sluice fish passage can deal with a difference in water level up to 50 cm. (Hofma, 2014)

Polder basin fish passage

Just as the polder fish sluice the basin fish passage is designed to cope with fluctuating discharges and little space. The polder basin fish passage consists of square basins, each basin has an overflow in the form of a gab in the basin wall. The windows are positioned on the upper side of the overflow. Each overflow has a height difference of 5 cm. The windows are 10 cm by 10 cm resulting in a maximum water discharge of about 10L/s. Figure 18 shows a functional polder basin fish passage.

The polder basin fish passage is mainly used for small polder fish like bream and small pike. (Hofma, 2014)

Figure 18 Polder basin fish passage (Hofma, 2014)

Fish passage Maelstede

In Maelstede a fish passage is located next to pumping station Maelstede. The passage consists of a pipe system, in this pipe system fish are able to swim from the polder against the stream into a container. Every two hours a valve is closed on the polder side of the container and the water in the container is being pumped to the Westerschelde. When the water is not pumped to the Westerschelde the fish have the chance to swim along with the water towards the polder. Figure 19 a schematization of the Maelstede fish passage is shown. The Maelstede fish passage allows fish to migrate from the polder to the Westerschelde and vice versa. (Griffioen, 2013)

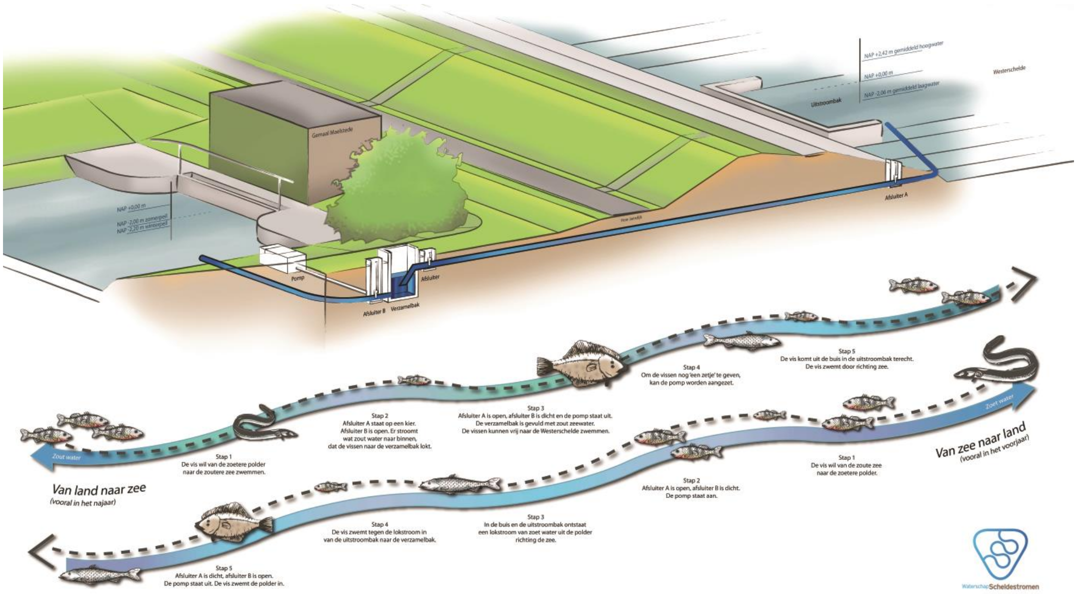

Figure 19 Fish passage Maelstede impression (Griffioen, 2013)

Fish passage Poppekinderen

In Middelburg there is a fish passage called Poppekinderen. By means of an attraction flow fish are lured into a container. The container is connected to the polder by means of pipe. At a set time the water from the container flows into the pipe toward the polder. The water is discharged by gravitational force into the polder. The water from the container that contains fish is are transported into the polder. On Figure 20 a schematization of the fish passage is shown. (Waterschap Scheldestromen)

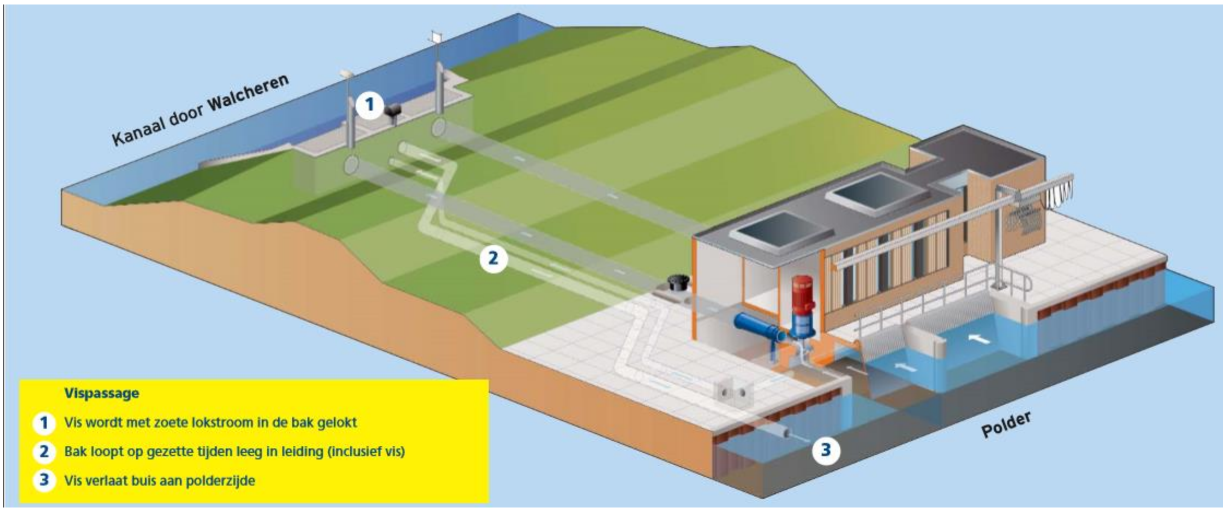

Figure 20 Fish passage Poppekinderen (Waterschap Scheldestromen)

Solar driven fish sluice

In the Berflobeek in Hengelo there is a fish passage working on solar energy. The fish sluice takes up little space and is able to overcome large water level differences. On Figure 21 a picture of the solar fish sluice can be seen. The solar driven fish sluice functions in cycles. The fish swim into a concrete container, the container is closed and in the container the water level is raised. The opening on the other side of the container opens. The raised water level and the open pipe provide the opportunity for the fish to swim into the pipe that leads upstream. When the fish have left the container the water level is lowered again, and the cycle starts from the beginning. (Waterinnovaties in Nederland, 2016) The pros and cons of the solar fish sluice can be found in Table 5.

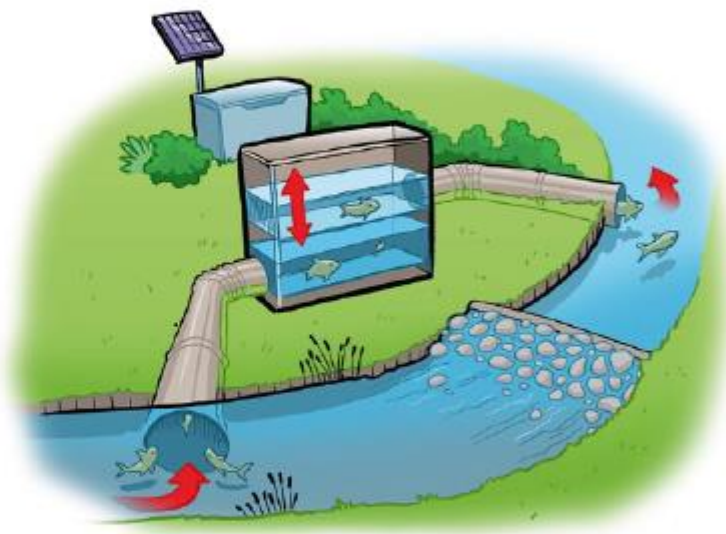

Figure 21 Solar driven fish sluice (Waterinnovaties in Nederland, 2016)

Table 5 Pros and cons fish sluice (Beeren, 2000)

Pros	Cons
Suited for a large diversity in fish species, not hindered by their size or swim capacity.	No continuous passage possible, only a sluice cycle.
Small surface area needed to overcome large water level differences.	A technical construction requires maintenance
	Strong fresh-salt water transition when implemented in coastal zones. This could affect the fish species.

Jack-screw fish passage

The jack-screw fish passage has a screw that transports water. The fish will be transported along with the water. The screw is positioned in a smooth pipe, the pipe and the screw are connected to each other. There is no space between the screw and the wall, the fish will be protected from being hurt of getting stuck. Figure 22 shows a schematization of the jack-screw passage. When the screw moves, water with the fish is transported up. (Fish Flow Innovations, 2017)

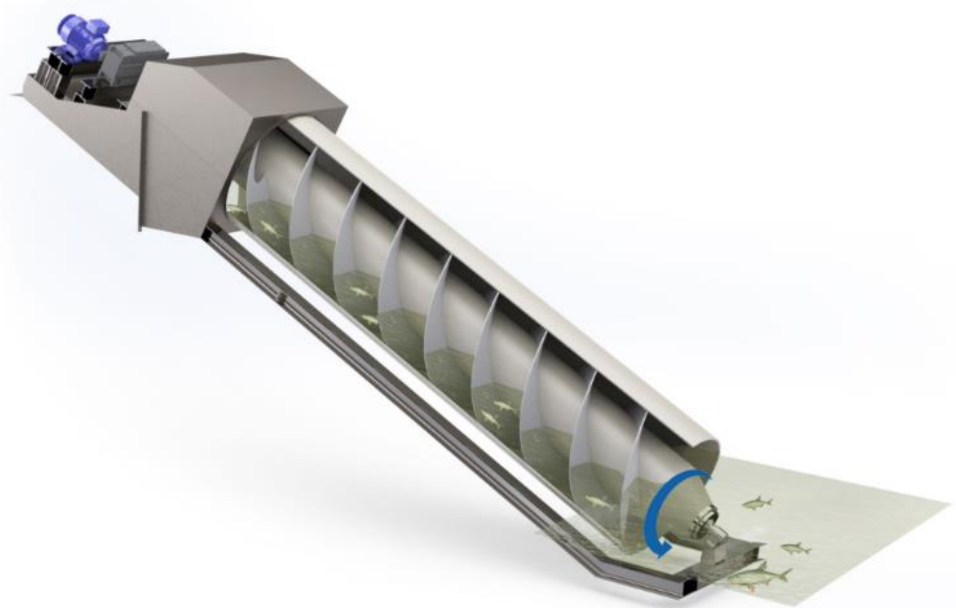

Figure 22 Jack-screw fish passage (Fish Flow Innovations, 2017)

Siphon fish passage Texel

The siphon fish passage makes use of the principle of a siphon. When there is a uninterrupted water connection between the reservoirs, the water flows from a high located reservoir over an obstacle to a lower located reservoir. The water flow stops when the water reservoir at the upstream side is empty, the water levels in the reservoirs are at the same level or when the connection between the reservoirs is broken.

On Texel, on the outside of the dyke there is a reservoir. This reservoir has a higher water level compared to the water on the inside of the container. The dyke forms the obstacle and the polder is the lower lying reservoir. The outer dyke reservoir is always located in the mouth of the pumping station or near a sluice because at those locations fresh water is being discharged into the sea, see Figure 23. This discharge flow acts as an attraction flow for the fish when the water flows from the pump via the passage to the sea. The hours the siphon passage is active depends on the difference in height between the reservoirs. On Texel the connection lies at +10 cm NAP, this results in an operational period of 6 to 7 hours per tidal cycle of 12,25 hours.

The siphon fish passage is fit for: 1. the three thorned stickleback; 2. the eel; and 3. the brackish water gudgeon. These are known species that make use of the siphon fish passage. However, the larvae of the halibut and the smelt would have the ability to migrate through the siphon fish passage as well. (Wintermans, 1999)

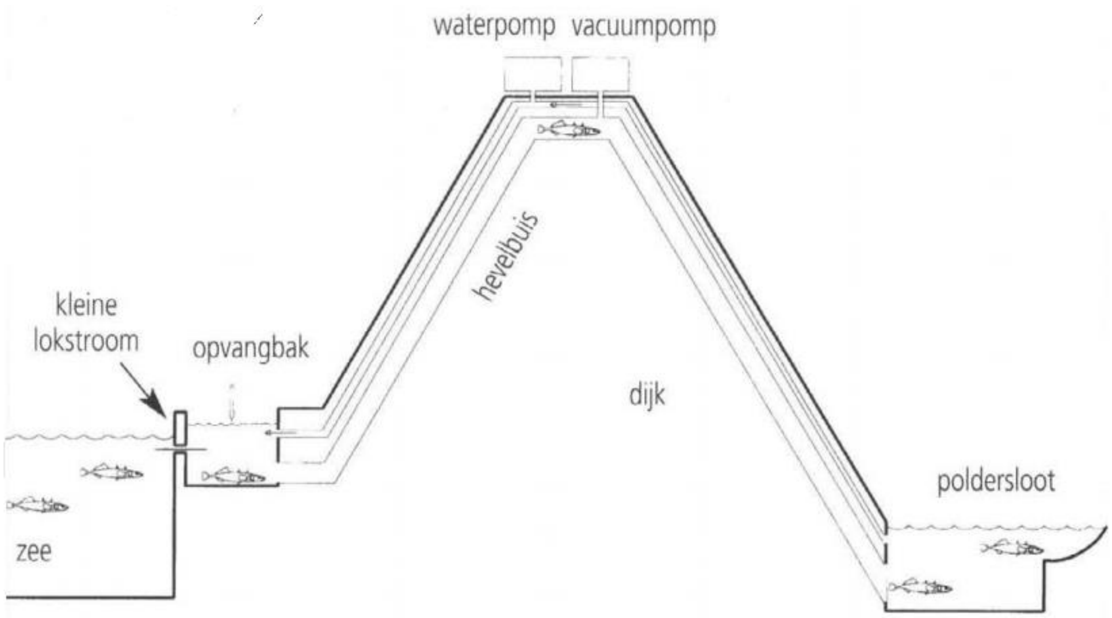

Figure 23 Fish passage Texel (Wintermans, 1999)

2.7 Design philosophy Ecological engineering

In this thesis a design will be made. For this design, the design philosophy of ecological engineering will be used.

Ecological engineering has emerged from the need to provide human welfare and protect the natural environment at the same time in the engineering practice. From the natural environment goods and services are acquired. *"Ecological engineering is the design of sustainable systems, consistent with ecological principles, which integrate human society with its natural environment for the benefit of both. It recognizes the relationship of organisms (including humans) with their environment and the constraints on design imposed by the complexity, variability and uncertainty inherent to natural systems."* Five ecological design principles have been identified. The goal for ecological engineering it to integrate the environmental support with the society. (Bergen, 2001)

The Ecological engineering design principles will be used for the design of the constructions of this thesis.

Design principle 1: The design is consistent with ecological principles
The first principle stands for the design of products with the help of the natural systems, by mimicking natural structures, self-organizing systems and succession. The complexity and diversity are the characteristics that allow an ecosystem to self-organize. The structure and diversity that is produced in large qualities allows the ecosystems to persist and stay healthy. An environment with closed process cycles maintains its ecosystem. (Bergen, 2001)

Design principle 2: design for site- specific context
There is a large spatial variation caused by the complexity and diversity of the ecosystem. Gaining information about the ecosystem as much as possible allows to be able to design something that suits the ecosystem and functions in it. The information about the ecosystem provides the opportunity for a holistic view. The cultural context of an ecosystem must not be forgotten. The acceptance by the local community by including them into the design process makes the project more likely to succeed. (Bergen, 2001)

Design principle 3: maintain the independence of design functional requirements
A complex ecosystem results in large levels of uncertainty, which cannot be reduced. Simple and workable solutions are preferred. A manner of dealing with the uncertainties is providing a tolerance level on the functional requirements for the design. By making this tolerance level as wide as possible uncertainties become accepted. (Bergen, 2001)

Design principle 4: Design for efficiency in energy and information
By letting nature help with the engineering the energy use is reduce. Using the energy from the natural environment like the sun and the water. When there is cooperation with the natural processes the system requires less information and energy and becomes self-organizational. (Bergen, 2001)

Design principle 5: Acknowledging the values and purposes that motivate design
The design is made to benefit the natural environment and the society. In order to avoid disasters failures, the designs are both fail-safe and safe-fail. (Bergen, 2001)

2.8 Open channel flow

For the civil engineering competences, a flow model has been evaluated. For this the following formulas could come in hand.

Laminar flows rarely occur in practice, accept for groundwater flow. The velocity and viscosity of the water influence the turbulent flow much less compared to laminar flow. When evaluating the water flow in the harbor a set of formulas is used. Below the possible formulas are explained shortly. (Nortier & de Koning, 1996)

2.8.1 Reynolds number

When calculating flow, the first thing to do is determining whether the flow is turbulent or laminar. This can be done by calculating the Reynolds number, this gives an indication how turbulent the water is. Turbulence expresses the fluctuation in water velocity. The more turbulent the water, the harder it is for particles to sink to the bottom.

Reynolds Number	$Re = \frac{V.4 \cdot R}{\nu}$
$\upsilon =$ Kinematic viscosity	[m²/s] water, 20°C= $1{,}00 \cdot 10^{-6}$
$\rho =$ Density of liquid	[kg/m³]
$V =$ Mean velocity	[m/s]
R = Hydraulic Radius = D/4	[m]
$Re =$ Reynolds Number	[1]
$Re > 4000$ Turbulent flow	
$Re < 2000$ Laminar flow	

Hydraulic Radius	$R = \frac{A}{P}$
$\mathrm{R} =$ Hydraulic Radius	[m]
$A =$ Wetted Area	[m²]
$P =$ Wetter Perimeter	[m]

(Nortier & de Koning, 1996)

2.8.2 Chezy

Chezy has developed a formula in order to calculate the average velocity in any random pipe in which the flow is uniform turbulent.

Chezy formula	$V = C \cdot \sqrt{R \cdot S_f}$
$V =$ Mean Fluid Velocity	[m/s]
$\mathrm{R} =$ Hydraulic Radius	[m]
$S_f =$ Slope energy / total head	[1]
$C = \sqrt{\frac{8g}{\lambda}}$ Chezy coefficient	[m$^{1/2}$/s]

(Nortier & de Koning, 1996)

2.8.3 Manning

Manning has developed the manning formula in 1890. The roughness factor n is tested widely for a variety of martials. Compared to Chezy, this makes applying the formula more time efficient.

Manning $\quad V = \frac{R^{\frac{2}{3}} \cdot S_f^{\frac{1}{2}}}{n}$

$$Q = \frac{1}{n} \cdot \frac{A^{\frac{5}{3}}}{P^{\frac{2}{3}}} \cdot S_f^{\frac{1}{2}}$$

$V =$ Mean Fluid Velocity	[m/s]
$\mathrm{R} =$ Hydraulic Radius	[m]

$S_f =$ Slope Total Head [1]
$A =$ Wetted Area [m^2]
$P =$ Wetter Perimeter [m]

$n =$ Mannings roughness coefficient [$s/m^{1/3}$] $C = \frac{R^{\frac{1}{6}}}{n}$
(Nortier & de Koning, 1996)

2.8.4 Conservation of mass

The law of conservation of mass means that the Q or discharge remains equal. The area and velocity per section are in relation with each other to the discharge. The formula is stated as± Q=A1*V1=A2*V2=A3*V3…. (Nortier & de Koning, 1996)

2.8.5 Conservation of energy

Just as mass, energy is conserved as well. The energy head H is calculated using Bernoulli´s equation. The loss in energy over the course of distance is represented by the difference in energy, Delta H. Bernoulli's equation is as follows:

$$H = y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$$

$y = \frac{p}{\rho \cdot g} =$ Pressure Head [m]
$z =$ Potential Head [m]
$\frac{u^2}{2g} =$ Velocity Head [m]
$\Delta H =$ Head Loss [m]
$g =$ earths gravity [m/s^2]
(Nortier & de Koning, 1996)

3 Methods

This research that has been performed consists of both qualitative and quantitative research. The methods that were used are discussed below. Desk research, interviews, calculations and a MCA formed the basis for this project.

3.1.1 Desk research

Desk research has been performed to find trustworthy information that was useful for the project. Scientific articles, official documents from the key stakeholders and reference projects have been used as sources. Google Scholar was the main source for the scientific articles. Furthermore, the archive of the municipality of Schouwen-Duiveland was used.

By searching for technical terms that consider the subject, the relevant documents were found. There was searched in English and in Dutch. The information that was searched mainly entailed policy documents about water quality and reports on how to deal with water quality problems.

3.1.2 Interviews

In interviews with the stakeholders in-depth information was gained about the current situation. An interview is considered a verbal exchange in which people are face to face. Information is obtained from the interviewee by the interviewer. Data was generated by asking questions. (Rowley, 2012)

The semi-structured interview technique was used. There is a variety in amount of question, order and degree of adapting the questions during the interview. In general, there are approximately 12 questions designed that are asked in about the same order. However, there is some flexibility in asking the questions. (Rowley, 2012) The reason for this was to ask about certain topics but to allow the conversation to flow more smoothly and to stimulate the interviewee to elaborate more on the answers.

In order to ask questions in a professional manner there were a couple of aspects that were consider. The interview was not being led by assumptions. The interviewer asked one question at a time that is specific and invites the interviewee to tell more and explain the answers. The interviewer was responsible to keep the conversation going and to gain the needed information from the interviewee. (Rowley, 2012)

Prior of these interviews an agenda with the questions that were ought to be asked in the interview were send to the interviewee. In accordance with (Silverman, 2010) the interviewer highlighted the most important aspects of the interview and made notes of that. The interviewee had the ability to add things to the record of the interview.

The data was processed in the following manner. First the data was organized. The text files were rearranged based on related subjects in order to answer the questions. Secondly, the interviewer got acquainted with the data. The third step was to interpret the data and fourthly to present this in this research. This manner of processing data is in line with the method of (Rowley, 2012).

3.1.3 Calculations

The design of for the fish passage has been calculated and can be found in Chapter 8.5. Furthermore, the changes in salinity concentration have been calculated, see chapter 8.3. The third set of calculation if about the water movement, this can be found in 8.6. The calculations are described step by step.

3.1.4 MCA

A Multi Criteria Analysis or MCA has been used to evaluate different options by means of objectives, that have been developed in cooperation with the stakeholders. For these objectives measurable criteria have been developed, each criterion has indicators. Furthermore, each criterion has a certain weight, influencing the contribution of the criterion to the choice. A preference is established by the MCA by evaluating the options against the objectives. The MCA can also be used as a means for communication. (Department for Communities and Local Government, 2009)

An MCA contributes in making the decision process more structured and open. The cost and the benefits are not compared in an MCA. The option with the highest score could be not the most optimal for improving the welfare. (Department for Communities and Local Government, 2009)

In a performance matrix the options are evaluated. The performance matrix consists of a row that contains the description of the alternative and the columns describe the performance of the alternative for each criterion. (Department for Communities and Local Government, 2009)

In the MCA for the fish passage a choice has been made based on criteria that objectively evaluated and graded the alternatives. How the criteria, and the weight of the criteria were determined can be read in Chapter 8.4.1.

4 Results

During this project results were produced in order to find an answer to the main question. In this chapter the most important results are discussed, for additional information there is referred to the appendixes.

The first subject that is discussed in the program of requirements, this is followed by the vision. Afterwards the chloride concentrations, the fish migration and the chemical water quality in the harbor are evaluated. This will provide a rough image of what water quality problems are likely to occur when a minimal water level is created, and what would be the most suitable alternatives to cope with those problems. The last result is an evaluation of the work process and the results.

4.1 Program of requirements

By means of desk research and interviews with the stakeholders this program of requirement is developed. First, desk research was performed to develop an area analysis in order to better understand the situation, see chapter 8.1. The stakeholder analysis was performed in order to determine the interests and stakes of the different stakeholders in this project, this analysis be found in chapter 8.2. Interviews were held with the different stakeholders during the process in order to allowing them to participate, gaining support for the project. The findings from these activities were combined in this program of requirements. In the program of requirements there will be referred to the origin of the requirements, stated in the appendix.

The program of requirements forms the framework for this research. Every requirement was met during the design process of the alternatives, during the design process this was checked multiple times in order to maintain the quality of the product of this research.

First the requirements are discussed; secondly the wishes; thirdly the preconditions and finally the assumptions.

4.1.1 Requirements

The requirements are aspects that have to be met, otherwise the design will not be approved by the stakeholders. There are two sets of requirements, the general requirements for the entire research project and the requirement specifically for the fish passage. For these sets there are technical requirements and functional requirements.

In Table 6 the requirements for the project are listed. The subject, description and source of the requirement are given. First the general requirements are given, followed by the requirements for the fish passage.

Table 6 General requirements

Requirements		
Technical requirements		
Requirement	**Description**	**Source**
Safety	The solution has to be safe to build, use and maintain.	Meeting with the municipality of Schouwen-Duiveland on 07-02-2017, Chapter 8.7.1
@	The water quality in the harbor of Zierikzee has to meet the EFWD requirements by the year 2021.	Meeting with the province of Zeeland on 13-03-2017, Chapter 8.7.5
		Meeting with water board Scheldestromen on 15-03-2017, Chapter 8.7.6

Construction aesthetics	If a construction is needed to safeguard the water quality, the construction has to suit the historical environment.	Zicht op 't Sas Masterplan omgeving haven 't Sas in Zierikzee Meeting with the municipality of Schouwen-Duiveland on 07-02-2017, Chapter 8.7.1
Water level in harbors	A minimal water level of +0,80 m NAP in the harbor of Zierikzee.	Meeting with the municipality of Schouwen-Duiveland 0n 07-02-2017, Chapter 8.7.1
Water retaining structure location	The water retain structure will be constructed under the double bascule bridge.	Meeting with the municipality of Schouwen-Duiveland 0n 07-02-2017, Chapter 8.7.1
Oxygen concentration	A minimal oxygen concentration of 5 mg/L in the water in the harbor of Zierikzee.	Sportvisserij Nederland
Explosives	Consider dealing with explosives when constructing the construction.	Area analysis, Chapter 8.1.13
Functional requirements		
Boat accessibility	The ships have to be able to move from one harbor to the other and in and out of the harbors.	Zicht op 't Sas, Masterplan omgeving haven 't Sas in Zierikzee
Communication	The results are able to be communicated in a clear manner.	Graduation manual HZ University of Applied Science 2016-2017
Judging alternatives	The evaluation and judgement of the optional solutions is to be objective and righteous.	Graduation manual HZ University of Applied Science 2016-2017
Construction	During the construction period the disruptions have to be limited as much as possible	Meeting with the municipality of Schouwen-Duiveland on 07-02-2017, Chapter 8.7.1
Economic growth possibilities	The possibility of economic growth in and around the harbor area have to stimulated.	Zicht op 't Sas Masterplan omgeving haven 't Sas in Zierikzee
Fish migration	The migrating fish have to be able to migrate, otherwise the requirements of the EFWD will not be met.	Meeting with the province of Zeeland on 13-03-2017, Chapter 8.7.5 Meeting with water board Scheldestromen on 15-03-2017, Chapter 8.7.6

Table 7 Fish passage requirements

Requirements fish passage		
Technical requirements		
Requirement	**Description**	**Source**
Entrance fish passage	Place the entrance of the fish passage in front of the migration line. The entrance has to be easy to reach for the fish.	(Beeren, 2000)
Attraction flow	An attraction flow has to be present and of sufficient power that it attracts the three-throned stickleback and the eel. The attraction flow has to be perpendicular to the main water flow.	(Beeren, 2000) Meeting with water board Schelderstromen on

	The water velocity of the attraction flow is 0,1 or 0,2 m/s, the fish have to be able to swim against is.	30-03-2017, Chapter 8.7.8
Maximum flow velocity free flow	When using a free flow in a fish passage the maximum flow velocity is 4 m/s.	Meeting with water board Schelderstromen on 30-03-2017, Chapter 8.7.8
Pipe diameter	A minimal pipe diameter of 200 mm for the pipes in fish passages.	Meeting with water board Schelderstromen on 30-03-2017, Chapter 8.7.8
Location fish passage exit	Between the exit for fish upstream and the construction there needs to be sufficient space, between 15 and 20 m. This is to prevent fish are carried along downstream due to overflows or turbines.	(Beeren, 2000)
Functional requirements		
Swim performance	The swim performance of the weakest fish species is decisive.	(Beeren, 2000)
Suited for multiple fish species	Fit for species that currently belong to the population in t' Sas	Meeting with water board Schelderstromen on 30-03-2017, Chapter 8.7.8
Mass migration	The fish passage needs to be dimensioned in a way it is able to facilitate mass migration peaks.	(Beeren, 2000)

4.1.2 Wishes

In the wishes for the project are listed. The stakeholder, the wishes and source of the wishes are given. The wishes are stated by the stakeholders, they are preferred to be met in this thesis, but this is not a requirement.

Table 8 Wishes stakeholders

Wishes per stakeholders		
Stakeholder	**Wishes**	**Source**
Municipality of Schouwen-Duiveland	• Using Leo Kaan's research as a basis for his thesis project. • A more attractive harbor area. • The proper water quality status when a minimal water level is created.	Meeting with the Municipality of Schouwen-Duiveland on 07-02-2017 Zicht op 't Sas Masterplan omgeving haven 't Sas in Zierikzee
Province of Zeeland	• A maintained or improved water quality in the harbor of Zierikzee. • Sustainable development of the harbor area of Zierikzee. • A sustainable, long-term construction that allows fish migration.	Meeting with the province of Zeeland on 13-03-2017
Water board Scheldestromen	• Maintaining the fish migration or improving it. • A sustainable construction. • The banks of the harbors lie within the "waterstaatwerk" zone. This means it is preferred not to build new constructions there.	Meeting with water board Schelderstromen on 15-03-2017
Vereninging Stad en Lande	• Maintain the historical look and character of Zierikzee. • The construction has to match the historical environment.	Meeting with Vereninging Stad en Lande on 20-03-2017
Inhabitants	• People that live in Zierikzee notice the harbors fall dry at low tide, this is according to them not a pleasant sight. The inhabitants prefer the harbors not to fall dry. • When the pump discharges its water into the harbor at low tide the water becomes turbid. There are algae blooms in the summer close to the discharge basin. The inhabitants prefer an improved water quality, so there are no algae blooms.	Meeting with the Municipality of Schouwen-Duiveland on 07-02-2017
Rijkswaterstaat	• The proper water quality status when a minimal water level is created in the harbor has to be proven to Rijkswaterstaat in order to obtain permits.	Meeting with water board Scheldestromen on 15-03-2017

4.1.3 Preconditions

Below the general precondition of the project are displayed. These preconditions need to be considered in this thesis project.

Table 9 General preconditions

General Preconditions		
Precondition	**Description**	**Source**
Tidal influences	Use the current tidal situation occurring in Zierikzee.	Paragraph 8.1.10
Costs	Keep the construction costs and maintenance costs as low as possible.	Meeting with water board Schelderstromen on 30-03-2017.
Sluice Havenkanaal	The sluice in the Havenkanaal closes at a water level of +1,85 m NAP.	Paragraph 8.1.9
Sustainability	A long-term designed solution, made of sustainable materials.	Meeting with water board Schelderstromen on 15-03-2017 Meeting with the province of Zeeland on 13-03-2017

4.1.4 Assumption tidal action

The tide is simulated as a sinus in which each high tide and low tide are equal in time. In reality this phenomenon rarely exists because the high tide wave moves faster compared to the low tide wave. The high tide wave influences the low tide wave, making the water level rise faster than fall. (Bosboom, 2009-2010)

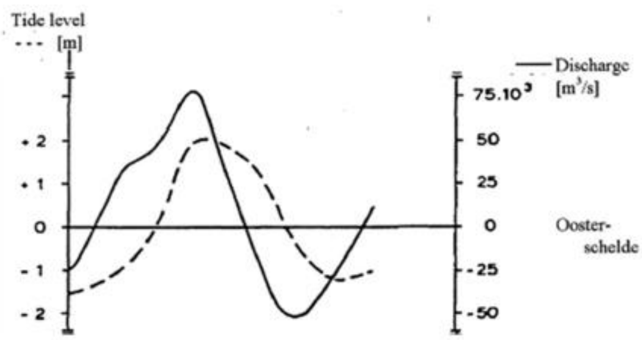

Figure 24 Tides in the Oosterschelde (Bosboom, 2009-2010)

4.2 Vision

This vision is a long-term look into the desired future of De Oude Haven and ‘t Sas. This vision was developed taking the wishes and requirements of the stakeholders into account. This vision acts as a guide for the development of the measures for the harbor and to make people enthusiastic about the harbors in Zierikzee. The target is written in the form of a story to trigger people to identify themselves in this image and to make them like this future.

4.2.1 Target

Zierikzee is a city in the province Zeeland, The Netherlands. It is a small city with just over 11000 inhabitants. The name Zierikzee comes from the word ‘Siric’ which in Old Dutch means ‘water’. Zierikzee is famous for its many monuments. The most prominent is The Sint-Lievensmonstertoren. It is 62 meters high, which makes it the highest tower of the city. The people of Zierikzee sometimes call the tower ‘de Dikke Toren’ which translates to ’the Fat Tower’. The Sint-Lievensmonstertoren is very similar to the Sint-Romboutstoren in Mechelen.

Other places of interest in Zierikzee are the Nobelpoort, the Noordhavenpoort, the Zuidhavenpoort, the Molen De Hoop, the Molen Den Haas and the Nieuwe Kerk.
Also, the City Hall of Zierikzee, built in the 16th century, is worth a visit. When you are getting thirsty from sightseeing find your way to ‘t Sas. Here you can find Grandcafé de Werf, a lovely place to have a break.

When you enter the city of Zierikzee the first thing you will see is De Oude Haven.
The Old Harbor has glistering water and beautiful flat boats. You will see the bascule bridge and the nice historic houses. When you look up, you will see the Sint-Lievensmonstertoren, which is always proudly watching over the little town and its people.

The sight provides a feeling of being there in the 19th century. When walking over the bascule bridge, the fresh salty air and the view gives people a feeling of freedom. Birds fly quietly over the water, looking for some fish to eat. The fish swim in the water, just deep enough so the birds won’t see them.

People parade over the sidewalks. Walking their dogs and playing with their children. Some of the children try to catch crabs and play in the water.
In the background you can hear soft music, coming from one of the restaurants. The music is seducing people to come to the restaurant and enjoy some wonderful food and wine. The water in the harbors is clean and there are lots of different species to see like eels and sticklebacks.

All around Zierikzee little signs provide information about what there is to see. This information lets the city be even more alive. But the signs are not the only ones who are always happy to provide information. The inhabitants of Zierikzee are always happy to tell tales about the history of Zierikzee. They are very proud of their city, the harbor and all the stories that have taken place in Zierikzee. So, don’t be shy! Ask the inhabitants about their town!

The nice environment is created through the cooperation of the entrepreneurs, the government and education sector. They are intertwined like a triple helix. The economic, political, social and specialist knowledge is gathered, resulting in an inviting harbor.

4.2.1.1 *Function of the harbor*

In the future De Oude Haven would maintain the historical harbor of Zierikzee. De Oude Haven will have a minimal water level, looking more beautiful. Flat boat will lay in the harbor waiting to be photographed.

‘t Sas will be redeveloped, allowing more boats to berth and allowing more activities to take place there.

4.2.2 Objectives

The target image has been translated into objectives. The objectives provide a concrete vision for the harbor of Zierikzee.

Water quality objectives:

- Good ecological water quality. More species will live in the harbors and migrate through it, improving the fish population.
- Good chemical water quality according to the EWFD in the harbors by 2024.

Cooperation objectives:

- Cooperation between the entrepreneurs in the harbor.
- Cooperation between the entrepreneurs, government and research and development institutes to offer opportunities to improve the harbor even more.

Environmental objectives:

- Providing people with a nice environment where the historical aspects are noticed and complement the water in the city.

Functional objectives:

- The “Oude haven” maintaining to be the historical harbor of Zierikzee.
- ‘T Sas maintaining to function as a harbor to stay for a short period, for people that travel by boat.

Management objectives:

- A well-maintained harbor that will continuously be improved and updated to the needs of the stakeholders.

4.2.3 Support method

To gain support for the vision, the opinions of the stakeholders have been included. This provides the first positive view on the vision.

To get support from a wider group of parties a newsletter could be spread by the municipality could be send to people to inform them about the wonderful vision for the future of Zierikzee. The vision will be accompanied with an illustration that provide people with a view of what the vision entails. See Figure 25 for the vision illustration.

Figure 25 Illustration harbor vision (Zijlstra N. , 2017)

4.3 Chloride concentration and the ecological effects

When a minimal water level is created, the tide is influenced, influencing the chloride concentration of the water in the harbor. Both the average chloride concentration and the fluctuations are important, because they affect the species in the water (Dam, Brakke wateren, 2014). For this reason, the chloride concentration in the harbor of Zierikzee is observed and evaluated.

First the mixing of the polder water with the Oosterschelde water is evaluated in order to determine the chloride gradient. Followed by an analysis of the seasonal differences considering the chloride in the water. The calculations can be found in 8.3.

4.3.1 A mix of polder and Oosterschelde water

The chloride concentration from the water in the polder behind pumping station ‘t Sas ranges from 2.000 mg Cl/L to 12.000 mg Cl/L. In the year 2011 the average chloride concentration was 6283 mg Cl/L. These numbers were obtained from water board Scheldestromen. At the pumping station regular water measurements were and are performed. These data can be found in paragraph 8.1.12. The water from the polder is pumped by pumping station ‘T Sas into the basin. The basin is in direct contact with the harbor of Zierikzee by means of a culvert. (Waterschap Scheldestromen, 2017) According to the target for brackish water the maximum salt content in the summer is not allowed to be more than three times the minimum winter salt content (Dam, 2002). The polder water does not meet this target. The maximum salt content in the summer, 12.000 mg Cl/L is higher than 3* 2.000 mg Cl/L or 6.000 mg Cl/L. On the other hand, the target also states that the summer chloride concentration is higher than the chloride concentration in the winter (Dam, 2002), this is fulfilled.

In the year 2016 the Oosterschelde had an average chloride concentration of 16.835 mg Cl/L. The highest chloride concentration in that year was 17.645 mg Cl/L and the lowest was 14.822 mg Cl/L. The water from the Oosterschelde flows through the channel, through De Nieuwe Haven into the harbor of Zierikzee. The distance between the Oosterschelde and the harbor of Zierikzee is approximately 3,10 km. (Rijkswaterstaat, 2016)

The water from the Oosterschelde and the polder mix in the harbor and in the cannel between Zierikzee and the Oosterschelde This could be seen in the results from the salinity measurement in the harbor. The measurement was performed by I. Zijlstra on 26-02-2017 during high tide. The locations of the measurements are provided on the map below, see Figure 26. The salinity was measured on 6 locations, A to F. The measurements show that the water from the two sources mixes in the harbor. The closer to pumping station ‘T Sas the lower the chloride concentration. A difference of approximately 1 mg/L chloride can be seen between the measurement in De Nieuwe Haven (D) and the measurement close to the pumping station (F). Between measure point D and F is a distance of approximately 600 m.

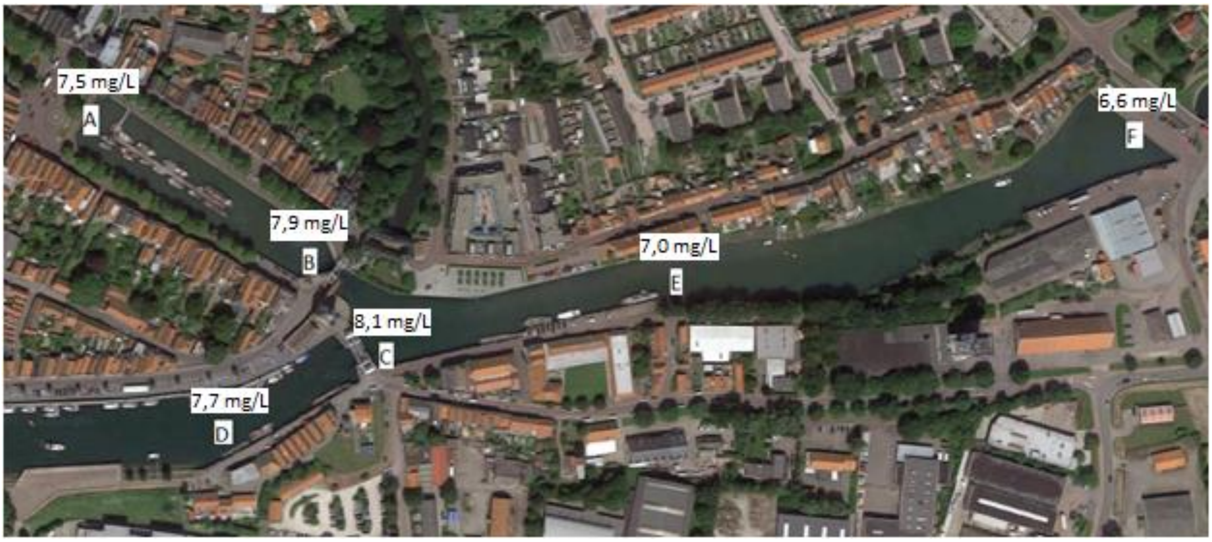

Figure 26 Locations and results salinity measurements 26-02-2017

The average chloride concentration of the Oosterschelde was plotted in combination with the findings from the chloride measurement on 26-02-2017. The gradient of the chloride is show over distance in Figure 27. The dots in the graph represent the measurement data and the dotted line shows the trend of the data. The expected chloride gradient is linear from 16,8 mg/L (average Oosterschelde) to 6,2 mg/L (Average polder water). The trend line is consistent with a gradual chloride gradient over time and the expectations. chloride over a distance of 3,1 km.

4.3.2 Seasonal differences

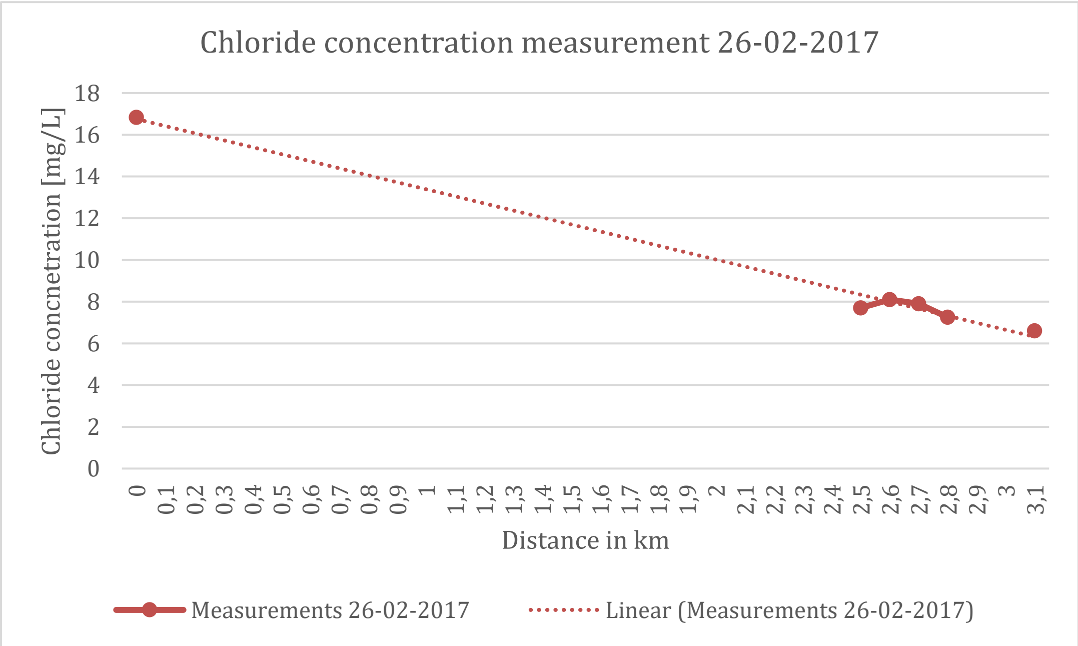

Figure 27 Graph chloride gradient over distance

In the harbor the summer and winter chloride concentration differ. In chapter 8.3 the calculation of these chloride concentration can be seen.

In the current situation the average summer chloride concentration in the harbor of Zierikzee is around 8500 mg/L, in the winter this is around 4200 mg/L. This shows that there is a difference of approximately 4300 mg/L between the summer and winter chloride concentrations. The chloride concentration has been calculated and this is similar to the concentrations in the current situation. This is in accordance with the target for brackish water, the chloride concentration being higher in the summer compared to the winter (Dam, 2002). The influences the minimal water level will have on the pump, the changes in water movement and the influences of the fish passage on the system, were not considered in this calculation. In Figure 28 the average seasonal difference can be seen between the polder, the Oosterschelde and the new situation is Zierikzee.

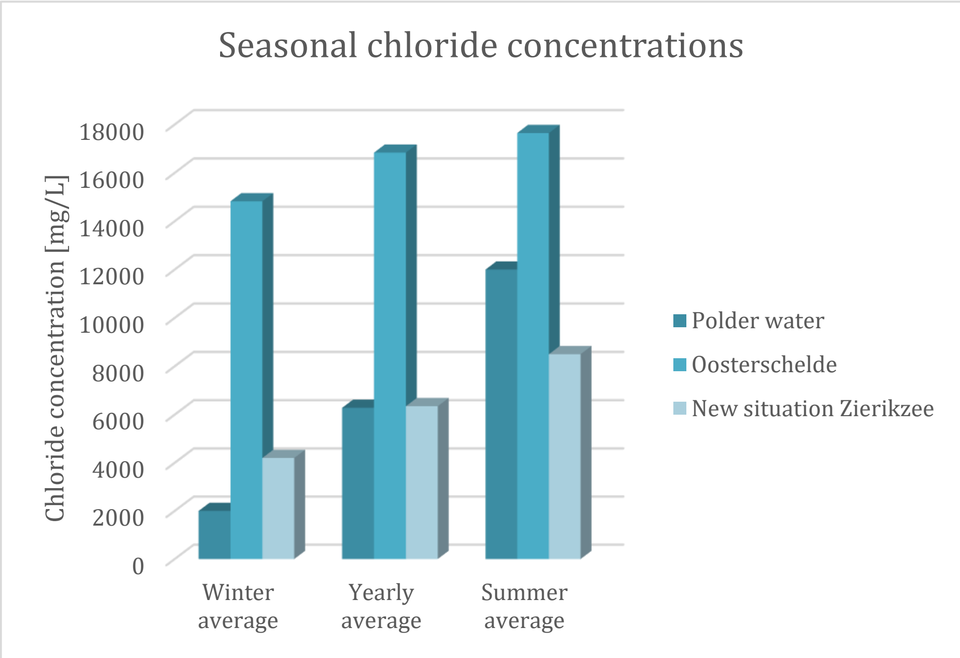

Figure 28 Seasonal chloride concentrations

However, when looking at the water movements in the harbor (see Chapter 8.6) and comparing this to the reduction in water refreshment (see 8.6.5) one can see that the Oude haven will reduce in water movement and refreshment. This combination creates a place where the water will become more stagnant and will likely stratify with a vertical chloride gradient increasing with depth. Because of the fact that saline water is denser compared to fresh water, the more saline water is expected to sink to the bottom. Furthermore, because relatively only the top layer of the water is refreshed due to the new minimal water level, the Oude haven will stratify and become more saline

On Figure 29 a schematization is shown of the predication how the chloride will move in the harbor. The top layer of the water, the water above the +0,80 mNAP will be refreshed most. Brackish water is pumped into the harbor. The water is predicted to become more stagnant, allowing the more saline water to sink, this is indicated by the arrows down on the harbor side of the figure. At the bottom a saline layer will appear, this layer is shown by means of the dark color at the bottom of the harbor.

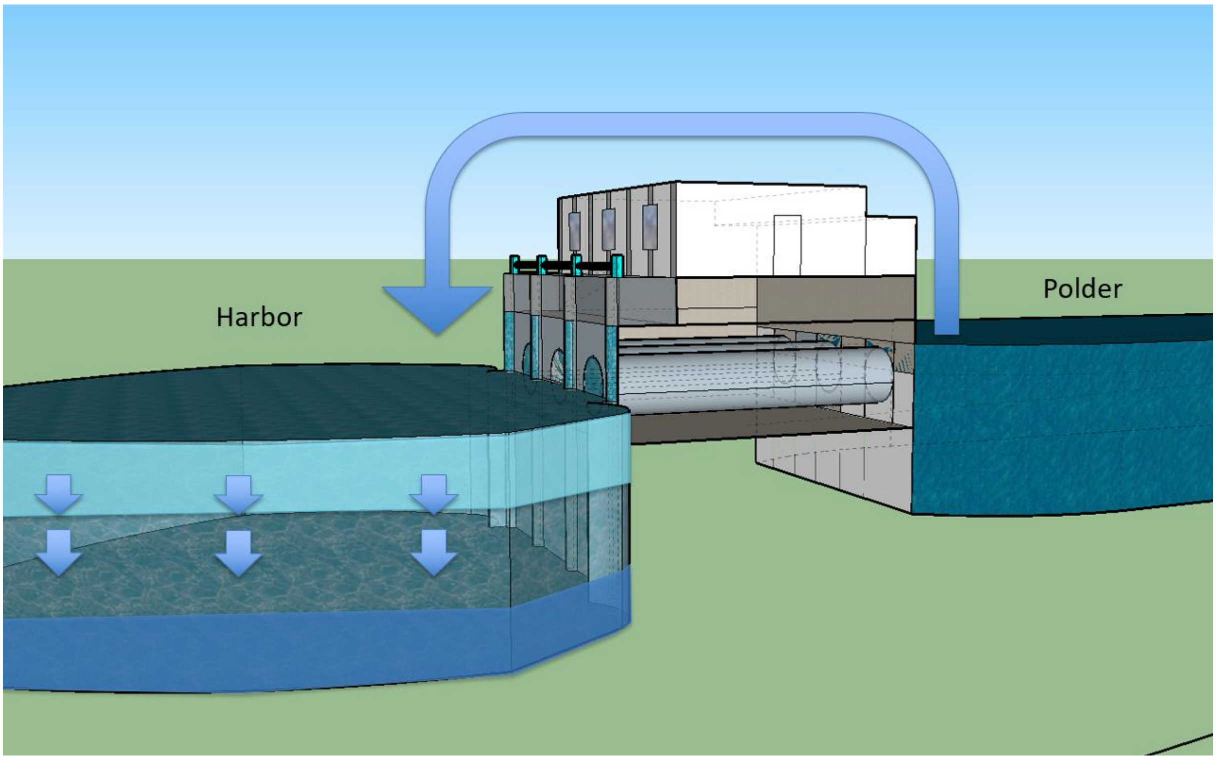

Figure 29 Schematization chloride movement

4.4 Fish migration

On the biological side of the water quality, a problem arises with the minimal water level for migratory fish. This problem will have negative aspect of the EWFD requirements and therefore this subject has been studied.

In the current situation, the fish species that present in the harbor of Zierikzee are known to be. In the estuary there are fish species that live their total life cycles in the estuary; and species that use the estuary as a temporally living place in their life cycle (STOWA, 2005). The migratory fish species have to cope with a set of obstacles, these obstacles are shown in Figure 30. To reach the harbor of Zierikzee the fish have to overcome the storm surge barrier (1) and the sluice (2). When a minimal water level of +0,80m NAP is implemented, an extra obstacle will be present for the fish. The set of sluice doors under the bascule bridge to hold the water and facilitate the minimal water level of +0,80m NAP from that obstacle. So, in the situation with a minimal water level, the fish have to overcome the storm surge barrier (1), the sluice (2), the sluice doors under the bascule bridge (3) and the pumping station 't Sas (4).

According to Marius van Wingerden: "Fish are attracted to the fresh water that is pumped from the polder into the harbor. This will not stop due to the additional sluice doors in the future situation. The sluice doors will likely not hinder the migrating fish, they will only be delayed. The fish will wait in front of the sluice doors, when they are closed and when the sluice doors are open the fish will swim to pumping station 't Sas." (Wingerden, 2017) The attraction of the migratory fish toward fresh water is confirmed by (Sorensen, 1986).

<u>The pumping station is considered the problematic obstacle for the fish.</u> Because of the minimal water level in the harbors the fish cannot pass the pumping station any more. In the current situation the fish are attracted by the attraction flow that was generated when the water level was low. Fresh polder water would flow through holes in the valve in pumping station, into the basin in front of pumping station 't Sas. When the water level is not sufficiently low to generate the attraction flow, the fish will not migrate. Therefore, this is the arising problem for the migrating fish. The fish passages are designed with the purpose to facilitate fish migration.

Figure 30 Map with the obstacles for fish migration highlighted.

4.4.1 Multi Criteria Analysis

In order to decide on what alternative is the most suitable to facilitate fish migration an MCA has been made. The detailed MCA can be found in chapter 8.4.

4.4.1.1 *Alternative solutions for the fish migration*

In total there were eight alternative fish passages designed to facilitate fish migration. For each alternative a short description is given and a 3D drawing to make it more easily to understand the fish passages. The 3D drawings were made in Sketchup. The designs have been made with to the requirements, wishes and preconditions of the stakeholders (chapter 4.1) in mind.

The “Fish migration manual for the recovery in Belgium and the Netherlands”, expert Marius van Wingerden and example projects were the inspiration sources for all the alternative fish passages. For each water type and situation there are a specific set of fish passages that could be implemented. The fish passages that are discussed below are fish passages that are suited for water where there is a fresh-salt water transition.

Alternative 1: the base situation represents the situation without sluice doors to hold the water, the tide still has a lot of influences on the harbor. All the other alternatives need to cope with a minimal water level of +0,80 mNAP.

Alternative 1: Base situation

The base situation is the situation without an added fish migration structure. The fish are able to swim through one of the “leaking” pipes of the pumping station. The water in the harbors is still under strong tidal influence and there are no sluice doors under the bascule bridge to hold the water. The polder pumping station discharges the water from the polder into a basin. The basin is directly connected to the harbor through a culvert. On Figure 31 a schematization of this alternative can be seen.

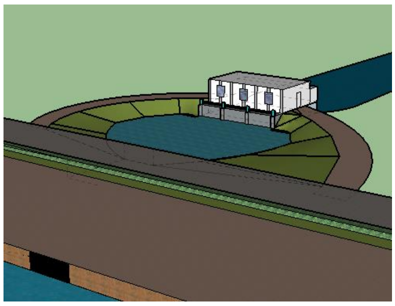

Figure 31 schematisation of the Base situation

Alternative 2: Fish sluice with mechanical door

In the base situation there is a discharge basin in which pumping station ‘t Sas pumps the polder water. In this alternative the discharge basin will function as a sluice. Ones every couple of hours a valve in the culvert closes. The water level in the discharge basin will be lowered by pumping water from the basin into the harbor. The water level in the basin will be lowered to a level of -1,90 m NAP during the summer and -1,70 m NAP in the winter This is 20 cm below the average summer and winter water levels in the polder. A mechanical door in the pipe will open, controlling the water velocity. The water will be discharged from the polder into the discharge basin by gravitational force. The fish will be able to swim against the water flow from the basin into the polder. Fish are able to migrate from the polder to the basin and vice versa. On Figure 32 a schematization of alternative 2 can be seen.

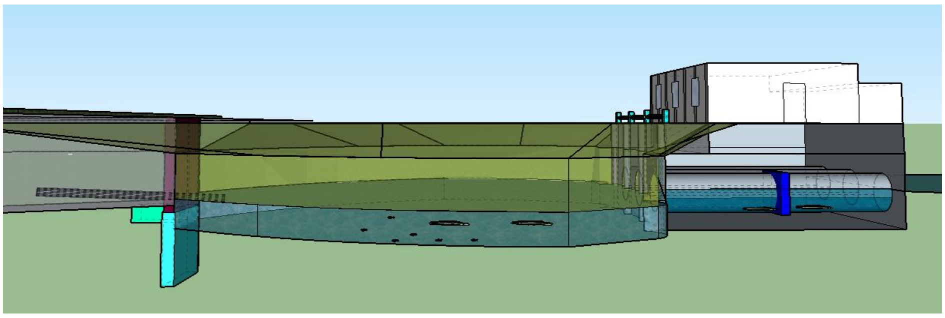

Figure 32Schematisation of the fish sluice with a mechanical door

Alternative 3: Fish sluice, basin will discharge in the polder

For the third alternative the base situation will be used as a sluice like alternative two, however the water from the basin will be discharged in the polder. Ones every couple of hours a valve in the culvert closes. The water level in the basin is higher than the water level in the polder. The pipes in pumping station ‘t Sas will be opened and because of the gravitational force the water is discharged from the basin into the polder. When the basin has emptied, the valve in the culvert will open and the basin will be connected to the harbor again. A schematization of alternative 3 can be seen on Figure 33.

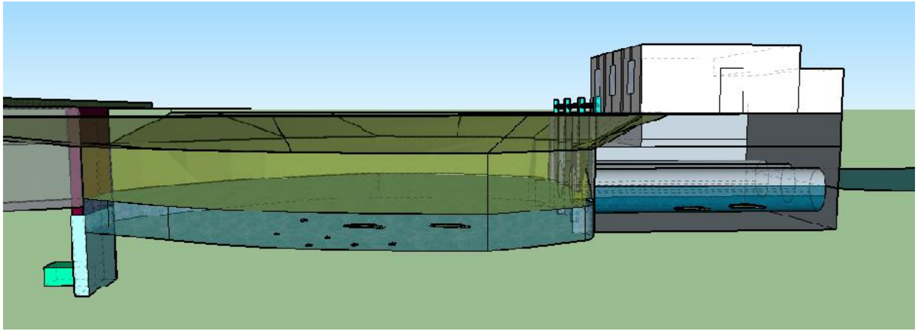

Figure 33 Schematisation of the fish sluice that discharges the basin in the polder

Alternative 4: Fish passage Maelstede
The Maelstede passage consists of a pipe system. In this pipe system fish are able to swim from the polder or the basin against the stream into the container. The water level in the container is equal to the water level of the basin. The cycle consists of four stages. In the first stage a pump creates an attraction flow in the basin, the valve on the basin side is open and the valve on the polder side of the container is closed. Fish will swim against the attraction flow from the basin into the container.
Next the container is closed on all sides and the pump is stopped. In the third stage the valve on the polder side is opened and the water from the container is discharged into the polder by gravitational force. The valve on the basin side is also opened, discharging water from the basin to the polder, creating an attraction flow in the polder. The fish from the polder swim against the flow and arrive in the container. The valve on the polder side closes and the cycle starts again, pumping the water from the container into the basin. The Maelstede fish passage allows fish to migrate from the polder to the basin and vice versa. Figure 34 shows a schematization of this Maelstede fish passage.

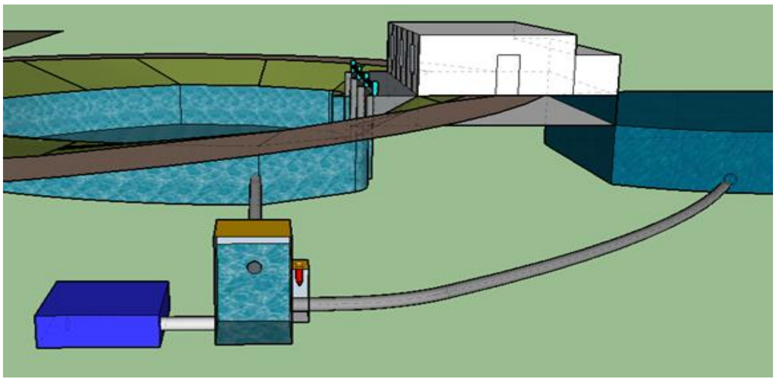

Figure 34Schematisation of fish passage Maelstede

Alternative 5: Fish passage Poppekinderen
In alternative 5 a container is placed into the basin. This container is connected to a pump that generates an attraction flow. This flow will attract fish to go into the container by swimming against the attraction flow, through a short pipe. At a set time the pipe to the basin is closed and a valve is opened at the bottom of the container. The water from the container flows into the pipe towards the polder. The water is discharged by gravitational force into the polder. The water from the container contains fish, which are transported along with the water into the polder. A schematization of alternative 5 can be seen on Figure 35.

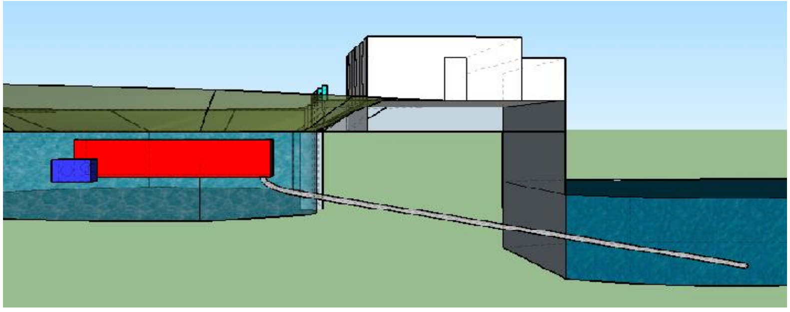

Figure 35 Schematisation of thePoppekinderen fish passage

Alternative 6: Syphon fish passage
The syphon fish passage consists of two pipes that connect the polder water to the water in the basin. In the most upper lying pipe the water flows from a high-located harbor into the lower lying polder. A vacuum pump prevents air bubbles from blocking the water flow. The second pipe functions as an attraction flow, pumping the water from the polder back into the container in the basin. A schematization of alternative 6 can be seen on Figure 36.

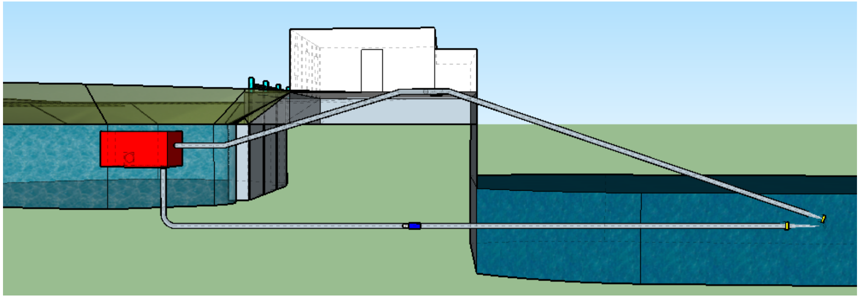

Figure 36 Schematisation of the syphon fish passage

Alternative 7: Fish friendly pump fish passage
The fish passage with two fish friendly pumps is similar to the syphon fish passage. The fish passage consists of two pipes that connect the polder water to the water in the basin. In the most upper pipe the water is pumped by a fish friendly pump from the polder to the container. This water flow generates a continuously controlled attraction flow. Through the lower lying pipe water is pumped from the container in the basin to the polder. This pump is also fish friendly. Both fish friendly pumps work continuously. Figure 37 shows a schematization of the fish passage with fish friendly pumps.

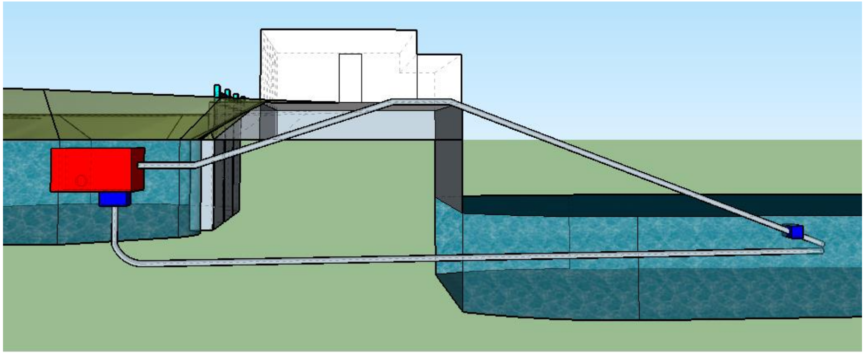

Figure 37 Schematisation of the fish passage with two fish friendly pumps

Alternative 8: Jack-screw fish passage
The jack-screw fish passage has a screw that transports water from the polder to the container that is connected to the basin. The fish will be transported along with the water from the polder to the basin and vice versa. The screw provides an attraction flow for the fish in the basin to migrate to the polder. Once the fish from the basin are in the container they will be transported into the polder by means of a pipe. During this transport time the valves that connect the container to the screw and the basin are closed. A valve that connects the container to the pipe that leads to the polder is opened. By gravitational force the fish are discharged into the polder. From this point the cycle has ended and starts from the beginning. Figure 38 shows a schematization of this jack-screw fish passage.

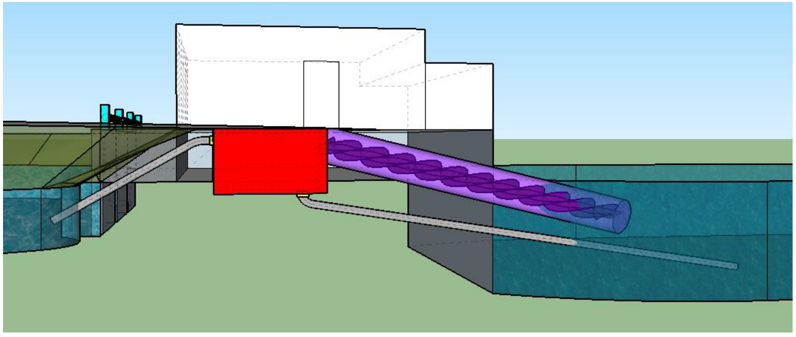

Figure 38 Schematisation of the jack-screw fish passage

4.4.1.2 *Criteria*
The criteria that are used for the MCA for the fish passage are discussed below. In total there are eight criteria. The eight criteria were developed in cooperation with the municipality of Schouwen-Duiveland with waterboard Scheldestromen. The criteria are listed on alphabetic order.

Table 10 Criteria MCA described

Criteria	Description
Aesthetics	The fish migration alternative will be placed in a historical environment. The physical appearance of the alternative has to contribute or match with the environment. The scores for the aesthetics of the construction are based on how much the construction will disturb or contribute to the environment in the harbor.
Accessibility	The construction has to be sufficiently functional. The amount of time the fish passage is functional has consequences on how much fish is able to migrate. A fish passage can facilitate fish migration continuously or in cycles. The time each cycle takes depends on the management of the construction. A continuous fish migration is most favorable, it is better equipped to cope with peak migration, and the fish do not have to wait in order to migrate.
Biological functionality	The biological functionality is the aspects that the fish are able to use the fish passage. With the biological functionality is meant the degree how easily fish are able to overcome the fish passage considering the biological aspects. Biological functioning depends on multiple aspects of the fish species.
Energy use	The fish passage construction all need an additional energy source in order to be functional. There are valves that open and close and pumps. Opening and closing valves does not use a lot of energy, pumping water however does.
Impact on the water system	The fish passages transport water from the basin to the polder and vice versa. The amount of influence the fish passages have on the water system dependents on the amount of water that is transported and the salt and other nutrient concentrations in the water. In the current situation the water in the polder is discharged into the harbor by pumping station ‘t Sas. The water that is discharged back into the polder changes the water balance influencing the pump; and could increase the salt intrusion into the polder. The water balance between the polder

	and the basin and indirectly the salt intrusion will be considered. The amount of water that is discharged from the basin into the polder is considered in this criterion.
Management and maintenance activities	The fish passages will be dealing with brackish water. Small elements that move are sensitive in brackish water. In order to control the decay and ensure the functionality of the fish passage, management and maintenance activities will need to be performed. How intense the management and maintenance activities are, is depended on the construction.
Reliability of the construction	A natural system copes with its own problems by adjusting it by natural processes. However. there are vulnerable components in a technical construction. These vulnerable components will not repair themselves when broken and could reduce the functionality and efficiency of the fish passage. An example of a vulnerable component is a mechanically closing valve. The more vulnerable components the less liable a construction is, resulting in more maintenance activities and malfunctions. The less vulnerable components in a construction, the better
Neglected criteria	The criteria that are mentioned above are not all the criteria that exist. They were chosen because they were found to be the most suitable criteria to judge the fish passages on. The criteria focus on the functionality of the fish passages. The criteria that are not mentioned above are neglected. These neglected criteria have the same value for each aspect or are dependent of the design. For example, the sustainability of the constructions and the infrastructure during the project. The neglected factor is assumed to be sufficient, otherwise the requirements of the project are not met. These neglected criteria will therefore not be considered.

4.4.1.3 *Grading the alternative solutions*

In order to determine what is the most suitable alternative, all alternatives were graded. The criteria were judged for each fish passage based on their characteristics. The score for each criterion is multiplied by the weight of the criteria, this result in the actual score per criteria. Per alternative solution all the actual scores for all the criteria are summed up, this number represents the total score for the alternative solution. The criteria, the weights of the criteria and the indicators are combined, the result is the MCA shown in Table 11. The alternative solution with the highest score is the most suitable option according to the MCA. In total 110 point could be achieved. In chapter 8.4 the scores given in the MCA are explained. In Table 12 a summary of the MCA scores is given.

Table 11 MCA Fish migration

Criteria	**Alternative 1: Base situation**		**Alternative 2: Fish sluice with mechanical door**		**Alternative 3: Fish sluice, basin discharges into the polder**		**Alternative 4: Fish passage Maelstade**		**Alternative 5: Fish passage Poppekinderen**		**Alternative 6: Syphon fish passage**		**Alternative 7: Fish friendly pump fish passage**		**Alternative 8: Jack-screw fish passage**		
	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	**Weight criteria**
Aesthetics	1	1	3	3	2	2	3	3	4	4	4	4	4	4	2	2	1
Accessibility	5	17.5	1	3.5	1	3.5	1	3.5	1	3.5	1	3.5	5	17.5	1	3.5	3.5
Biological functioning	2	11	3	16.5	1	5.5	2	11	5	27.5	5	27.5	5	27.5	5	27.5	5.5
Energy use	5	10	1	2	5	10	3	6	4	8	2	4	2	4	1	2	2
Impact on the water system	5	10	5	10	1	2	2	4	3	6	4	8	4	8	5	10	2
Management and maintenance intensity	2	6	3	9	3	9	2	6	2	6	4	12	4	12	3	9	3
Reliability of the construction	2	10	2	10	3	15	2	10	4	20	5	25	5	25	3	15	5
Total Score		**65.5**		**54**		**47**		**43.5**		**75**		**84**		**98**		**69**	

Table 12 Summary MCA scores from low to high

Alternative solutions	MCA score	MCA score in percentage
Alternative 4: Fish passage Maelstede	43,5	39,5%
Alternative 3: Fish sluice, basin discharges into the polder	47	42,7%
Alternative 2: Fish sluice with mechanical door	54	49,1%
Alternative 1: Base situation	65,5	59,5%
Alternative 8: Jack-screw fish passage	69	62,7%
Alternative 5: Fish passage Poppekinderen	75	68,2%
Alternative 6: Syphon fish passage	84	76,4%
Alternative 7: Fish friendly pump fish passage	**98**	**89,1%**

4.4.1.4 *Sensitivity of the MCA*

In order to test how sensitive the MCA is to the weights of the criteria the weights were adjusted. The weight of the aesthetics was increased. This resulted in a decrease in the weight of the criteria energy use, accessibility and the impact on the water system. The explanation of the sensitivity test can be found in chapter 8.4.4. Table 13 shows the outcome of the MCA sensitivity test. In total 105 point could be achieved. In Table 14 a summary of the sensitivity MCA scores is given.

Table 13 MCA fish migration sensitivity test

Criteria	Alternative 1: Base situation		Alternative 2: Fish sluice with mechanical door		Alternative 3: Fish sluice, basin discharges into the polder		Alternative 4: Fish passage Maelstade		Alternative 5: Fish passage Poppekinderen		Alternative 6: Syphon fish passage		Alternative 7: Fish friendly pump fish passage		Alternative 8: Jack-screw fish passage		
	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	**Weight criteria**
Aesthetics	1	3	3	9	2	6	3	9	4	12	4	12	4	12	2	6	3
Accessibility	5	12.5	1	2.5	1	2.5	1	2.5	1	2.5	1	2.5	5	12.5	1	2.5	2.5
Biological functioning	2	11	3	16.5	1	5.5	2	11	5	27.5	5	27.5	5	27.5	5	27.5	5.5
Energy use	5	5	1	1	5	5	3	3	4	4	2	2	2	2	1	1	1
Impact on the water system	5	5	5	5	1	1	2	2	3	3	4	4	4	4	5	5	1
Management and maintenance intensity	2	6	3	9	3	9	2	6	2	6	4	12	4	12	3	9	3
Reliability of the construction	2	10	2	10	3	15	2	10	4	20	5	25	5	25	3	15	5
Total Score		**52.5**		**53**		**44**		**43.5**		**75**		**85**		**95**		**66**	

Table 14 Summary MCA outcome sensitivity test from low to high

Alternative solutions	MCA score	MCA score in percentage
Alternative 4: Fish passage Maelstede	43,5	41,4%
Alternative 3: Fish sluice, basin discharges into the polder	44	41,9%
Alternative 1: Base situation	52,5	50,0%
Alternative 2: Fish sluice with mechanical door	53	50,4%
Alternative 8: Jack-screw fish passage	66	62,9%
Alternative 5: Fish passage Poppekinderen	75	71,4%
Alternative 6: Syphon fish passage	85	81,0%
Alternative 7: Fish friendly pump fish passage	**95**	**90,5%**

4.4.1.5 *Conclusion MCA fish migration*

The fish friendly pump fish passage has received the highest score in the MCA and in the sensitivity test. Next in line was the Syphon fish passage and third in line was fish passage Poppekinderen.

In the original MCA, alternative 7 had received a score of 89,1%. This is 12,7% higher than the Syphon fish passage.
Furthermore, alternative 7: Fish friendly pump fish passage had received a score of 90,5% in the sensitivity MCA. This is 9,5% more than the Syphon fish passage.

According to the findings in the MCA's alternative 7 is the most suitable alternative for the situation. Figure 39 show a schematization of the fish friendly pump fish passage.

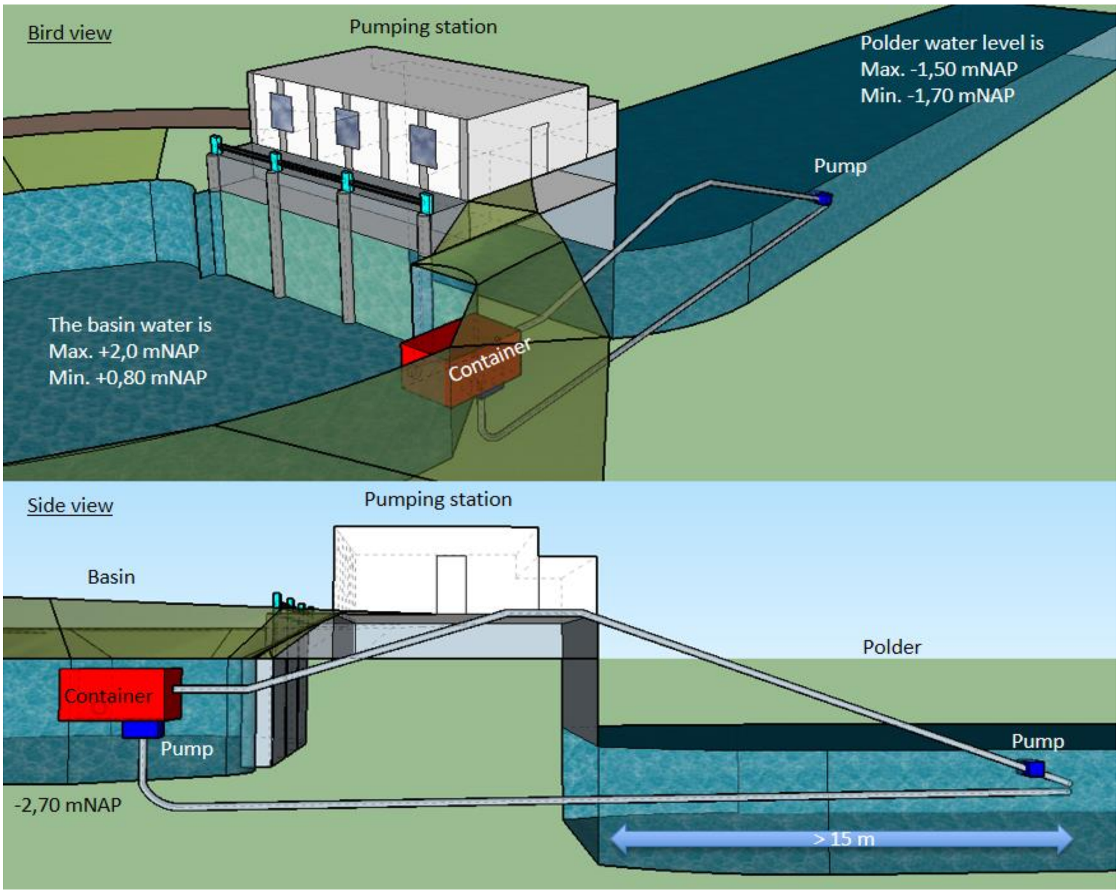

Figure 39 Schematisation Alternative 7: Fish friendly pump fish passage.

4.4.2 Design fish passage

The fish passage is dimensioned roughly. Instead of two fish friendly pumps only one is needed due to an adjustment in the design, the functionality remains the same. The reason for only one fish friendly pump is that the pipe that transports water from the harbor to the polder can be laid with a negative slope. The negative sloped pipe will allow water transport by means of gravitational force. The technical drawing of the fish passage can be found in chapter 8.5.3.

The design is split into four elements that each will be discussed: the container, the foundation, the pipe and the pump. The pipe and pump are calculated into more detail, the calculation of this can be found in chapter 8.5. The reasons for the detail of the pump and the pipe in the construction were the Civil Engineering competences that needed to acquired.

Container

A concrete prefabricated container has been chosen for the fish passage. The reason a prefab container has been chosen was the better quality of concrete due to the more controlled production process; the implementation time of the fish passage is reduced; and there is less noise when implementing the fish passage. The size of the prefab container was determined by studying other fish passages with containers that are used as reservoirs. The fish passages were similar in function and type of fish that needed to migrate.

The concrete should be made of a durable mix, the cover should be able to withstand both salt-laden and freeze thaw environment. Moreover, the reinforcement cover should be between 1,5 and 2 inches thick to cover the steel. The reinforcement itself must be free of rust. (FEMA)

One of the walls of the container has an opening. Through this opening fish will enter the container. There are two pipes connected to the container.

The container consists of four separate walls with the floor poured in between the walls. The outside of the container is rougher due to the pouring of the concrete; the inside of the container is smooth. The other characteristics of the concrete container can be found in Table 15.

Table 15 Characteristics concrete container Fabiton (Wit, 2017)

Characteristic	Details
Dimensions outside of the container	4640x1640x2000 mm
Dimensions inside of the container	4400x1400x1800 mm
Wall thickness	120 mm
Floor thickness	200 mm
Holes for pipes	2 x
Concrete quality	C35/45
Environmental class	XA3
Reinforcement steel	125 kg p/m^3
Weight	12.500 kg
Costs with transport to Zierikzee (not loading off the truck)	€8.500,00 excluding BTW

Foundation

In order to support the container a foundation has been designed. The choice was made to use concrete piles. The size of the piles and the slab was estimated by studying reference projects. In total the container rests on a foundation of six piles. Each pile has a diameter of 200 mm. The total length of the piles is approximately 6 m. The piles will be standing on sand layer. The sand layer starts at a level of – 6,0 m NAP, the piles will stop at -7,0 m NAP.

In between the container and the piles there is a concrete slab with a thickness of 250 mm. The concrete slab functions as a surface that divides the loads evenly from the container to the piles.

Pipe

The pipe of the fish passage has been calculated using the program called Sigma. This program calculated the cross-section of the pipe. The part of the pipe with the most soil load was calculated because this part of the pipe has to cope with the heaviest loads. In Sigma the pipe is calculated according to the NEN-3650 and the NEN-3651. The calculation of the pipe can be found in chapter 8.5.

The pipe that has been selected for the fish passage is a PE-100 250 mm and 22,7 mm pipe. The diameter of the inside of the pipe is 204,6 mm.

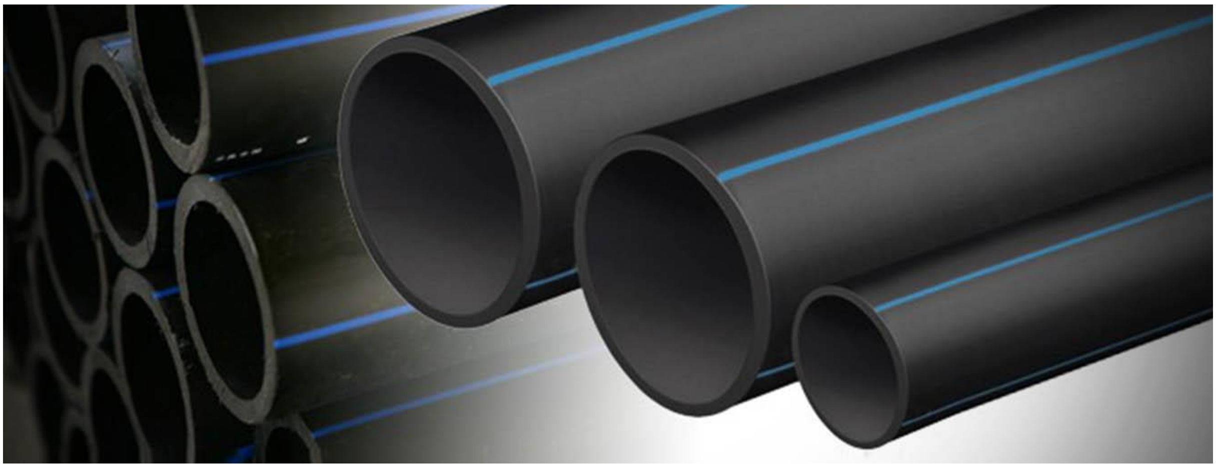

Figure 40 PE-100 pipes (Wavin, 2017)

Pump

Water board Scheldestromen advised the pumps from Hidrostal for the fish passage. The F06 pump has been used in another fish passage. The F06K-M pump has been selected for the fish passage. The pump selection was based on the Q-H curves (Hidrostal , 2017) of the F06 pumps from Hidrostal. The calculations for the pump can be found in chapter 8.5.1.

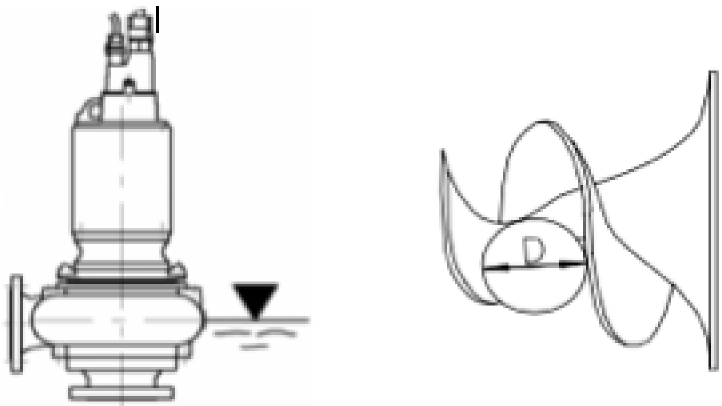

Figure 41 schematic views Hidrostal F06K pump type (Hidrostal , 2017)

4.4.3 Construction planning

The construction of the fish passage will approximately take three months. The planning starts on the first of April 2018 and ends at the sixth of July. The construction planning can be found in chapter 8.5.4

4.4.4 Construction costs

The construction of the fish passage will cost, including BTW 93.541,99 euros. The list with all the construction costs can be found in chapter 8.5.4.1. These costs were made in the program GWW Kosten.

Total (excluding BTW)	€ 77.307,43
BTW-21%	€ 16.234,56
Total (including BTW)	**€ 93.541,99**

(GWW Kosten, I. Zijlstra, 2018)

The main cost sources are: Materials; labor; equipment; and contractors. Figure 42 shows the main cost groups.

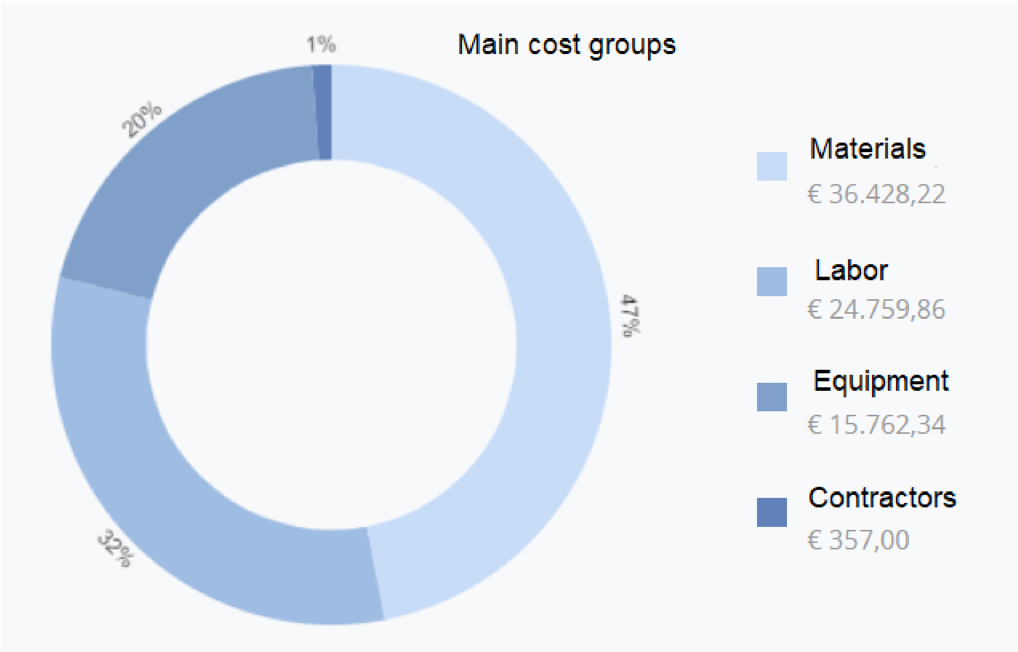

Figure 42 Main cost groups (GWW Kosten, I. Zijlstra, 2018)

4.4.5 Fish passage maintenance

Fish passages undergo kinds of challenges. There is the challenge of the fish passage getting clogged and challenges considering the measurements of the fish passage. The clogging can be caused by a fish passage being closed, materials obstructing or stopping the flow. Challenges with the measurement are thinks like an attraction flow being too low, the location of the entrance and the dimensions of the fish passage. (Arcadis, 2013)

In order to keep the fish passage functional, maintenance activities will need to be planned. A yearly monitoring plan of the fish passage is required to see how the fish passage functions over time. To optimize this, a protocol is advised to be written on how to judge the functionality of the fish passage and to detect aspect that need maintenance.

The findings of the monitoring are advised to be communicated in a clear manner to the office that is responsible for the functionality of the fish passage. The findings of the monitoring can then be translated into maintenance actions.

4.5 Chemical water quality

There are a variety of causes that influence the chemical water quality in the harbor. The new situation is analyzed and predictions of how the water quality will be influenced are made. A set of measures to improve the water quality are displayed and evaluated, resulting in a choice for the most suitable measure. In order to grasp the whole picture multiple aspects of the situation are studied. The water from the polder, the residence time of the water and the velocities are evaluated and combined with the findings from the chloride concentration analysis.

Further information and calculations can be found in chapter 8.6.

4.5.1 Polder water

The polder water is mixed with the water from the Oosterschelde. The Waterboard had a record with nutrients within the polder water available. These nutrients were evaluated by means of the chemical target for brackish water (Chapter 2.2.4). This is relevant because this water is discharged in the harbor and therefore influences the water quality.

In strongly brackish water the nitrogen-phosphate relationship is often low, lower than 6. This shows that the nitrogen is the limiting factor in the primary production. (Dam, Brakke wateren, 2014) This relationship is confirmed in the polder water, as can be seen in Table 16. A high nitrogen concentration results in a high chlorophyll concentration. (Dam, Brakke wateren, 2014)

The target for brackish water has been compared with the available data from the polder water. The average P concentration is 1,22 mg/L, this is higher than the target of 1 mg/L. The average oxygen saturation is 131,27%, being outside of the preferred range of 70% to 120%. The minimal transparence of the polder water is 0,2 m, this does not meet the target of a minimal of 0,7 m. These data have been derived from the Waterboard Scheldestromen and can be found in chapter 8.1.12. In the chloride chapter the target for the chloride concentration has been found not met.

From these findings one can conclude that the challenges of brackish water are confirmed to be eutrophication and turbidity (STOWA, 2005). The eutrophication changes the composition of the community due to the boost in phytoplankton growth, reducing the transparency of the water.

Table 16 N/P relationship in the polder water (Waterschap Scheldestromen, 2017)

Element	Nitrogen (N)	Phosphorous (P)	Relationship N/P
Minimal concentration	1,30 mg/L	0,27 mg/L	4,81
Maximal concentration	8,70 mg/L	2,60 mg/L	3,35
Average concentration	4,13 mg/L	1,22 mg/L	3,39
Summer average concentration	3,87 mg/L	1,97 mg/L	1,96
Winter average concentration	4,40 mg/L	0,47 mg/L	9,36

4.5.2 Residence time

Because of the retaining structure that will be implemented when a minimal water level is created the residence time of the water is evaluated. The time the water is present in the harbor has influences on the availability of nutrients and the mixing of the water. According to (Soares, 2008) a short residence time results in a more dynamic system compared to a longer residence time. The residence time is related to the water column changes and the biomass of the phytoplankton. The residence time is calculated for the entire harbor of Zierikzee and the Oude haven. The reason for this has to do with differences in water flow, this is explained in the next chapter. The calculation can be found in chapter 8.6.5.

The current residence time of the entire harbors in Zierikzee is 10,39 hours. In the situation with a minimal water level of +0,80 m NAP the time to refresh the harbor increases with 11,59 hours. In the new situation the refreshment of the harbor of Zierikzee takes 21,98 hours.

For the Oude haven the current residence time is 17,89 hours. When a minimal water level is implemented this residence time is prolonged with 8,36 hours. In the new situation the Oude haven will need 26,25 hours to refresh.

4.5.3 Velocities in the harbor

Sam Bom, hydraulic engineer at Svasek has made in 2016 a model about how the sediment would behave in the harbor, considering the current and new situation. The data from this prior research was used in order to study the water movement for this thesis. The figures that show the velocities over a period of 12 hours can be found in Chapter 8.6.3. The figures were laid over each other with a transparency of 40% in Photoshop CC. On Figure 43 the water velocities are shown during full tidal cycle of 12 hours. It can be seen that the water velocity is significantly less in the middle of the harbor in the current situation than the velocities during the tidal cycles in the new situation with a minimal water level. Furthermore, on the west side of the harbor, in the Oude haven a slight reduction in velocity can be seen compared to the current situation.

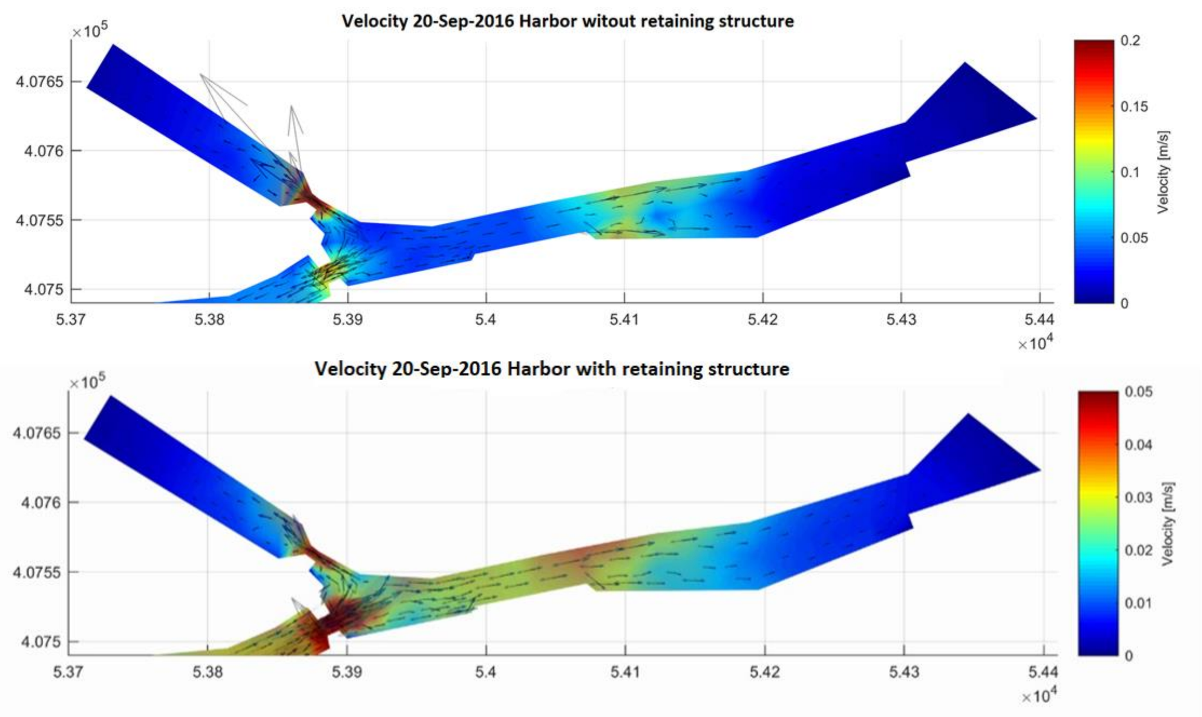

Figure 43 Comparing the velocities from the current situation with the velocities from the situation with a minimal water level

4.5.4 Evaluation water quality

The water in the polder is eutrophic and turbid. In the current situation the people of Schouwen-Duiveland have noticed algae blooms in the harbor, this is a sign of eutrophication. Most of the brackish waters are naturally eutrophic (Dam, Brakke wateren, 2014). This shows there is a high likelihood that the harbor of Zierikzee will become eutrophic as well in the new situation.

An increase in velocity is consistent with an increase in turbulence. This is according to the Reynolds formula. The more turbulent the water, the more the water mixes. This indicates that the middle of the harbor will be mixed well, so stagnant water will likely not be found here.

On the other hand, the flow in the Oude haven is slightly reduced in velocity (Figure 43) and the residence time is increased (Chapter 8.6.5). In other words, there is a chance on stratification in this area. The Oude haven will likely become a zone in that will accumulate nutrients (Smith, 2003); decrease in oxygen concentration (Mihelcic, 2010); and will develop a vertical saline gradient (chapter 4.3).

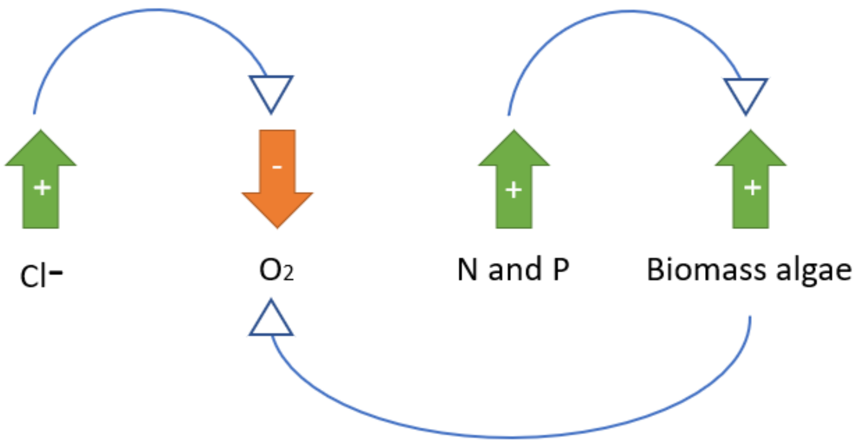

Figure 44 Causal chain water quality

On Figure 44 the causal chain of the water quality in the harbor schematized. The increase in chloride will decrease the oxygen concentration by reducing the saturation ability (Bayley, 1972) and by stratifying the water. The increase in N and P will increase algae growth. When the algae die, they will in turn decrease the oxygen concentration.

Because the increase in chloride will influence the species in the ecosystem the algae that will grow in this situation will be different compared to algae present in the current situation. Research has not been performed on the species of alga and therefore, the consequences of those species are yet unknown.

The stratification is expected to be a continuous problem, throughout all seasons due to lack of wind, reduced water flow and increase in chloride. The algae growth problem is likely to be only present in the summer periods due to the more favorable circumstances for the algae species.

A same situation as in the Oude haven is predicted in the east of ‘t Sas. However, because in the calculation of the model of Sam Bom pumping station ‘t Sas was not included the water flows that are generated by the pump cannot be seen on Figure 43. Pumping station ‘t Sas is an active pumping station that in the winter period, pumps almost every day, see chapter 8.3. The water that is pumped in will form a flow toward the middle of the harbor. The water that is discharged in the harbor will likely be very turbulent, therefor the water is mixed in this region. An indication of the estimated flow including the pumping station can be seen in chapter 8.6.4.

However, the pumping station is mainly active during the winter periods. Therefore, the water quality problems are expected to only be present during the summer periods on the east side of ‘t Sas. In the summer periods, the water becomes stagnant and the algae have the opportunity to grow.

4.5.5 Measure to improve the water quality

In the previous section the water quality problems have been identified. In the theoretical framework multiple measures that could improve the water quality were discussed. In order to find a suitable alternative to cope with the water quality problem, the possible alternatives were evaluated. In Chapter 8.6.6 these alternatives were evaluated, considering the information found by means of evaluating the water flow; whether the measures are practical; and the theory from the theoretical framework. From the evaluation four possible alternatives were identified. The four alternatives were designed and evaluated. By means of argumentation the most suitable measure was selected. The description of the alternatives can be found in Chapter 8.6.7, the argumentation for the most suitable solution can be found in chapter 8.6.8. Of those four alternative a turbine has been selected as the most suitable for the situation.

4.5.5.1 *Turbine*

A turbine within the Oude haven is to be positioned to generate a water flow. The water will be mixed due to the turbine. A turbine is not directly advised for the east side of ‘t Sas. In that area there are more influences that need to be considered. Therefore, there the focus is now on the Oude haven.

Artificial destratification eliminates the chemical and the thermal barriers for fish and other organisms, increasing their habitat. The biomass, species and production rate of the algae are all influenced by the artificial aeration-circulation manners. The observed change is caused by the changes in pH, available light and nutrient status. With a high energy system, the lake can be de-stratified in order to control algal blooms. The algae will be redistributed throughout the water column, this limits the amount of light available for photosynthesis with as a result a reduction in productivity of the algae. (Lorenzo, 1977)

Water from the harbor flows into the turbine via the lowest pipe, the turbine adds power to the water and provides an increase in water velocity, the water exits the turbine into the harbor via the top pipe. A nozzle will be placed on the inlet and outlet of the turbine to change the angle of the water flow, optimizing the mixing of the water. The water in the harbor is mixed by means of turbulent flow produced by a turbine. This movement prevents stratification of the water; it reduces the nutrient availability in turn limiting the algae growth and odors. On Figure 45 a schematization can be seen.

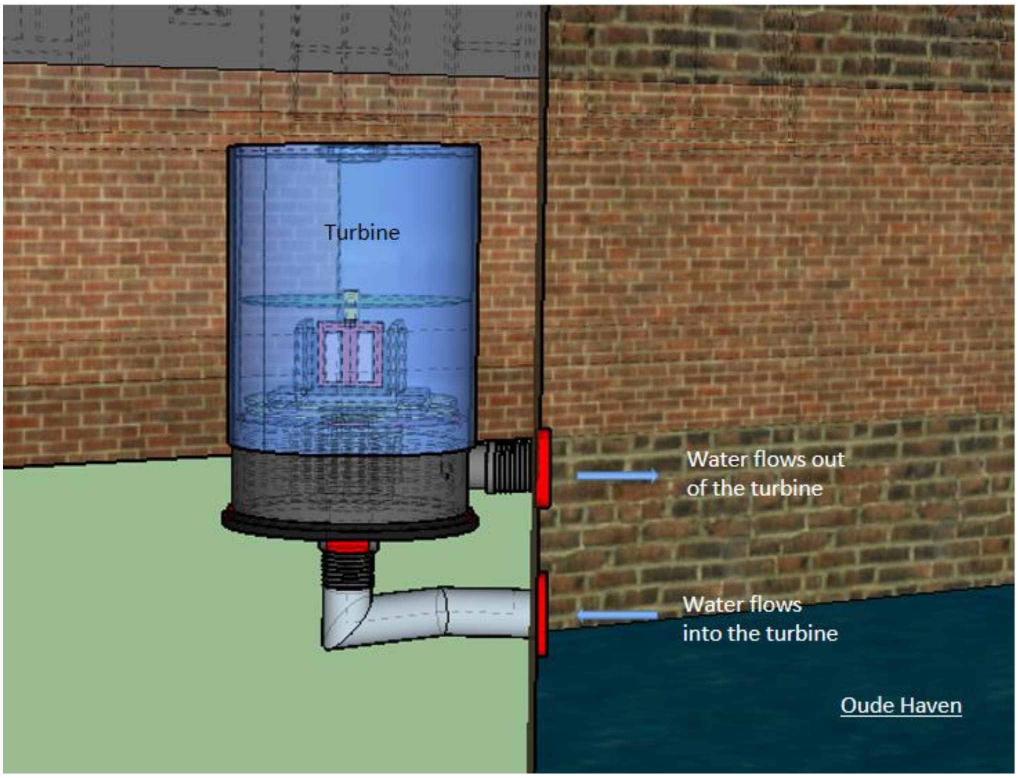

Figure 45 Side view alternative 4: Turbine

4.6 Evaluate the work process and the product

In this thesis research there were three main subjects: the chloride concentration in the harbor, the fish passage and the water refreshment. For each subject, a small review is written on the work that has been performed. Furthermore, the products are evaluated based on the principles of ecological engineering.

4.6.1 Chloride concentration

The chloride concentration was studied because of the impact it has on the species. When the fish migrate this gradient of chloride is interesting, since it influences the other species in the area. The chloride concentration was measured was to see whether the species would have to deal with an abrupt chloride concentration increase when traveling from the harbor to the polder or vice versa.

In the section about the chloride concentration one measurement is performed. This is not representative for the actual situation. There was no data available over a long period of the chloride concentration and no means to measure this for at least one year. However, this one measurement proofs that the water from the salty Scheldt mixes with the brackish water from the polder. And that there is a gradual horizontal chloride gradient in the environment, having no extreme impacts on the species in the system. However, it is found that there likely will be a vertical saline gradient, the deeper the more saline the water will be.

The advice is to measure the seasonal chloride concentrations in the harbor and to make a prediction by means of a calculation how the chloride concentration will change compared to the new situation with a minimal water level and how the chloride concentration will fluctuate seasonally.

4.6.2 Fish passage

The types of fish passages were designed using the known handbook for fish migration (Vismigratie, Een handboek voor het herstel in Vlaanderen en Nederland) and the advice from Marius van Wingerden (an expert on fish migration from waterboard Schelderstromen).

Of each alternative the characteristics were carefully studies and evaluated by means of an MCA. The criteria of the MCA were developed in cooperation with the municipality of Schouwen-Duiveland which is the client and Marius van Wingerden. A sensitivity test was performed on the MCA in order to test whether the solution with the highest score was stable when changing the weights of the criteria. The result was that the MCA was stable, and the outcomes were useful to base a choice on. All the choices about why a certain score is given to an alternative for a criterion are explained, making it for every person understandable how the MCA was filled out and how the choice was made for the particular fish passage.

The designs of the different alternatives were made in 3D. This gave the stakeholders a good view of what was being designed. Marius van Winderden, Leo Kaan and Marco de Bruine have noted that this was very strong because it made everything very clear.

The design of the fish passage was based on reference project that were alike this one. Calculations were made to test the design for the fish passage. These calculations prove that the fish passage is of quality, along with the technical drawings.

Because the fish passage could not be tested in the limited time and means, this would be advised to do in the future.

4.6.3 Chemical water quality

In order to study how the minimal water level influences the water quality the refreshment of the water and the movements of the water were studied.

The water movement was studied by means of manual calculation and by a model made by Svasek. Svasek is a company in water hydraulics. The model was validated by means of the manual calculations. The pumping station was not included in this calculation because those values are not predictable. The influence on the water movement has been estimated and made visual. The calculations were kept simple because there are a lot of factors that influence the system, a conformation that is model is representative was sufficient for this thesis project.

Secondly the refreshment of the water is the harbor was studied. By calculating the difference in refreshment time between the current and new situation a prediction could be made on where problems would occur.

The findings from the water movement and refreshment, saline gradient, water movement and theoretical framework were combined and resulted in a conclusion that the Oude Haven will likely have problems regards chemical water quality.

The combination of the different findings with the theory is strong because it proves there is a problem will arise in the future situation.

4.6.4 Design principles of ecological engineering

In the theoretical framework the principles of ecological engineering were explained. The goal was to work in this thesis according to those principles. In this chapter this thesis is reviewed whether it is in accordance with the principles of ecological engineering.

Design principle 1: The design is consistent with ecological principles
The first principle stands for the design of products with the help of the natural systems, by mimicking natural structures, self-organizing systems and succession (Bergen, 2001). The fish passage that was designed had the purpose to allow the fish their natural course. This design was specially made to facilitate the migratory fish in the ecosystem with a migration route, as the natural course has been obstructed by means of a pumping station.
On the other hand, the turbine improves the water quality, in turn contributing to an ecosystem that is in balance. This is positive for the system, facilitating a stable state.

Design principle 2: Design for site- specific context
The fish passage has been designed for the specific location is ´T Sas. Information was gathered about the water and the fish species forming a basis for the design. This is in line with the second principle. The situation is viewed from different directions, creating a relative holistic view. The stakeholders were involved in this thesis, generating support for the project. However, more information and research is required to capture the entire picture. Advice is given on these aspects in the recommendations.

Design principle 3: Maintain the independence of design functional requirements
By evaluating the water quality from different sides, multiple water quality problems were identified. There are uncertainties in whether these problems will occur. However, by analyzing the situation from different side there is a high likelihood the problems will occur, decreasing the uncertainty. In order to deal with these problems a variety of solutions are provided. The most suitable alternatives are noted. However, if the situation changes, the other alternatives are already described and thought of. This creates the ability to be adaptive and flexible in the project.

Design principle 4: Design for efficiency in energy and information
The fish passage uses electricity for the fish friendly pump. The reason for this is that this guarantees the functionality compared to energy sources like wind. In the design this principle is not met. It is possible to include a mechanism to power the fish passage by means of solar energy in combination with a generator to facilitate continuous energy supply. But this is not in

the scope of this thesis. The energy source has not been evaluated, this is a subject for further research.

Design principle 5: Acknowledging the values and purposes that motivate design
The design of the fish passage did not consider the fail-safe and safe-fail principle. In order to guarantee this, the pipes need to be closed when the pump is off. This way the fish passage does not allow water flow from the polder to the harbor or the other way around. If the pump fails the water will not be able to flow and negatively influence the polder nor the harbor side, avoiding large consequences to the ecosystem

5 Discussion and recommendations

The results of the research were given, in this chapter the results are discussed and evaluated on how reliable they are.

5.1 Chloride concentration

For the analysis of the chloride concentration there was a lack of data. There was no record of the chloride concentration in the harbor of Zierikzee. The analysis was based on the data from the polder and from the Oosterschelde and on one measurement in the harbor.

One measurement was performed to gather data on the chloride concentration about the water in the harbor. One measurement was not representative. However, it gave a conformation that currently there is a weak chloride gradient between the Oosterschelde and the harbor.

In order to give an indication on the seasonal differences in chloride concentration in the harbor a calculation was made. The data that was available was used for it. There was only data on the chloride concentration in the polder for the year 2014; the one measurement of the harbor; and the discharge data of one month. Because of this the summer discharge was estimated to be 50% the discharge of the winter discharge of the pump. In the calculation the influences of the new fish passage were not included.

The analysis of the chloride concentration in the harbor did show that there will likely occur a problem by the layers of different chloride concentration that will form in the new situation. An indication of the location of this problem was made by combining the chloride calculations; the calculations of the water refreshment; and the figures on water movement in the harbor.

Multiple measurements over a period longer than one year, to take into account the different seasons are needed to make the data usable for other purposes than a conformation. In this research this subject was not studied further because the research is broad.

The advice is to measure the seasonal chloride concentrations in the harbor, gain information about the polder chloride concentration and to make a prediction by means of a calculation how the chloride concentration will change compared to the new situation with a minimal water level and how the chloride concentration will fluctuate seasonally. The water movement of the harbor should be taken into account.

5.2 Fish passage

5.2.1 Neglected criteria MCA

In the MCA there is a criterion with neglected criteria included. One of the neglected criteria is the costs. Marius van Wingerden has advised to not include the costs in the MCA due to the fact that this in practice the costs are not relevant for the functionality of the fish passage. Furthermore, Marius van Wingerden noted that the costs cannot be calculated accurately in advance due to unexpected situations and the detail. According to Marius van Wingerden, the expert on fish migration at water board Scheldestromen, money does not play a large role in the decisions, what is important is that the fish migration is facilitated.

5.2.2 Pump

Water board Scheldestromen advised the pumps from Hidrostal. Due to the confidentiality of Hidrostal only limited information was available to select a pump. In another fish passage the F06 pumps were used, therefore information was available, and the water board had experience with the type of pump. The F06K-M pump has been selected for the fish passage. When all the fish passage under the jurisdiction of the fish passage have the same pump, the maintenance activities are for each pump the same. The people who perform the maintenance can always perform it because is the same for each fish passage, they have knowledge about it and have the tools available. This makes the maintenance activities simpler, increases the trustworthiness of the pumps and decreases the costs.

The choice was based on the Q-H curves of the F06 pumps from Hidrostal. The Q-H curve of the F06K-M does not a perfectly match the characteristics of the fish passage. The work zone is not the most efficient. However, further researching the pumps fall outside the research scope of this thesis.

5.2.3 Chloride concentration hinterland

The fish passage constantly pumps water from the polder to the harbor and vice versa. The water that pumped from the harbor into the polder could have consequences due to the chloride in the water. The chloride concentration could increase in the polder, with negative consequences for the environment. Therefore, this needs to be researched.

5.2.4 Entrance fish passage

The entrance of the fish passage could be optimized. Lights could be used to lure the fish into the container. The design of the entrance of the fish passage could be developed into more detail in a future study.

5.2.5 Stress

The fish are subjected to a certain level of stress, since they are discharged from one waterbody to the next. The stress the fish will experience when they make use of the fish passage has not been research. When designing the fish passage the stress for the fish was designed as low as possible, think of the bends etc. However, it could be useful to test the stress levels of the fish after they have used the fish passage. This information is useful to determine whether the fish passage is effective.

5.3 Chemical water quality

The findings from the water movement, residence time, saline gradient, and theoretical framework were combined and resulted in a conclusion that the Oude Haven will likely have problems regards chemical water quality. This shows an integral approach to this project.

The water movement was studied by means of manual calculation and by a model made by Svasek. Svasek is a company in water hydraulics. The model was validated by means of the manual calculations. The pumping station was not included in this calculation because those values are not predictable. The influence on the water movement has been estimated and made visual. The calculations were kept simple because there are a lot of factors that influence the system, a conformation that is model is representative was sufficient for this thesis project.

Secondly the refreshment of the water is the harbor was studied. By calculating the difference in refreshment time between the current and new situation a prediction could be made on where problems would occur.

There was no data available on the chemicals in the harbor water over a long period of time. It is advised to perform measurement on the chemical components of the harbor water over a minimal period of one year. These measurements could be used to calculate the nutrients in the harbor in the future situation. Furthermore, these chemical calculations could be combined with the water movement and water refreshment finding in order to get a more detailed image of the situation.

6 Conclusions

In this thesis the water quality of the harbor of Zierikzee has been studied. Multiple perspectives were evaluated in order to answer the question: “What are the consequences on the water quality when a minimal water level of +0,80 mNAP is implemented in the projected separated harbor of Zierikzee?”. Is question has been answered by answering the sub questions. First the requirements for the water quality were studied. A vision was written to guide this project. This was followed by an analysis of the chloride concentration in the harbor, the fish migration and the overall water quality.

6.1 Requirements for the water quality

In the theoretical framework the policies about water quality are discussed. Furthermore, the requirements from the stakeholders were described. These policies and requirements formed the basis for this research. The reason for this was that the water quality needs to be safeguarded.

6.2 Vision

A vision about Zierikzee and the water quality was written. In this vision the requirements from the stakeholders and the policy documents were kept in mind. This vision acts as a communication tool to express and explain the situation to the people and to gain support for the implementation for the project.

6.3 Chloride concentration and the ecological effects

It is expected that the harbor will become more saline in the Oude haven. The water in the Oude haven in likely to stratify due to a reduction in water movement and a prolonged residence time. There will be a vertical gradient of chloride, the concentration of chloride will increase with depth.

6.4 Fish migration

In the present situation the harbors have an open connection with the Oosterschelde and therefore are subjected to the tide. Fish migration is possible through a leaking pipe in pumping station ‘t Sas. When the minimal water level will be created with the sluice doors the fish will not be able to migrate any more.

The harbor is able to meet the biological water quality requirements for the fish by implementing a fish passage with a fish friendly pump. The fish will be able to migrate from the harbor to the polder and vice versa.

6.5 Chemical water quality

By studying the water movement and refreshment on the water in the harbor a water quality problem has been identified when a minimal water level is implemented.

In the Oude haven the velocity of the water is reduced and the refreshment time is increased. In other words, there is a chance on stratification in this area. An increase in chloride will decrease the oxygen concentration by reducing the saturation ability (Bayley, 1972) and by stratifying the water. The increase in N and P will increase algae growth. When the algae die, they will in turn decrease the oxygen concentration.

In order to safeguard the water quality in the Oude haven a turbine is suggested to be installed to mix the water in the harbor. Artificial destratification eliminates the chemical and the thermal barriers for fish and other organisms, increasing their habitat. The biomass, species and production rate of the algae are all influenced by the artificial aeration-circulation manners. The observed change is caused by the changes in pH, available light and nutrient status. With a high energy system, the lake can be de-stratified in order to control algal blooms. The algae will be redistributed throughout the water column, this limits the amount of light available for photosynthesis with as a result a reduction in productivity of the algae. (Lorenzo, 1977)

6.6 Additional research topics

In order to fully capture all aspects that come with implementing a minimal water level, more subjects need to be studied in addition to the already mentioned subjects.

6.6.1 Algae in new situation

It is predicted that the chloride concentration will increase in the harbor of Zierikzee. This increase in chloride will influence the species in the ecosystem. The algae that will grow in this situation will be different compared to algae present in the current situation. In this research the algae species were not studied. It is advised to research what algae species are likely to be found when the chloride concentration will increase in the harbor. Furthermore, the effects of these algae on the environment are advised to be studied.

6.6.2 Pumping station ‘t Sas

Like mentioned before, the fish passage pumps water back and forth between the harbor and the polder. Pumping station ‘t Sas is therefore influenced on the amount the station should or should not pump. Because of the minimal water level in the harbor the discharge periods of pumping station ‘t Sas need to be considered, just as the pump capacity.

6.6.3 Nutrient balance

Currently, there is on data available on the nutrients in the harbor of Zierikzee. It is advices to monitor these nutrients for a least one year and to calculate the nutrient balance in order to confirm the stated water quality problems will arise.

6.6.4 Water quality east side ‘t Sas

On the east side of ‘t Sas it is predicted that water quality problems will arise in the summer. However, the new situation with the pumping station and the fish passage might influence this area. Therefore, research is advised to be performed on how these aspects influence the water quality.

6.6.5 Sediment

The sediment transport and siltation of the harbors was not part of this research. The water flow through the harbors will change due to the minimal water level, this will change the sediment transport. In order to determine how often dredging activities have to be executed, this is a subject that needs to be further researched.

6.6.6 Pollution in the sediment

In order to further improve the water quality and to achieve a healthy ecosystem, there has to be dealt with the pollution in the sediment in the harbors. Research should be performed on the nature of the pollution and how it could affect the ecosystem. Based on this decision can be made on how to deal with the polluted soil.

6.6.7 Strength quay walls

There is speculation about whether the quay walls are of proper state. Research has been performed on this, however the municipality of Schouwen-Duiveland does not trust this research. Therefore, the quay walls need to be research and their quality needs to determined.

6.6.8 Climate change

Climate change will influence the water system in the future. The influences of this are not included in this research project. However, in order to prepare for the future, the impacts of climate change on the water system and ecosystem are advised to be studied.

6.6.9 Energy source fish passage

The energy source of the fish passage has not been studied into detail in this thesis. In order to meet the design principles of ecological engineering the design of the fish passage needs to be energy efficient. It is possible to include a mechanism to power the fish passage by means of solar energy in combination with a generator to facilitate continuous energy supply. It is advised to study the options for the energy supply with energy efficiency in mind.

6.6.10 Fail-safe and safe-fail fish passage

The design of the fish passage did not consider the fail-safe and safe-fail principle. In order to prevent large consequences if the fish passage fails to function it is advised to obtain fail-safe and safe-fail principle in the design of the fish passage.

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8 Appendices

8.1 Area analyses

In order to analyze the area, the real-life situation has been broken down into five layers. The costumers, streets, parcels, elevations and land use has been researched.

8.1.1 General description research area

The research area in which the tidal influenced will be reduced concerns De Oude Haven and ‘t Sas in Zierikzee. Both are harbors in the city center of Zierikzee. Along with the Nieuwe haven these harbors form “The harbor” in Zierikzee. The Nieuwe haven does not fall under the research area. The surface of the harbors together is 26.801 m2. There is an average water depth of 2,60 m. The harbors have a water flow of 6.24 m3/sec. On the west and south side of Zierikzee lies the provincial road N256. The N256 connects Rotterdam with the municipality of Noord-Beveland.

In the picture below the research area is shown. On this map the locations of the three harbors are shown. The Nieuwe haven and ‘t Sas are separated by a double bascule bridge. De Oude Haven and ‘t Sas are separated by the Zuid- en Noordhavenpoort. De Oude Haven is the most photographed part of the city, this is due to the large amount of historical buildings. At the head of t’ Sas the polder pump is located. This pump system pumps the water coming from the hinterland from the scouring basin into the harbor. (Gemeente Schouwen-Duiveland , 2015)

Figure 46 Overview harbors Zierikzee (Google Maps, 2017)

8.1.2 Nieuwe haven

The Nieuwe haven has taken shape during the construction of the Havenkanaal. A sluice is located a couple of hundred meters away from ‘t Sas, in the Havenkanaal. This sluice closes and retains the water when the water level in the Oosterschelde is above 2,00 m NAP. The sluice is part of the primary coastal defense. The harbor area behind the sluice is considered as part of the secondary coastal protection.

The Nieuwe haven has both recreational and commercial shipping functions. The sluice side of the Nieuwe haven is the home of the fleet of the fishing companies of Zierikzee, see Figure 47. There are multiple docking places for small vessels along the Nieuwe haven. Near the double Bascule Bridge there is less space available for docking. During the summer period many tourists visit Zierikzee by boat. Because of the limited availability of docking places, in the Nieuwe haven it is most of the time fully booked.

The quay wall along the Nieuwe haven has been reconstructed and reinforced in 2006.

Figure 47 Nieuwe haven (Nieuwe haven)

8.1.3 Oude Haven

The classical canal houses, the old masonry quay wall, the centuries old town wall and the harbor doors make De Oude Haven look very authentic. De Oude Haven makes for the most touristic attraction in Zierikzee. Since the 1990 De Oude Haven was established as a museum harbor. A floating jetty was constructed to berth historical vessel. (Gemeente Schouwen-Duiveland , 2015) On Figure 48 an image of De Oude haven is shown.

Figure 48 Oude haven (Zierikzee Oude Haven)

8.1.4 ‘t Sas

The purpose of ‘t Sas as work-harbor was lost when the double bascule bridge was constructed. Originally there was a metal bridge over the harbor to reach the city. The double bascule bridge replaced the metal bridge, adding a more classical look to the area. The bascule bridge limited the width of the vessel to go in and out of the harbors to 11,50 m. This made it not possible anymore for the work vessel to get into ‘t Sas.

On the side of the Scheeptimmerdijk a gas factory stood there from 1860 to 2005. Because of the gas factory there is polluted sludge in the harbor. The factory was demolished and new apartments, with a nice view over the harbor were constructed. Asbestos was found there of class three.

In the harbor the water depth has decreased because of neglected dredging activities. The quays and banks have decayed. When the water level is low the sad quays and banks appear, giving the area a rather grievous look. The area looks less attractive and has decreased in accessibility of ‘t Sas. Historical vessels are located in ‘t Sas. The historical vessels are able to remain in ‘t Sas because of their low immersion.

In 2013 a new berth place has been constructed near the northern harbor door. In the summer periods the Nieuwe haven harbors 5 to 8 rows of ships next to each other. This could lead to conflicts and could jeopardize the safety in the harbor.

In ‘t Sas dredging practices have been executed to increase the possible to sail out of the harbor during low water levels. The limited water depth however still prevents vessels to leave or enter the harbor during extremely low water levels. (Gemeente Schouwen-Duiveland , 2015)

Figure 49 Overview recent constructive activities in Zierikzee (Zijlstra I.)

8.1.5 Impression existing situation

On the following images an impression is given of the present situation of the harbors of Zierikzee.

Figure 53 Top view harbors Zierikzee (Nieuwe haven)

Figure 54 Bascule bridge and Noordhavenpoort (Zierikzee Oude haven)

Figure 52 Nieuwe haven with vessels (Gemeente Schouwen-Duiveland , 2015)

Figure 50 Low tide in the harbors (Gemeente Schouwen-Duiveland , 2015)

Figure 51 Pumping station (Gemeente Schouwen-Duiveland , 2015)

8.1.6 Future

The existing variation in functions of the three harbors is big. The functions of the harbors in will not change much from the existing functions in the future. In the summer months ‘t Sas will function as a passage harbor. More efficient use of space will increase the capacity for the amount of ships in the harbor. In the summer period each night about 150 people stay with their vessels in de harbor. The Nieuwe haven will rearrange the of berth places to harbor more vessels. d of the harbor housing will be created with their own jetties. The future plans for the harbors are described in the Havenvisie and Havengebruiksplan. (Gemeente Schouwen-Duiveland , 2015)

Master plan and vision

The Master plan and harbor vision are important documents for the research project. In 2015 the master plan has been presented. In this master plan the spatial planning of the research area has been established. In the Havenvisie and Havengebruiksplan, presented in 2012, the vision for the future in the harbors is described.

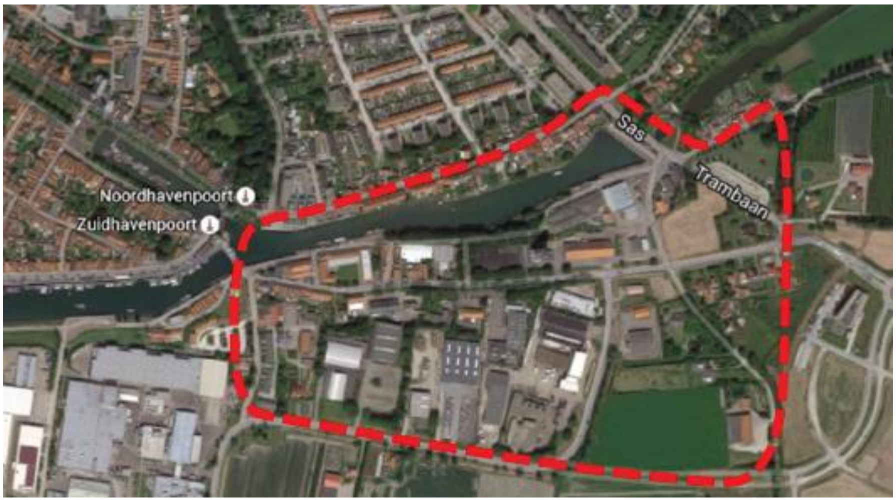


Figure 55 Development area masterplan Zicht op ‘t Sas” (Gemeente Schouwen-Duiveland , 2015)

Masterplan “Zicht op ‘t Sas”

‘t Sas is known as a deteriorated area, development of the area is necessary. The existing spatial planning gives an uncertain message, housing and businesses are mixed. The geographical location and the historical elements of Zierikzee are positive elements that could contribute to a pleasant living area. ‘t Sas is being described in the structural vision of 2030 as the new city entrance to Zierikzee. It will form a smooth transition to the historical city center. Along the banks of ‘t Sas multiple monuments are located. In the present situations these monuments are not highlighted strong enough.

The master plan describes limits, opportunities and improvement points per use-function. The area will be divided into sub-areas:

- Harbor
- Water city
- Between the dykes
- City entrance
- Company campus

These sub-areas can be seen on the map of Zierikzee on Figure 56. Some of the sub-areas overlap somewhat.

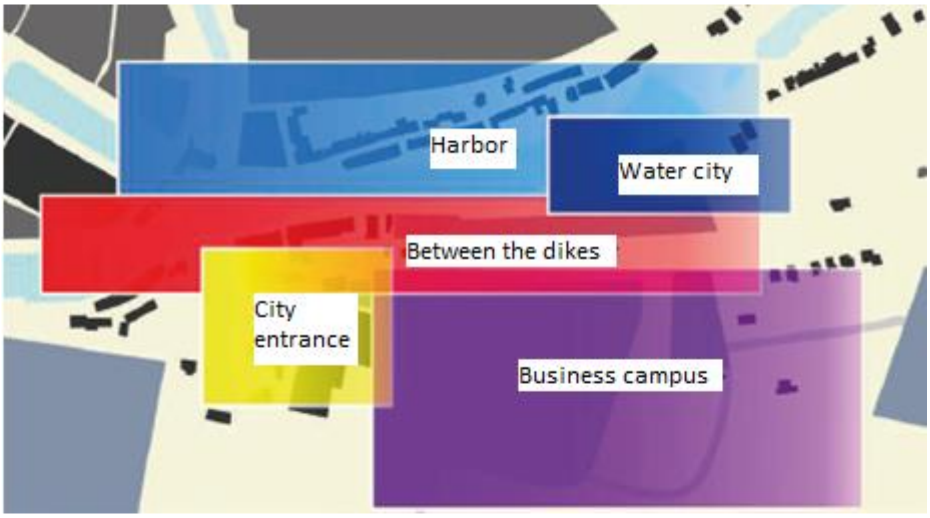


Figure 56 Division function-areas masterplan (Gemeente Schouwen-Duiveland , 2015)

The research will mainly focus on the harbor. In particular the development of a plan to create an ecologically responsible minimal water level in the De Oude Haven and ‘T Sas in Zierikzee.

The sub-area “Between the dykes” considers an historical environment. In this area the harbors, the city doors and the recognizable dyke patterns are considered. Monumental buildings surround the area. The bascule bridge along with the Zuidhavenpoort gives the area an impressive look.

In the sub-area “Water city” many futuristic opportunities are present. There are no marine activities, giving the feeling that the city has pulled itself back. The Vissersdijk act as the transition zone between land and water. The open character op the area is fundamental for the experience. At the head of the harbor housing will be created with their own jetties. (Gemeente Schouwen-Duiveland , 2015)

Harbor vision

The Havenvisie and Havengebruiksplan have been established along with the goal to achieve future-proof harbors. This means a sustainable, safe and economically growing harbor. The large variations in functions need to be structured. Therefore, a broad analysis of the current users of the area has been made.
The most important points in the Havenvisie are the following:

- Touristic passengers are at walking distance of the city center.
- Commercial fishing on a location where loading and disposal is possible.
- Concentrate the loose berth places with a joined entrance and facilities.

To realize an extension in berth places in the Nieuwe haven research has been executed multiple times. One of the researches was about the optimization of the quay walls in the Nieuwe Haven by steel pile sheets. The pile sheets would make a bigger water depth possible. Because of the geometry of the dikes, a bigger water surface would be created. However, there would appear problems with the exploitation of the space. Besides this, high costs would be needed to relocate the dyke, rendering this option not profitable.

Because of safety aspects the Nieuwe Haven needs to be optimized. During extreme busy periods in the summer, safety cannot be assured in the harbors. Big investments are not possible because of a lack of investment capital.

The harbor ‘t Sas is not optimally used because of overdue dredging activities, tidal influence and limited water depth. Redevelopment of ‘t Sas offers opportunities for existing users from the Nieuwe haven, as for the attraction of new users.

De Oude Haven will maintain its function as museum harbor. An option is to add an extra jetty to place another historical “Platbodem” vessel in the harbor. The quay wall of De Oude Haven will need to be renovated within a couple of years. There are plans to construct a floating stairs with a hinge at the head of the quay wall when the quay wall is being renovated.
(Projectbureau Vrolijks, 2012)

Masterplan, harbor vision and thesis research
Both the Havenvisie and the Masterplan describe that they want to optimize the harbor area. In the master plan, guidelines are describing for the development of the harbor. The main focus in this research project is ‘t Sas and De Oude Haven. In the masterplan the following requirements are formulated:

- More berth places.
- Inventory of the situation and maintenance of the banks and quay walls.
- The quality of the banks and quay wall need to be improved.
- Enlarge the water depth by the use of dredging activities or the instalment of a reduced tidal influence.
- Enlarge the water-experience.

The thesis research will focus on the creation of a reduced tidal influence and the enlargement of the water-experience.

8.1.7 Water jurisdiction

The management of the water in the Netherlands has been divided. For this project the most important parties in relation to the water are Rijkswaterstaat and water board Scheldestromen.

Rijkswaterstaat has the responsibility to manage the water quality (Figure 58) and water quantity (Figure 58) in the harbors. The harbors in Zierikzee are considered part of the Oosterschelde.

The water board is responsible for the water behind the harbors, in the polder and for pumping station ‘t Sas.

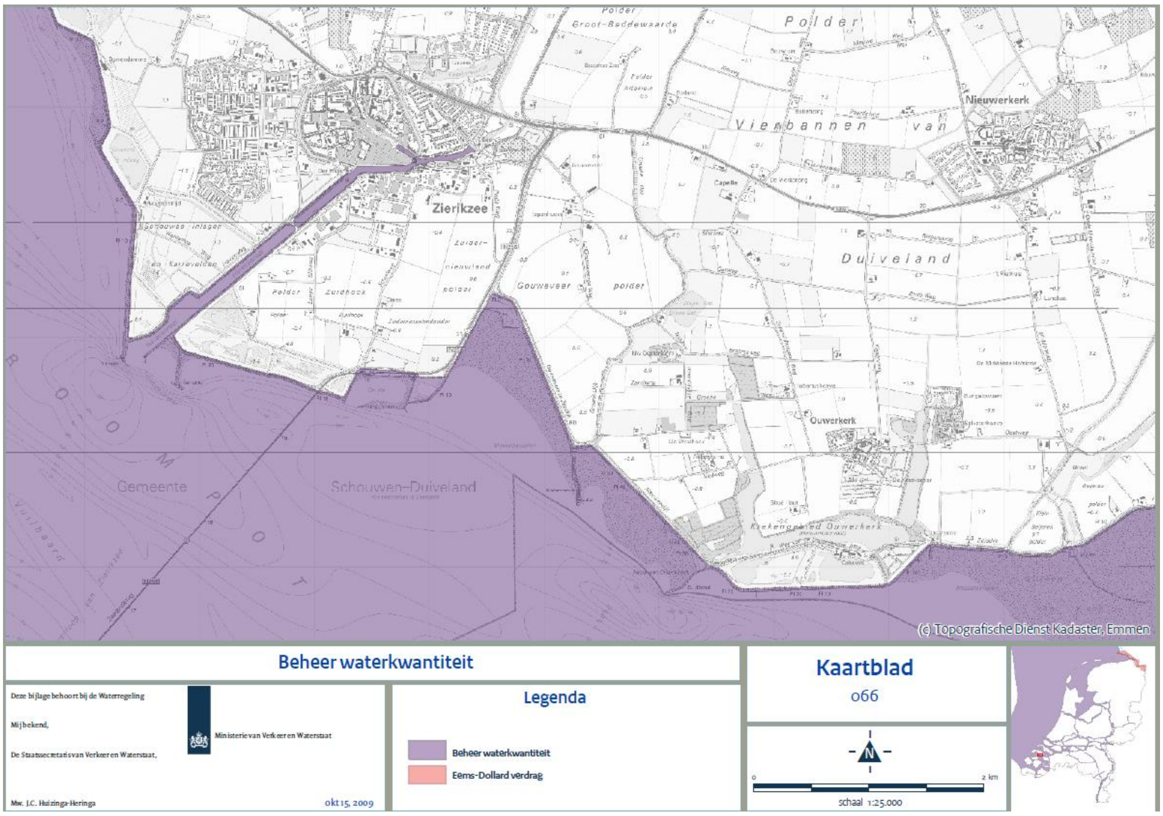


Figure 58 Water quantity management map (Huizinga-Heringa, Beheer waterkwantiteit, 2009)

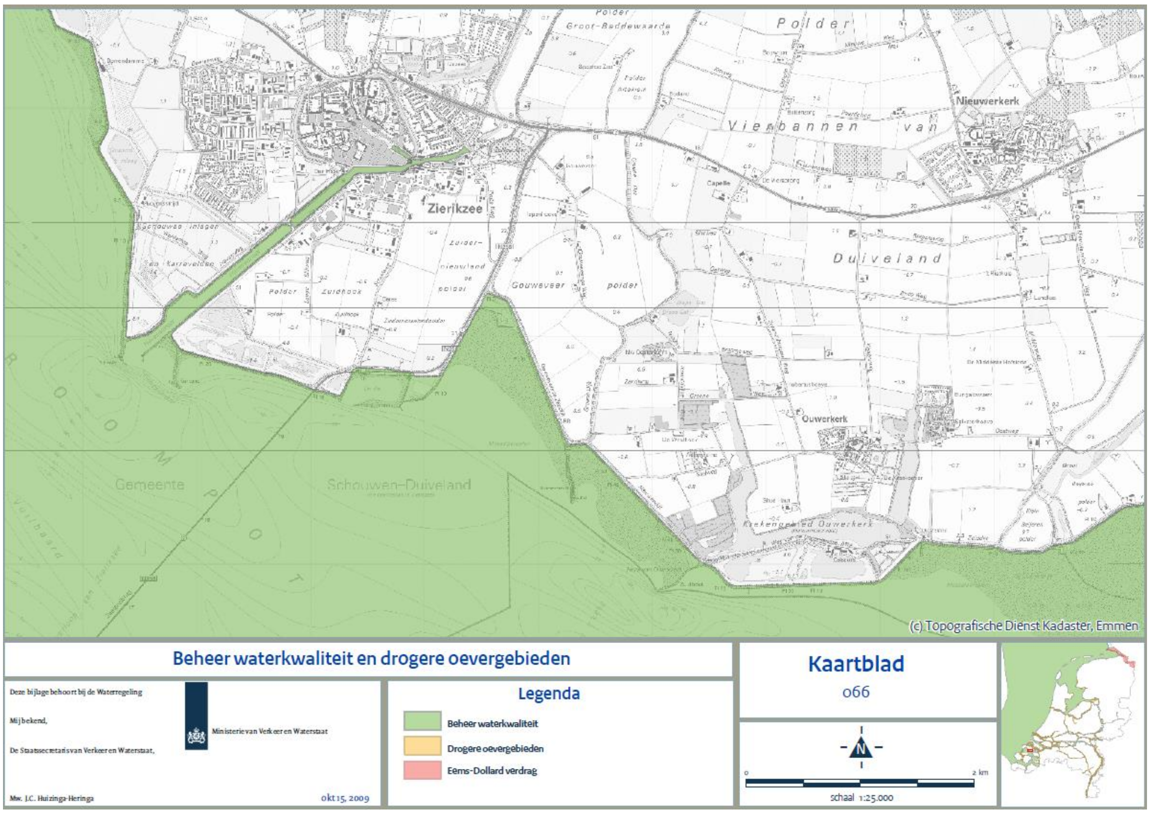


Figure 57 Water quality management map (Huizinga-Heringa, 2009)

8.1.8 Parcels

Geology

The soil in the harbors consists of sea sand and clay. On the west side of ‘t Sas the soil is made up out of sea sand and clay on top of a layer of river sand and clay. Figure 60 shows the soils types in the harbor.

Figure 60 Soil types in the harbors (EduGIS, 2017)

When the south quay walls of ‘t Sas were renewed soil measurements were performed. By probing the characteristics of the soil were identified.

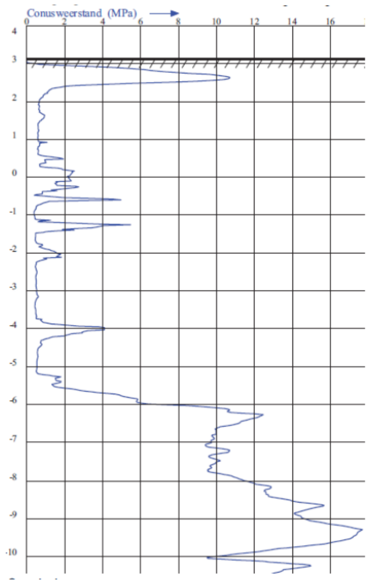


Figure 59 Probing results (Langenhuijzen, 2015)

Until 1 m depth the soil consists of sand. Underneath this sand layer there is are layers of clay. These clay layers together have a thickness of 8 m. The clay layers are recognized by the low conus resistance. Under the clay layer a strong sand layer is present. Figure 59 shows the probing results.

Elevations

The head of the quay walls around the harbors de Oude haven and ‘t Sas are at +3,00 m NAP. The sluice in front of the harbors closes when water levels are higher than +2,00 m NAP. This means the water level in the harbors is always minimally 1 m below the head level of the quay wall.

When the water retaining door will be installed the minimal water level will be +0,80 m NAP. The tide has the possibility to fluctuate 1,20 m, between +0,80m NAP and +2,00 m NAP.

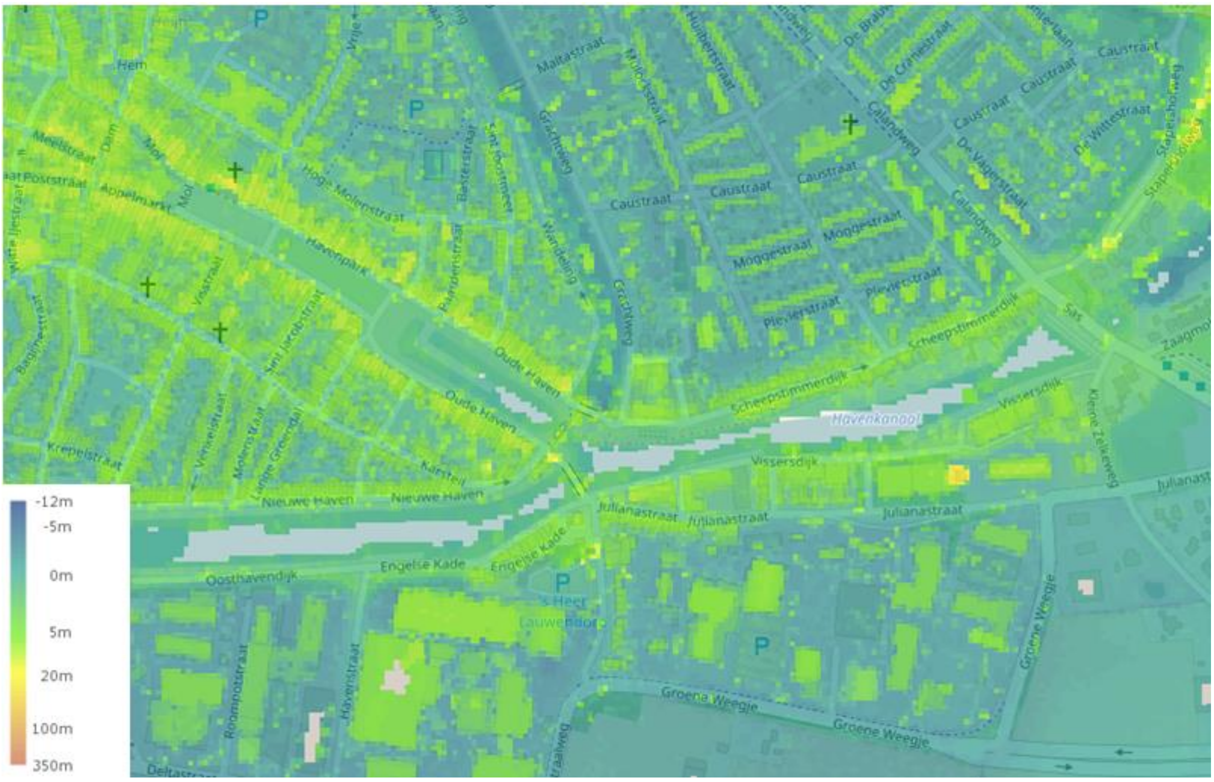


Figure 61 Elevations in research area (EduGIS, 2017)

Pumping station

Pumping station ´t Sas is located on the most east side of ‘t Sas. It pumps water from the polder into ‘t Sas, that leads to the sea. Pumping station ‘t Sas consists of two pumps, each with a capacity of 110 m^3/min. The pumps can elevate the water up to 2,50 m.

During the summer the average water level in the polder is approximately -1,50 m NAP, during the winter the average water level is approximately -1,70 m NAP. The water in the polder is brackish to salt water.

The pumps stop when the water level in the harbors is above +1,85 m NAP. This is because the sluice in the Nieuwe haven will close at water levels above +1,95 mNAP, the water can be pushed up against the sluice. When the sluice has opened again the pumps automatically start working too. The amount of water that is pumped depends on the time the sluice has been closed. The sluice doors must remain a retaining function at a water level of +2,00 m NAP. When the pumps cannot discharge polder water for a long period, it could cause water damage in the polder.

The pumps have a free discharge pipe with a water pressure valve. When the water level is sufficiently low water can be freely discharged from the polder into the harbor. The pump discharges on a small basin that is directly connected to ‘t Sas by means of a culvert under the road. The bottom of the basin is at -2,30 m NAP.

When a minimal water level is being created pumping station ‘t Sas will be influenced.

Pumping station ‘t Sas falls under the jurisdiction of water board Scheldestromen. The catchment area consists of 2255 ha. (Brinke, 2015) On Figure 62 the catchment area of pumping station ‘t Sas is shown.

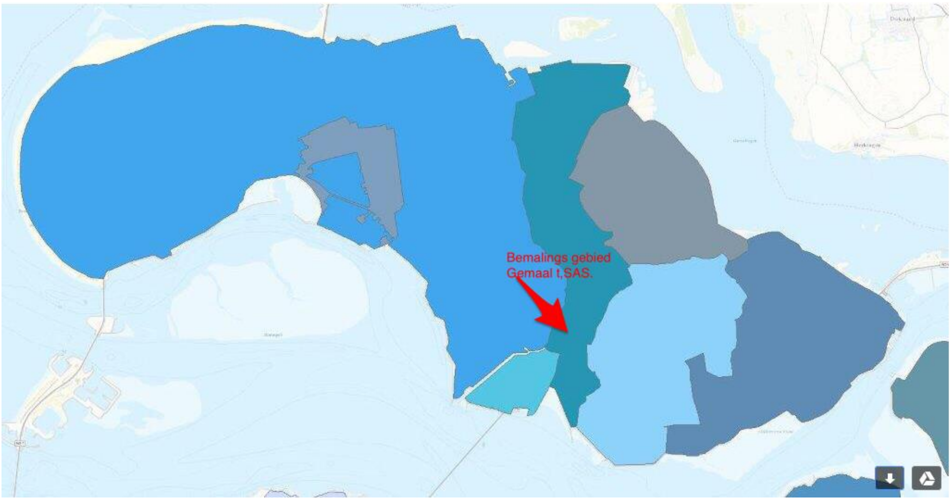


Figure 62 Catchment area pumping station (Brinke, 2015)

8.1.9 Water level difference

The harbor in Zierikzee consists of brackish water. From the harbor the fish want to migrate to the polder and vice versa. The water in the polder is also brackish. The area is a fresh-salt water transition zone. Figure 63 shows a schematization of the differences in water level between the harbor and polder. Pumping station ‘t Sas has to overcome 2,30 and 3,70 m when there is a minimal water level of 0,80 m NAP.

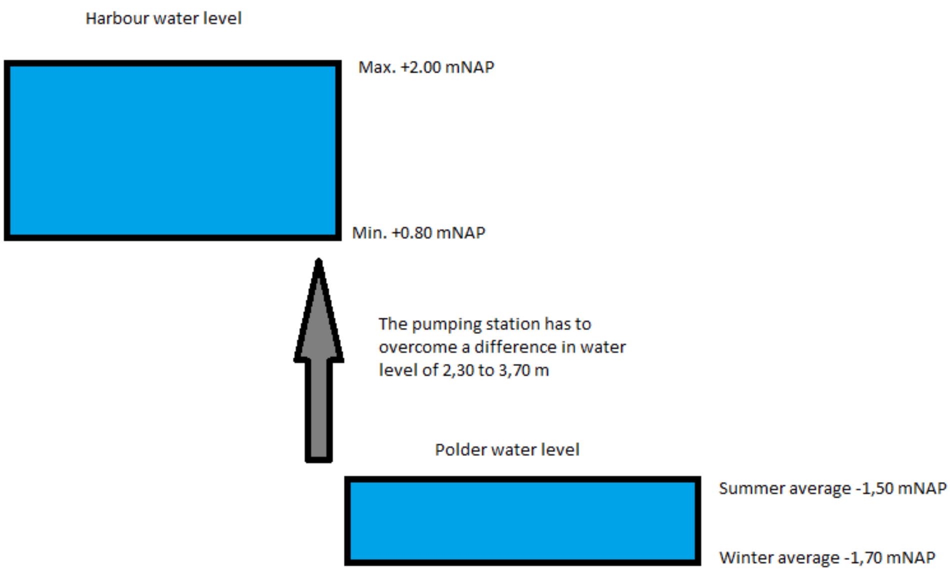


Figure 63 Schematization water level difference between the harbor and the polder

8.1.10 Tidal influences

There is a strong tidal influence in the harbor of Zierikzee. Rijkswaterstaat records tidal data all around the Netherlands. The raw data has been made into a clear graph, see Figure 64. The different tidal situations and the average water level are given in Table 17.

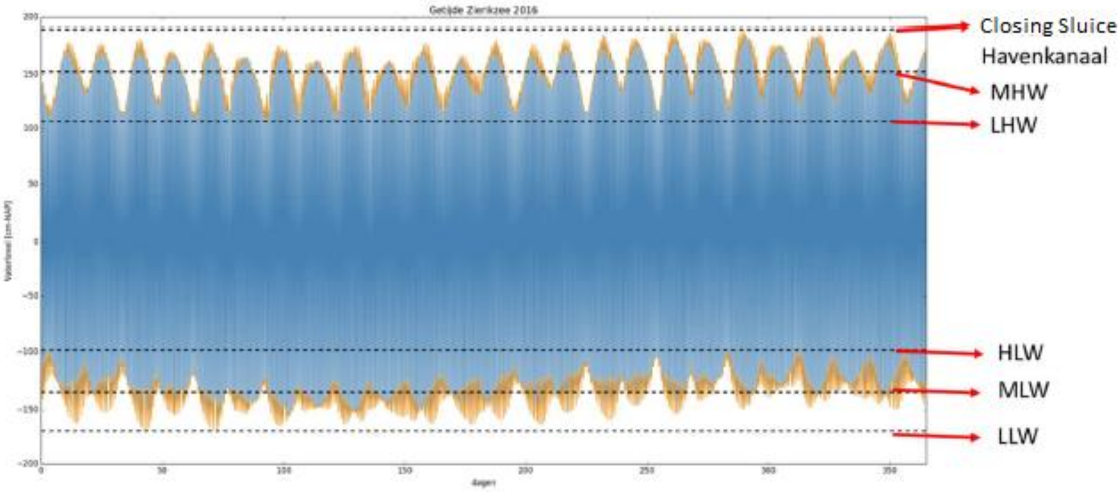


Figure 64 Graph that shows the tide in Zierikzee 2016 (Vlieger, 2016)

Table 17 Tide situations and their water level values in Zierikzee 2016 (Vlieger, 2016)

Situation tide	Water levels
HHW (High High Water)	1,89 m NAP
MHW (Mean High Water)	1,52 m NAP
LHW (Low High Water)	1,07 m NAP
HLW (High Low Water)	-0,98 m NAP
MLW (Mean Low Water)	-1,34 m NAP
LLW (Low Low Water)	-1,69 m NAP
Mean water level	0,09 m NAP

The average tidal cycle of Zierikzee in 2016 has been plotted in Figure 65. The average high tide, average low tide and average mean tide are shown. This provides a clear view how the tide acts in the harbor of Zierikzee.

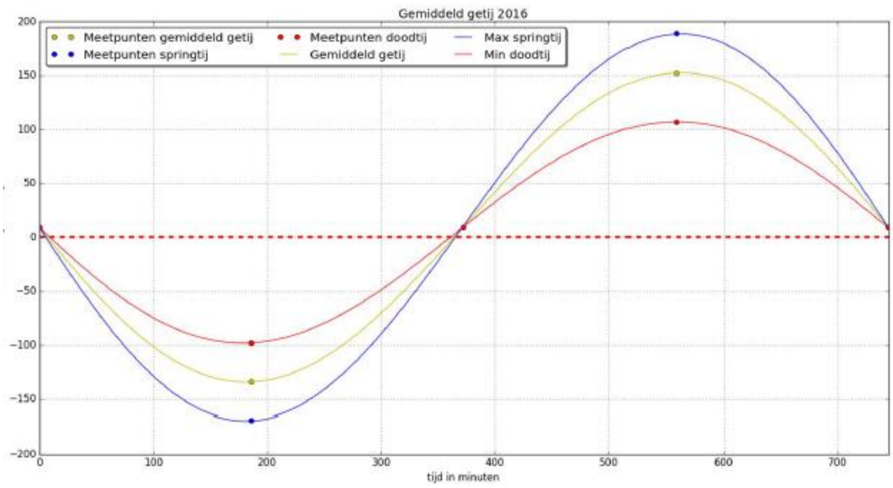


Figure 65 Average tidal cycle Zierikzee 2016 (Vlieger, 2016)

Sailing in and out of the harbors

Each day there are two 3,5-hour time lapses during which ships can sail between ‘t Sas and De Oude Haven. In these time windows there the water level in the harbors is above +0,80 mNAP. On Figure 66 a graph is shown with an indication of the time slots in which ships are able to move between the harbors.

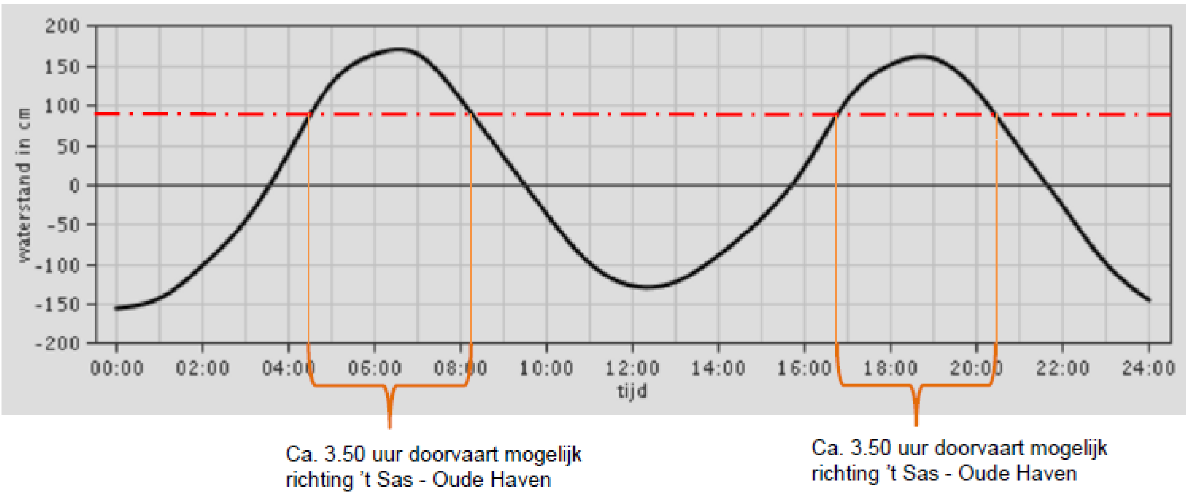


Figure 66 Sailing between ‘t Sas and De Oude Haven (Kaan, Getijde tabel, 2017)

8.1.11 Type brackish water

The harbors of Zierikzee are medium brackish and have a water depth larger than 1,5 m. As can be seen in Figure 67

Figure 67 Classification harbor (Gotjb, 2002)

8.1.12 Nutrients in the polder water

The water board has performed measurements on the chemical substances in the polder water. The measurements were taken near pumping station 't Sas. The polder water is pumped into the harbors. The nutrients and chemical substances in the polder water have an impact the water quality in the harbors. This data can be used to determine the influence of the minimal water level of +0,80 mNAP on the water quality. The data about the chemical substances can be found in Table 18.

Table 18 Polder water nutrient data (Waterschap Scheldestromen, 2017)

Parameter:	BZV5	CHLFa	Cl	Cu	DIEPTE	GELDHD	GEUR	KLEUR	N	NH3	NH4	NO2	NO3
WNS:	WNS2250	WNS2260	WNS2261	WNS742	WNS875	WNS2534	WNS2981	WNS1230	WNS2333	WNS1405	WNS2336	WNS4188	WNS4142
Hoedanigheid:	O2	NVT	NVT	NVT	NVT	NVT	NVT	NVT	N	NVT	N	NVT	NVT
Eenheid:	mg/l	ug/l	mg/l	ug/l	dm	mS/cm	DIMSLS	DIMSLS	mg/l	mg/l	mg/l	mg/l	mg/l
7-1-2014	< 3	3,1	2000	2,7	2,0		reukloos	kleurloos	7,0	< 0,01	0,40	0,079	5,9
7-3-2014	< 3	180	3900	< 1,0	2,0		reukloos	zwak geel	3,6	< 0,01	< 0,1	0,062	2,2
6-5-2014	13	370	10000	2,2	2,0		reukloos	groen	1,6	< 0,01	0,23	0,034	< 0,04
4-7-2014	9,0	37	12000	3,4	2,0		reukloos	zwak geel-groen	1,3	< 0,01	< 0,1	0,026	< 0,04
8-9-2014	96	3000	4400	2,4	2,0		gronderig	bruin	8,7	< 0,01	< 0,1	0,013	< 0,04
11-11-2014	< 3	20	5400	< 1,0	2,0		reukloos	zwak geel	2,6	0,013	1,2	0,36	0,49
Aantal	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum	3,00	3,10	2000,00	1,00	2,00	7,00			1,30	0,01	0,10	0,01	0,04
Maximum	96,00	3000,00	12000,00	3,40	2,00	31,00			8,70	0,01	1,20	0,36	5,90
Gemiddelde	21,17	601,68	6283,33	2,12	2,00	18,17			4,13	0,01	0,36	0,10	1,45
Stand deviatie	36,89	1.183,13	3.869,07	0,96	0,00	9,72			3,04	0,00	0,43	0,13	2,33
Zomergemiddelde	39,33	1.135,67	8.800,00	2,67	2,00	24,33			3,87	0,01	0,14	0,02	0,04
SD Zomergemiddelde	49,12	1623,12	3939,54	0,64	0,00	9,87			4,19	0,00	0,08	0,01	0,00
Percentiel:	11,00	275,00	7.700,00	2,63	2,00	23,00			6,45	0,01	0,80	0,08	2,85
Wintergemiddelde	3,00	67,70	3766,67	1,57	2,00	12,00			4,40	0,01	0,57	0,17	2,86

Parameter:	O2	O2	OB	P	pH	PIGMT	PO4	STROMSTR	T	TROEBHD	WATDTE	WOPP
WNS:	WNS1436	WNS2352	WNS6066	WNS2354	WNS1588	WNS1593	WNS4144	WNS3032	WNS1923	WNS2586	WNSLZE2820	WNSLZE100
Hoedanigheid:	NVT	NVT	NVT	P	NVT	NVT	NVT	NVT	NVT	NVT	NVT	NVT
Eenheid:	mg/l	%	mg/l	mg/l	DIMSLS	ug/l	mg/l	DIMSLS	°C	DIMSLS	dm	DIMSLS
7-1-2014	9,4	82	14	0,30	8,1	3,4	0,28	geen stroming	7,9	zwak opalescent	15	schoon
7-3-2014	16	140	50	0,27	8,2	120	0,17	geen stroming	8,6	zwak opalescent	13	schoon
6-5-2014	> 20	> 200	170	1,3	8,5	< 2	1,0	geen stroming	17,0	zwak troebel	16	schoon
4-7-2014	16	> 200	110	2,0	8,3	18	1,9	geen stroming	26,0	opalescent	13	schoon
8-9-2014	8,1	91,0	660	2,6	8,2	370	1,0	zwak	21,7	opalescent	6,0	hooistort of organisch afval
11-11-2014	8,4	74,6	43	0,83	8,1	5,7	0,83	geen stroming	9,4	helder	13,0	schoon
Aantal	6	6	6	6	6	6	6	6	6	6	6	6
Minimum	8,10	74,60	14,00	0,27	8,10	2,00	0,17		7,90		6,00	
Maximum	20,00	200,00	660,00	2,60	8,50	370,00	1,90		26,00		16,00	
Gemiddelde	12,98	131,27	174,50	1,22	8,23	86,52	0,86		15,10		12,67	
Stand deviatie	5,00	57,94	244,31	0,94	0,15	146,12	0,62		7,65		3,50	
Zomergemiddelde	14,70	163,67	313,33	1,97	8,33	130,00	1,30		21,57		11,67	
SD Zomergemiddelde	6,06	62,93	301,72	0,65	0,15	208,00	0,52		4,50		5,13	
Percentiel:	16,00	170,00	140,00	1,65	8,25	69,00	1,00		19,35		14,00	
Wintergemiddelde	11,27	98,87	35,67	0,47	8,13	43,03	0,43		8,63		13,67	

Parameter:	ZICHT	Zn	Zn	sNO3NO2	NKj
WNS:	WNS2199	WNS2207	WNS2209	WNS1745	WNS2323
Hoedanigheid:	NVT	Nf	NVT	N	N
Eenheid:	cm	ug/l	ug/l	mg/l	mg/l
7-1-2014	80	13	38	6,0	0,99
7-3-2014	60	< 7,8	< 7,8	2,3	1,3
6-5-2014	30	< 7,8	< 7,8	< 0,05	1,6
4-7-2014	30	< 7,8	< 7,8	< 0,05	1,3
8-9-2014	20	< 7,8	< 7,8	< 0,05	8,7
11-11-2014	> 130	< 7,8	< 7,8	0,85	1,8
Aantal	6	6	6	6	6
Minimum	20,00	7,80	7,80	0,05	0,99
Maximum	130,00	13,00	38,00	6,00	8,70
Gemiddelde	58,33	8,67	12,83	1,55	2,62
Stand deviatie	41,67	2,12	12,33	2,35	2,99
Zomergemiddelde	26,67	7,80	7,80	0,05	3,87
SD Zomergemiddelde	5,77	0,00	0,00	0,00	4,19
Percentiel:	75,00	7,80	7,80	2,95	2,00
Wintergemiddelde	90,00	13,70	13,70	3,05	1,36

8.1.13 Explosives

As a result from the past wars there are explosives in the ground in Zierikzee. The red color implicates a very high chance of coming across explosives, orange indicates a high chance. On Figure 68 the red and orange color are present in the area of ‘t Sas and De Oude Haven. (Gemeente Schouwen-Duiveland)

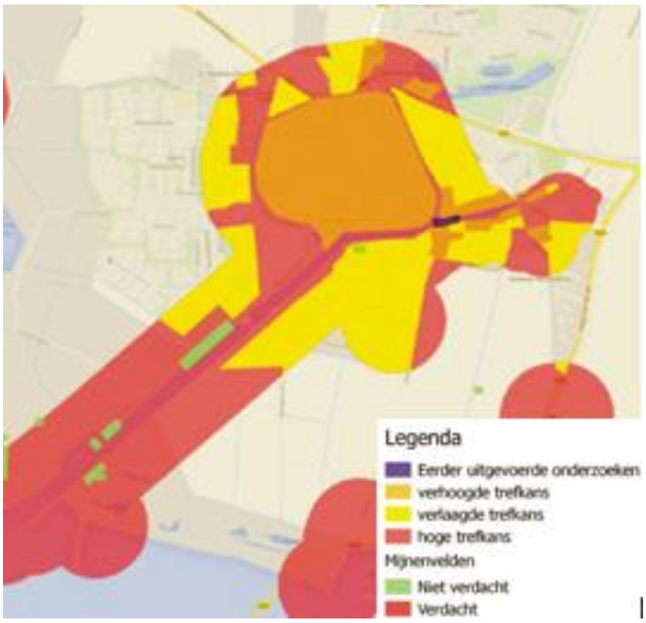


Figure 68 Probality of coming across explosives (Gemeente Schouwen-Duiveland)

The harbor of Zierikzee were three times under attack during the second world war. On 11th and 12th of May 1944, on the 29th of December 1944 and on the 5th of January 1945 shootings and bombardments took place. In the harbor the following objects could be expected:

- 20 mm gun munition
- Missiles with 60 lbs. fight button
- Through munition of 250 lbs., 500 lbs. and 1000 lbs. (Langenhuijzen, 2015)

8.1.14 Harbor bottom level

Svašek has performed research on the how water in the harbor acts before and after the water retaining structure has been implemented. A flow model has been made in FINEL2D of the Oosterschelde in order to calculate the siltation of the harbor. (Bom, 2016)

The water level and flow were determined on certain locations in the harbor, these places are shown as dark dots in Figure 69. The SC in the figure means that those are the Cross-Sections that were calculated.

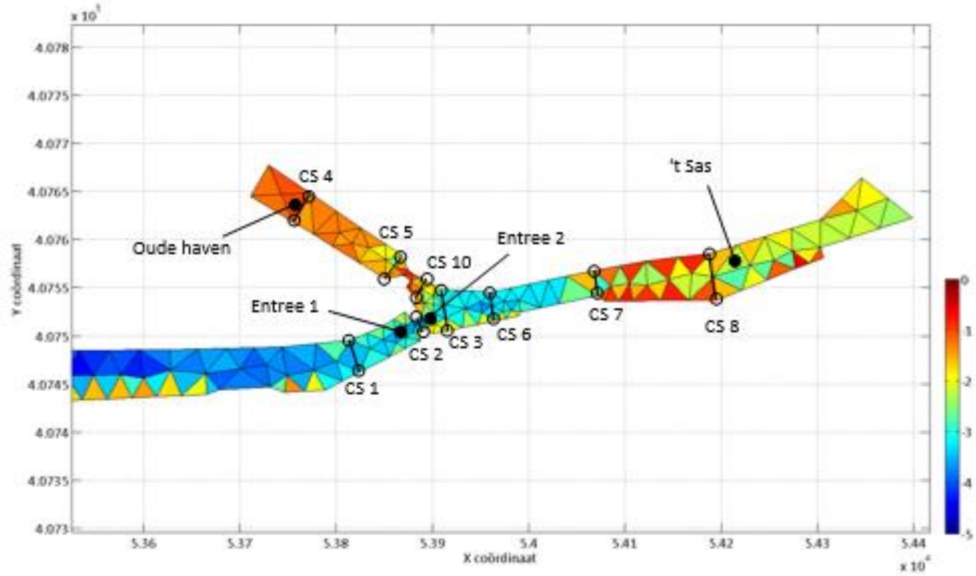


Figure 69 locations and cross-sections for results flow model (Bom, 2016)

The discharge at cross-section 3 has been plotted in Figure 70. The left graph shows the discharge during extremely high tide, the right graph shows the discharge during low tide. The model shows that the closing of the doors results in a small shock wave and that in the negative peaks there are some fluctuations. These fluctuations are present both with and without the water retaining structure. The turn of the tide from negative direction to positive goes abruptly because of the retaining structure. When the structure is opened and closed there is a high discharge present, causing extra fluctuations in the discharge. (Bom, 2016)

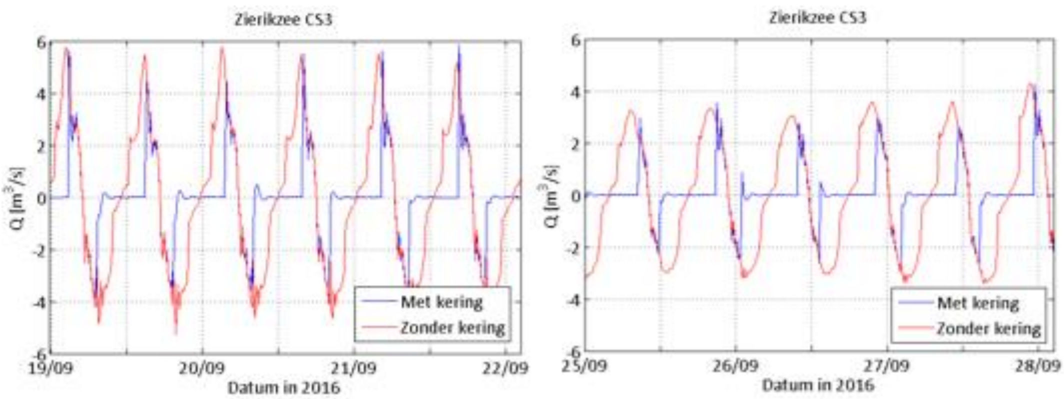


Figure 70 Results model CS3. The discharges with and without retaining structure. The left picture is during extremely high tide (spring tij), the right picture is during neap tide. (Bom, 2016)

8.1.15 Present fish population

The fish population in water body 't Sas has been sampled and evaluated in the year 2011 by water board Scheldestromen. The fish population in 't Sas is typical for brackish water. There are five fish species. 't Sas has been assessed as being of moderate (matig) ecological quality. Table 19 shows the fish population in 't Sas, the caught fish and the estimation of the abundance of the species. Below each fish species is discussed shortly.

Table 19 Fish population 't Sas (Wingerden, 2017)

Specie name	Amount	Abundancy
Common goby	64	1%
Sand smelts	131	2%
Flounder	1	0%
Three-thorned stickleback	5963	62%
Eel	4	35%

The three-thorned stickleback

The Gasterosteus aculeatus or three-thorned stickleback is a rather small fish from the family of the sticklebacks or Gasterosteidae. There are three hard thorns located on top of his back, see Figure 71. Furthermore, the three-thorned stickleback has thorns behind every chest fin and in front of the anal fin. The sides of the fish are silver with black stripes or spots. During the reproduction period the male's appearance changes. His belly becomes bright red and his back and iris become blue. Sticklebacks do not have scales, instead they have plates on their body. The salter the water in the environment of the stickleback, the more plates will be present on the sides of the fish. The stickleback grows larger in salt water, up to 12 cm. In fresh water the stickleback only grows to about 8 cm in length.

Figure 71 The three-thorned stickleback (www.visclublint.be)

The three-thorned stickleback reproduces in fresh water. When the eggs hatch the fish migrate toward the sea. The stickleback grows up in the salty coastal water. When the three-thorned sticklebacks are ready to reproduce they migrate to fresh water again.

The three-thorned stickleback is found in a large part of Europe. In the North and South of Europe the stickleback lives mainly along the coast. In the middle of Europe, the three-thorned stickleback is found in fresh water rivers, lakes and canals. There are three forms of the three-thorned stickleback:

- The Leiurus-form lives permanently in fresh water.
- The Semiarmatus-form migrates, it grows up in the sea and reproduces in fresh water.
- The Trachurus- form lives permanently in salt water.

Between the months April and July, the three-thorned stickleback reproduces. The male builds a nest using slime, plants and sand. He lures the female in the nest by performing courtship or mating behavior. After the fertilization, the male guards the nest. (RAVON, Reptielen Amfibieen Vissen Onderzoek Nederland, 2014) The three-thorned stickleback is a sight-predator. three-thorned stickleback mainly eats small aquatic organisms like mosquito larvae, water fleas and nymphs. Small sticklebacks prefer to eat plankton, larger stickleback prefer to eat larger invertebrates. (Cools, 2012) In Table 20 the characteristics of the three-thorned sticklebacks are presented.

Table 20 Characteristics three-thorned stickleback (Beeren, 2000)

Fish species	Three-thorned stickleback
Flow preference	Tolerant flow
Reproduction manner	On plants
Migration type	Anadromous
Position in water column	Pelagic/demersal
Migration period	March-April
Reproduction temperature	-
Sprint speed	1,5 m/s

The eel

The eel or Anguilla anguilla comes from the family of eels or Anguillidae. The eel has a long cylindrical body. During the eel's lifecycle its appearance changes. When the eel is a larva it lives in the sea, it has the shape of a willow leaf and is transparent. Near the coast the 8 cm long larvae transform to little eels also called elvers, see Figure 72 Elver .

Figure 72 Elver (www.nevepaling.nl)

The eels that grow up in fresh water and along the coast have a black/green back and white belly, they are called red eel. The fully-grown eels that migrate to the sea are called silver eels. The silver eels have silver/white sides and big eyes. The female eels can reach a length up to 100 cm, however the males only grow up to a maximum of 50 cm.

The eel's living environment consist of the coastal zones and the fresh water that are in contact with each other. The eel is found in the whole of Europe. The eel reproduces at great depth in salt water. The adult eel migrates from the end of the summer till winter from the fresh water toward the sea. The eels swim about 6000 km to the reproductive area in the Sargasso Sea, which is a region in the north of the Atlantic Ocean. The migratory peak lies in October. The migration from the fresh water mainly takes place during the night during high discharge periods. After reproducing the older eels die. The larvae migrate via sea currents toward the coastal areas, they feed on plankton and some solved organic materials. When the larvae have reached the coast, they transform into elvers. The elver moves from the tidal zone to the mouth of the river. The eels grow up in the fresh water. Depended on the food availability, they migrate hundreds of kilometers land inward.

During the day the eel hides between the aquatic plants, in hollow banks, between stones or digs itself in. The eels feed on macro fauna and fish, dependent on the climate and food availability. After five to twelve years the eels have reached adulthood. When the eels are isolated and are unable to migrate, the eels become much older compared to when they migrate. (RAVON, Reptielen Amfibieen Vissen Onderzoek Nederland, 2014) See

Table 21 Characteristics eels (Beeren, 2000)

Fish species	European eel (adult)	European eel (juvenile)
Flow preference	Tolerant flow	Tolerant flow
Reproduction manner	Pelagofiel	-
Migration type	Catadromous	Catadromous
Position in water column	Benthic	Pelagic
Migration period	June-December	April-May
Reproduction temperature	-	-
Sprint speed	1,0 m/s	0.5 m/s

Flounder

The fish species Flounder or in Dutch called Bot belongs to the family of the Pleuronectidae or righteye flounders. Both eyes of the flounder are located on the dark green-red side of its body, this is often the right side of the fish. The light-colored side of the fish is directed toward the bottom, see Figure 73. Flounders can reach a length of about 50 cm. The flounder can in estuaries be confused with the dab and the plaice, because of their similar appearance.

Figure 73 Flounder (Herder J. , 2015)

The flounder is found in all European coastal areas, estuaries and connected fresh waters. The reproduction zone is located between 20 and 40 m below the water surface, and between 50 to a 100 km from the coast. The eggs and larvae from the flounders are Pelagofiel. When the larvae have reached a length of 1 cm its left eye move to the rights side of its body and the flounder larvae becomes a flat fish. The juvenile flounder migrates to brackish water to grow up. After 2 to 3 years the flounder has become sexually mature. From this moment the flounders swim back to the sea to reproduce, they will not return to the brackish water. In the Netherlands, the flounder lives in large rivers and lakes that are in contact with the sea.

The flounder is rarely found in fresh water. Therefore, the flounder has been included into the Visserijwet or Fish-law with a minimal length of 20 cm. (RAVON, Reptielen, Amfibien, Vissen, Onderzoek en Bescherming, 2015) In Table 22 the characteristics of the flounder are listed.

Table 22 Characteristics Flounder (Beeren, 2000)

Fish species	Flounder
Flow preference	Tolerant flow
Reproduction manner	Pelagofiel
Migration type	Catadromous
Position in water column	Benthic
Migration period	May-June
Reproduction temperature	-
Sprint speed	-

Common Goby

The common goby is related to the goby family or the Gobiidae. The Latin name for common goby is Pomatoschistus microps. The common goby is a small benthic fish species. It has an upstanding beak and a transparent body and fins. The belly fins are connected *and* function as a suction cup. The male changes color during the reproduction period. Its first back fin will have a blue to black stain. The common goby can reach a length of about 6 cm. From the head to the first back fin the common goby does not have scales.

Figure 74 Common goby (Herder J. , 2015)

the common goby is found in most of the European coastal areas. The common goby lives in estuaries and other brackish to light brackish waters. In fresh waters the species is spotted as well, the waters however do have to be connected to the coast.

The common goby lives on the sand and bottoms made out of mud. The common goby feeds on invertebrate species. The reproduction period starts in February and ends in September. The female will lay eggs several times within this period. The eggs are laid between stones, shells and plants, the male guards the eggs until they hatch.

In the fresh waters of the Netherlands the common goby is rare. It mainly lives in the transition zones between fresh and salt water. Their living environment is spread wide and therefore has little threats. However, the living environment has declined by the construction of dams. (RAVON, Reptielen, Amfibien, Vissen, Onderzoek, Nederland, 2015)

Sand smelt

The sand smelt or Atherina presbyter has a body with a bright blue-green color with a shining tripe over the length, see Figure 75. Up close on the edge of the scales there are small black pigment stains. The tail of the sand smelt has a fork shape and the eyes are relatively large. The sand smelt has two separate fins on its back, a chest fin and an anal fin. The species can grow up to a length of 21 cm.

The sand smelt feeds on zooplankton, small crustaceans and fish larvae.


Figure 75 Sand smelt (Onderwater, 2017)

This fish species prefers to swim in groups. They live in estuaries along the coast. The sand smelt prefers calm waters with vegetation.

The reproduction period starts in April and ends in June. The eggs are laid on seaweed. (Vlierhuis, 2016)

8.1.16 SWOT-Analysis

The area analysis has provided an objective view on the research area. The strengths, weaknesses, opportunities and threats have been derived from the area analysis, called a SWOT-analysis. This SWOT-analysis will help the development of the projects by creating a clear image of the area.

The SWOT considers the area from a technical point of view. This information is very useful in developing the manners to maintain and improve the water quality. In Table 23 the SWOT is given.

Table 23 SWOT-Analysis research area

SWOT-Analysis

Strengths:	**Weaknesses:**
• The docking piers that fluctuate along with the water • Prior research has been performed on the research area • Fish record show that there are fresh and salt fish species in the harbor • Limited wave influences due to the small water surface • Limited wind influence because the harbor is surrounded by buildings	• Small available space • Strong tidal influence • Polder water with high nutritional values • Less refreshment of the water due to the minimal water level • Four fish migration obstacles
Opportunities:	**Threats:**
• Rainwater and sewer water are collected separately. • There is a canal around the city of Zierikzee. • Pumping station 't Sas • Comparable areas from which knowledge can be obtained. • Available data that could be useful in the project. • Available knowledge and experts that could be useful in the project. • Brackish water in the polder	• Pollution in the soil of the harbor bottom. • Explosives on the ground around the harbors. • Water quality problems: Algae blooms and anoxic situation • Weak quay walls • Fish migration not possible • Siltation in the harbor • Salinization of the groundwater • Groundwater level fluctuation

8.2 Stakeholder Analysis

The stakeholder analysis gives an overview of the people and organization that have a stake in the project. It considers the interests and the preferences of the stakeholders. The stakeholders are dynamic and can therefor change during a project. A good relationship with the stakeholders contributes to a more qualitative project.

An orientation on what stakeholders might be interested in the project and an inventory of the nature of the stakeholders has been made. With this information the existing stakeholder relationship and the preferred stakeholder relationship for this project are determined.

8.2.1 Orientation of the stakeholders

The stakeholders are divided into three groups: public, private and community. The private stakeholders are further divided into stakeholders that are independent and dependent of the harbor in relation to their income. This gives a rough view of the stakeholders.

8.2.1.1 *Public*

Municipality of Schouwen-Duiveland

Municipality of Schouwen-Duiveland is the client of the project. The municipality has developed a master plan for the area; the harbors in Zierikzee are part of this development plan.

The municipality responsible for the ground water in the urban areas; and for the collection and transportation of wastewater and rainwater through a sewer network. (Rijksoverheid, 2016)

Province of Zeeland

The provinces translate the policies and guidelines that the Rijksoverheid has made into regional measures. The provinces are responsible for the groundwater quality and operational tasks. (Rijksoverheid, 2016)

The Province of Zeeland is committed to the economic growth and innovations of Zeeland. The strategic location of Zeeland, at sea and between Rotterdam and Antwerp is being used. The province is concerned with the spatial planning and economic aspects of the project. (Province of Zeeland, sd)

Water board Scheldestromen

The water boards together are responsible for the regional waters of the Netherlands. The water boards make sure there is sufficient fresh water; take care of the fish population; protect the country against floods; and clean the wastewater. Management plans are made by the water boards in order to maintain the water quality in the water bodies they are responsible for. (Rijksoverheid, 2016)

Water board Scheldestromen is an organization that is responsible for the water management in Zeeland. Scheldestromen manages the dikes and dunes, water quality, roads and cycle paths. The water board works with the EWFD policies in order to improve the water quality. (Waterschap Scheldestromen, 2017)

Pumping station ‘t Sas pumps water from the polder into ‘t Sas. This pump is being influenced by the project. The realization of a minimal water level has consequences for the amount of water the pump may discharge and the pump efficiency. Because this pumping station falls under the jurisdiction of the water board they are interested in the project. Furthermore, the project considers the water quality of two harbors in Zeeland.

Rijkswaterstaat

Rijkswaterstaat (RWS) is responsible for the management of large water bodies like rivers and the part of the sea that belongs to the Netherlands. RWS makes sure the dykes, dams, flood retaining structures and weirs function properly. The “room for the river” principle is a project RWS executed to provide the rivers with more space in order to take a more natural route. In times of high water or storm surges RWS warns the responsible government bodies. (Rijksoverheid, 2016)

Rijkswaterstaat is committed to achieve a good balance between economy, environment and housing in the Netherlands. Rijkswaterstaat contributes to the facilitation of the living environment, safety and reachability in the Netherlands. (Rijkswaterstaat, 2017)

This project has to do with the livability around the harbors and the economy in Zierikzee.

Ministry of economy
The ministry of economy has the aim to make a sustainable and an entrepreneurial Netherlands. The ministry of economy has the purpose to create a good environment for entrepreneurs and a strong international position in the market. (Rijksoverheid, sd)

The project improves the environment; in turn this creates opportunities for economic growth in Zierikzee.

Ministry of Infrastructure and the environment
The ministry of infrastructure and the environment has the goal to provide nice environments, they must be reachable, clean and livable. The infrastructure considers rail, air, roads and waterways. The ministry of infrastructure is a stakeholder for this project because the project has a waterway as a subject. (Rijksoverheid, sd)

National monument organization
The national monument organization or NMo is active in conserving cultural heritage. The research area is filled with monuments. The environment around the monuments will be adjusted therefor the NMo shall be of interest in the project.

Knowledge sector research and development
Knowledge of science and being practical are most essential in a project. The HZ University of Applied Science has the Delta Academy. In the Delta Academy students learn how to deal with water related problems.

The project is of interest for the HZ University of Applied Science because Iris Zijlstra is a student at the HZ University of Applied Science. Also, cooperation in such a project offers opportunities for the university.

Zeeuwse Milieufederatie (ZMF)
The Zeeuwse Milieufederatie (ZMF) strives for a beautiful and sustainable Zeeland. Association Stad en Lande is an organization part of the ZMF. (ZMF, 2017)

Association Stad en Lande
Association Stad en Lande has the goal to maintain the urbanized and landscape and enhance it on Schouwen-Duiveland. The Association Stad en Lande also contributes to the spread of the historic knowledge of Schouwen-Duiveland. (ZMF, 2017)

Association Stad en Lande will have an interest in the project because its concerns the planning of an area in the historical city Zierikzee.

8.2.1.2 *Private*

The private stakeholders are grouped in stakeholders that are dependent of the harbor and the stakeholders that are independent of the harbor in relation to their profits.

<u>Depending of the harbor</u>

The restaurants and hotel around the harbors are influenced by the development of the harbors. The development of De Oude Haven is therefore of their interest.

De Oude Haven hotel

On the Northeast side of De Oude Haven the hotel De Oude Haven is located. The hotel is a bed and breakfast in a historical building. People stay in the bed and breakfast because it is located in the most historical part of Zierikzee.

Grandcafé de Werf

Grandcafe de Werf is a grand café with a pleasant terrace looking out over the harbor. The Grandcafe serves people Italian food.

Grieks Restaurant Rhodos Zierikzee

The Greek restaurant called Rhodos is not located directly at the harbor but near the most northern part of De Oude Haven, on the west corner of De Oude Haven. This restaurant is across Café-Restaurant De Proeverij.

Café-Restaurant De Proeverij

Restaurant De Proeverij is located on the northwest corner of De Oude Haven. The restaurant lies directly at De Oude Haven.

Watersport Association Zierikzee

The Watersport Vereninging Zierikzee has been established in 1961. The organization is part of the Watersportverbond. The watersport Association Zierikzee manages the marina behind the sluice, in the Nieuwe haven. (Watersport Vereniging Zierikzee, 2017)

<u>Independent of the harbor</u>

The stakeholders that are independent of the harbor considering their income are listed below. The independent stakeholders are the private companies who are in the research area.

Profile Car & Tyreservice Zierikzee

The Profile Car and Tyreservice is located near pumping station ‘t Sas, on the east corner of ‘t Sas. The Profile Car and Tyreservice provides service for cars and car tyres. (Profile Car and Tyreservice Zierikzee, 2017)

Stichting Radio Omroep Schouwen-Duiveland

Next to the Profile Car and Tyreservice is the building of the Stichting Radio Omroep Schouwen-Duiveland. Radio Schouwen-Duiveland is a local radio station of the inhabitants of Schouwen-Duiveland. (Radio Omroep Schouwen-Duiveland (ROSD), 2017)

Tandartspraktijk Zierikzee

On the west side of De Oude Haven there is a dentist practice. The dentist provides teeth service to the people in Zierikzee.

Delta Elektronika B.V.

On the south side of ‘t Sas Delta Elektronika B.V. is located. Delta Elektronika designs and manufactures DC power units. (Delta Elektronika , 2017)

H. Terpstra Pensioen B.V.

H. Terpstra Pensioen B.V. is located on the north side of ‘t Sas. The company provides the service to help people with their pensions.

E.J.K. Kozijnen
On the northwest side of ‘t Sas E.J.K. Kozijnen is located. E.J.K. Kozijnen delivers, installs and gives advice about window frames. (E.J.K. Kozijnen, 2017)

Gall & Gall
The Gall & Gall is a liquor store on the west corner of De Oude Haven. It sells liquor to people with an age above 18. (Gall & Gall, 2017)

Fisheries
The fishing fleet berths at the quay walls of the Nieuwe haven. This is close to the research area. The fisheries sell the fish to restaurants, on the market and to other shops.

8.2.1.3 *Community*

Tourists
There is a lot of tourism in Zierikzee. People visit the city because of its beautiful authentic environment. Tourism is an important income source for the city of Zierikzee.

In the project the most photographed and visited area is being developed, therefor the tourists need to be considered.

There are tourists that spend one day and tourists that stay multiple days, spending the night. These are both considered under the name “Tourist”.

People living in Zierikzee
The people who live in Zierikzee will be affected by the project. It will improve the living environment.

8.2.2 Inventory nature of the stakeholders

To determine how a stakeholder is influenced or affected by the project and how the stakeholders can be of use, an inventory has been made. The inventory in Table 25 lists the stakeholders, their interests in the project, their objectives, the possible cooperation gab, the causes of the gab, how to solve the gab, the available resources and the level of dependency, the attitude towards the project and a SWOT. The dependency on the stakeholders is evaluated by means of Table 24.

Table 24 The dependency of the stakeholders (Stakeholder map, n.d.)

	Limited importance	Great importance
Limited options to replace	Medium dependency	High dependency
Can easily be replaced	Limited dependency	Medium dependency

The attitude toward the project gives a sight whether the stakeholders are parties that would work against or along with the project. Addressing the stakeholders like a SWOT (Strength, Weakness, Opportunity and Threat) provides information about what the stakeholder could mean to the project.

Table 25 Inventory nature stakeholders

Stakeholder group	Stakeholder	Interests	Objectives	Expected situation gab	Causes gab	Possible solutions gab	Available resources	Level of dependency	In favor of against project	SWOT
Public	Municipality of Schouwen-Duiveland	Client, Improving the harbors in Zierikzee	Improving the harbor area, making it more attractive.	Not sufficient knowledge present for the project. Lack of communication between stakeholders.	Not the suitable education for the project. First the projects are developed before talking to the stakeholders.	Gain knowledge from others. Cooperate with stakeholders from the absolute beginning of the project.	Information Knowledge/skill Money Position in network Legitimacy Organization	High dependency	In favor	Strength
	Province of Zeeland	Economic growth and innovations of Zeeland	Creating economic opportunities.	Shortage of money.	Other priorities.	Creating economic innovations.	Information Knowledge/skill Money Position in network Legitimacy Organization	Medium dependency	In favor	Opportunity
	Water board Scheldestromen	Safety, water quality, water quantity and water management	A good water quality in De Oude Haven and in 't Sas. Fish having the opportunity to migrate. Maintain the efficiency and capacity of pumping station 't Sas.	Fish migration limited and degrading water quality. Efficient use of pumping station 't Sas is not possible.	Minimal water level and less water refreshment. Not taking the Q-H curve into account.	Creating a fish passage. Taking water quality improvement measures. Taking the existing Q-H curve of the pumps into account.	Information Knowledge/skill Money Position in network Legitimacy Organization	High dependency	In favor of improving water quality, against the creation of a fish migration problem.	Strength and threat
	Rijkswaterstaat	Improving the living environment, safety and reachability	A nice environment in and around the harbor of Zierikzee	Decreasing environment.	Decrease in water quality.	Measures to improve water quality and the environment.	Knowledge/skill Money Position in network Legitimacy Organization	Medium dependency	In favor	Opportunity
	Ministry of economics	A good environment for entrepreneurs and a strong international competition position in the market	Creating economic opportunities.	Decrease in economic opportunities.	Decrease environment.	Improving the environment, creating economic growth options.	Knowledge/skill Money Position in network Legitimacy Organization	Limited dependency	In favor	-
	Ministry of Infrastructure and environment	Provide a reachable, clean and livable environment	A nice environment in and around the harbor of Zierikzee.	Decreasing environment.	Decrease in water quality.	Measures to improve water quality and the environment.	Knowledge/skill Money Position in network Legitimacy Organization	Medium dependency	In favor	-
	National monument organization	Conserving cultural heritage	Maintain the cultural heritage in the harbors and enlarge the connection	Monument degradation	Construction could damage the monuments.	Careful communication and monitoring of the monuments during construction practices.	Information Money Position in network Legitimacy Organization	Medium dependency	In favor to improve the area, against if the monuments will be jeopardized.	Threat

			between culture and the city.							
	Knowledge sector research and development (R&D)	Spread knowledge and gain knowledge	Using Zierikzee as a research area.	Subjects to research.	No research requests.	Cooperation with the municipality of Schouwen-Duiveland and the water board Scheldestromen.	Knowledge/skill Position in network Legitimacy Organization	Medium Dependency	In favor	Opportunity
	Zeeuwse Milieufederatie (ZMF)	Maintain the urbanized landscape and enhance, spread of the historic knowledge	Maintain the cultural heritage in the harbors and enlarge the connection between culture and the city.	Monument degradation and loss bond between the culture and the city.	By construction the monuments could get damaged and less cohesion between structures in the city.	Careful communication and planning of the project in relation to the monuments.	Information Knowledge/skill Position in network Legitimacy Organization	Limited Dependency	In favor to improve the area, against if the monuments will be jeopardized	Threat
	Association Stad en Lande	Maintain the urbanized landscape and enhance, spread of the historic knowledge	Maintain the cultural heritage in the harbors and enlarge the connection between culture and the city.	Monument degradation and loss bond between the culture and the city.	By construction the monuments could get damaged and less cohesion between structures in the city.	Careful communication and planning of the project in relation to the monuments.	Information Knowledge/skill Position in network Legitimacy Organization	Medium dependency	In favor to improve the area, against if the monuments will be jeopardized	Opportunity
Private (dependent on the harbor)	De Oude Haven hotel	Providing people with a nice stay	Enlarge the group of people that want to stay in Zierikzee	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Legitimacy	Limited dependency	In favor, but do not look forward to the construction period during which their clients are disturbed.	-
	Grandcafé de Werf	Serving people food and drinks	Enlarge the amount of people that want to eat and drink in Zierikzee.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Legitimacy	Limited dependency	In favor, but do not look forward to the construction period during which their clients are disturbed.	-
	Grieks Restaurant Rhodos Zierikzee	Serving people food and drinks	Enlarge the amount of people that want to eat and drink in Zierikzee.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Legitimacy	Limited dependency	In favor, but do not look forward to the construction period during which their clients are disturbed.	-
	Café-Restaurant De Proeverij	Serving people food and drinks	Enlarge the amount of people that want to eat and drink in Zierikzee.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Legitimacy	Limited dependency	In favor, but do not look forward to the construction period during which their	-

									clients are disturbed.	
	Watersport Association Zierikzee	Providing water sports facilities in Zierikzee	Providing more water sports facilities.	Less people drawn to the harbors during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Manpower Position in network Legitimacy Organization	Limited dependency	In favor, but do not look forward to the construction period during which their clients are disturbed.	Opportunity
Private (independent on the harbor)	Profile Car & Tyreservice Zierikzee	Providing car and tyre service	Increasing the number of customers for car and tyre service.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information	Limited dependency	In favor	-
	Stichting Radio Omroep Schouwen-Duiveland	Making a radio program	Increase the amount of people that listen to the radio program.	Reduction of listeners and a disruption of the work environment.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Position in network Legitimacy Organization	Limited dependency	In favor	Opportunity
	Tandartspraktijk Zierikzee	Providing teeth service	Increase the number of costumers.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information	Limited dependency	In favor	-
	Delta Elektronika B.V.	Designing and manufactures DC power units	Increase the costumers for DC power units.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information	Limited dependency	In favor	-
	H. Terpstra Pensioen B.V.	Helping people with their pensions	Increase the costumers for pension advice.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information	Limited dependency	In favor	-
	E.J.K. Kozijnen	Delivering, installing and giving advice about window frames	Increase the costumers for window frames.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information	Limited dependency	In favor	-
	Gall & Gall	Selling liquor	Increase the amount of liquor being sold.	Reduction of customers during construction period.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information	Limited dependency	In favor	-
	Fisheries	Making sufficient profit with fishing.	Enlarging the profit made with fishing.	Occupation berth places.	Increased recreation activities.	Create clear fishery intended berth places	Information	Limited dependency	In favor	Opportunity
Community	Tourists	Nice environment, and sufficient activities	Enjoying the area, having a nice experience.	Reduction environment during construction.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Legitimacy	High dependency	In favor	Opportunity
	People living in Zierikzee	The living environment.	Enhancing the living environment.	Reduction environment during construction.	Noise and possible road obstacles.	Short implementation period with limited disruptions.	Information Legitimacy	High dependency	In favor	Opportunity

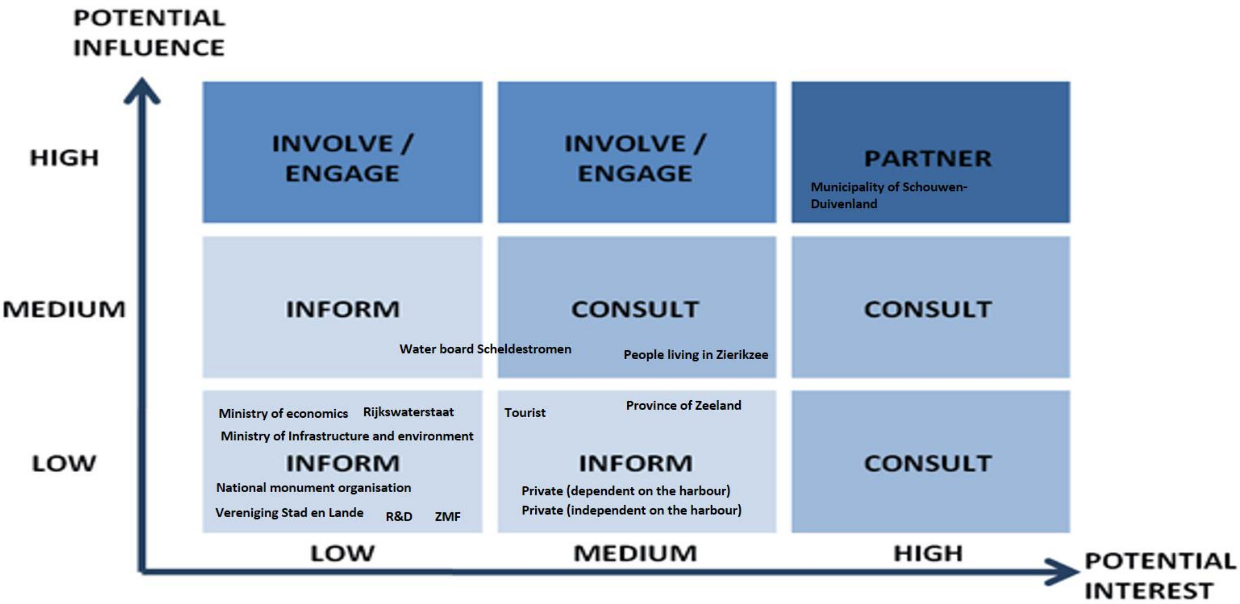
8.2.3 Current and preferred stakeholder relationship

The stakeholder relationship was in the beginning of the project a lot different than the preferred relationship. Therefore, the difference between the two is shown.

Stakeholder relationship start project

As can be seen in Table 26 most of the stakeholders are in the “Inform” boxes. This means the stakeholders are only informed about the project. The inhabitants and the water board are currently consulted on the project. With this stakeholder relationship status, the project has a large chance to be blocked in a later stadium. This stakeholder relationships were identified by means of interviews with the stakeholders.

Table 26 Current stakeholder relationships



Preferred stakeholder relationship

In the start situation of stakeholder relationship many stakeholders were only informed. In the preferred stakeholder relationships more stakeholders are consulted, involved and made partner in the project, instead of just informing them. This can be seen in Table 27. These preferred relationships were designed my means of the stakeholder analysis, weighing the powers and interests.

The municipality of Schouwen-Duiveland is the client of the project with high interest and high influence. The water board has a large influence due to the fact that the water quality is their responsibility. Therefore, the municipality and water board are partners.

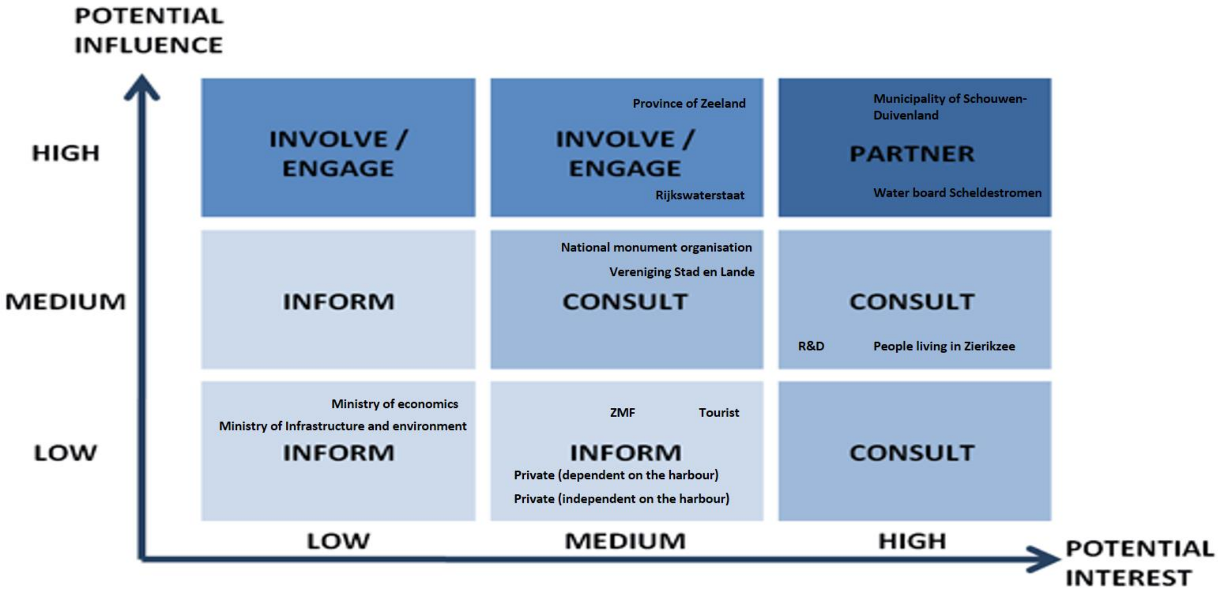
The Province of Zeeland and Rijkswaterstaat have a medium interest in the project but have a high influence. The Province of Zeeland and Rijkswaterstaat are involved in the project.

The National monument organization, the Vereninging Stad en Lande, the Research and Development institutes and the people of Zierikzee will be consulted in the project.

The Ministry of economy, the ministry of infrastructure and the environment, the ZMF, tourists and the private sector who are independent and who are dependent of the harbor, will be informed about the project.

By cooperating with the stakeholders in the form of partnership, involvement, consultation and informing the project gets another dimension. Not only the opinion and ideas form others are taken into account, also the likeability of the project is being enlarged.

Table 27 Preferred stakeholder relationships



Achieving the preferred stakeholder relationship
In order to achieve the preferred stakeholder relationship, the four different relationships have a different approach. All stakeholders were approached as soon as possible to improve the relationships.

The municipality of Schouwen-Duiveland is the partner. The municipality is being involved in the development of the project, during meetings with the municipality the status of the project will be discussed, and the municipality has the ability to express their opinion. The municipality will have the ability to contribute in the decisions that will be made.

Involvement means that the stakeholders have the change to give advice on the project and make recommendations. Meeting will be held to discuss the project. The advice and recommendations will be considered in the project.

The stakeholders that are consulted shall be asked for their opinion on the project. The advice and recommendations of the stakeholder shall not be taken into account, unless their opinion have considerable effect on the project. During a meeting the project shall be discussed, and the stakeholders are asked to express their opinion. T

Informing the stakeholders consists of providing stakeholders with information about the project. The stakeholders will be informed when sufficient and relevant information is available. For example, when the design of the harbor has been finished or when the construction plans are finished. This information has to be certain because if there are uncertainties the information opens a discussion. This is not the meaning of the information.

The information will be send via email, social media and letter. The email and letter are ways that reach all the stakeholders. Via social media a very wide audience can be reached form and provide information to people that are not directly stakeholders but are interested in the project.

8.3 Chloride concentration calculation

Calculation chloride concentration harbor Zierikzee			
Pump data pumpingstation ´t Sas			
Day	m3/dag	Month number	Average m3 /dag
12-11-2016	439134	12 (winter)	337511,0323
13-11-2016	639185		
14-11-2016	414640	Estimates summer discharge	168755,5161
15-11-2016	721910		
16-11-2016	1292510		
17-11-2016	1534532		
18-11-2016	3276440		
19-11-2016	1680149		
20-11-2016	1072187		
21-11-2016	1770047		
22-11-2016	1348358		
23-11-2016	1057569		
24-11-2016	719065		
25-11-2016	722734		
26-11-2016	438384		
27-11-2016	319622		
28-11-2016	404628		
29-11-2016	384774		
30-11-2016	388320		
1-12-2016	420055		
2-12-2016	370763		
3-12-2016	273038		
4-12-2016	278401		
5-12-2016	318307		
6-12-2016	321630		
7-12-2016	297118		
8-12-2016	539343		
9-12-2016	191145		
10-12-2016	222890		
11-12-2016	1200380		
12-12-2016	0		
13-12-2016	0		
14-12-2016	365610		
15-12-2016	4932		
16-12-2016	402654		
17-12-2016	203628		
18-12-2016	234423		
19-12-2016	156016		
20-12-2016	441892		
21-12-2016	173660		
22-12-2016	656947		
23-12-2016	134724		
24-12-2016	691143		
25-12-2016	221813		
26-12-2016	1256857		
27-12-2016	0		
28-12-2016	319379		
29-12-2016	197274		
30-12-2016	180349		
31-12-2016	388471		

Calculation chloride concentration harbor Zierikzee

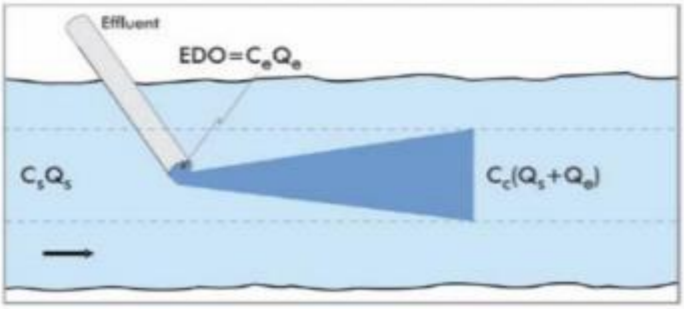
Chloride concentration polder MPN1129 periode 7-1-2014 t/m 11-11-2014		
7-1-2014	2000	mg Cl/L
7-3-2014	3900	mg Cl/L
6-5-2014	10000	mg Cl/L
4-7-2014	12000	mg Cl/L
8-9-2014	4400	mg Cl/L
11-11-2014	5400	mg Cl/L

Summary Chloride concentration polder MPN1129 periode 7-1-2014 t/m 11-11-2014		
Aantal	6	mg Cl/L
Minimum	2000	mg Cl/L
Maximum	12000	mg Cl/L
Gemiddelde	6283,333333	mg Cl/L
Stand deviatie	3869,065348	mg Cl/L
Zomergemiddelde	8800	mg Cl/L
SD Zomergemiddelde	3939,543121	mg Cl/L
Percentiel:	7700	mg Cl/L
Wintergemiddelde	3766,666667	mg Cl/L

Data harbor Zierikzee		
Agerage chloride concentration	7420	mg Cl/L
Surface area harbor	24800	m2
High tide	1,55	mNAP
Low tide	-1,3	mNAP
Average water level (old)	0,6	mNAP
Average water level (new)	0,8	mNAP
Average bottom level harbor	-1,85	mNAP
Current situation		
Minimal water depth	0,55	m
Maximal water depth	3,4	m
Average water depth	1,975	m
Minimal volume	13640	m3
Maximal volume	84320	m3
Average volume	48980	m3
Future situation with a minimal water level of +0,80mNAP		
Minimal water depth	2,65	m
Maximal water depth	3,4	m
Average water depth	3,025	m
Minimal volume	65720	m3
Maximal volume	84320	m3
Average volume	72695	m3

Calculation chloride concentration harbor Zierikzee

Formula used



$$C_sQ_s \quad + C_eQ_e \qquad = \quad C_c(Q_s\text{-}Q_e)$$

$$Fd = \frac{Q_e}{Q_s + Q_e}$$

Chloride concentration current situation (average) winter
4229,653519 mg Cl/L
Chloride concentration current situation (average) Summer
8489,566492 mg Cl/L
Difference chloride concentration current situation (average) Summer and winter
4259,912973 mg Cl/L

Chloride concentration new situation (average) winter
4414,095144 mg Cl/L
Chloride concentration new situation (average) Summer
8384,514866 mg Cl/L
Difference chloride concentration new situation (average) Summer and winter
3970,419723 mg Cl/L

Limitations

The summer discharge was estimated to be 50% the discharge of the winter discharge of the pump.

Only data was available about the winter discharge of one month and for one year.

There was only data on the chloride concentration in the polder for the year 2014.

The influences of the new fish passage were not included in this calculation.

8.4 Fish migration

8.4.1 Multi Criteria Analysis

Alternative solutions for the fish migration

In total there are eight alternative solutions to facilitate fish migration. For each alternative the positive and negative aspects, the way the fish passage functions will be discussed below, and 3D drawings are provided of the alternatives to make it more easily to understand the fish passages.

Alternative 1: Base situation

In Table 28 the positive and negative aspects of the base situation are listed. On Figure 76 a schematization of the base situation is shown. The white building is pumping station ‘t Sas with the basin in front of it and the polder behind it. The black square represents the culvert. The culvert lies under the road and connects the basin to the harbor.

Table 28 Positive and negative aspects of Alternative 1: Base situation

Positive aspects	Negative aspects
No additional costs.	Fluctuation in the tide result in a less attractive appearance of the harbors in Zierikzee.
Known to be functional.	Only small species are able to migrate through the leaking door in pumping station ‘t Sas.
Continuing the maintenance cycle.	
Pumping station ‘t Sas is the single structure that needs maintenance.	
Continuous fish migration.	

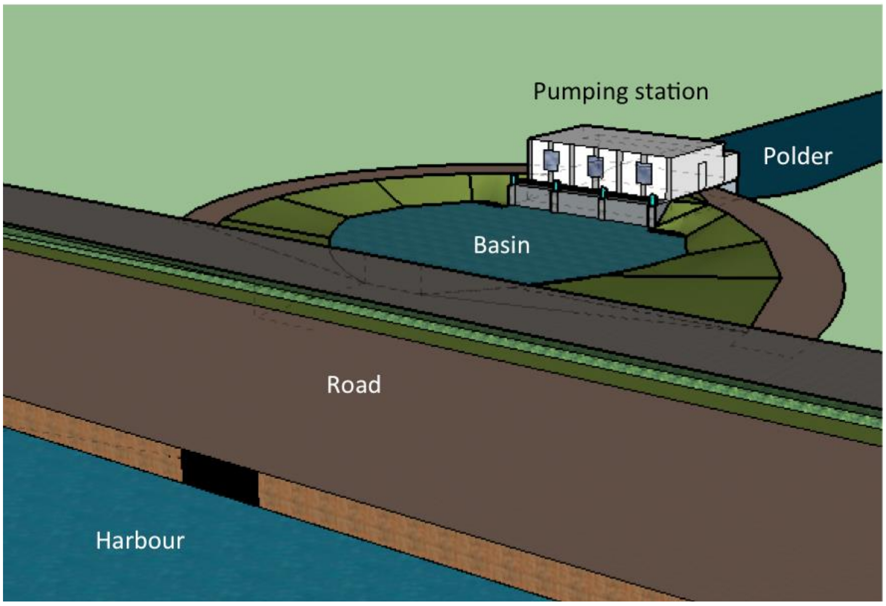


Figure 76 Schematization base situation

Alternative 2: Fish sluice with mechanical door

The negative and positive characteristics of the fish sluice with the mechanical door are given in Table 29. On Figure 77 a schematization of the fish sluice with the mechanical door is shown. On the left a large valve is shown in pink. When the valve is closed it is positioned in the bright blue zone. The green box is the motor that opens and closes the valve. The pump also reduces the water level in the basin and discharges it by means of a pipe into the harbor. The dark blue box within pumping station ‘t Sas represents the mechanical door. The cycle is illustrated in the drawing.

Table 29 Positive and negative aspects of Alternative 2: Fish sluice with mechanical door

Positive aspects	Negative aspects
Making use of pumping station ‘t Sas.	Valves that move in the brackish water will need regular maintenance.
No salt intrusion into the polder.	Small operational timeframe.
Door in pumping station ‘t Sas that controls the water velocity	Functional in cycles. (Beeren, 2000)
The fish will be able to migrate in both directions: to the sea and to the polder.	Expensive when a water level difference over 0,80 m has to be overcome. (Heuts, 2013)
Controlling the water velocity with the mechanical doors.	
Suitable for multiple fish species, regardless their size. **(Beeren, 2000)**	
Possible to overcome large water level differences. **(Beeren, 2000)**	
Limited clogging possibilities. **(Heuts, 2013)**	

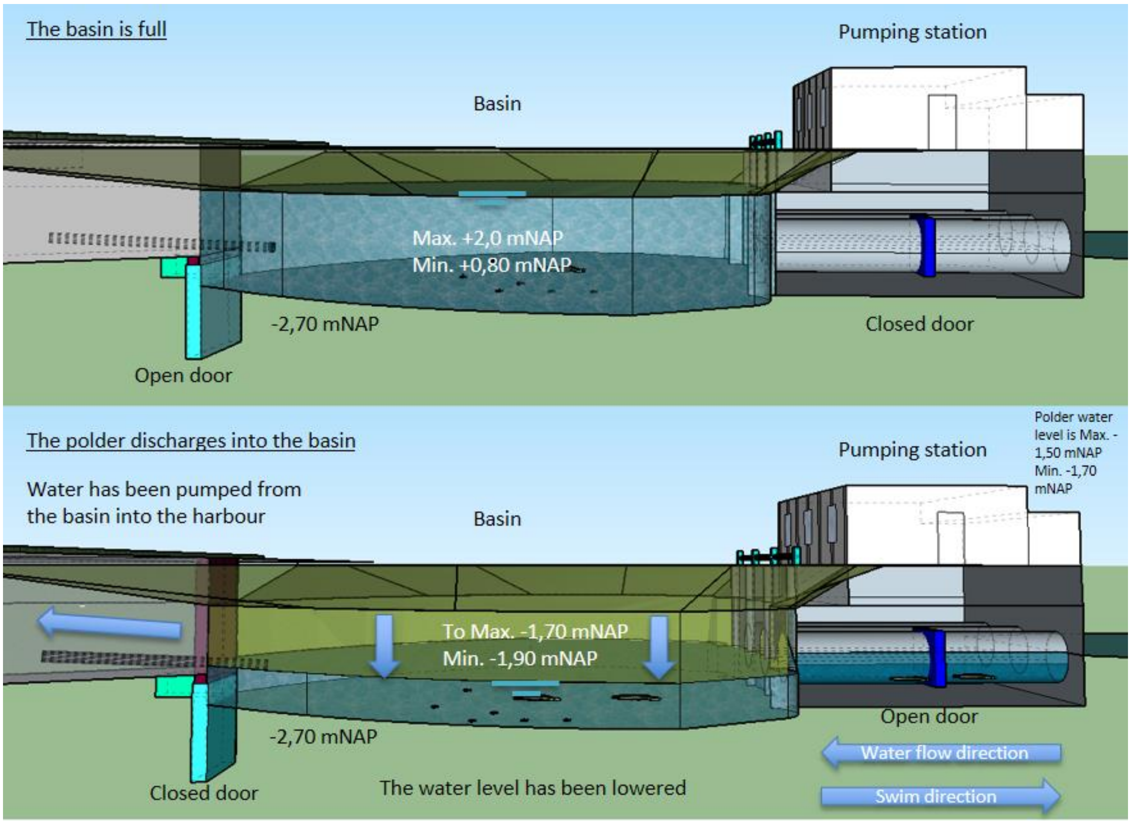


Figure 77 Schematization of the fish sluice with mechanical door

Alternative 3: Fish sluice, basin will discharge in the polder
In Table 30 the positive and negative aspects of the fish sluice are listed. On Figure 78 a schematization of the fish sluice is shown. On the left a large valve can be seen in pink. When the valve is closed it is positioned in the bright blue zone. The green box is the motor that opens and closes the valve. The pipes in pumping station ‘t Sas will be opened and the whole basin will discharge into the polder.

Table 30 Positive and negative aspects of Alternative 3: Fish sluice, basin will discharge in the polder

Positive aspects	Negative aspects
Making use of pumping station ‘t Sas.	Valve that moves in the brackish water will need regular maintenance.
Free discharge	Fish gather in the last layer of water that will be discharged. When discharging the water, the basin will never completely empty. Fish might not use the fish passage efficiently.
Suitable for multiple fish species, regardless their swim capacities and their size. **(Beeren, 2000)**	Small operational timeframe.
Possible to overcome large water level differences. **(Beeren, 2000)**	Functional in cycles. (Beeren, 2000)
Limited clogging possibilities. **(Heuts, 2013)**	Large amount of water that flows into the polder.
	Large salt intrusion into the polder.

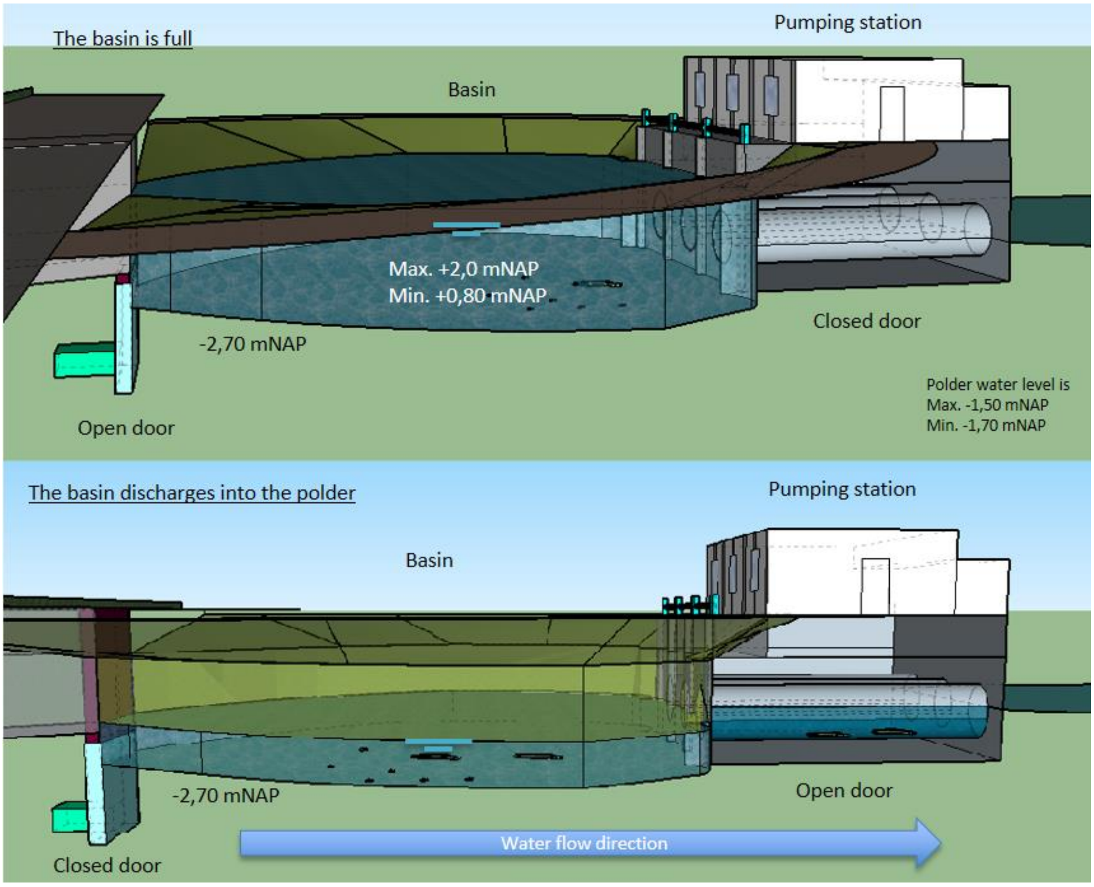


Figure 78 Schematisation of the fish sluice that discharges into the basin

Alternative 4: Fish passage Maelstede
The negative and positive characteristics of the Maelstede fish passage are given in Table 31. In Figure 79 a schematization of the Maelstede fish passage is show in the way it could be implemented in the harbors. A pipeline goes from the basin to the polder, the container collecting the fish is shown in yellow and the purple box is the pump. The small yellow boxes on the side of the container collecting the fish are valves. In red the valves are shown. These can block the flow to the polder or to the harbor. In Figure 80 the pump cycle of the Maelstede fish passage is visualized.

Table 31 Positive and negative aspects of the Alternative 4: Fish passage Maelstede

Positive aspects	Negative aspects
The container in which the fish are collected is not in the brackish water.	Pipes in brackish water will need regular maintenance because of the “palingbrood”.
Migration in two directions.	Valve that moves in the brackish water will need regular maintenance.
Discharge the water from the harbor into the polder by gravitational force. The water is pumped from the polder to the harbor.	Discharging brackish water into the polder.
	Large distance for fish to swim on their own strength.

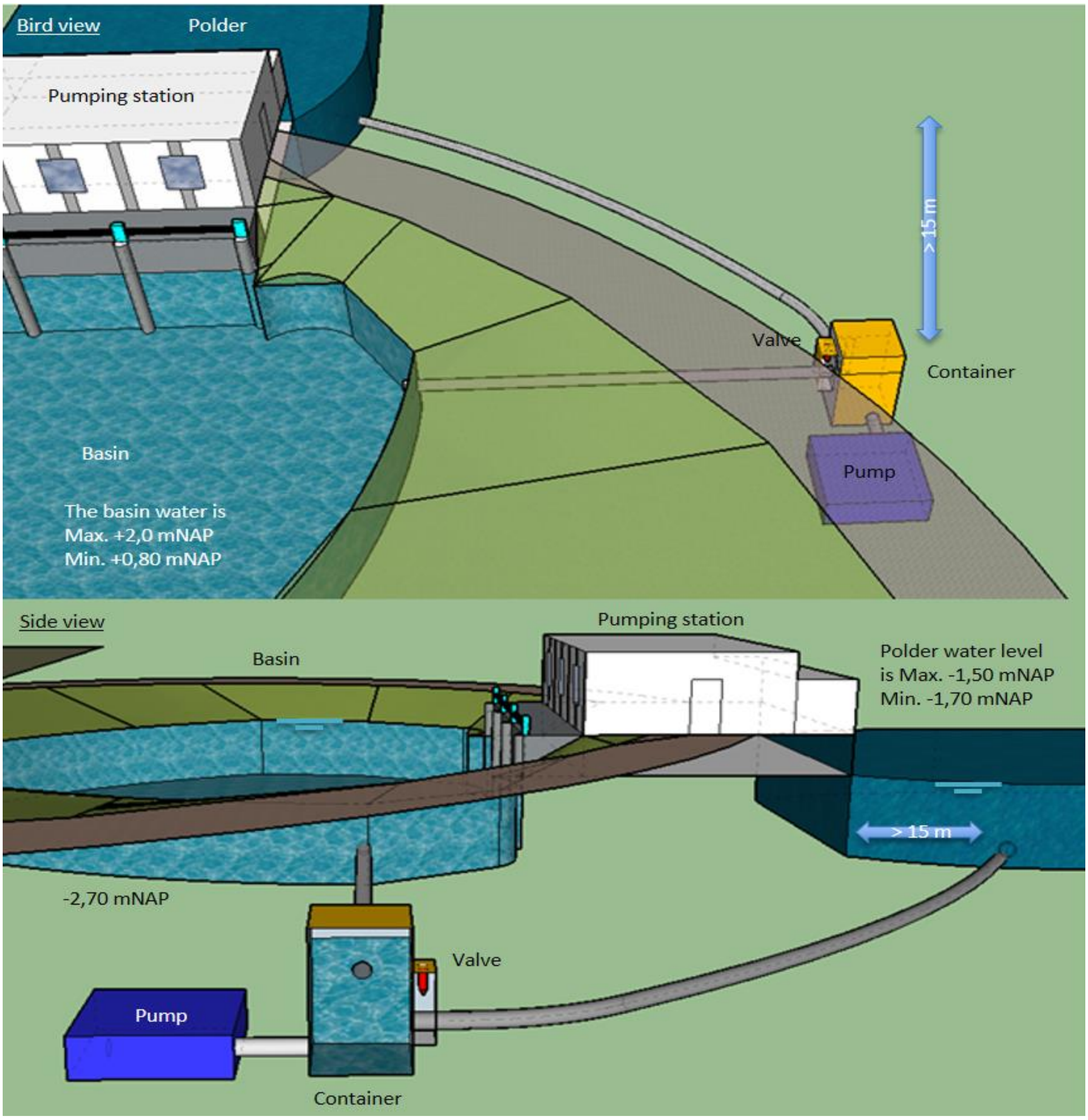


Figure 79 Schematization Maelstede fish passage in Zierikzee

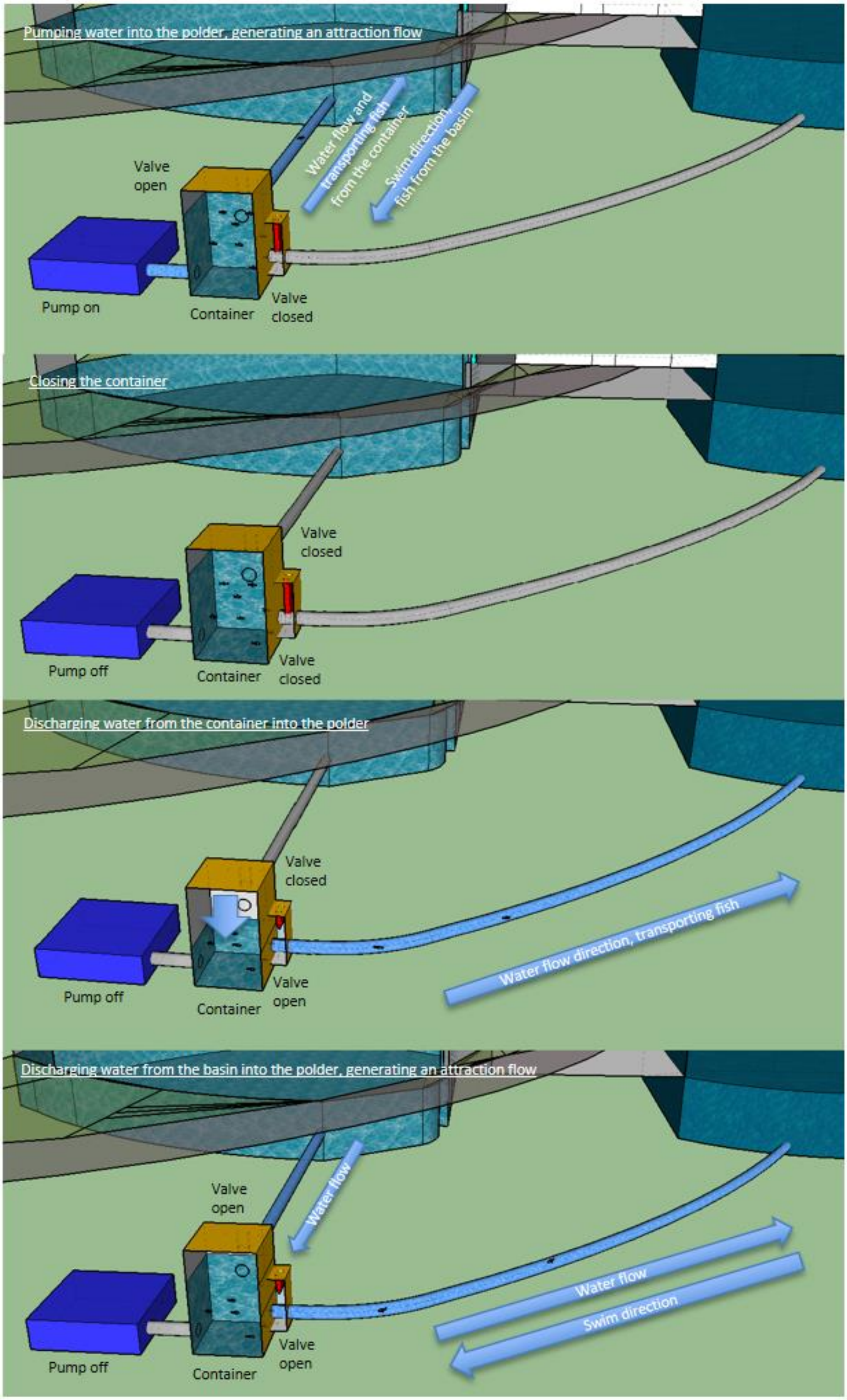


Figure 80 A schematization of how the cycle of the Maelstede fish passage works

Alternative 5: Fish passage Poppekinderen
In Table 32 the positive and negative aspects of the Poppekinderen fish passage are summed up. Figure 81 shows a schematic drawing of the Poppekinderen fish passage. The Red box represents the collection container with a pipe into the basin. The pump, shown in purple, generates an attraction flow. There is a pipe connected to the bottom of the container, every few hours the pipe opens, and the fish will flow into the polder. Figure 82 provides a schematization of how the fish passage functions.

Table 32 Positive and negative aspects of Alternative 5: Fish passage Poppekinderen

Positive aspects	Negative aspects
Free flow discharge.	Pipes in brackish water will need regular maintenance because of the "palingbrood"
Functional all year.	Stressful transport for the fish.
Not dependent on water level.	Discharging brackish water into the polder.
Constant attraction flow.	Working in cycles

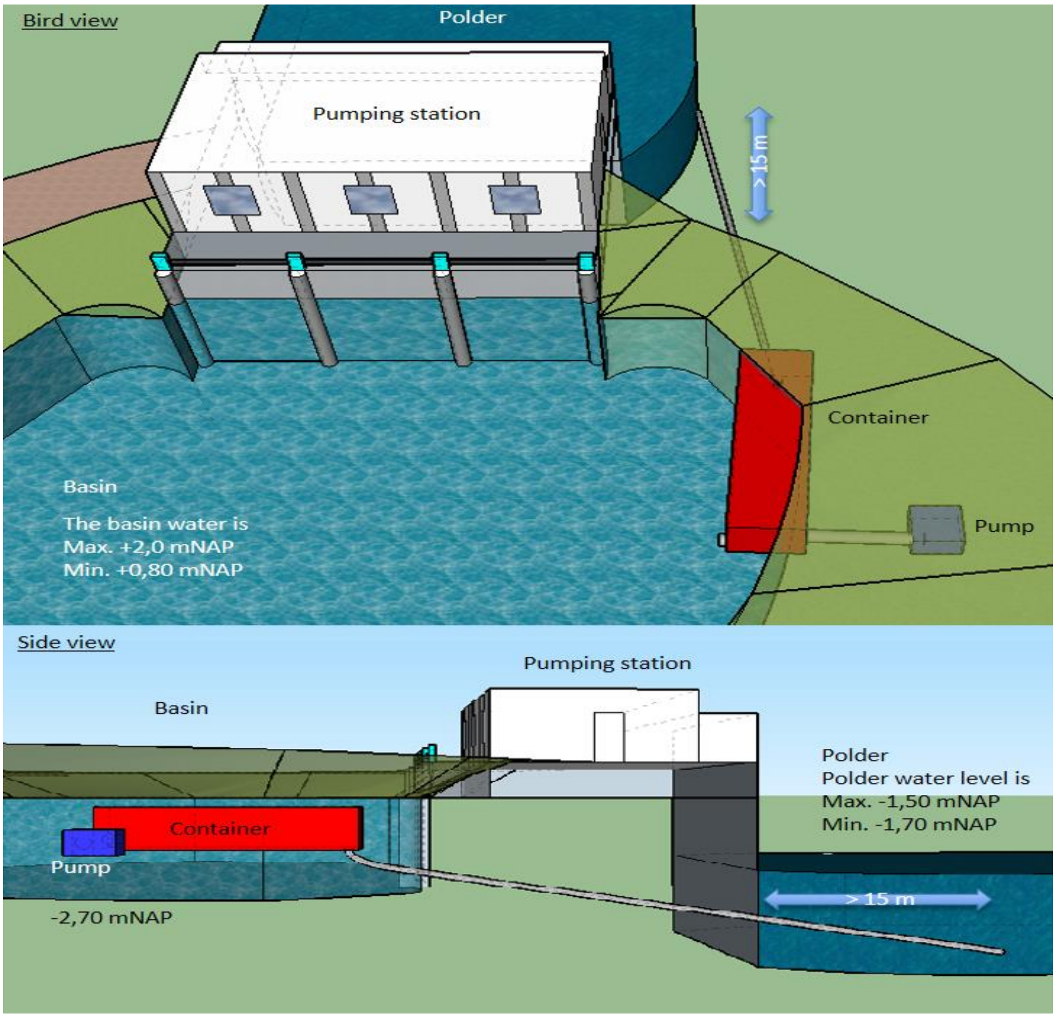


Figure 81 Schematisation applying fish passage Poppekinderen

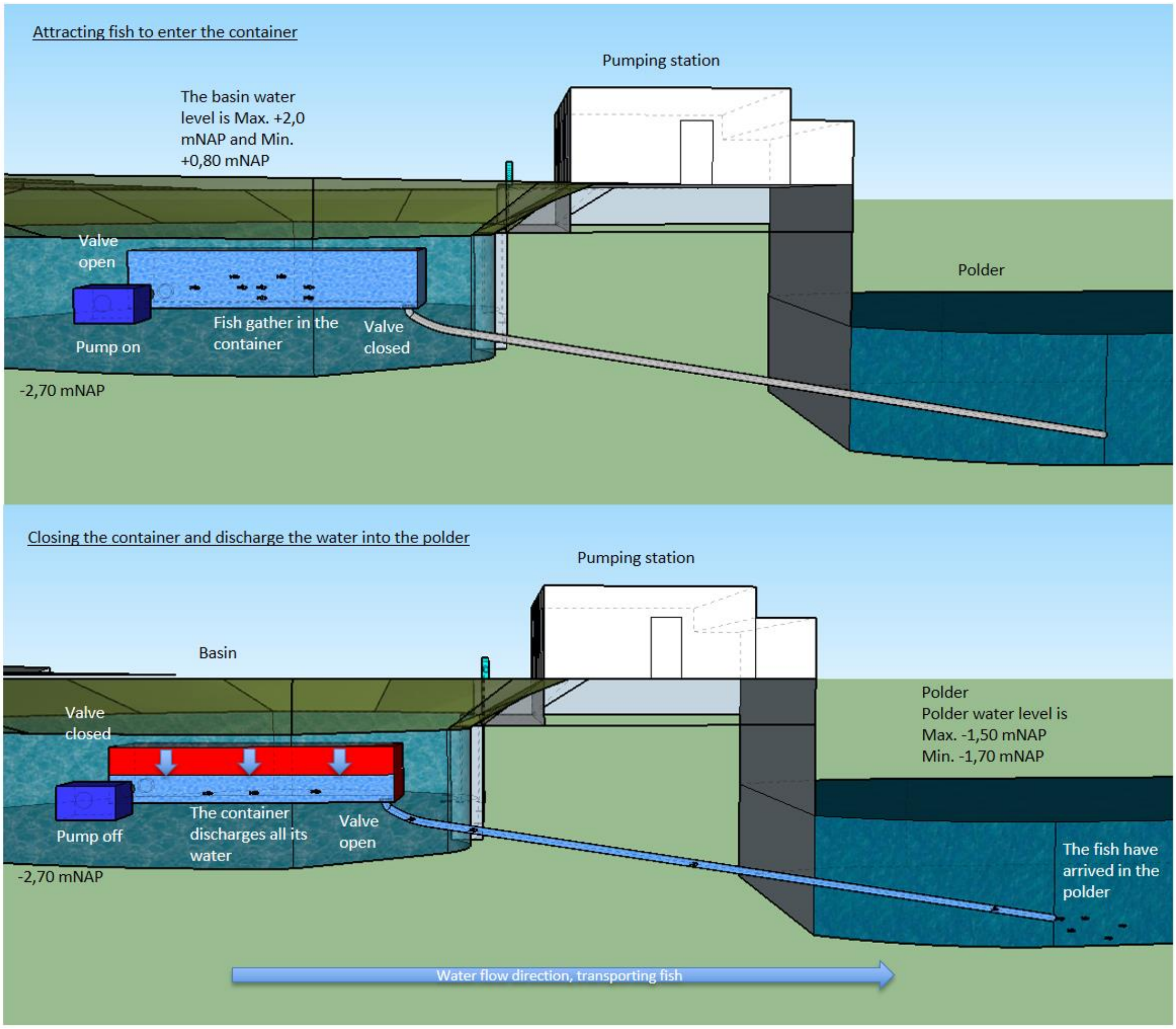


Figure 82 A schematization how the Poppekinderen fish passage works

Alternative 6: Syphon fish passage

In Table 33 the positive and negative aspects of the syphon fish passage are summed up.

Table 33 Positive and negative aspects of Alternative 6: Syphon fish passage

Positive aspects	Negative aspects
Small surface area needed.	Brackish water discharging into the polder.
Fit for overcoming large water level differences.	Pipes in brackish water will need regular maintenance because of the “palingbrood”
A controlled attraction flow.	No continuous migration, the fish passage is functional in cycles.
Suited for three thorned stickleback, the eel, the brackish water gudgeon and possibly the smelt and larvae of the halibut **(Wintermans, 1999)**	Technical construction requires maintenance activities.
Suited for multiple fish species regardless of their swim capacities. **(Beeren, 2000)**	
Independent of the free discharge of water. **(Beeren, 2000)**	

Figure 83 shows a schematic drawing of the syphon fish passage. The red box represents the container in which the fish will be collected. There is a pipe that comes out of the container into the basin, allowing fish to enter it. There are two pipes leaving the container in the direction of the polder. The most upper pipe used by fish to migrate. This pipe is connected to the blue box, representing a vacuum pump. The lower lying pipe is used for the generation of an attraction flow, water is pumped from the polder to the basin. The purple box that is connected to the lowest lying pipe represents the pump. On each pipe there is a yellow object drawn, these represent the valves that close the pipes depending on the phase in the cycle.

In the first functionality cycle the valve that connects the container to the basin and the valve that connects the pump to the container are open. The pump generates an attraction flow attracting fish into the container. At the end of this phase the valve that connects the container to the basin; and the valve that connects the pump to the container are closed. The valve that connects the pipe to the vacuum pump is opened. The vacuum pump "sucks" the water from the container into the polder. After this the cycle starts from the beginning. The phases of the cycles are visualized in Figure 84.

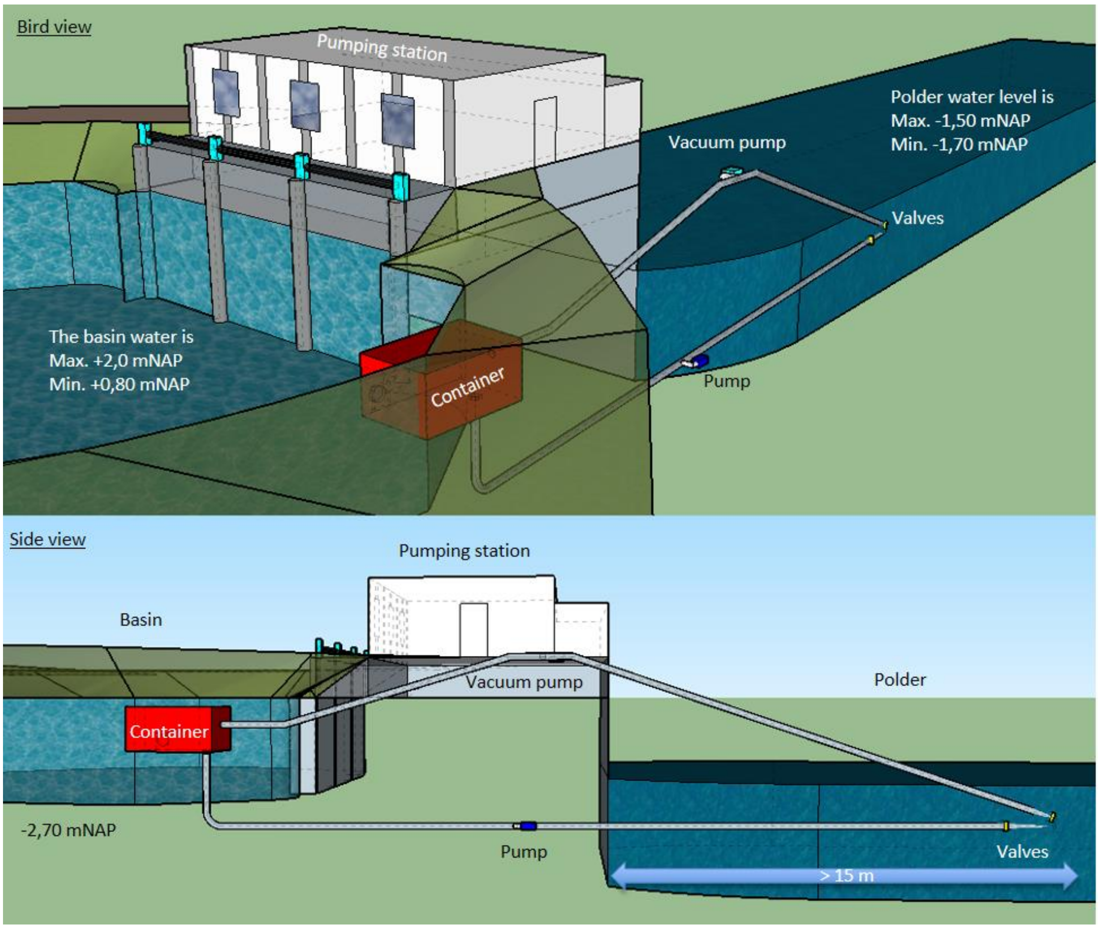


Figure 83 Schematization syphon fish passage

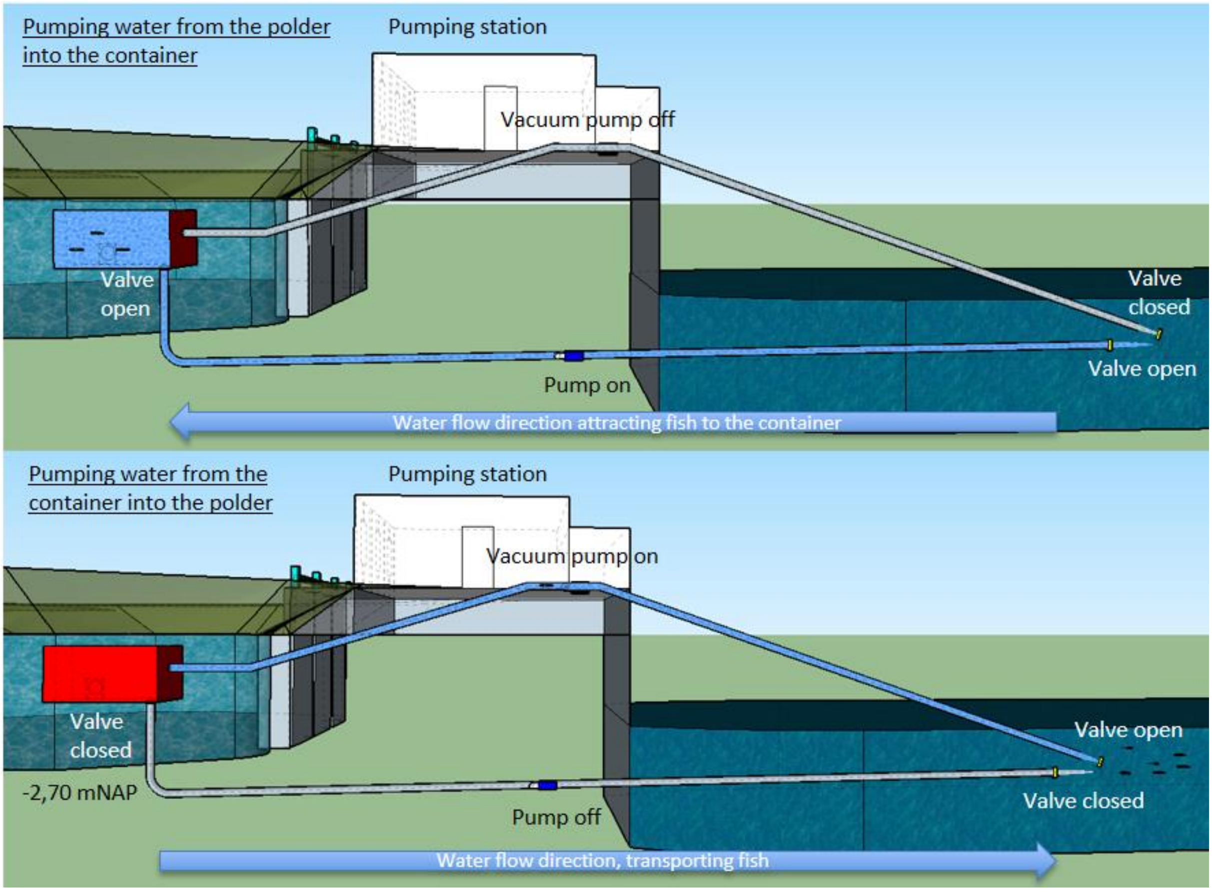


Figure 84 Schematization how the syphon fish passage works

Alternative 7: Fish friendly pump fish passage
In Table 34Table 32 the positive and negative aspects of the fish passage with fish friendly pumps are given. In Figure 85 the fish passage with the two fish friendly pumps are schematically shown. The red box represents the container in which the fish are collected. The two dark purple boxes represent the fish friendly pumps. In Figure 86 the functionality is schematized.

Table 34 Positive and negative aspects of Alternative 7: Fish friendly pump fish passage

Positive aspects	Negative aspects
A controlled and constant attraction flow.	Pipes in brackish water will need regular maintenance because of the “palingbrood”. This is the formation of a crust on the inside of the pipe.
Constant migration.	

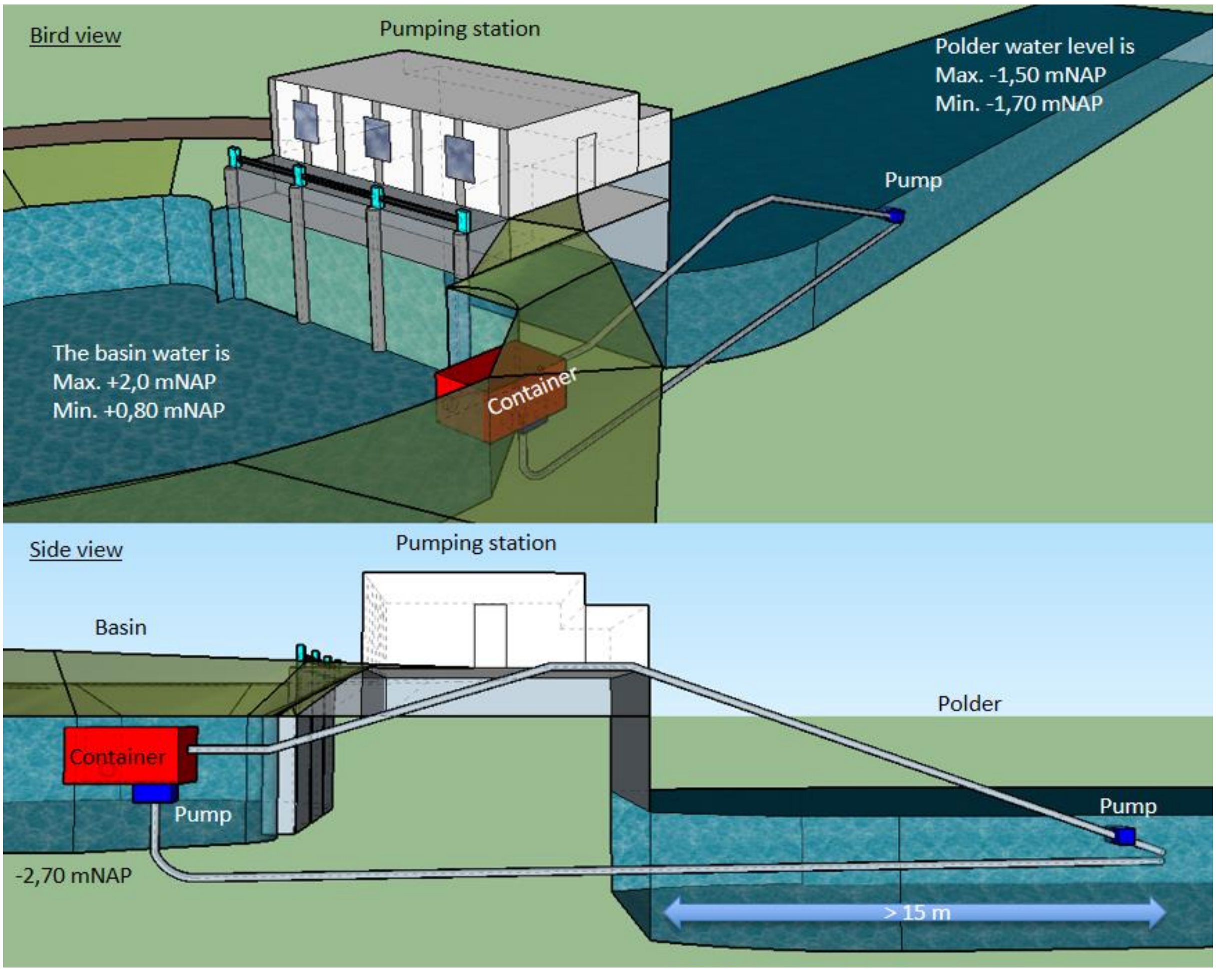


Figure 85 Schematisation of the fish passage with two fish friendly pumps

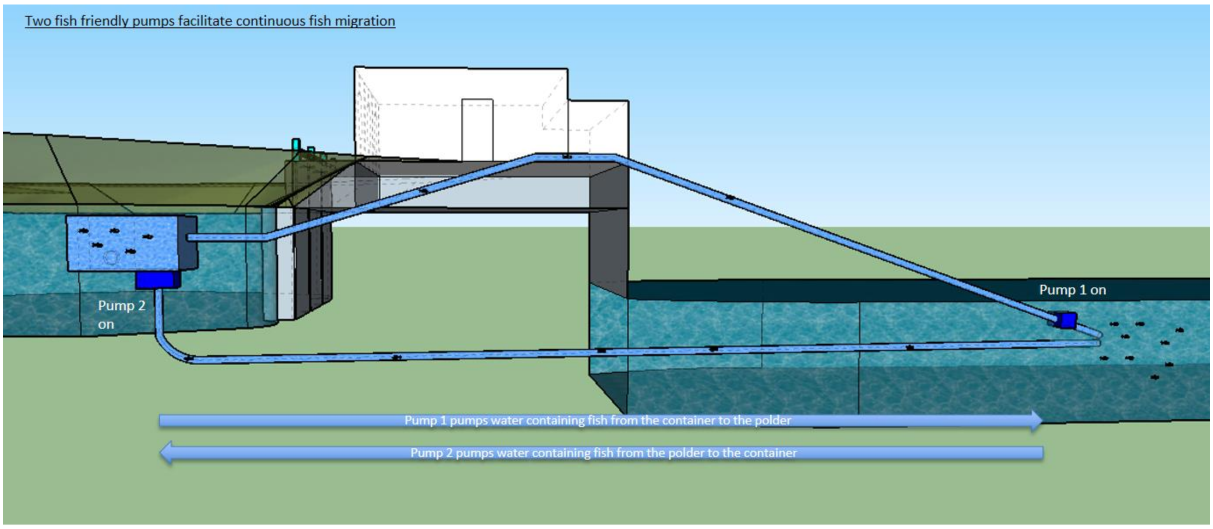


Figure 86 Schematisation how the fish friendly fish passage works

Alternative 8: Jack-screw fish passage

The positive and negative aspects of the jack-screw fish passage are listed in Table 35. On Figure 87 a schematic drawing is shown of the jack-screw fish passage. The jack-screw is positioned within the pink box that represent the cover. Water will be scooped up in the polder by the jack-screw and transported up toward the basin. A pipe transports water back from the basin to the polder. This process has been visualized in Figure 88.

Table 35 Positive and negative aspects of Alternative 8: jack-screw fish passage

Positive aspects	Negative aspects
Additional water pump capacity.	Expensive.
Two-way fish migration.	Brackish water is discharged into the polder.
Suited for multiple fish species regardless of their swim capacities.	A technical construction requires maintenance.
Small surface space needed.	Cyclic functionality. (Beeren, 2000)
Able to overcome large differences in water level. **(Beeren, 2000)**	
The amount of fish that pass is independent of the size of the container. **(Beeren, 2000)**	

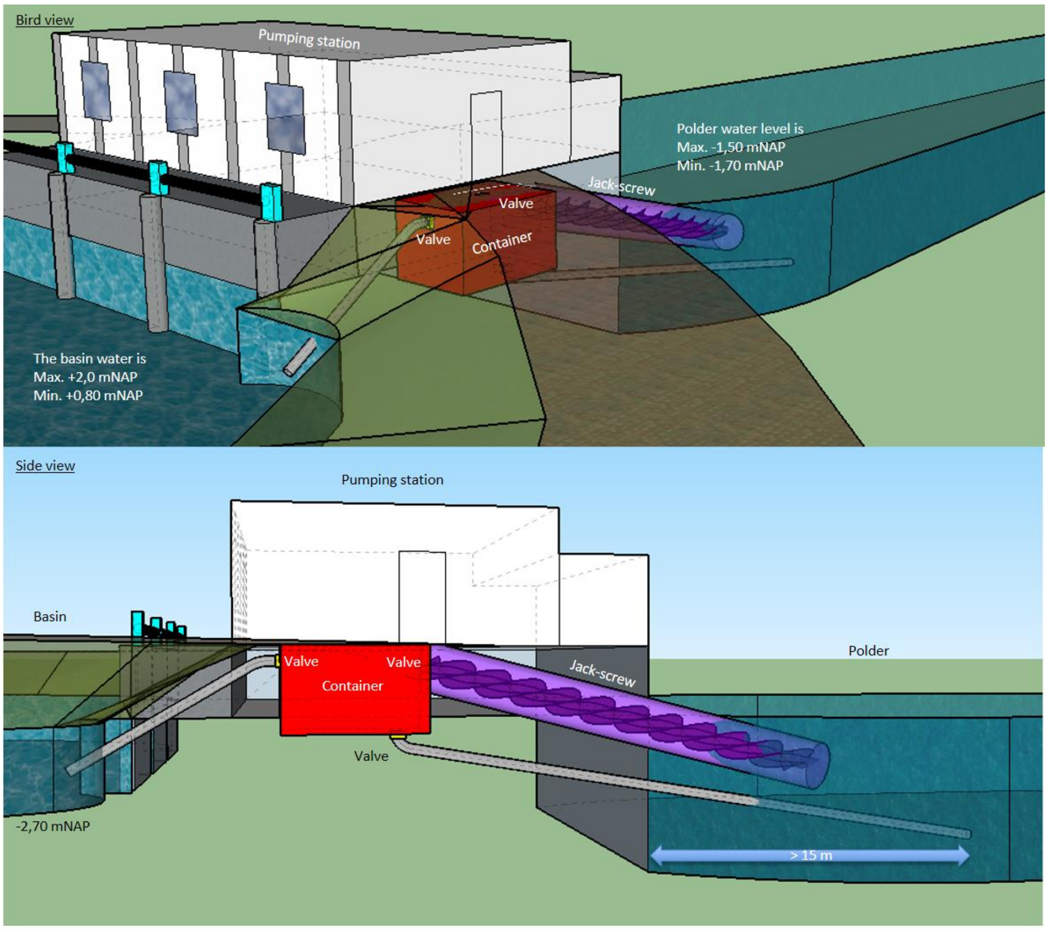


Figure 87 Schematization of the jack-screw fish passage

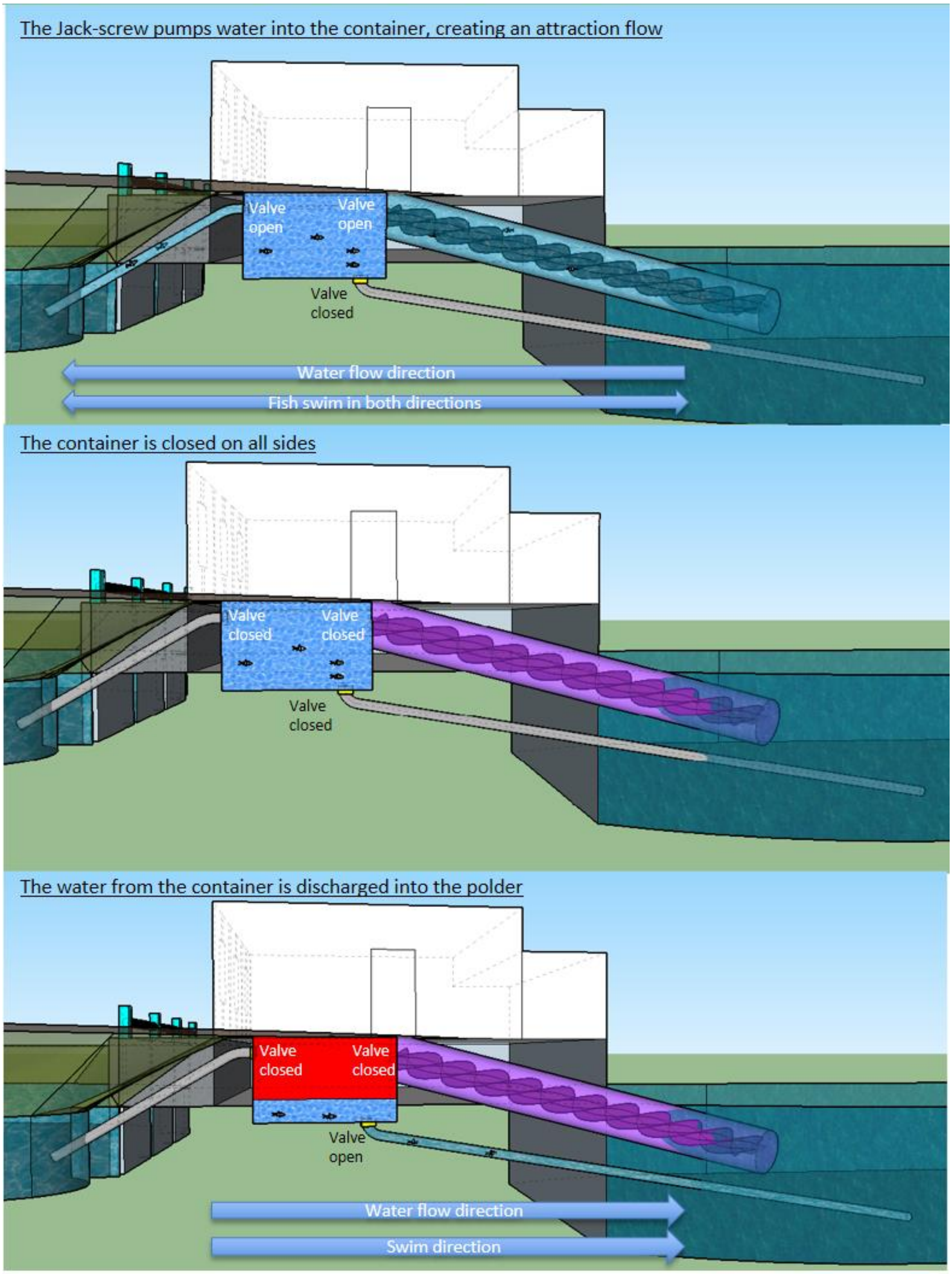


Figure 88 Schematization how the jack-screw fish passage works

8.4.2 Decision process criteria

To explain how the MCA criteria were made, the process is described below. Three sets of criteria were made in order to reach the fourth and final set of criteria. Each set of criteria will be discussed; the thoughts behind the criteria are shared as well.

Criteria made before the designing of the alternatives

During the exploration of the area and learning about the different fish passages the first criteria were written. These criteria were described before the alternatives were developed. The criteria were general for the construction of an object; they focused on the goal of the master plan. However, this MCA was about choosing a fish passage, which has different priorities for choosing the most suitable. In Table 36 the first set of criteria can be read.

Table 36 The first set of MCA criteria, written before the designing of the alternatives

Criteria	Short description
Safety	Safety above all. The construction or solutions has to be safe to use, construct, maintain and manage. The solutions' ability to be trustworthy is taken up in this criterion.
Costs	The costs are considered as a criterion. The costs are preferred to be as low as possible.
Maintenance	The design is preferred to be simple in maintenance activities. This means without having the obligation to use special material or difficult actions.
Aesthetics	The construction will be placed in a historical environment. The physical appearance of the solution has to contribute to the environment.
Boat accessibility	The ships have to be able to sail in and out of the harbor. The construction must not influence this negatively.
Economic growth possibilities	The possibility of economic growth in and around the harbor area.
Berthing capacity	It is preferred that the berth capacity is minimally reduced.
Sustainability	The solution being long-term, positively influencing the natural environment.
Water quality	Sufficient water quality contributes to the natural environment of the whole aquatic system. It provides comfort in the harbors.
Construction time	The total time the construction of the fish passage will take. This criterion is important because during the construction period the environment will be disrupted.
Neglected criteria	In the MCA there are some criteria neglected. These neglected criteria have the same value for each aspect or are dependent of the design. For example, the durability and the infrastructure of the project. The neglected factor is assumed to be sufficient, otherwise the requirements of the project are not met.

The criteria made during the design period of the alternatives

The second set of criteria was more focused on the aspects of a successful fish passage. The alternatives were designed, and meetings were held with water board Scheldestromen. Marius van Wingerden has contributed in developing the alternatives by providing information about existing fish passages and developments. The second set of criteria can be read in Table 37.

Table 37 Second set of criteria, made during the design process of the alternative fish passages

Criteria	Short description
Aesthetics	The solution will be placed in an historical environment. The physical appearance of the solution has to contribute or match the environment.
Attraction	The efficiency of the fish passage is largely determined by the attraction of the fish to the fish passage. The attraction flow of one fish passage could be more effective than others.
Construction costs	The construction costs are preferred to be as low as possible. To make this criterion measurable for each optional fish passage an estimation of the costs will be performed based on calculations and/or a comparison with other projects.
Construction time	The total time the construction or implantation of the fish passage will take is referred to as the construction time. This criterion is important because during the construction period the environment will be disrupted. The most preferred construction period is the shortest. The short construction time may however not jeopardize the other criteria.
Fail-safety	Safety above all. The construction has to be safe to use, construct, maintain and manage. The solutions' ability to be trustworthy is taken up in this criterion. The way a construction fails is being judged.
Flexibility of the construction	The construction has to be flexible, easily to adapt if needed when the situation changes. The construction has to deal with fluctuations in water levels and in discharges.
Functionality	The construction has to be sufficiently functional. The period per day the fish passage functions per day is judged. The time the fish passage function has consequences on how much fish is able to migrate.
Maintenance costs per year	The design that is preferred has simple maintenance activities with a low frequency. This means without having the obligation to use of special material or difficult actions. The maintenance costs per year will be evaluated.
Vulnerability of the construction	A natural system copes with its own problems. However, there are vulnerable components in a technical construction. These vulnerable components could reduce the functionality and efficiency of the construction. An example of a vulnerable component is a mechanically closing valve. The less vulnerable components the better.
Neglected criteria	In the MCA there are some criteria neglected. These neglected criteria have the same value for each aspect or are dependent of the design. For example, the durability and the infrastructure of the project. The neglected factor is assumed to be sufficient, otherwise the requirements of the project are not met.

The criteria made after the alternative designs were finished

By thinking from the water boards perspective new criteria were developed with their indicators. This third set of criteria was used to judge the alternative fish passages for the first time. Marius van Wingerden had advised to rethink the criteria like costs. In practice the costs are not relevant for the functionality of the fish passage and they cannot accurately be calculated in advance due to unexpected situations and the detail. With this information the third set of criteria was written. In Table 38 the third set of criteria can be seen.

The criteria, weight of the criteria and the outcome was discussed with KEN Engineering, water board Scheldestromen and the municipality of Schouwen-Duiveland. The actors had the chance to comment. These comments were incorporated into the fourth and final set of criteria. The criteria that were use are discussed in paragraph 4.4.1.2.

Table 38 The third set of criteria, made after finishing the designs of the alternative fish passages

Criteria	Description
Aesthetics	The fish migration alternative will be placed in an historical environment. The physical appearance of the solution has to contribute or match the environment. The scores for the aesthetics of the construction are based on how much the construction will disturb or contribute to the environment in the harbor. It ranges from disturbing the environment to adding value to the environment.
Energy use	The fish passage construction all need an additional energy source in order to be functional. There are valves that open and close and pumps. Opening and closing valves does not use a lot of energy, pumping water however does.
Continuity	The construction has to be sufficiently functional. The time the fish passage function has consequences on how much fish is able to migrate. A fish passage can facilitate fish migration continuously or in cycles. The time each cycle takes depends on the management of the construction. A continuous fish migration is most favorable, it is better equipped to cope with peak migration and the fish do not have to wait in order to migrate. Cycles could cause disruptions for the fish.
Reliability of the construction	A natural system copes with its own problems by adjusting it by natural processes. However, there are vulnerable components in a technical construction. These vulnerable components will not repair themselves when broken and could reduce the functionality and efficiency of the fish passage. An example of a vulnerable component is a mechanically closing valve. The more vulnerable components the less liable a construction is, resulting in more maintenance activities and malfunctions. The less vulnerable components in a construction, the better.
Swim distance	The distance the fish have to swim is dependent on how many fish will overcome the fish passage. The swim distance is a very critical subject for a fish passage. The fish will have to swim on their own strength against the water flow. The shorter the swim distance, the more fish will be likely to overcome the fish passage.
Neglected criteria	In the MCA there are some criteria neglected. These neglected criteria have the same value for each aspect or are dependent of the design. For example, the durability of the constructions and the infrastructure during the project. The neglected factor is assumed to be sufficient, otherwise the requirements of the project are not met.

8.4.3 Indicators criteria

In order to be able to judge the fish passages on the criteria each should have indicators. The score a criterion can receive lie between 1 and 5. 1 represents a very bad score, and 5 a very good score. In Table 39 the five indicators per criteria are given. This will be used as the basis of the MCA.

Table 39 The indicators of the criteria per score explained

Criteria	Score 1	Score 2	Score 3	Score 4	Score 5
Aesthetics	The construction disturbs the environment.	The construction disturbs the environment minimally.	The construction does not disturb nor adds value to the environment.	The construction adds a small value to the environment.	The construction adds great value to the environment.
Accessibility	Cyclic fish migration.	-	-	-	Continuous fish migration.
Biological functioning	The fish will very likely have trouble overcoming the fish passage.	The fish will likely have trouble overcoming the fish passage.	Some fish species will likely have trouble overcoming the fish passage and some fish species will likely overcome the fish passage.	The fish will likely overcome the fish passage.	The fish will very likely overcome the fish passage.
Energy use	One large pump pumps water out of the basin.	Two pumps to pump water out of the 2 containers.	One pump pumps water out of the one containers.	One attraction-flow pump.	No water needs to be pumped.
Impact on the water system	A large quantity of water is discharged into the polder. The water quantity comparable to the volume of the basin.	The fish passage discharges water the quantity larger than a container in the polder.	The fish passage discharges water the quantity of a container in the polder.	There is an approximately equal exchange in water quantity.	No water is discharged into the polder.
Management and maintenance intensity	More than two times a year.	Two times a year.	One time a year.	One time in one and a half year.	Once every two years
Reliability of the construction	>5 vulnerable components in the construction.	≥4 and <5 vulnerable components in the construction.	≥ 3 and <4 vulnerable components in the construction.	≥ 2 and < 3 vulnerable components in the construction.	≥ 0 and <2 vulnerable components in the construction.
*Vulnerable component = Elements of the construction that move *Volume basin = The volume of the water in the basin on the Oosterschelde side of pumping station ‘t Sas. *Overcoming = Migrating by means of the fish passage *Disturbs the environment = Directs the eye toward it, not in line with the historical environment.					

Criteria weight
In the MCA one criteria is more important than the other, this is incorporated into the framework. In order to determine the weight of the criteria in the project Table 40 has been made. The criteria on the left were compared with the criteria on the top row. If the criteria on the left are more important than the criteria on the top row it gets a score of 1. If the criteria on the left is less important than the criteria on the top row it receive a 0. When the two criteria are equally important the score is a 0.5.

When weighing the criteria, the focus lay on giving the fish their best chance to migrate.

Table 40 The weight determination of the criteria

Criteria	Aesthetics	Accessibility	Biological functioning	Energy use	Impact on the water system	Management and maintenance intensity	Reliability of the construction	**Weight**
Aesthetics	x	0	0	0	0	0	0	**0**
Accessibility	1	x	0	1	1	0	0.5	**3.5**
Biological functioning	1	1	x	1	1	1	0.5	**5.5**
Energy use	1	0	0	x	0.5	0.5	0	**2**
Impact on the water system	1	0	0	0.5	x	0.5	0	**2**
Management and maintenance intensity	1	1	0	0.5	0.5	x	0	**3**
Reliability of the construction	1	0.5	0.5	1	1	1	x	**5**

The biological functionality and the reliability of the construction have received the highest scores. In order to include the aesthetics in the grading process the 0 will be replaced by a score of 1. In Table 41 the explanation for the choices in weight is given.

Table 41 Explanation of the choices for the weights of the criteria

Criteria	Aesthetics	Aesthetics explained	Accessibility	Accessibility explained	Biological functioning	Biological functioning explained	Energy use	Energy use explained	Impact on the water system	Impact on the water system explained	Management and maintenance intensity	Management and maintenance intensity explained	Reliability of the construction	Reliability of the construction explained	Weight
Aesthetics	x	x	0	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the accessibility of the fish passage is said to be more important.	0	The biological factors of the fish passages have consequences for how many fish will be able to pass. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the biological functionality is said to be more important.	0	The energy use influences the costs of the project and the sustainability, which influences the functionality. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the energy use is said to be more important.	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage, it does however influences the health of the water system. The impact on the water system is more important than the aesthetics. The aesthetics does not contribute to the efficiency of the fish passage	0	The frequency of the management and maintenance activities influences the quality of the fish passage, malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the management and maintenance intensity of the construction is said to be more important.	0	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the reliability of the construction is said to be more important.	**1**
Accessibility	1	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the accessibility of the fish passage is said to be more important.	x	x	0	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish can enter the passage but if the fish cannot pass the passage because of the biological factors they will not be able to migrate. Therefore, the biological functionality is said to be more important.	1	Whether the fish migration happens in cycles or continuously influences the likelihood the fish will swim into the fish passage. The energy use influences the costs of the project and the sustainability, which influences the functionality. The energy use influences the efficiency of the fish passage less than the accessibility. Therefore, the accessibility of the fish passage is said to be more important.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage, it does however influences the water system. The accessibility influences the efficiency of the fish passage by allowing fish to enter the passage. Therefore, the accessibility of the passage is more important.	0	If the fish enter the fish passage but cannot pass because of malfunctions due to the maintenance and management activities the fish passage is not efficient. The management and maintenance activities are considered more important.	0.5	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. Both criteria are equality important.	**3.5**
Biological functioning	1	The biological factors of the fish passages have consequences for how many fish will be able to pass. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the biological functionality is said to be more important.	1	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish can enter the passage but if the fish cannot pass the passage because of the biological factors they will not be able to migrate. Therefore, the biological functionality is said to be more important.	x	x	1	The energy use influences management and the sustainability of the fish passage. The biological factors of the fish passages have consequences for how many fish will be able to pass. Therefore, the biological functionality is said to be more important.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefor the biological functionality is the more important criterion.	1	Management and maintenance activities do not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefore, the biological functionality is considered more important.	0.5	The biological factors of the fish passages have consequences for how many fish will be able to pass. The reliability of the construction is the level of certainty the fish passage will function, so without malfunctions. Both criteria are equally important because both criteria consider the possibility the fish will overcome the passage.	**5,5**

Energy use	1	The energy use influences the costs of the project and the sustainability, which influences the functionality. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the energy use is said to be more important.	0	Whether the fish migration happens in cycles or continuously influences the likelihood the fish will swim into the fish passage. The energy use influences the costs of the project and the sustainability, which influences the functionality. The energy use influences the efficiency of the fish passage less than the accessibility. Therefore, the accessibility of the fish passage is said to be more important.	0	The energy use influences management and the sustainability of the fish passage. The biological factors of the fish passages have consequences for how many fish will be able to pass. Therefore, the biological functionality is said to be more important.	x	x	0.5	Both the energy use and the impact on the water system do not directly influence the efficiency of the fish passage. Both do however are considered in the management of the fish passage, therefore these criteria are equally important.	0.5	The energy use and management and maintenance activities both do not directly influence the efficiency of the fish passage and are therefore equality important.	0	The energy use influences management of the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability of the fish passage is said to be more important.	**2**
Impact on the water system	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage, it does however influences the health of the water system. The impact on the water system is more important than the aesthetics. The aesthetics does not contribute to the efficiency of the fish passage	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage, it does however influences the water system. The accessibility influences the efficiency of the fish passage by allowing fish to enter the passage. Therefore, the accessibility of the passage is more important.	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefor the biological functionality is the more important criterion.	0.5	Both the energy use and the impact on the water system do not directly influence the efficiency of the fish passage. Both do however are considered in the management of the fish passage. Therefore, these criteria are equally important.	x	x	0.5	Both the management and maintenance activities and the impact on the water system do not directly influence the efficiency of the fish passage. Both criteria have an influence on entire the system. The criteria are equally important.	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage but the total water system. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability is considered the more important criteria.	**2**
Management and maintenance intensity	1	The frequency of the management and maintenance activities influences the quality of the fish passage, malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the management and maintenance intensity of the construction is said to be more important.	1	If the fish enter the fish passage but cannot pass because of malfunctions due to the maintenance and management activities the fish passage is not efficient. The management and maintenance activities are considered more important.	0	Management and maintenance activities do not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefore, the biological functionality is considered more important.	0.5	The energy use and management and maintenance activities both do not directly influence the efficiency of the fish passage and are therefore equality important.	0.5	Both the management and maintenance activities and the impact on the water system do not directly influence the efficiency of the fish passage. Both criteria have an influence on entire the system. The criteria are equally important.	x	x	0	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The management and maintenance activities are a consequence of the malfunctions. Therefore, the reliability of the construction is more important.	**3.0**
Reliability of the construction	1	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the reliability of the construction is said to be more important	0.5	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. Both criteria are equality important.	0.5	The biological factors of the fish passages have consequences for how many fish will be able to pass. The reliability of the construction is the level of certainty the fish passage will function, so without malfunctions. Both criteria are equally important because both criteria consider the possibility the fish will overcome the passage.	1	The energy use influences management of the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability of the fish passage is said to be more important.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage but the total water system. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability is considered the more important criteria.	1	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The management and maintenance activities are a consequence of the malfunctions. Therefore, the reliability of the construction is more important.	x	x	**5**

Explanation scores MCA
In this sub-chapter the scores of the MCA for each criterion is explained for all the alternatives. This helps to better understand the MCA and the choices that were made.

Table 42 Alternative 1: base situation MCA scores explained

Alternative 1: Base situation		
Criteria	Score	Justification
Aesthetics	1	The base situation already exists. Nothing changes about this. There is no minimal water level of +0,80 m NAP so the deteriorated banks and quay walls will be visible. This appearance does disrupt the environment.
Accessibility	5	The fish migration is continuous. The fish continuously have the opportunity to move through the open spaces in the door of pumping station ‘t Sas.
Biological functioning	2	There is only during a very short period an attraction flow. Therefore, fish could have trouble finding the passage place.
Energy use	5	There is no additional pump needed to facilitate fish migration.
Impact on the water system	5	No water is discharged into the polder because of the valve that only opens in the direction of the basin.
Management and maintenance activities	2	It is estimated that the maintenance and management activities would take place once very one and a half year.
Reliability of the construction	2	In pumping station ‘t Sas the doors in the pipes and the pumps are vulnerable. There are three doors and two pumps.

Table 43 Alternative 2: Fish sluice with mechanical door MCA scores explained

Alternative 2: Fish sluice with mechanical door		
Criteria	**Score**	**Justification**
Aesthetics	3	The base situation with pumping station ‘t Sas stays the same, however a valve will be added in the culvert. People will not see this so the sluice will not add nor decrease the environment.
Accessibility	1	The fish migration is cyclic. Each cycle the water in the basin has to be pumped to the harbor in order to lower it. When the water in the basin in lowered the mechanical door is opened and fish are able to migrate for a period. When the water level from the basin and the polder are equal the valve in the culvert will be open again, the water will full up the basin and close the door in the pipe.
Biological functioning	3	The fish will be able to swim on their own strength through the pipe when the mechanical door is open. The water flow is controlled by the door.
Energy use	1	The water in the basin will be lowered. The water is pumped to the harbor. This is a large amount of water and will cost each cycle a lot of energy.
Impact on the water system	5	No water is discharged into the polder because of the mechanical valve that only opens when the water in the polder is higher than the water in the basin. By gravitational force the water from the polder is discharged into the basin.
Management and maintenance activities	3	There are several larger objects that need management and maintenance activities therefor the intensity is estimated on once every year.
Reliability of the construction	2	In total there are five vulnerable components: The mechanical door in the pipe, the valve in the culvert, two pumps to open and close the valve and door, a small valve to close the pipe that leads from the basin to the harbor.

Table 44 Alternative 3: Fish sluice, basin discharges into the polder AMCA scores explained

Alternative 3: Fish sluice, basin discharges into the polder		
Criteria	Score	Justification
Aesthetics	2	The base situation with pumping station 't Sas stays the same, however a valve will be added in the culvert. People will not see this so the sluice will not add nor decrease the environment. However, the large amount of water that will be discharged to the polder will have negative effects, because of the salt intrusion.
Accessibility	1	The sluice works in cycles. The valve in the culvert is closed, the doors in pumping station 't Sas are opened. The water is discharged from the basin into the polder. When the water levels of the polder and the basin are equal the door in pumping station 't Sas is closed and the valve in the culvert is opened, allowing water to enter the basin again.
Biological functioning	1	When the water discharges from the basin into the polder the fish will likely stay in the last centimeters of water in the basin. This could cause problems for the migration.
Energy use	5	The water from the basin will discharge under gravitational force into the polder, therefore no water will need to be pumped.
Impact on the water system	1	A very large amount of water is discharged from the basin into the polder. This has consequences on the land and water behind the pump.
Management and maintenance activities	3	There are several larger objects that need management and maintenance activities, therefor the intensity is estimated on once every year.
Reliability of the construction	3	In total there are four vulnerable components: The door in the pipe, the valve in the culvert and two generators to open and close the valve and door.

Table 45 Alternative 4: Fish passage Maelstede MCA scores explained

Alternative 4: Fish passage Maelstede		
Criteria	Score	Justification
Aesthetics	3	The base situation with pumping station 't Sas stays the same, the fish passage and the container will be underground, so no one will notice the passage.
Accessibility	1	The Maelstede fish passage functions cyclically. Fish are attracted from the basin to the container and discharged into the polder and vice versa.
Biological functioning	2	The fish have to swim quite a long distance in order to reach the container. This distance could cause problems for the migration.
Energy use	3	There is one pump that pumps the water in the container to the basin.
Impact on the water system	2	The Maelstede fish passage discharges water from the basin into the polder. Per cycle the quantity of this water is more than the container alone.
Management and maintenance activities	2	Because the fish passage has small valves that are subjected to brackish water it is estimated that the maintenance and management activities would take place every half year.
Reliability of the construction	2	Fish passage Maelstede has three vulnerable components: the pump and the two valves that close the pipes.

Table 46 Alternative 5: Fish passage Poppekinderen MCA scores explained

Alternative 5: Fish passage Poppekinderen		
Criteria	**Score**	**Justification**
Aesthetics	4	The base situation with pumping station ‘t Sas stays the same, the container is visible in the basin. People will have the opportunity to look inside the container through the grid that is placed on top of the container.
Accessibility	1	Fish passage Poppekinderen works in cycles. Fish are attracted to the container, the container is closed, the valve of the pipe that leads to the polder is opened and the water is discharged into the polder.
Biological functioning	5	When the fish are inside the fish passage, by gravitational force they are discharged into the polder. The fish do not have a choice and will all make it across the fish passage.
Energy use	4	The container discharges by gravitational force into the polder. The only pump that is needed is one to generate the attraction flow.
Impact on the water system	3	Each cycle the fish passage discharges the water from the container into the polder.
Management and maintenance activities	2	Because the fish passage has small valves that are subjected to brackish water it is estimated that the maintenance and management activities would take place every half year.
Reliability of the construction	4	Fish passage Poppekinderen has three vulnerable components: The pump and two small valves to close the pipes.

Table 47 Alternative 6: Syphon fish passage MCA scores explained

Alternative 6: Syphon fish passage		
Criteria	**Score**	**Justification**
Aesthetics	4	The base situation with pumping station ‘t Sas stays the same, the container is visible in the basin. People will have the opportunity to look inside the container through the grid that is placed on top of the container.
Accessibility	1	The migration takes place in cycles in this fish passage. There is an attraction flow that attracts the fish. When the attraction flow pipe is closed, the pipe that is connected to the vacuum pump opens and the fish are transported to the polder.
Biological functioning	5	When the fish are inside the fish passage, they are discharged into the polder by suction force. They do not have a choice and will all make it across the fish passage.
Energy use	2	The fish passage uses two pumps: one pumps the water from the polder to the basin as an attraction flow and a vacuum pump to transport the fish to the polder.
Impact on the water system	4	The syphon fish passage works in cycles. Each cycle water is pumped from the polder into the basin and vice versa. The cycle is approximately in balance considering the water use of the fish passage.
Management and maintenance activities	4	There are several large objects that need maintenance activities. The intensity is estimated to be once everyone and a half year.
Reliability of the construction	5	There are six vulnerable components in the syphon fish passage design: There are four valves that close the pipes, a pump and a vacuum pump.

Table 48 Alternative 7: Fish friendly pump fish passage MCA scores explained

Alternative 7: Fish friendly pump fish passage		
Criteria	**Score**	**Justification**
Aesthetics	4	There is a minimal water level of +0,80 m NAP, this is said to be the new standard. The base situation with pumping station ‘t Sas stays the same, the container is visible in the basin. People will have the opportunity to look inside the container through the grid that is placed on top of the container.
Accessibility	5	The fish migration is continuously. The two pumps keep the process going.
Biological functioning	5	When the fish are inside the fish passage, they are pumped into the polder. They do not have a choice and will all make it across the fish passage. The fish migration is facilitated in both directions.
Energy use	2	The fish passage uses two fish friendly pumps: one pumps the water from the polder to the basin and one pumps the water from the basin to the polder.
Impact on the water system	4	The fish passage works continuously. Water is pumped from the polder into the basin and vice versa. The cycle is approximately in balance considering the water use of the fish passage.
Management and maintenance activities	4	There are several large objects that need maintenance activities. The intensity is estimated to be about once everyone and a half year.
Reliability of the construction	5	The fish friendly pump fish passage has two vulnerable components. These components are the two fish friendly pumps.

Table 49 Alternative 8: Jack-screw fish passage MCA scores explained

Alternative 8: Jack-screw fish passage		
Criteria	**Score**	**Justification**
Aesthetics	2	The jack-screw fish passage has a large cover. The outside will be made covered with bricks to make it blend in. The jack-screw fish passage is large, this disturbs the environment somewhat.
Accessibility	1	The fish passage works in cycles. The jack-screw move the water to a container that is connected to the basin. The water that flow to the basin acts as an attraction flow. The container is closed, and a valve opens that discharged water freely to the polder.
Biological functioning	5	When the fish are inside the fish passage they are pumped into the polder. They do not have a choice and will all make it across the fish passage. The fish migration is facilitated in both directions.
Energy use	1	Large amounts of water have to be moved in order to facilitate fish migration. The jack-screw acts as a large pump, it even adds pumping capacity to pumping station ‘t Sas.
Impact on the water system	5	No water from the basin is discharged into the polder. The water from the polder is pumped to a container and that is released back into the polder.
Management and maintenance activities	3	There are several large objects that need maintenance activities. The intensity is estimated to be about once every year.
Reliability of the construction	3	The jack-screw fish passage has four vulnerable components: The jack-screw itself and the three valves

8.4.4 Sensitivity of the MCA

In order to test how sensitive, the MCA is to the weights of the criteria the weights were adjusted. The weight of the aesthetics was increased. This resulted in a decrease in the weight of the criteria energy use, accessibility and impact on the water system. See Table 50 for the weights for the criteria in the sensitivity test. In Table 51 the choices for these weights are explained.

Table 50 Weight determination sensitivity test MCA

Criteria	Aesthetics	Accessibility	Biological functioning	Energy use	Impact on the water system	Management and maintenance intensity	Reliability of the construction	**Weight**
Aesthetics	x	1	0	1	1	0	0	**3**
Accessibility	0	x	0	1	1	0	0.5	**2.5**
Biological functioning	1	1	x	1	1	1	0.5	**5.5**
Energy use	0	0	0	x	0.5	0.5	0	**1**
Impact on the water system	0	0	0	0.5	x	0.5	0	**1**
Management and maintenance intensity	1	1	0	0.5	0.5	x	0	**3**
Reliability of the construction	1	0.5	0.5	1	1	1	x	**5**

Table 51 explanation choices weights sensitivity MCA

Criteria	Aesthetics	Aesthetics explained	Accessibility	Accessibility explained	Biological functioning	Biological functioning explained	Energy use	Energy use explained	Impact on the water system	Impact on the water system explained	Management and maintenance intensity	Management and maintenance intensity explained	Reliability of the construction	Reliability of the construction explained	Weight
Aesthetics	x	x	1	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish could be delayed or confused. The aesthetics of the construction is seen as more important. The aesthetics is more important because of location of the fish passage in the historical environment.	0	The biological factors of the fish passages have consequences for how many fish will be able to pass. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the biological functionality is said to be more important.	1	The energy use influences the costs of the project and the sustainability. However, the aesthetics is more important because of location of the fish passage in the historical environment.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage. The aesthetics is more important because of location of the fish passage in the historical environment.	0	The frequency of the management and maintenance activities influences the quality of the fish passage, malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the management and maintenance intensity of the construction is said to be more important.	0	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the reliability of the construction is said to be more important.	**3,0**
Accessibility	0	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish could be delayed or confused. The aesthetics of the construction is seen as more important. The aesthetics is more important because of location of the fish passage in the historical environment.	x	x	0	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish can enter the passage but if the fish cannot pass the passage because of the biological factors they will not be able to migrate, therefore the biological functionality is said to be more important.	1	Whether the fish migration happens in cycles or continuously influences the likelihood the fish will swim into the fish passage. The energy use influences the costs of the project and the sustainability, which influences the functionality. The energy use influences the efficiency of the fish passage less than the accessibility. Therefore, the accessibility of the fish passage is said to be more important.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage, it does however influences the water system. The accessibility influences the efficiency of the fish passage by allowing fish to enter the passage. therefore, the accessibility of the passage is more important.	0	If the fish enter the fish passage but cannot pass because of malfunctions due to the maintenance and management activities the fish passage is not efficient. The management and maintenance activities are considered more important.	0.5	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. Both criteria are equality important.	**2.5**
Biological functioning	1	The biological factors of the fish passages have consequences for how many fish will be able to pass. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the biological functionality is said to be more important.	1	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish can enter the passage but if the fish cannot pass the passage because of the biological factors they will not be able to migrate, therefore the biological functionality is said to be more important.	x	x	1	The energy use influences management and the sustainability of the fish passage. The biological factors of the fish passages have consequences for how many fish will be able to pass. Therefore, the biological functionality is said to be more important.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefor the biological functionality is the more important criterion.	1	Management and maintenance activities do not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefore, the biological functionality is considered more important.	0.5	The biological factors of the fish passages have consequences for how many fish will be able to pass. The reliability of the construction is the level of certainty the fish passage will function, so without malfunctions. Both criteria are equally important because both criteria consider the possibility the fish will overcome the passage.	**5,5**

Energy use	0	The energy use influences the costs of the project and the sustainability. However, the aesthetics is more important because of location of the fish passage in the historical environment.	0	Whether the fish migration happens in cycles or continuously influences the likelihood the fish will swim into the fish passage. The energy use influences the costs of the project and the sustainability, which influences the functionality. The energy use influences the efficiency of the fish passage less than the accessibility. Therefore, the accessibility of the fish passage is said to be more important.	0	The energy use influences management and the sustainability of the fish passage. The biological factors of the fish passages have consequences for how many fish will be able to pass. Therefore, the biological functionality is said to be more important.	x	x	0.5	Both the energy use and the impact on the water system do not directly influence the efficiency of the fish passage. Both do however are considered in the management of the fish passage, therefore these criteria are equally important.	0.5	The energy use and management and maintenance activities both do not directly influence the efficiency of the fish passage and are therefore equality important.	0	The energy use influences management of the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability of the fish passage is said to be more important.	**1,0**
Impact on the water system	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage. The aesthetics is more important because of location of the fish passage in the historical environment.	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage, it does however influences the water system. The accessibility influences the efficiency of the fish passage by allowing fish to enter the passage. Therefore, the accessibility of the passage is more important.	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefor the biological functionality is the more important criterion.	0.5	Both the energy use and the impact on the water system do not directly influence the efficiency of the fish passage. Both do however are considered in the management of the fish passage, therefore these criteria are equally important.	x	x	0.5	Both the management and maintenance activities and the impact on the water system do not directly influence the efficiency of the fish passage. Both criteria have an influence on entire the system. The criteria are equally important.	0	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage but the total water system. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability is considered the more important criteria.	**1,0**
Management and maintenance intensity	1	The frequency of the management and maintenance activities influences the quality of the fish passage, malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the management and maintenance intensity of the construction is said to be more important.	1	If the fish enter the fish passage but cannot pass because of malfunctions due to the maintenance and management activities the fish passage is not efficient. The management and maintenance activities are considered more important.	0	Management and maintenance activities do not directly influence the efficiency of the passage. The biological functionality of the fish passage does directly influence the efficiency because it considers how easily the fish could overcome the passage. Therefore, the biological functionality is considered more important.	0.5	The energy use and management and maintenance activities both do not directly influence the efficiency of the fish passage and are therefore equality important.	0.5	Both the management and maintenance activities and the impact on the water system do not directly influence the efficiency of the fish passage. Both criteria have an influence on entire the system. The criteria are equally important.	x	x	0	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The management and maintenance activities are a consequence of the malfunctions. Therefore, the reliability of the construction is more important.	**3,0**
Reliability of the construction	1	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The aesthetics does not contribute to the efficiency of the fish passage. Therefore, the reliability of the construction is said to be more important	0.5	Whether the fish migration happens in cycles or continuously influences the likely hood the fish will swim into the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. Both criteria are equality important.	0.5	The biological factors of the fish passages have consequences for how many fish will be able to pass. The reliability of the construction is the level of certainty the fish passage will function, so without malfunctions. Both criteria are equally important because both criteria consider the possibility the fish will overcome the passage.	1	The energy use influences management of the fish passage. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability of the fish passage is said to be more important.	1	The impact on the fish passage has on the water system does not directly influence the efficiency of the passage but the total water system. The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The reliability is considered the more important criteria.	1	The fish passage reliability influences the malfunctions and thus the efficiency of the fish passage. The management and maintenance activities are a consequence of the malfunctions. Therefore, the reliability of the construction is more important.	x	x	**5,0**

8.5 Fish passage calculations

8.5.1 Pump

Water velocity in the pipe by gravitational force

Colebrook-White formula

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{k_s}{3{,}70 \cdot D} + \frac{2{,}51}{Re \cdot \sqrt{\lambda}}\right)$$

Data

Symbol	value	unit
ks PE pipe	0,4	[mm]
D total	0,25	
D inside	0,2046	[m]

Find lambda

ks/(3.70*D)	0,000528388
1/√λ	6,554094724
λ	0,02327955

Darcy-Weisbach formula

$$\Delta E\ a-b = \lambda \cdot \frac{L}{D} \cdot \frac{u^2}{2g} + \xi_{in} \cdot \frac{u^2}{2g} + \xi_{out} \cdot \frac{u^2}{2g}$$

Data

Symbol	Value	Unit	Allocation
L	42	[m]	Drawing fish passage
D	0,2	[m]	Drawing fish passage
λ	0,02327955	[-]	Calculated with the Darcy-Weisbach formula
g	9,81	[m/s^2]	
ξin	0,588176431	[-]	Formula from book "Toegepaste Vloeistofmechanica, hydraulica voor waterbouwkundigen" by I.W. Nortier and P. de Koning
ξout	1	[-]	Formula from book "Toegepaste Vloeistofmechanica, hydraulica voor waterbouwkundigen" by I.W. Nortier and P. de Koning
ξangle	0,185	[-]	Formula form book "Toegepaste Vloeistofmechanica, hydraulica voor waterbouwkundigen" by I.W. Nortier and P. de Koning

-

Maximum velocity in the pipe

$+2.00 = -1{,}70 + \Delta E_{a\text{-}b}$

$\Delta E_{a\text{-}b}$ max	3,7	[m]
U max [m/s]	3,347860649	**[m/s]**

Minumum velocity in the pipe

$+0.80 = -1{,}50 + \Delta E_{a\text{-}b}$

$\Delta E_{a\text{-}b}$ min	2,3	[m]
U min [m/s]	2,639553255	**[m/s]**

Bernoulli formula

$$y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$$

Formula rewritten

$$y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \left(\lambda \cdot \frac{L}{D} + \xi_f\right) \cdot \frac{u^2}{2g}$$

Data

Symbol	value	unit
h1 max level of the pipe	2	[m]
h1 min level of the pipe	0,8	[m]
h2 max level of the pipe	-1,7	[m]
h2 min level of the pipe	-1,5	[m]
Velocity max in the pipe h1 max and h2 max	**3,301048469**	**[m/s]**
Velocity min in the pipe h1 min and h2 min	**2,602645135**	**[m/s]**
Velocity in the pipe h1 min and h2 max	2,713445126	[m/s]
Velocity in the pipe h1 max and h2 min	3,210591571	[m/s]
Δ H max in the pipe h1 max and h2 max	**4,488356682**	**[m]**
Δ H min in the pipe h1 min and h2 min	**3,460991182**	**[m]**
Δ H in the pipe h1 min and h2 max	3,607757682	[m]
Δ H in the pipe h1 max and h2 min	4,341590182	[m]

Calculation fish friendly pump

Q

Water flow out of the container	0,01	[m3/s]
Maximum water flow in the pipe	0,103705496	[m3/s]
Maximum to pump	**0,113705496**	**[m3/s]**
	113,7054962	**[l/s]**
Minimum water flow in the pipe	0,081764508	[m3/s]
Minimum to pump	**0,091764508**	**[m3/s]**
	91,76450835	**[l/s]**

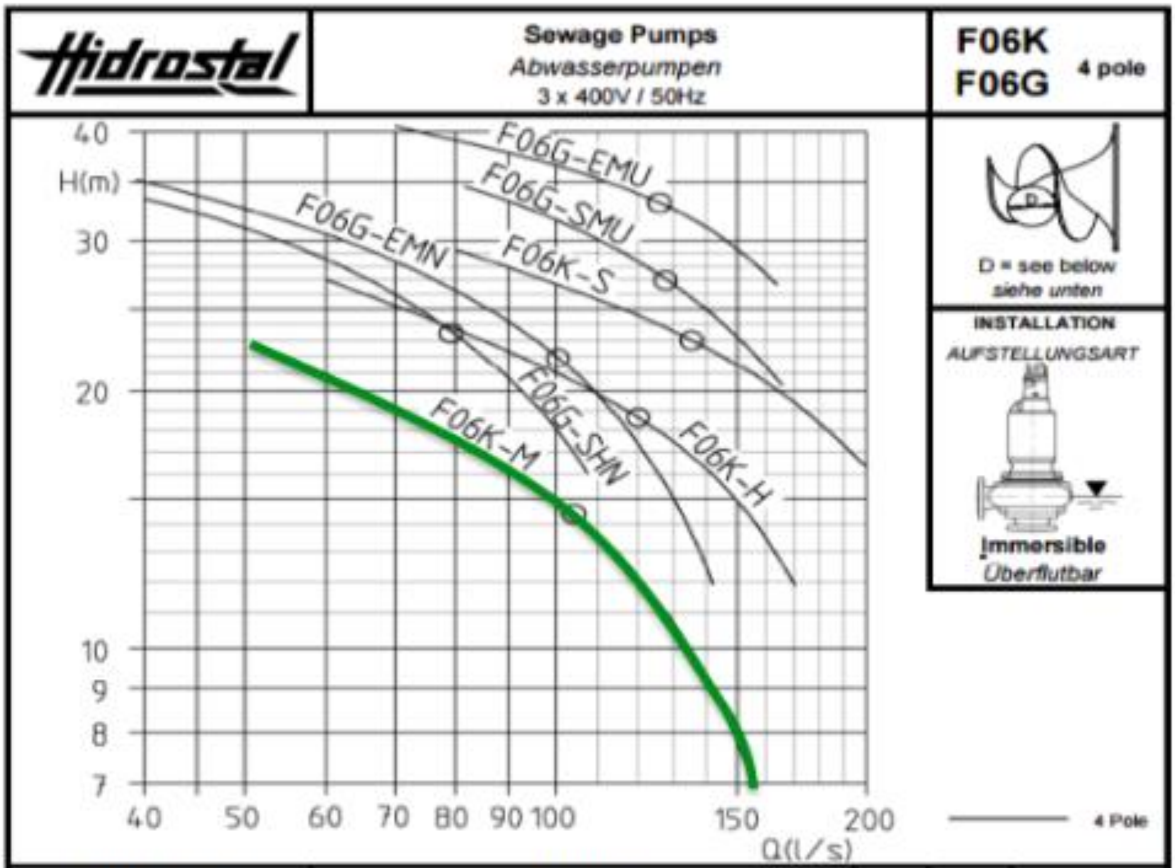
H = H stat + Δ H

H max	**8,188356682**	[m]
H min	**5,760991182**	[m]

Hidrostal fish friendly pump information

The F06 pump has been used in other fish passage of water board Scheldestromen. Therfore the different F06 pumps are shown. The H is relatively low in relation to the Q, therfore pump F06K-M has been selected.The H-Q curve of this pump does not perfectly match the characterisitics of the fish passage. This could be optimized by evaluating other pump types. This is excluded from this research due to the reference of the waterboard for this particular pump type.

http://www.hidrostal.co.uk/pumpfinder/stage4.php?ref=f06k&type=immersible



HYDRAULIC *HYDRAULIK*			MOTOR *MOTOR*									
Type *Typ*	IMPELLER *LAUFRAD*	Free Passage *Kugeldurchlass*	Type *Typ*	Pole *Polzahl*	Cable Set *Kabelsatz*	Length *Länge*	P_N	O I_N	□ I_A/I_N	Weight Hyd.+ Mot. *Gewicht Hyd.+ Mot.*		Cable *Kabel*
	Type	mm				m	kW	A	1	kg		
F06K	M	115	FE030X4		+ NC1B4O - 10		22.0	43.0	7.3	638		(2)4x6+4x1.5
F06G	SHN	75	FE030X4		+ NC1B4O - 10		30.0	56.0	5.7	638		(2)4x6+4x1.5
F06K	H	115	FE030X4		+ NC1B4O - 10		30.0	56.0	5.7	638		(2)4x6+4x1.5
F06G	EMN	90	FE030X4		+ NC1B4O - 10		30.0	56.0	5.7	638		(2)4x6+4x1.5
F06K	S	115	FE050X4		+ NE1B5O - 10		50.0	92.0	6.5	765		(2)4x10+4x1.5
F06G	SMU	115	FE050X4		+ NE1B5O - 10		50.0	92.0	6.5	765		(2)4x10+4x1.5
F06G	EMU	120	FE090X4		+ NE1B5O - 10		75.0	106.0	10.1	772		(2)4x10+4x1.5

MAX. O AMP. FOR THERMAL PROTECTOR SETTING (EXTRA QUICK TRIP - 6 SEC OR LESS); INCL. SERVICE FACTOR AND FRICTION LOSSES OF MECH. SEALS / BEARINGS	THERMOBLOCK AUF MAX. O AMP. EINSTELLEN (WERT ENTHÄLT ÜBERLASTFAKTOR UND REIBUNGSVERLUSTE MECH. DICHTUNGEN / LAGER)
□ = STARTING CURRENT / NOMINAL CURRENT; VALUES FOR DOL	□ = ANLAUFSTROM / NENNSTROM; WERTE FÜR DIREKTANLAUF
ABOVE DATA BASED ON 40°C MAX AMBIENT TEMP.; 3x400V, 50Hz.	ANGABEN BEZIEHEN SICH AUF UMGEBUNGSTEMP. VON 40°C 3x400V, 50Hz.
ACCORDING ISO 9906: 1999, ANNEX A	GEMÄSS ISO 9906: 1999, ANNEX A
ENCLOSURE - IP68	SCHUTZART IP68

File: U:\Engineering\Konstruktion\ Technisches Büro\DB 4	Drawn By / Bearb. Datum Visum : 12.09.06 pda / db Approved by / Gepr. Datum Visum : 14.04.08 gb	No: 06 - K 7056b

Graph 1 Hidrostal F06 pump characteristics (Hidrostal, 2017)

Pump conclusion
The pumps from Hidrostal were advised by water board Scheldestromen. The F06 pump has been used in another fish passage. The F06K-M pump has been selected for the fish passage. This was based on the Q-H curves of the F06 pumps from Hidrostal.

8.5.2 Pipe type calculation

The program that is used for the pipe calculation is called Sigma. This program calculates the cross-section of the pipe. The part of the pipe with the most soil load was calculated. Sigma calculates the pipe according to the NEN-3650 and the NEN-3651. Below all the information used for the calculation is explained and finally the calculation report from Sigma is given.

Pipe characteristics

Open slot construction
Because not only the pipe, but also the container and the foundation have to be constructed in the ground the construction of the pipe would be an open slot. An HDD (Horizontal Directional Drilling) would not be practical since the container and the foundation will be constructed too.

Material
A PE-100 pipe was chosen as pipe type. PE was chosen because this material is easy to install, they are light so no foundation needs to be constructed, the material is strong and flexible. Furthermore, it is better suited to deal with the salt environment compared to concrete and rust-free steal. The flexibility reduces the changes of tears or breaks in the pipe, reducing the maintenance. According to (Bureau Leiding) the PE pipes will function at least 60 years, after use the pipes can be recycled. The pipe has to cope with brackish water and a soil layer of 5,7 m. Steel is not suited for the brackish water. Concrete would have been possible, but the material is much heavier in comparison to the PE.

Measurements
Water board Scheldestromen has advised to use a diameter of 200 mm for the inside of the pipe, the reason had to do the size of the fish and the facilitating peak migration. Therefor a PE-100 pipe with a total diameter of 250 mm and a wall thickness of 22,7 mm has been used. The bends are smooth and have the same characteristics as the straight pipe, a 250 mm diameter; and 22,7 mm wall thickness. The radius of the bends are 1,5*D or 1,5*250=375 mm.

Traffic load
Above the fish passage there will be no traffic. There is a walking path, so people will walk on the soil on top of the fish passage. This load is not taken into account in the calculation.

Importance factor
In order to determine the factor of importance three tables were used from the NEN-3650. From Table 52 the human risk factor was determined and from Table 53 the material factor. B was chosen for the human risk factor because the primary water defense lies in front of the harbor as an additional protection and due to that Zierikzee is not a large city. F was chosen for material factor because of the monument in Zierikzee. They have a large historical value. Combining B and F in Table 54 give an importance factor of 0,80.

Table 52 Table to determine the importance factor, human risk factors ("Transportleidingen", 2012)

Factor	Risico van levensgevaar voor personen
A	Geen reëel levensgevaar
B	Levensgevaar voor enkele mensen
C	Levensgevaar voor veel mensen

Table 53 Table to determine the importance factor, material risk ("Transportleidingen", 2012)

Factor	Schade door inundatie	Schade aan de waterkering	Hinder scheepvaart	Verstoring waterhuishouding
D	Agrarisch gebied met weinig bebouwing	Waterkeringen langs kleine wateren, bijvoorbeeld binnenboezems	Geen	Gering
E	Klein stedelijk gebied of gebied met dorpsbebouwing, weinig industrie	Grote boezem- of kanaaldijken	Geringe of matige hinder	Enige stagnatie van wateraan- en -afvoer
F	Belangrijke bebouwing, veel industrie	Bijvoorbeeld primaire waterkering als schaardijk, kade aan grote boezem zonder boezemscheidingen	Zeer belangrijke hinder	Ernstige verstoring bijvoorbeeld in verband met drinkwatervoorziening

Table 54 Table to determine the importance factor ("Transportleidingen", 2012)

Personele risicofactor	Materiële risicofactor		
	D	E	F
C	0,75	0,75	0,75
B	0,90	0,85	0,80
A	1,00	0,95	0,85

Implementation characteristics
The fish passage lies parallel to a "waterstaatwerk" or water retaining structure from Rijkswaterstaat.

Construction subsidence differences
Because the pipe has to lay at 5,7 meters below the surface at the lowest point, slot type C way chosen. This allows a comfortable workspace. The diameter of the pipe is 250 mm. From Table 55 a construction subsidence difference of 25 mm was determined.

Table 55 Construction subsidence difference fv for well compacted additional soil underneath and next to the pipe in a dry slot and a continuous settlement profile (fv in mm) (“Transportleidingen”, 2012)

Tabel C.4 — Uitvoeringszakkingsverschil f_v voor goed verdichte aanvulgrond onder en naast de leiding in een droge sleuf en een continu zakkingsprofiel (f_v in mm)

Grondsoort	Slappe klei/veen						Stijve klei						Normaal zand						Hard zand					
Dekking (m)	2,5			1,25			2,5			1,25			2,5			1,25			2,5			1,25		
Sleuftype	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
D nom. (mm)																								
100	10	15	20	10	15	20	10	10	15	10	10	10	0	5	5	0	5	5	0	5	5	0	0	5
200	10	15	25	10	15	20	10	15	15	10	10	15	0	5	5	0	5	5	0	5	5	0	0	5
300	10	20	25	10	15	20	10	15	20	10	10	15	0	5	5	0	5	5	0	5	5	0	0	5
400	10	20	30	10	15	25	10	15	20	10	10	15	0	5	5	0	5	5	0	5	5	0	0	5
450	10	20	30	10	15	25	10	15	20	10	10	15	0	5	5	0	5	5	0	5	5	0	0	5
600	15	20	35	15	20	25	10	15	25	10	10	15	5	5	5	5	5	5	5	5	5	5	5	5
750	15	25	35	15	20	25	10	15	25	10	15	20	5	5	10	5	5	5	5	5	5	5	5	5
900	15	25	40	15	20	25	10	15	25	10	15	20	5	10	10	5	5	5	5	5	5	5	5	5
1 200	15	25	40	15	20	30	10	20	30	10	15	20	5	10	10	5	5	5	5	5	5	5	5	5

In de tabellen C.3 en C.4 geven a, b en c sleuftypen aan die zijn bepaald door de sleufbreedte *b* op buisasniveau, uitgedrukt in de uitwendige middellijn D_0 van de leiding:

— voor sleuftype a geldt: $b \leq 1{,}5\ D_0$;

— voor sleuftype b geldt: $1{,}5\ D_0 < b \leq 3\ D_0$;

— voor sleuftype c geldt: $b > 3\ D_0$.

Settlement difference
The settlement difference for clay is 25 mm, this can be seen in Table 56.

Table 56 Settlement difference (“Transportleidingen”, 2012)

Overzicht zettingsverschillen volgens NEN 3650

		Grondsoort			
		Slappe klei/veen	Stijve klei	Normaal zand	Hard zand
f_z	[mm]	25	15	0	0

Settlement percentage
The soil in the subjected area consists of clay and is compacted. Table 57 shows a value of 0,10 for the settlement percentage.

Table 57 Settlement percentages (“Transportleidingen”, 2012)

Sleufvulling		Grondsoort			
		Veen/slappe klei	Stijve klei	Normaal zand	Hard zand
Onverdicht	μ	0,20	0,15	0,075	0,075
Verdicht	μ	0,10	0,075	0,02	0,02

Marston factor
The standard value used as Marston factor is 0,3 for cohesive soils. The soil in the subjected area consists mainly of clay, a cohesive soil. Therefore, the Marston factor of 0,3 is used.

Pipe support
The pipe is not supported vertically or horizontally.

Fluid characteristics

The pipe will transport brackish water. The volumetric weight of the water fluctuates, therefor the volumetric weight of brackish water is used in the calculation.
The design pressure in the pipe is 0,045 N/mm2. For pipes the standard temperature difference is 10,0 degrees Celsius. No data is available about the temperature in the harbor of Zierikzee during the year. Therefor the standard value is used.

Soil characteristics
The ground level of pumping station ‘t Sas is at +3,70 m NAP (AHN, 2017).
Because there is no record of the groundwater level at the pumping station ‘t Sas the average ground water level is calculated. The average ground water level will be between +0.80m NAP in the harbor and -1,60 m NAP in the polder. This results in a ground water level at -0,4m NAP. The ground water level in relation to the ground surface level is 4,10 m. The lowest point of the pipe is at -2,10 m NAP. The ground that covers the pipe at this point is 5,8 m thick.

The soil characteristics found in a CPT of the ground close to the quay wall are used for the calculation. They are assumed equal.
The characteristics of the clay are shown in Table 58. For determining the “beddingsconstante” Table 59. The value of kv min is 0,0033 and the value of kv average is 0,005.

Table 58 Soil parameters (“Transportleidingen”, 2012)

Overzicht grondparameters volgens NEN 3650

			Zand				Klei				Veen	
			Vast		Matig	Los	Vast		Matig	Slap	Slap	
Volumiek gewicht droge grond	γ_d	[kN/m³]	20	19	18	17	20	19	17	14	12	10
Volumiek gewicht natte grond	γ_n	[kN/m³]	22	21	20	19	20	19	17	14	12	10
Inwendige wrijvingshoek grond	φ	[°]	40	35	32.5	30	25	17.5	17.5	17.5	15	15
Effectieve cohesie	c'	[kN/m²]	0	0	0	0	15	13	5	0	2.5	1
Ongedraineerde schuifsterkte	c_u	[kN/m²]	0	0	0	0	200	100	50	25	20	10
E-modulus sleufmateriaal	E_1	[MN/m²]	20	20	10	5	2	2	1	0.5	0.2	0.2
E-modulus ondergrond	E_{100}	[MN/m²]	110	75	45	15	10	10	2	1	0.5	0.2
Samendrukkingsconstante	C'_p	[-]	1500	1000	600	200	30	25	15	7	7.5	5
Relatieve verplaatsing	δ_d	[mm]	1-3	1-3	3-5	5-8	2-4	2-4	4-6	6-10	6-10	10-15

Table 59 Beddingsconstante (“Transportleidingen”, 2012)

Overzicht beddingconstante volgens NEN3650									
Grondsoort	Slappe klei/veen		Stijve klei		Normaal zand			Hard zand	
Beddingconstante [N/mm³]	$k_{v,min}$	$k_{v,gem}$	$k_{v,min}$	$k_{v,gem}$	$k_{v,min}$	$k_{v,gem}$		$k_{v,min}$	$k_{v,gem}$
Uitwendige middellijn [mm]						1 m	3 m		
100	0.007	0.011	0.016	0.024	0.04	0.045	0.11	0.1	0.158
200	0.004	0.006	0.0085	0.013	0.022	0.025	0.058	0.055	0.087
300	0.0025	0.004	0.006	0.009	0.016	0.018	0.04	0.04	0.063
400	0.002	0.003	0.0045	0.007	0.012	0.015	0.032	0.03	0.0475
450	0.0018	0.0028	0.004	0.006	0.01	0.013	0.029	0.025	0.0395
600	0.0014	0.0022	0.003	0.005	0.008	0.011	0.022	0.02	0.0315
750	0.0011	0.0018	0.0025	0.004	0.006	0.009	0.018	0.0176	0.0278
900	0.001	0.0016	0.0021	0.0034	0.006	0.008	0.015	0.0161	0.0254
1200	0.0008	0.0012	0.0017	0.0027	0.004	0.007	0.012	0.0137	0.0216

Safety zone
The water retaining structure close to the fish passage is concealed. The quay wall of ‘t Sas is the water retaining structure, see Figure 89. Between the water retaining construction and the fish passage there is a distance of approximately 22 meters. The dyke underneath the quay wall has a height above the ground of 4,10-2,40 = 1,7 m. The rule of thumb is that the safety zone has a width of 4*H. 1,7*4=6,8. This is less than 22 meters, so the fish passage is not in the safety zone of the water retaining construction. This means NEN-3651 is not applicable. There are no pump characteristics available.

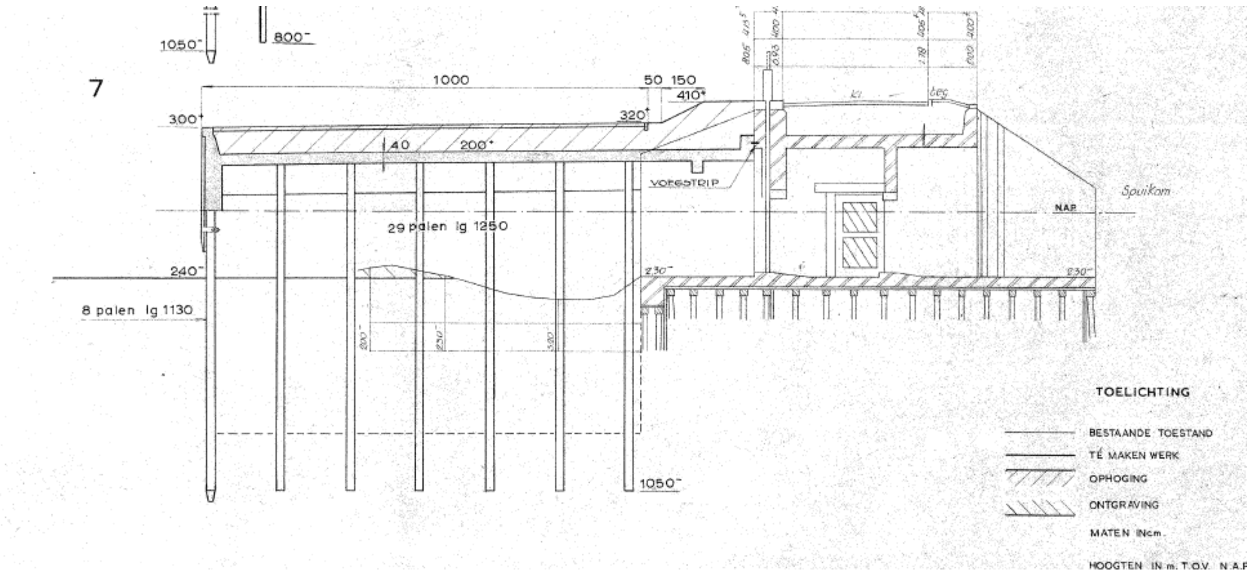


Figure 89 technical drawing quay wall ‘t Sas (Schouwen-Duivenland)

Sigma report

Sterkteberekening van een leiding in open sleuf conform NEN 3650/3651:2012				Sigma 2016 1.4 ©
Algemene gegevens				
Naam van het project : Pipe Thesis PE				
Projectonderdeel : Vis passage 2 vis vriendelijke pompen				
Importantiefactor S : 0,8				
Materiaalgegevens				
Materiaalsoort:	PE			
Kwaliteit:	PE 100			
Lange-duur treksterkte	MRS	= 10	N/mm^2	
Materiaalfactor	γ_M	= 1,25	-	
Toelaatbare langeduur spanning	$\bar{\sigma}_t$	= 8,00	N/mm^2	
Elasticiteitsmodulus korte duur	E	= 975	N/mm^2	
Elasticiteitsmodulus lange duur	E'	= 350	N/mm^2	
Lineaire uitzettingscoëfficiënt	α_T	= $16{,}0 \cdot 10^{-5}$	mm/(mm·K)	
Alfa Tangentiëel / Alfa Axiaal	α_σ	= 0,65	-	
Toelaatbare deflectie	δ	= 8	%	
Leidinggegevens				
Uitwendige middellijn	D_e	**= 250,00**	mm	
Wanddikte	d_n	**= 22,7**	mm	
Wanddikte bocht	t	= 22,7	mm	
Bochtstraal	R	= 375,00	mm	
Procesgegevens				
Soort leiding (Vloeistof / Gas / Drukloos)		= Vloeistof		
Ontwerpdruk	p_d	= 0,045	N/mm^2	
Volumieke massa vloeistof	ρ	= 1025	kg/m^3	
Temperatuurverschil	Δt	= 10	°	
Aanleggegevens				
Ligging: Evenwijdig aan een waterstaatswerk				
Zettingslengte	L	= 40.000	mm	
Dekking van de leiding t.o.v. maaiveld	H	= 5,80	m	
Gronddekking boven de grondwaterstand	H_d	= 4,10	m	
Gronddekking onder de grondwaterstand	H_n	= 1,70	m	
Belastinghoek	α	= 180	°	
Ondersteuningshoek	β	= 70	°	
Uitvoeringszakkingverschil	f_v	= 25,0	mm	
Zettingsverschil	f_z	= 25	mm	
Klinkpercentage	μ	= 0,1	%	
Marstonfactor	f_m	= 0,3	-	
Gegevens waterstaatswerk i.v.m. berekening veiligheidszone				
Waterstaatswerk: Verheeld				
				14-05-2017 22:18:14

1.4.0.0/07-2016/10-10383703

- 1 -

Grondmechanische gegevens

Grondsoort		= Klei	
Volumiek gewicht droge grond	γ_d	= 14	kN/m³
Volumiek gewicht natte grond	γ_n	= 14	kN/m³
Volumiek gewicht water	γ_w	= 10	kN/m³
Inwendige wrijvingshoek grond	φ	= 17,5	°
Effectieve cohesie	c'	= 0	kN/m²
Ongedraineerde schuifsterkte	c_u	= 25	kN/m²
E-modulus sleufmateriaal	E_1	= 0,5	MN/m²
Minimale verticale beddingconstante	$k_{v,min}$	= 0,0033	N/mm³
Gemiddelde verticale beddingconstante	$k_{v,gem}$	= 0,005	N/mm³
Niet rekenen met horizontale steundruk			
Geen grondmechanisch onderzoek uitgevoerd	γ	= 1,1	

Verkeersbelasting

Geen verkeersbelasting ingevoerd

Rekenen met ontlastende invloed wegdek: Geen ontlastende invloed

Sterkteberekening van een leiding in open sleuf conform NEN 3650/3651:2012	Sigma 2016 1.4 ©

1. Eigenschappen van de leiding

Inwendige middellijn	$D_i = D_e - 2 \cdot d_n$	= 204,60	mm
Gemiddelde middellijn	$D_g = (D_e + D_i)/2$	= 227,30	mm
Uitwendige middellijn+bekleding	$D_o = D_e + 2 \cdot e$	= 250,00	mm
Uitwendige straal	$r_e = D_e / 2$	= 125,00	mm
Inwendige straal	$r_i = D_i / 2$	= 102,30	mm
Gemiddelde straal	$r_g = (r_e + r_i) / 2$	= 113,65	mm
Traagheidsmoment buis	$I_b = (D_e^4 - D_i^4) \cdot \pi/64$	= 105.728.989,31	mm^4
Weerstandsmoment buis	$W_b = I_b / r_e$	= 845.831,91	mm^3
Wandtraagheidsmoment	$I_w = d_n^3 / 12$	= 974,76	mm^4/mm^1
Wandweerstandsmoment	$W_w = d_n^2 / 6$	= 85,88	mm^3/mm^1

2. Toetsing of vereenvoudigde berekeningsmethode is toegestaan

Voor vloeistofleidingen geldt: $H^3 \cdot D_i^5$ moet kleiner dan 40 m^8 zijn.
H is de druk in meters vloeistofkolom.
Rekening houdende met g = 9,81 m/s^2 volgt:

$$H = \frac{p_d}{\rho \cdot g}$$

$$H = \frac{45.000}{1.025 \cdot 9,81} = 4,48 \text{ m} \rightarrow H^3 \cdot D_i^5 = 4,48^3 \cdot 0,20^5 = 0,032 \text{ m}^8$$

3. Berekening van de veiligheidszone

$$R_B = 8 \cdot \sqrt[8]{H^3 \cdot D_i^5}$$

$$R_B = 8 \cdot \sqrt[8]{4,48^3 \cdot 0,20^5} = 5,21 \text{ m}$$

Veiligheidszone = $4 \cdot H_{werk} + R_B = 4 \cdot 0,00 + 5,21 = 5,21$ m

4. Berekening van de spanningen s_p en s_{pl} t.g.v. inwendige druk

$D_g/d_n = 227,30/22,70 = 10,01 \rightarrow D_g/d_n \leq 20 \rightarrow$ Dikwandige leiding

$$\sigma_p = \frac{r_e^2 + r_i^2}{r_e^2 - r_i^2} \cdot p_d$$

$$\sigma_p = \frac{125,00^2 + 102,30^2}{125,00^2 - 102,30^2} \cdot 0,045 = 0,23 \text{ N/mm}^2$$

$$\sigma_p(bi) = \frac{2 \cdot R - 0,5 \cdot D_e}{2 \cdot R - D_e} \cdot \sigma_p$$

$$\sigma_p(bi) = \frac{2 \cdot 375 - 0,5 \cdot 250,0}{2 \cdot 375 - 250,0} \cdot 0,23 = 0,28 \text{ N/mm}^2$$

$$\sigma_p(bu) = \frac{2 \cdot R + 0,5 \cdot D_e}{2 \cdot R + D_e} \cdot \sigma_p$$

$$\sigma_p(bu) = \frac{2 \cdot 375 + 0,5 \cdot 250,0}{2 \cdot 375 + 250,0} \cdot 0,23 = 0,20 \text{ N/mm}^2$$

$\sigma_{y1} = \sigma_p(bi) = 0,28$ N/mm²

$\sigma_{pl} = \upsilon \cdot \sigma_p = 0,4 \cdot 0,28 = 0,11$ N/mm²

Toelaatbare spanning = $\bar{\sigma}_t \cdot S = 8,00 \cdot 0,80 =$ **6,40** N/mm²

5. Berekening reroundingfactor f_{rr}

$$f_{rr} = 1 / \left(1 + \frac{2 \cdot p_d \cdot r_g^3 \cdot k_y}{E \cdot I_w} \right)$$

$$f_{rr} = 1 / \left(1 + \frac{2 \cdot 0{,}045 \cdot 113{,}65^3 \cdot 0{,}102}{975 \cdot 974{,}76} \right) = 0{,}99$$

6. Berekening van de neutrale grondbelasting Q_n

$q_n = \gamma \cdot \gamma_d \cdot H_d + \gamma \cdot \gamma_n \cdot H_n - \gamma_w \cdot H_w$

$q_n = 1{,}1 \cdot 14 \cdot 4{,}10 + 1{,}1 \cdot 14 \cdot 1{,}70 - 10 \cdot 1{,}70 = 72{,}32 \text{ kN/m}^2$

$Q_n = q_n \cdot D_o$

$Q_n = 72{,}32 \cdot 10^{-3} \cdot 250{,}0 = 18{,}08 \text{ N/mm}^1$

7. Berekening van de passieve grondbelasting Q_p

$$\sigma_{vert} = \frac{\gamma_d}{\gamma} \cdot H_d + \frac{\gamma_n}{\gamma} \cdot H_n - \gamma_w \cdot H_w$$

$$\sigma_{vert} = \frac{14}{1{,}1} \cdot 4{,}10 + \frac{14}{1{,}1} \cdot 1{,}70 - 10 \cdot 1{,}70 = 56{,}82 \text{ kN/m}^2$$

$\sigma_{hor} = \sigma_{vert} \cdot (1 - \sin(\varphi))$

$\sigma_{hor} = 56{,}82 \cdot (1 - \sin(17{,}5)) = 39{,}73 \text{ kN/m}^2$

$$\sigma_0' = \frac{\sigma_{vert} + \sigma_{hor}}{2}$$

$$\sigma_0' = \frac{56{,}82 + 39{,}73}{2} = 48{,}28 \text{ kN/m}^2$$

$p'_f = \sigma_0' \cdot (1+\sin(\varphi)) + c \cdot \cos(\varphi)$

$p'_f = 48{,}28 \cdot (1+\sin(17{,}5)) + 0 \cdot \cos(17{,}5) = 62{,}79 \text{ kN/m}^2$

$$G = \frac{E_{100}}{2 \cdot (1 + \upsilon)}$$

$$G = \frac{1}{2 \cdot (1 + 0{,}4)} = 0{,}36 \text{ MN/m}^2$$

$$Q = \frac{\sigma_0' \cdot \sin(\varphi) + c \cdot \cos(\varphi)}{G}$$

$$Q = \frac{48{,}28 \cdot \sin(17{,}5) + 0 \cdot \cos(17{,}5)}{0{,}36 \cdot 10^3} = 0{,}041$$

$$p'_{max} = (p'_f + c \cdot \cot(\varphi)) \cdot \left(\frac{0{,}5 \cdot D_0}{0{,}5 \cdot D_0 + H}^2 + Q \right)^{\frac{-\sin \varphi}{1+\sin \varphi}} - c \cdot \cot(\varphi)$$

$$p'_{max} = (62{,}79 + 17{,}5 \cdot \cot(0)) \cdot \left(\frac{0{,}5 \cdot 0{,}25}{0{,}5 \cdot 0{,}25 + 5{,}80}^2 + 0{,}04 \right)^{\frac{-\sin 17{,}5}{1+\sin 17{,}5}} - 0 \cdot \cot(17{,}5)$$

$p'_{max} = \mathbf{131{,}34} \text{ kN/m}^2$

$Q_p = p'_{max} \cdot D_o$

$Q_p = 131{,}34 \cdot 10^{-3} \cdot 250{,}0 = 32{,}83 \text{ N/mm}^1$

8. Berekening van de reële grondbelasting Q_k

$$z_{max} = 0{,}25 \cdot \frac{D_o}{E_1^{1,5} \cdot \sqrt{H/D_o}}$$

$$z_{max} = 0{,}25 \cdot \frac{0{,}25}{0{,}5^{1,5} \cdot \sqrt{5{,}80/0{,}25}} = 0{,}037 \text{ m}$$

$$q_k = q_n + \frac{\frac{\mu \cdot D_o}{z_{max}} \cdot (q_p - q_n)}{1 + \frac{q_p - q_n}{z_{max} \cdot k_{v,min}}}$$

$$q_k = 72{,}32 + \frac{\frac{0{,}1 \cdot 0{,}25}{0{,}037} \cdot (131{,}34 - 72{,}32)}{1 + \frac{131{,}34 - 72{,}32}{0{,}037 \cdot 0{,}0033 \cdot 10^6}} = 99{,}35 \text{ kN/m}^2$$

$Q_k = q_k \cdot D_o$

$Q_k = 99{,}35 \cdot 10^{-3} \cdot 250{,}0 = 24{,}84 \text{ N/mm}^1$

9. Berekening van de verkeersbelasting Q_v volgens Geen NEN 3650-1:C.17

Geen verkeersbelasting ingevoerd

$Q_v = 0 \text{ N/mm}^1$

10. Berekening van de stijfheidsverhouding grond/leiding l

$$\lambda = \sqrt[4]{\frac{D_o \cdot k_{v,gem}}{4 \cdot E \cdot I_b}}$$

$$\lambda = \sqrt[4]{\frac{250{,}0 \cdot 0{,}005}{4 \cdot 975 \cdot 105.728.989{,}31}} = 0{,}0013 \text{ mm}^{-1}$$

11. Berekening van de indirect overgedragen bovenbelasting (1e en 2e jaar)

Zettingslengte L = 40.000 mm

$\lambda \cdot L = 0{,}0013 \cdot 40.000 = 52{,}78$

i = 0,961 (= 96,1 % inklemming)

$B_z = 0{,}0000107$ (volgens NEN 3651 - 8.5.2.4 tabel 5)

$Q_z = B_z \cdot f_v \cdot D_o \cdot k_{v,gem}$

$Q_z = 0{,}0000107 \cdot 25{,}0 \cdot 250{,}0 \cdot 0{,}005 = 0{,}00033 \text{ N/mm}^1$

$$Q_d = Q_z \cdot \lambda \cdot L \cdot (i + \frac{i \cdot \lambda \cdot L}{6})$$

$$Q_d = 0{,}00033 \cdot 0{,}0013 \cdot 40.000 \cdot (0{,}961 + \frac{0{,}961 \cdot 0{,}0013 \cdot 40.000}{6}) = 0{,}17 \text{ N/mm}^1$$

12. Berekening van de indirect overgedragen bovenbelasting (na 2 jaar)

$Q_z = B_z \cdot (f_v + 1{,}5 \cdot f_z) \cdot D_o \cdot k_{v,gem}$

$Q_z = 0{,}0000107 \cdot (25{,}0 + 1{,}5 \cdot 25) \cdot 250{,}0 \cdot 0{,}005 = 0{,}00084 \text{ N/mm}^1$

$$Q_d = Q_z \cdot \lambda \cdot L \cdot (i + \frac{i \cdot \lambda \cdot L}{6})$$

$$Q_d = 0{,}00084 \cdot 0{,}0013 \cdot 40.000 \cdot (0{,}961 + \frac{0{,}961 \cdot 0{,}0013 \cdot 40.000}{6}) = 0{,}42 \text{ N/mm}^1$$

13. Berekening evenwichtsdraagvermogen en controle met bovenbelastingen

Berekening evenwichtsdraagvermogen

$B = D_o = 0{,}25$ m
$B/L = 0{,}1$
$Z = h + D_o / 2 = 5{,}80 + 0{,}25 / 2 = 5{,}93$ m
$S_c = 0{,}2 \cdot B/L = 0{,}02$
$d_c = 0{,}4 \cdot \tan^{-1}(Z/B) = 0{,}4 \cdot \tan^{-1}(5{,}93/0{,}25) = 0{,}61$
$P_{we} = 0{,}85 \cdot c_u \cdot (\pi + 2) \cdot (1 + S_c + d_c)$
$P_{we} = 0{,}85 \cdot 25 \cdot (\pi + 2) \cdot (1 + 0{,}02 + 0{,}61)$
$P_{we} = 178{,}25$ kN/m^2 = 0,18 N/mm^2
$P_{weDo} = P_{we} \cdot D_o = 0{,}18 \cdot 250{,}00 = 44{,}56$ N/mm^1

Controle bovenbelastingen met evenwichtsdraagvermogen

Situatie 1e en 2e jaar			*Conclusie:*
Q_k =	24,84	N/mm^1	Geen aanpassing
Q_v =	0,00	N/mm^1	van Q_d nodig
Q_d =	0,17	N/mm^1 +	
Σ =	25,00	N/mm^1	

Situatie na 2 jaar			*Conclusie:*
Q_n =	18,08	N/mm^1	Geen aanpassing
Q_v =	0,00	N/mm^1	van Q_d nodig
Q_d =	0,42	N/mm^1 +	
Σ =	18,50	N/mm^1	

14. Momenten en spanningen t.g.v. directe en indirecte bovenbelastingen (1e en 2e jaar)

Moment t.g.v. Q_k en Q_v

$M_q = K_b \cdot (Q_k + Q_v) \cdot r_g$
$M_q = 0{,}178 \cdot (24{,}84 + 0{,}00) \cdot 113{,}65$
$M_q = 502{,}45$ Nmm/mm^1

Moment t.g.v. Q_d

$M_{qd} = K_{b,ind} \cdot Q_d \cdot r_g$
$M_{qd} = 0{,}122 \cdot 0{,}17 \cdot 113{,}65$
$M_{qd} = 2{,}31$ Nmm/mm^1

Spanning t.g.v. M_q en M_{qd}

$\sigma_q = f_{rr} \cdot (M_q + M_{qd}) / W_w$
$\sigma_q = 0{,}99 \cdot (502{,}45 + 2{,}31) / 85{,}88 = \mathbf{5{,}80}$ N/mm^2

15. Momenten en spanningen t.g.v. directe en indirecte bovenbelastingen (na 2 jaar)

Moment t.g.v. Q_n en Q_v

$M_q = K_b \cdot (Q_n + Q_v) \cdot r_g$
$M_q = 0{,}178 \cdot (18{,}08 + 0{,}00) \cdot 113{,}65$
$M_q = 365{,}75$ Nmm/mm^1

Moment t.g.v. Q_d

$M_{qd} = K_{b,ind} \cdot Q_d \cdot r_g$
$M_{qd} = 0{,}122 \cdot 0{,}42 \cdot 113{,}65$
$M_{qd} = 5{,}77$ Nmm/mm^1

Spanning t.g.v. M_q en M_{qd}

$\sigma_q = f_{rr} \cdot (M_q + M_{qd}) / W_w$
$\sigma_q = 0{,}99 \cdot (365{,}75 + 5{,}77) / 85{,}88 = \mathbf{4{,}27}$ N/mm^2

16. Berekening van de spanning s_{bx} t.g.v. uitvoeringszakkingverschil f_v

$$\sigma_{bx} = C_z \cdot f_v \cdot \sqrt{\frac{E \cdot k_{v,gem}}{d_n}}$$

$$\sigma_{bx} = 0{,}00383 \cdot 25{,}0 \cdot \sqrt{\frac{975 \cdot 0{,}005}{22{,}7}} = \mathbf{0{,}04} \text{ N/mm}^2$$

17. Berekening van de spanning s_{bx} t.g.v. uitvoeringszakkingverschil f_v en zettingsverschil f_z

$$\sigma_{bx} = C_z \cdot (f_v + 1.5 \cdot f_z) \cdot \sqrt{\frac{E \cdot k_{v,gem}}{d_n}}$$

$$\sigma_{bx} = 0{,}00383 \cdot (25{,}0 + 1.5 \cdot 25) \cdot \sqrt{\frac{975 \cdot 0{,}005}{22{,}7}} = \mathbf{0{,}11}\ \text{N/mm}^2$$

18. Berekening van de spanning s_{ax} t.g.v. temperatuurverschil

$$\sigma_{ax} = \Delta t \cdot \alpha_g \cdot E$$

$$\sigma_{ax} = 10 \cdot 0{,}00016 \cdot 975 = \mathbf{1{,}56}\ \text{N/mm}^2$$

19. Berekening van de spanningsverhogingsfactoren van de bocht

Berekening van de factoren i_x, i_{xp}, i_y en i_{yp} van de bocht:

$$r = \left(\frac{D_o}{2} + \frac{D_o - 2 \cdot t}{2}\right) / 2 = 113{,}65 \text{ mm}$$

$$h = \frac{t \cdot R}{r^2} = \frac{22{,}7 \cdot 375}{113{,}65^2} = 0{,}66$$

$$k = \frac{1{,}65}{h} = \frac{1{,}65}{0{,}66} = 2{,}50$$

$$i_x = \frac{0{,}9}{h^{(2/3)}} = \frac{0{,}9}{0{,}66^{(2/3)}} = 1{,}19$$

$$c_2 = 1 + 3{,}25 \cdot (p_d/E) \cdot (r/t)^{(5/2)} \cdot (R/r)^{(2/3)}$$

$$c_2 = 1 + 3{,}25 \cdot (0{,}045/975) \cdot (113{,}65/22{,}7)^{(5/2)} \cdot (375{,}00/113{,}65)^{(2/3)} = 1{,}02$$

$$i_{xp} = \frac{i_x}{c_2} = \frac{1{,}19}{1{,}02} = 1{,}17$$

$$i_y = 2 \cdot i_x = 2 \cdot 1{,}19 = 2{,}38$$

$$i_{yp} = 2 \cdot i_{xp} = 2 \cdot 1{,}17 = 2{,}33$$

20. Toetsing op minimale ringstijfheid S_N

$$S_N = E \cdot \frac{I_w}{D_g^3}$$

$$S_N = 975 \cdot \frac{974{,}76}{227{,}3^3} = 0{,}0809 \text{ N/mm}^2 = \mathbf{80{,}93}\ \text{kN/m}^2$$

Minimaal vereiste ringstijfheid = **2** kN/m²

21. Toetsing op implosie: berekening van de alzijdige overdruk

Veiligheidsfactor γ voor langdurige onderdruk: $\gamma = 3$

Veiligheidsfactor γ voor kortdurende onderdruk: $\gamma = 1{,}5$

$$p_o = \frac{1}{\gamma \cdot (1 - \nu^2)} \cdot \frac{24 \cdot E \cdot I_w}{D_g^3}$$

$$p_{o,kort} = \frac{1}{1{,}5 \cdot (1 - 0{,}4^2)} \cdot \frac{24 \cdot 975{,}00 \cdot 974{,}76}{227{,}30^3} = 1{,}54 \text{ N/mm}^2$$

$$p_{o,lang} = \frac{1}{3 \cdot (1 - 0{,}4^2)} \cdot \frac{24 \cdot 350{,}00 \cdot 974{,}76}{227{,}30^3} = 0{,}28 \text{ N/mm}^2$$

Conclusie: Kans op implosie bij **27,67** m grondwater boven de leiding

22. Berekening van de optredende en toelaatbare deflectie

$$\delta_Y = \frac{(0{,}089 \cdot Q - 0{,}083 \cdot Q_{n;h} + 0{,}048 \cdot Q_d) \cdot r_g^3}{E' \cdot I_w}$$

$$\delta_Y = \frac{(0{,}089 \cdot (Q_n + Q_v) - 0{,}083 \cdot (1 - \sin\varphi) \cdot (Q_n + Q_v) + 0{,}048 \cdot Q_d) \cdot r_g^3}{E' \cdot I_w}$$

$$\delta_Y = \frac{(0{,}089 \cdot (18{,}08 + 0{,}00) - 0{,}083 \cdot (1 - \sin(17{,}5°)) \cdot (18{,}08 + 0{,}00) + 0{,}048 \cdot 0{,}42) \cdot 113{,}65^3}{350 \cdot 974{,}76} = \mathbf{2{,}49}\ \text{mm}\ (= 1{,}10\%)$$

Toelaatbare deflectie = 8% · importantiefactor S · D_g = 0,08 · 0,8 · 227,30 = **14,55** mm

23. Berekening van het totaal aan optredende spanningen (1e en 2e jaar)

Optredende spanningen in omtreksrichting van de leiding

$\sigma_{y2} = \alpha_{\sigma} \cdot (\sigma_q + i_{yp} \cdot \sigma_{bx})$

σ_{y2} = 0,65 · (5,80 + 2,33 · 0,04) = **3,83** N/mm²

Optredende spanningen in langsrichting van de leiding

$\sigma_x = \sigma_{pl} + \alpha_{\sigma} \cdot i_{xp} \cdot \sigma_{bx} + \sigma_{ax}$

σ_x = 0,11 + 0,65 · 1,17 · 0,04 + 1,56 = **1,71** N/mm²

Toelaatbare spanning = $\bar{\sigma}_{rt}$ · S = 8,00 · 0,80 = **6,40** N/mm²

24. Berekening van het totaal aan optredende spanningen (na 2 jaar)

Optredende spanningen in omtreksrichting van de leiding

$\sigma_{y2} = \alpha_{\sigma} \cdot (\sigma_q + i_{yp} \cdot \sigma_{bx})$

σ_{y2} = 0,65 · (4,27 + 2,33 · 0,11) = **2,94** N/mm²

Optredende spanningen in langsrichting van de leiding

$\sigma_x = \sigma_{pl} + \alpha_{\sigma} \cdot i_{xp} \cdot \sigma_{bx} + \sigma_{ax}$

σ_x = 0,11 + 0,65 · 1,17 · 0,11 + 1,56 = **1,76** N/mm²

Toelaatbare spanning = $\bar{\sigma}_{rt}$ · S = 8,00 · 0,80 = **6,40** N/mm²

1.4 0.0/07-2016/10-10383703

Conclusion calculation
In the Sigma calculation there are 24 separate calculation steps. The steps in which a check is perform are clarified below. All checks on the pipe have been approved. This means the pipe is in accordance with the NEN-3650. The PE-100 250 mm and 22,7 mm pipe is used in the fish passage.

Ring stiffness, step 20
The minimal ring stiffness is 2 kN/m2. The occurring ring stiffness is 80,93 kN/m2. 80,93 kN/m2 > 2 kN/m2 so the ring stiffness is approved.

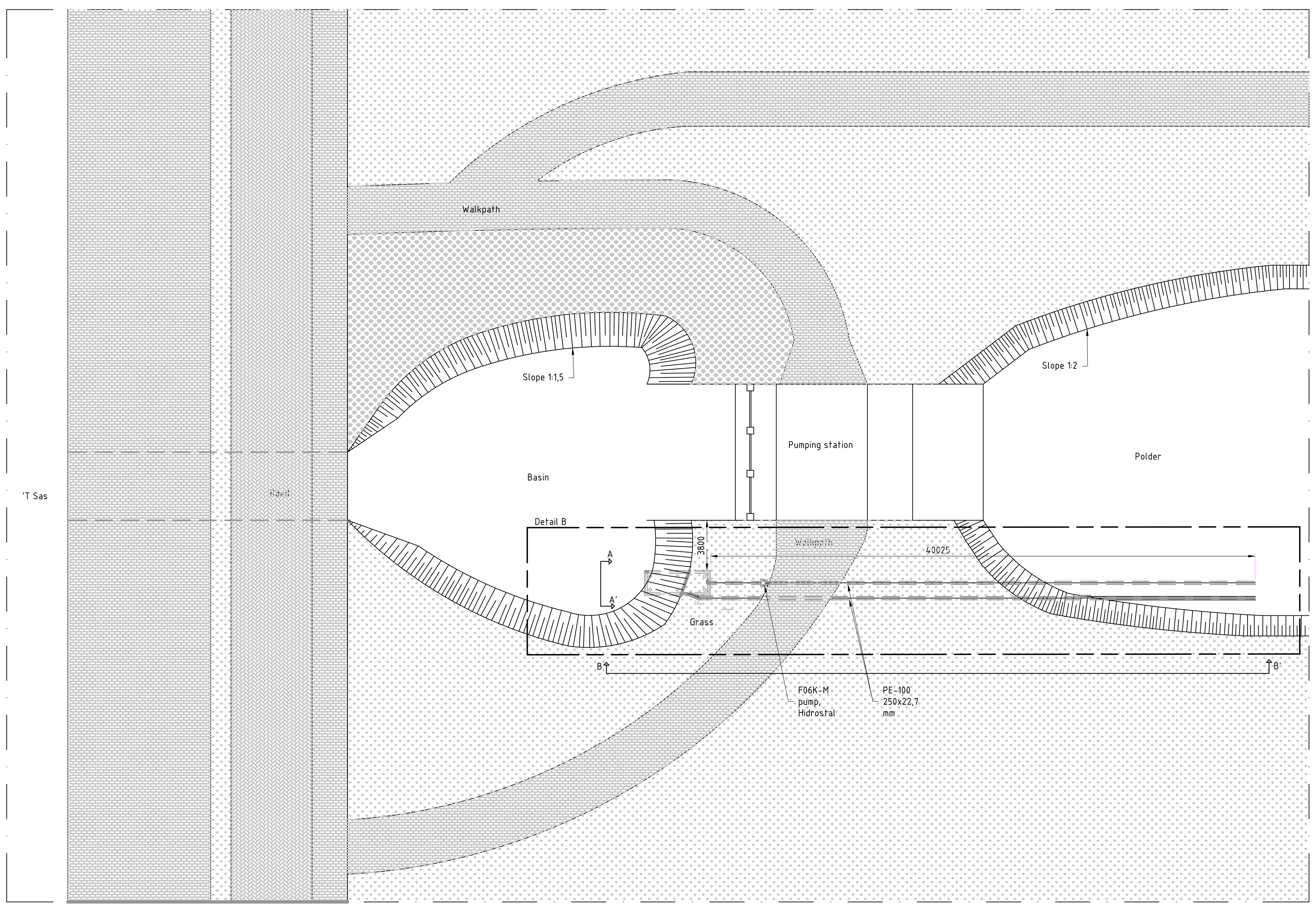
Deflection, step 22
The maximum allowed deflection of the pipe is 14,55 mm. The deflection that occurs is 2,49 mm. The deflection is approved because 2,49 mm < 14,55 mm.

Tension first and second year, step 23
The maximum allowed tension in the first and second year of the pipe is 6,40 N/mm2. The tension that occurs is 3,83 N/mm2 for the cross-section of the pipe and 1,71 N/mm2 for the total length of the pipe. The tension is approved because 3,83 N/mm2 < 6,40 N/mm2 and 1,71 N/mm2 < 6,40 N/mm2.

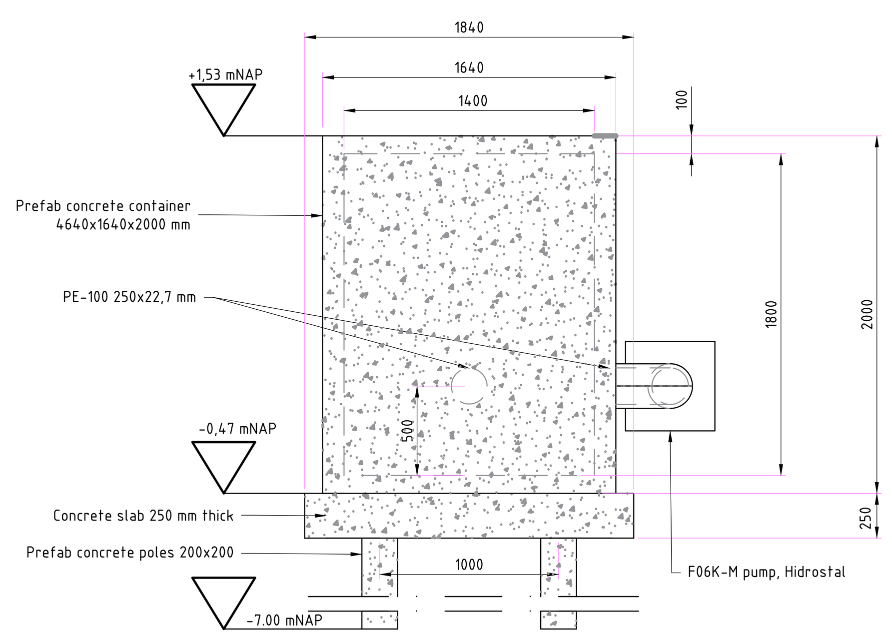
Tension after two years, step 24
The maximum allowed tension after two years when the pipe is laid the pipe is 6,40 N/mm2. The tension that occurs is 2,94 N/mm2 for the cross-section of the pipe and 1,76 N/mm2 for the total length of the pipe. The tension is approved because 2,94 N/mm2 < 6,40 N/mm2 and 1,76 N/mm2 < 6,40 N/mm2.

8.5.3 Technical drawing fish passage

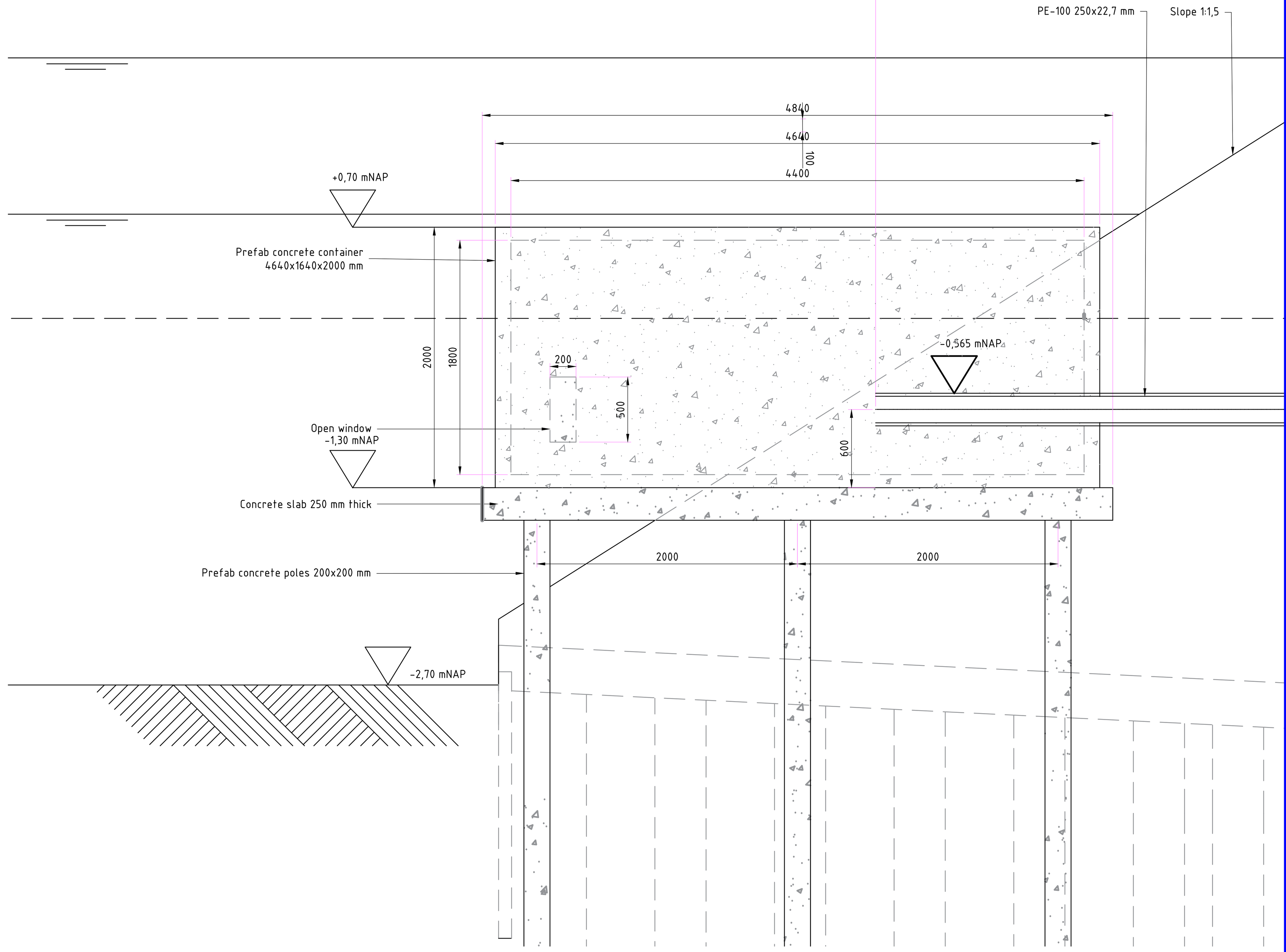
Top view
Scale 1: 200



View AA'
Scale 1: 25

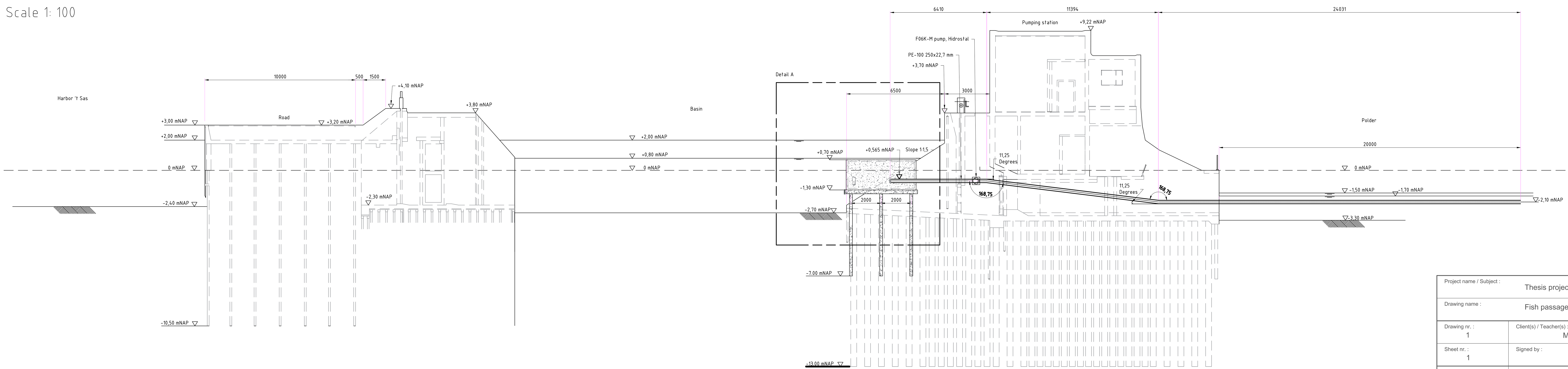


Detail A
Scale 1: 25



Detail B
Scale 1: 50

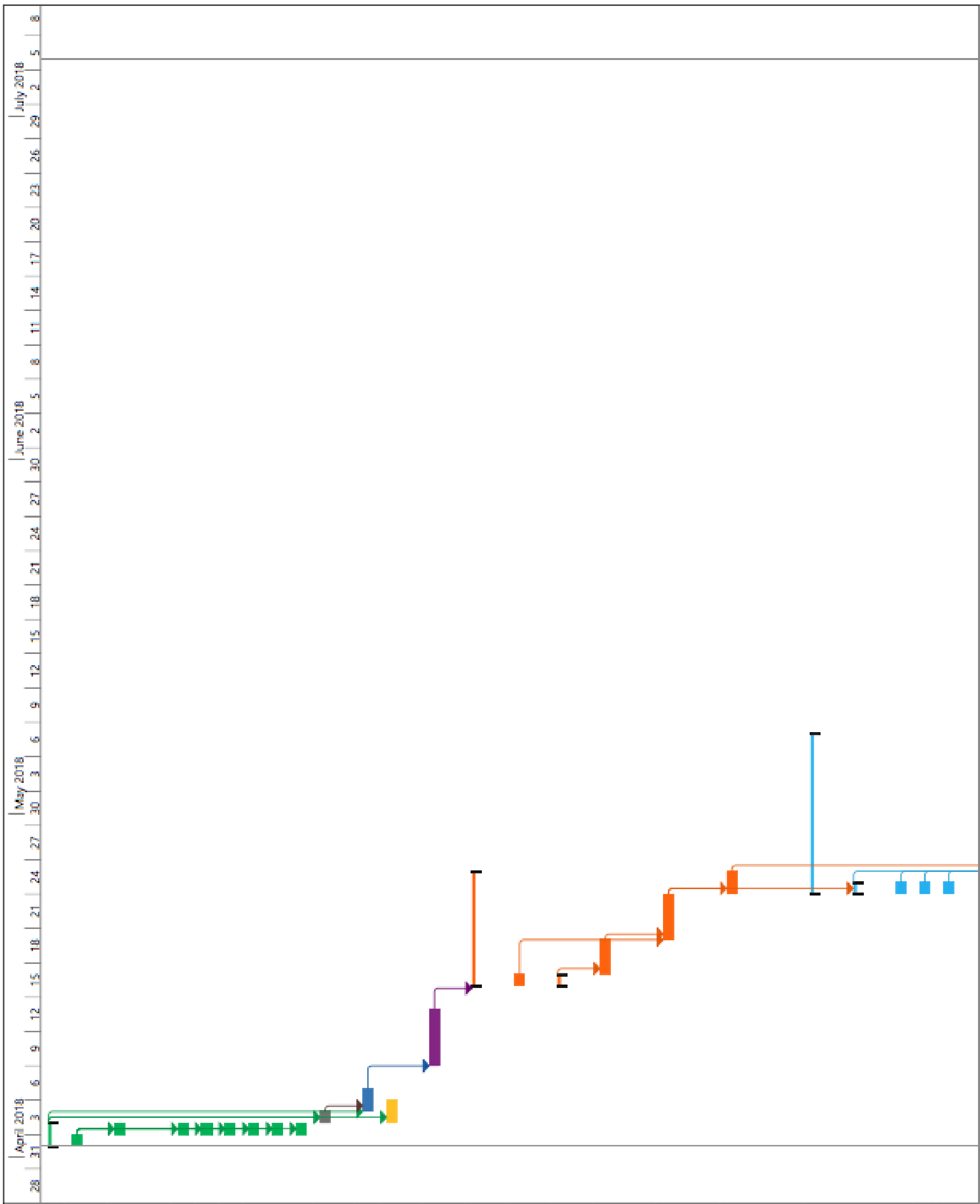
View BB'
Scale 1: 100



Project name / Subject :	Thesis project I. Zijlstra, KEN Engineering		
Drawing name :	Fish passage with a fish friendly pump		
Drawing nr. : 1	Client(s) / Teacher(s) : Municipality of Schouwen-Duivenland		
Sheet nr. : 1	Signed by : I. Zijlstra		
Date : 28-05-2017	Scale : See drawing	Hogeschool Zeeland AET, CE and DM	
Modif.: 0	Size : A0		
Course-code :	Seen :		
Class : AET, CE	Mark :	EDISONWEG 4 - 4382 NW VLISSINGEN - (0118) 489273	

8.5.4 Implementation strategy

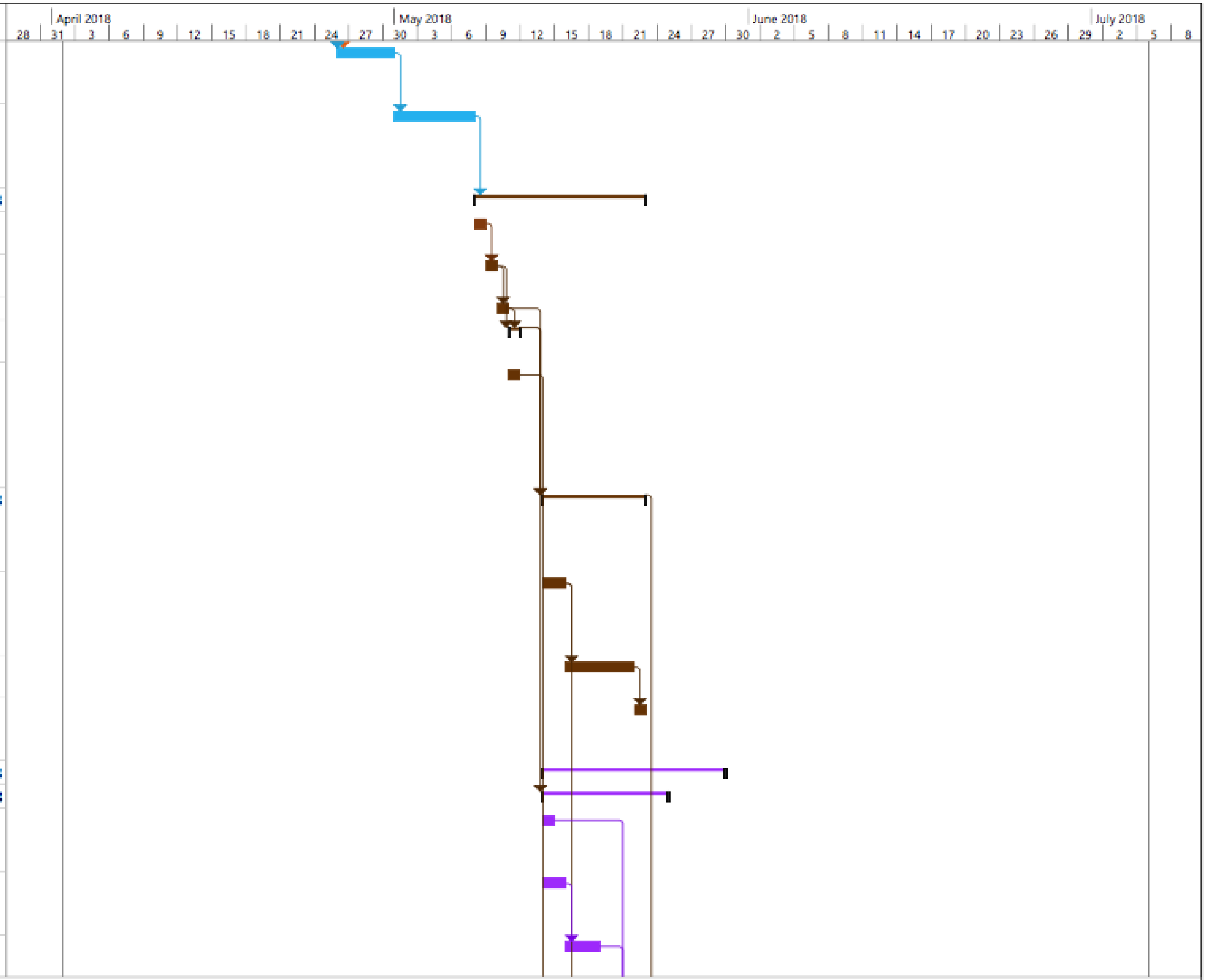
ID	Task Name	Duration	Start	Finish
1	**Set up building site**	**2 days**	**Mon 4/2/18**	**Tue 4/3/18**
2	Container for employees	1 day	Mon 4/2/18	Mon 4/2/18
3	Building site security (camera surveillance)	1 day	Tue 4/3/18	Tue 4/3/18
4	Electicity	1 day	Tue 4/3/18	Tue 4/3/18
5	Water	1 day	Tue 4/3/18	Tue 4/3/18
6	Toilet	1 day	Tue 4/3/18	Tue 4/3/18
7	Fence	1 day	Tue 4/3/18	Tue 4/3/18
8	Information signs	1 day	Tue 4/3/18	Tue 4/3/18
9	Garbage containers	1 day	Tue 4/3/18	Tue 4/3/18
10	Toolbox Dangerous Situations	1 day	Wed 4/4/18	Wed 4/4/18
11	Remove paved area	2 days	Thu 4/5/18	Fri 4/6/18
12	Sample soil for contaminants	2 days	Wed 4/4/18	Thu 4/5/18
13	Perform explosives survey	5 days	Mon 4/9/18	Fri 4/13/18
14	**Sheet piles for draining the building site**	**8 days**	**Mon 4/16/18**	**Wed 4/25/18**
15	Delivery sheetpiles	1 day	Mon 4/16/18	Mon 4/16/18
16	**Delivery sheetpile installment tools**	**1 day**	**Mon 4/16/18**	**Mon 4/16/18**
20	Set up the vibration installation	3 days	Tue 4/17/18	Thu 4/19/18
21	Installing sheetpiles by vibrating	2 days	Fri 4/20/18	Mon 4/23/18
22	Break up and transport the sheetpile installation material	2 days	Tue 4/24/18	Wed 4/25/18
23	**Draining the building site**	**10 days**	**Tue 4/24/18**	**Mon 5/7/18**
24	**Delivery drain materials**	**1 day**	**Tue 4/24/18**	**Tue 4/24/18**
25	Pipes	1 day	Tue 4/24/18	Tue 4/24/18
26	Pumps	1 day	Tue 4/24/18	Tue 4/24/18
27	Connection materials	1 day	Tue 4/24/18	Tue 4/24/18



Project: thesis fish passage con
Date: Tue 5/23/17

Page 1

ID	Task Name	Duration	Start	Finish
28	Installing the drainage system	3 days	Thu 4/26/18	Mon 4/30/18
29	Monitoring the ground water level between the sheetpiles	5 days	Tue 5/1/18	Mon 5/7/18
30	**Excavation**	**11 days**	**Tue 5/8/18**	**Tue 5/22/18**
31	Toolbox Dangerous Situations	1 day	Tue 5/8/18	Tue 5/8/18
32	Land surveying excavation	1 day	Wed 5/9/18	Wed 5/9/18
33	Delivery excavator	1 day	Thu 5/10/18	Thu 5/10/18
34	**Preperations for foundation**	**1 day**	**Fri 5/11/18**	**Fri 5/11/18**
35	Excavate to -1,55 mNAP (concrete pile 0,5 m above surface and 0,5 m around foundation) 94 m3	1 day	Fri 5/11/18	Fri 5/11/18
36	**Preperations for the pipe, 20 cm extra under pipe for sand, slope 1:3**	**7 days**	**Mon 5/14/18**	**Tue 5/22/18**
37	Part pipe straight from container, 530 m3	2 days	Mon 5/14/18	Tue 5/15/18
38	Part pipe with slope, 1005 m3	4 days	Wed 5/16/18	Mon 5/21/18
39	Part pipe straight into polder water, 235 m3	1 day	Tue 5/22/18	Tue 5/22/18
40	**Foundation**	**12 days**	**Mon 5/14/1ɛ**	**Tue 5/29/18**
41	**Concrete piles**	**9 days**	**Mon 5/14/1ɛ**	**Thu 5/24/18**
42	Delivery concrete piles 200 mm 6 m length	1 day	Mon 5/14/18	Mon 5/14/18
43	Delivery pile driving installation material	2 days	Mon 5/14/18	Tue 5/15/18
44	Building up the pile driving installation	3 days	Wed 5/16/18	Fri 5/18/18

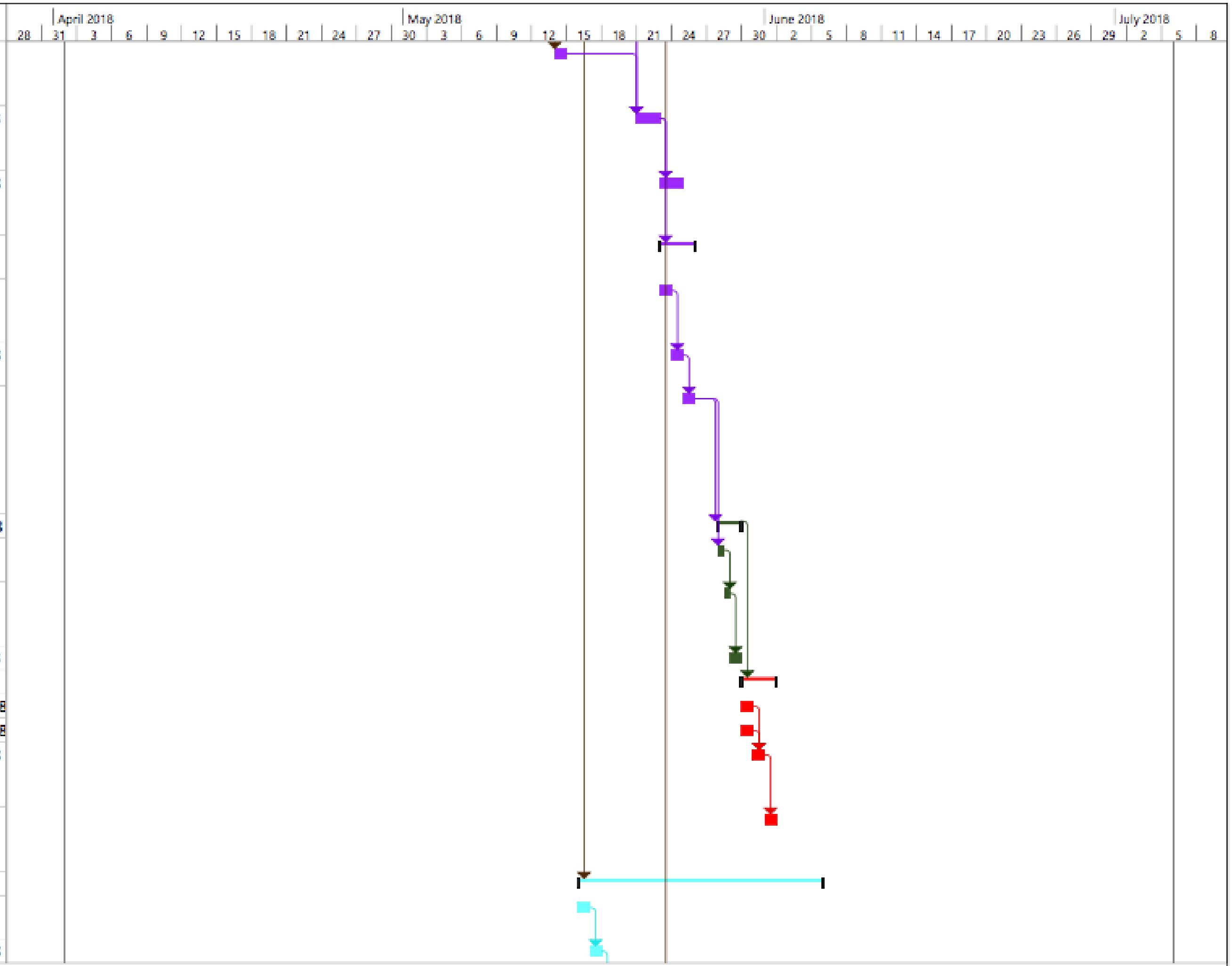


Project: thesis fish passage con
Date: Tue 5/23/17

Task	Project Summary	Manual Task	Start-only
Split	Inactive Task	Duration-only	Finish-only
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks
Summary	Inactive Summary	Manual Summary	External Milestone
Deadline	Progress	Manual Progress	

Page 2

ID	Task Name	Duration	Start	Finish
45	Line out the position of the piles	1 day	Mon 5/14/18	Mon 5/14/18
46	Driving the concrete piles into the ground	2 days	Mon 5/21/18	Tue 5/22/18
47	Break up the installation and transport	2 days	Wed 5/23/18	Thu 5/24/18
48	**Soil compaction concrete slab**	**3 days**	**Wed 5/23/18**	**Fri 5/25/18**
49	Delivery soil compaction machine	1 day	Wed 5/23/18	Wed 5/23/18
50	Compacting the soil	1 day	Thu 5/24/18	Thu 5/24/18
51	Add sand and companct untill the desired ground level is reached for the concrete slab.	1 day	Fri 5/25/18	Fri 5/25/18
52	**Concrete slab**	**2 days**	**Mon 5/28/18**	**Tue 5/29/18**
53	Line out the concrete slab	0.5 days	Mon 5/28/18	Mon 5/28/18
54	Make a wooden mould for the concrete slab	0.5 days	Mon 5/28/18	Mon 5/28/18
55	Poor the concrete	1 day	Tue 5/29/18	Tue 5/29/18
56	**Concrete container**	**3 days**	**Wed 5/30/18**	**Fri 6/1/18**
57	Delivery crane	1 day	Wed 5/30/18	Wed 5/30/18
58	Delivery container	1 day	Wed 5/30/18	Wed 5/30/18
59	Positioning container on concrete slab	1 day	Thu 5/31/18	Thu 5/31/18
60	Connect the container to the concrete slab	1 day	Fri 6/1/18	Fri 6/1/18
61	**Fish friendly pump**	**15 days**	**Wed 5/16/18**	**Tue 6/5/18**
62	Delivery soil compaction machine	1 day	Wed 5/16/18	Wed 5/16/18
63	Compacting the soil	1 day	Thu 5/17/18	Thu 5/17/18



Project: thesis fish passage con
Date: Tue 5/23/17

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Progress · Manual Progress

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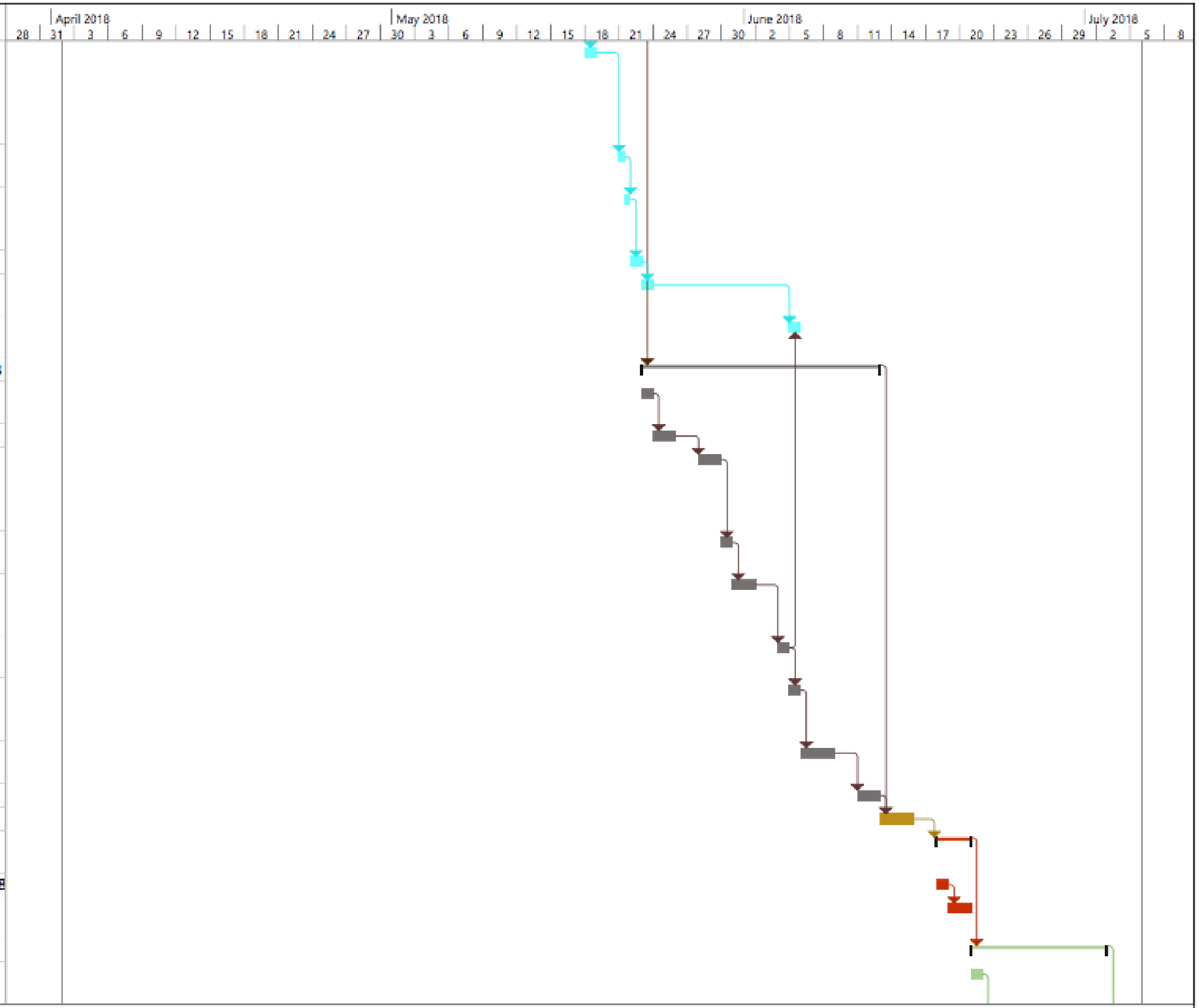
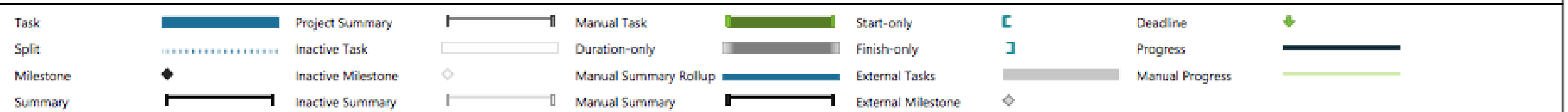
ID	Task Name	Duration	Start	Finish
64	Add sand and companct untill the desired ground level is reached for the concrete slab.	1 day	Fri 5/18/18	Fri 5/18/18
65	Line out the concrete slab	0.5 days	Mon 5/21/18	Mon 5/21/18
66	Make a wooden mould for the concrete slab	0.5 days	Mon 5/21/18	Mon 5/21/18
67	Poor the concrete	1 day	Tue 5/22/18	Tue 5/22/18
68	Delivery fish friendly pump	1 day	Wed 5/23/18	Wed 5/23/18
69	Installing the fish friendly pump	1 day	Tue 6/5/18	Tue 6/5/18
70	**PE Pipe**	**15 days**	**Wed 5/23/18**	**Tue 6/12/18**
71	Delivery compaction machine	1 day	Wed 5/23/18	Wed 5/23/18
72	Compacting soil	2 days	Thu 5/24/18	Fri 5/25/18
73	Make a compacted sand layer of 200 mm as a pipe foundation, 20 m3	2 days	Mon 5/28/18	Tue 5/29/18
74	Connect the PE pipe to the container	1 day	Wed 5/30/18	Wed 5/30/18
75	Lay the PE pipe from the container to the pump	2 days	Thu 5/31/18	Fri 6/1/18
76	Connect the PE pipe to the pump	1 day	Mon 6/4/18	Mon 6/4/18
77	Lay the PE pipe from the pump to the polder water	1 day	Tue 6/5/18	Tue 6/5/18
78	Cover the pipe with the excavated soil	3 days	Wed 6/6/18	Fri 6/8/18
79	Compacting soil	2 days	Mon 6/11/18	Tue 6/12/18
80	Restore slope basin	3 days	Wed 6/13/18	Fri 6/15/18
81	**Stop drainage building site**	**3 days**	**Mon 6/18/18**	**Wed 6/20/18**
82	Stop pumps	1 day	Mon 6/18/18	Mon 6/18/18
83	Break up and transport drainage	2 days	Tue 6/19/18	Wed 6/20/18
84	**Remove sheetpiles**	**8 days**	**Thu 6/21/18**	**Mon 7/2/18**
85	Delivery sheetpile removal material	1 day	Thu 6/21/18	Thu 6/21/18

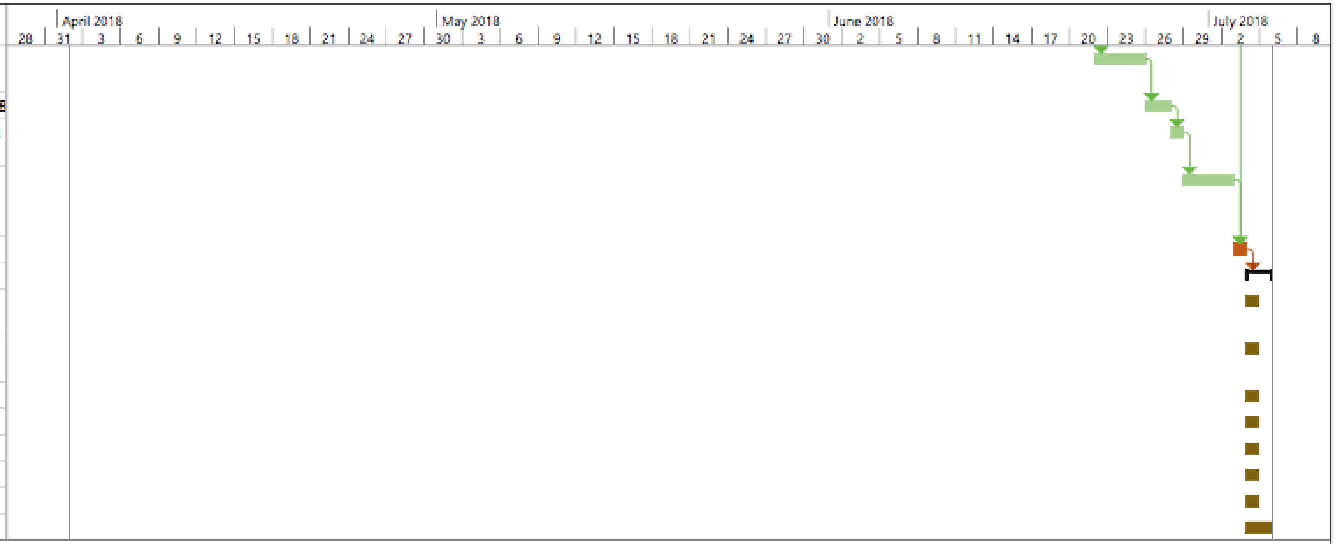


Project: thesis fish passage con
Date: Tue 5/23/17



Page 4

ID	Task Name	Duration	Start	Finish
86	Construct sheetpiles removal installation	2 days	Fri 6/22/18	Mon 6/25/18
87	Remove sheet piles	2 days	Tue 6/26/18	Wed 6/27/18
88	Transport the sheet piles	1 day	Thu 6/28/18	Thu 6/28/18
89	Break up installation and transport materials	2 days	Fri 6/29/18	Mon 7/2/18
90	Repave the walk path	1 day	Tue 7/3/18	Tue 7/3/18
91	**Clean up building site**	**2 days**	**Wed 7/4/18**	**Thu 7/5/18**
92	Container for employees	1 day	Wed 7/4/18	Wed 7/4/18
93	Building site security (camera surveillance)	1 day	Wed 7/4/18	Wed 7/4/18
94	Electicity	1 day	Wed 7/4/18	Wed 7/4/18
95	Water	1 day	Wed 7/4/18	Wed 7/4/18
96	Toilet	1 day	Wed 7/4/18	Wed 7/4/18
97	Fence	1 day	Wed 7/4/18	Wed 7/4/18
98	Information signs	1 day	Wed 7/4/18	Wed 7/4/18
99	Garbage containers	2 days	Wed 7/4/18	Thu 7/5/18



Project: thesis fish passage con
Date: Tue 5/23/17

Task, Split, Milestone, Summary, Project Summary, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, External Tasks, External Milestone, Deadline, Progress, Manual Progress

8.5.4.1 *Construction costs*

Activities	Amount	Unit	Price
Objects in the ground			***€ 3.445,92***
Delivery and instalment sheetpile			€ 2.789,76
Delivery and vibrating steel sheetpiles, high frequency, PU 16D, sheet pile length 10 m, projectsize 100 m	1	m	€ 1.358,45
Delivery and vibrating steel sheetpiles, high frequency, PU 16D, sheet pile length 10 m, projectsize 25 m	1	m	€ 1.431,31
Foundation container			€ 656,16
Driving concrete piles into the ground, dimensions 180 x 180 mm, length 8 m, vertically	6	piece	€ 656,16
Concrete granulate	20	m3	€ 0,00
Test explosives (Costs to be determined)			€ 0,00
Sleuf- en sleufloze technieken			***€ 7.720,66***
Ground work for the pipe			€ 5.106,20
Excavate clay, separate, width bottom 2,00 - 3,00 m, depth 2,50 - 3,00 m	1770	m3	€ 3.677,41
Add fill sand in slot, width slot bottom 1,00 - 2,00 m, thickness 0,40 m	100	m3	€ 1.428,79
Ground work for the container			€ 2.614,46
Excavate and fill hole, mechanical, gas en water, length 2,00 m, width 2,00 m, depth 1,00 m, clay	94	m3	€ 2.614,46
Gas- en waterleiding			***€ 9.755,33***
PE Pipe			€ 9.755,33
Delivery and positioning PE-100-pipe, diameter 250 mm, PN 10, SDR 17, colour black with a blue stripe, pipe length 12 m	84	m	€ 9.755,33
Ground works			***€ 24.279,36***
Separation, compaction, profiling ground			€ 24.237,50
Compaction black ground, width 3,00 to 6,00 m, surface area to 1.000 m2	625	m2	€ 24.237,50
Culture technical ground works			€ 41,86
Restore slope water way, slope length 4,00 - 8,00 m, ground to process 1,00 - 2,00 m3/m1, size project water way 50 m	20	m	€ 41,86
Substrate			***€ 784,17***
Breaking up pavement			€ 46,02
Breaking up pavement baked bricks, place them in the berm	50	m2	€ 46,02
Restore pavement			€ 738,15
Restore pavement baked bricks, briks from the berm, quality A 4-12, width 1,50 - 3,00 m	50	m2	€ 738,15
Fish friendly pump (Costs to be determined)			***15.000,00***
Hidrostal F06K-M			€ 0,00

Concrete prefab container			***€ 8.500,00***
Concrete prefab container 464 x 164 x 200 cm, Concrete quality C35/45, environmental class XA3			€ 8.500,00
Concrete prefab container 464 x 164 x 200 cm, Concrete quality C35/45, environmental class XA3	1	piece	€ 8.500,00
Crane positioning container			***€ 162,00***
Crane			€ 162,00
Rough-terrain crane, 20 tons	3	hour	€ 162,00
Drainage			***€ 5.739,20***
Open drainage			€ 5.739,20
Rent centrifugaalpomp with electric motor, pump capacity 120 m3 per hour	12	week	€ 5.030,88
Installing membrane pump	1	piece	€ 370,32
Removal membrane pump	1	piece	€ 337,99
Land surveying			***€ 1.920,80***
Land surveying			€ 1.920,80
Land surveying sheetpiles	1	piece	€ 313,60
Land surveying pipe	1	piece	€ 627,20
Land surveying poles	1	piece	€ 117,60
Land surveying excavation	1	piece	€ 627,20
Land surveying concrete slab	2	hour	€ 235,20

Total (excluding BTW)	€ 77.307,43
BTW-21%	€ 16.234,56
Total (including BTW)	**€ 93.541,99**

(GWW Kosten, I. Zijlstra, 2018)

8.6 Water quality

8.6.1 Evaluation quality model Svasek

When looking at the models from (Bom, 2016) a few things were noticed:

- The tide goes in and out of the harbor with a higher velocity in the new situation with a minimal water level compared to the current situation.
- The time the water in the harbor moves is less in the new situation. In the current situation there is a more gradual flow of water. In the new situation with a minimal water level the water is hold until the water level is at the sufficient level, this holding reduces the flow. When the doors open and the water “bursts” in and out of the harbor.
- The wind and waves were not included in the calculations of the model. The wind is not expected to have a large influence on the water movement. However, the waves could have some influences.
- In the model the pumping station ‘t Sas is not taken into account. This does influence the water flow in the harbor.
- The arches in the quay walls are not considered, but only open area under bridge. Only 10,80 m is used for the width of the channel under the bridge. See Figure 90.

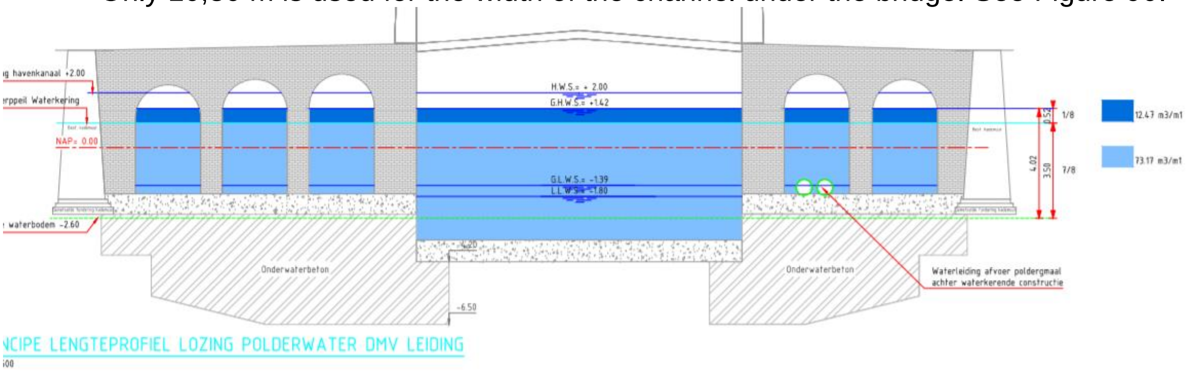


Figure 90 Design water retaining structure (Kaan)

In total, data is available on ten cross sections (CS) of the harbor. Five cross sections were evaluated. CS 1 is the cross section in front of the retaining structure. CS 2 is the cross section of the retaining structure. CS 6 and CS 7 are in the harbor ‘t Sas and CS 4 is in de Oude haven. These cross sections were selected because of the average flow over time. In order to evaluate the data from the model made by Svasek, calculations were made. The principle of Bernoulli was used to evaluate the model. The flow model was evaluated on specific moments in time during one tidal cycle. Five moments in time were evaluated, during these moments there was the most water movement in the harbor and therefore most interesting to study. The time slot considered the upcoming tide, the moment the tide turns and the outgoing tide. This time slot was selected by looking at the water velocity map from Svasek. The discharge, the velocity, the levels and bottoms levels were derived from the provided model.

By comparing the findings from the model to fluid dynamic calculations the model was evaluated. Because of the complexity of the water flow, the calculation was kept basic. Where the model and the calculation deviated, explanations were sought.

Because of the changing harbor bottom, the assumption was made that the shape of the cross sections was rectangular. Furthermore, the bends in the harbor were not taken into account in the calculation.

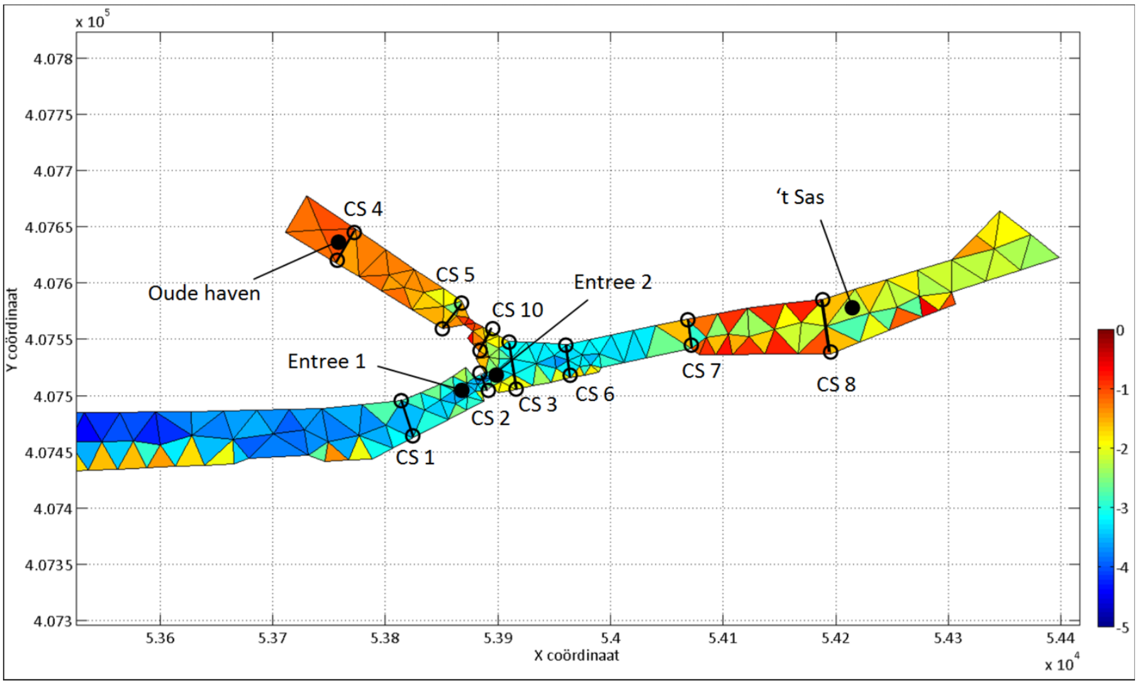


Figure 91 Svasek model of the depth of the harbor of Zierikzee with the cross sections indicated (Bom, 2016)

Mass balance
With the continuity principle or the conservation of mass principle the water flow in the harbor is studied. The mass balance equation is Q=A1*V1=A2*V2=A3*V3..

The velocities were calculated with the mass balance equation with the given discharge from the model and the measured wetted area. These velocities were compared to the velocities from the model. The discharge was evaluated in the same way, only instead of the discharges, the velocities were changed.

Water velocity
Small differences in velocity were found between the model and the mass balance equation. It has been found that when the tide is flowing in, the water in the model from Svasek flows slower into the harbor than in the mass balance equation. Furthermore, the outgoing tide flows slower out of the harbor than compared to the mass balance. However, at the retaining structure, this is opposite.

Discharge
According to the mass balance, more water is discharged when water is flowing in the harbor and less water is discharged when the water is flowing out of the harbor compared to the Svasek model. This is in relation with the velocity since Q=A*V.
Like the velocity, the data has shown that the opposite happens at the retaining structure (CS 2), here the discharge is larger according to the model.

Comparing the discharge and velocity
The differences between the calculations in velocity and discharge are present. However, considering the model of Svasek has considered more data and factors and the mass balance is very simple this shows that the model has considered the law of conservation of mass. This suggests that the model is representative for the actual situation.

It can be clearly seen that when the wetted area becomes smaller, the flow velocity increases to balance the discharge. The differences in values can be explained by the roughness of the harbor walls and bottom; the bottom slopes; the friction at the bends, splits and tightening of the harbor.

Energy balance

The formula of Bernoulli is used to evaluate how the energy acts in the harbor. Like the mass, energy does not get lost. Therefore, this is represented by the head loss in the equation of Bernoulli.

The Delta H calculated with the characteristics from the mass balance are compared to the Delta H calculated with the numbers from the Svasek model. The head loss between the different calculation is minimal, suggesting that these findings are consistent with the real situation.

8.6.2 Calculations evaluation model Svasek

Verification Flow Model Svasek With retaining structure Time 4:00

Evaluating Cross Section 1

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	2,2	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,035	[m/s]
Hydraulic Radius	R	3,165644172	[m]
Wetted Area	A	103,2	[m^2]
Wetter Perimeter	P	32,6	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (maps)		24	m
Water level (Svasek)		0,8	[mNAP]
Bottom level harbor (Svasek)		-3,5	[mNAP]
Water depth		4,3	m
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	ν	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	ν	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 2

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	6	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,05	[m/s]
Hydraulic Radius	R	2,230434783	[m]
Wetted Area	A	41,04	[m^2]
Wetter Perimeter	P	18,4	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		10,8	m
Water level (Svasek)		0,8	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		3,8	m
*Assume square harbor bottom			
celcius and salt water)	ν	0,00141	[m^2/s]

Pagina 1

Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 4 because of riptide

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-0,46	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,01	[m/s]
Hydraulic Radius	R	1,8	[m]
Wetted Area	A	72	[m^2]
Wetter Perimeter	P	40	[m]
Mannings roughness coefficient	n	0,028	[s/$m^{1/3}$]
Width harbor (drawing Leo Kaan)		36	m
Water level (Svasek)		0,8	[mNAP]
Bottom level harbor (Svasek)		-1,2	[mNAP]
Water depth		2	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 6

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	3,75	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,032	[m/s]
Hydraulic Radius	R	3,157894737	[m]
Wetted Area	A	120	[m^2]
Wetter Perimeter	P	38	[m]
Mannings roughness coefficient	n	0,028	[s/$m^{1/3}$]
Width harbor (drawing Leo Kaan)		30	m
Water level (Svasek)		0,8	[mNAP]
Bottom level harbor (Svasek)		-3,2	[mNAP]
waterdepth		4	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 7

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	3,3	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,035	[m/s]
Hydraulic Radius	R	2,94047619	[m]

Wetted Area	A	98,8	[m^2]
Wetter Perimeter	P	33,6	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		26	m
Water level (Svasek)		0,8	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		3,8	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Calculating the difference Balance of mass

Mass Balance formula	Q=A1*V1=A2*V2=A3*V3....

The A is set and is not able to change, therefore only the Q and V are evaluated

Velocity

	V According to Mass balance	V according to Svasek	Differences model and	Unit
CS 1	0,021317829	0,035	-0,013682171	m/s
CS 2	0,14619883	0,05	0,09619883	m/s
CS 4	-0,006388889	0,01	-0,016388889	m/s
CS 6	0,03125	0,032	-0,00075	m/s
CS 7	0,03340081	0,035	-0,00159919	m/s

Discharge

	Q According to Mass balance calculation	Q according to Svasek model	Differences model and mass balance	Unit
CS 1	3,612	2,2	1,412	m3/s
CS 2	2,052	6	-3,948	m3/s
CS 4	0,72	-0,46	1,18	m3/s
CS 6	3,84	3,75	0,09	m3/s
CS 7	3,458	3,3	0,158	m3/s

Bernoulli check

Formula used $y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$

Check Delta H

	Delta H with info from model	Delta H with V according to mass balance	Differences model and mass balance	Unit
H CS1	4,300062436	4,300023163	-3,92737E-05	m
Delta H CS 2	0,499935015	0,498933759	-0,001001256	m
Delta H CS 4	2,300057339	2,300021082	-3,62573E-05	m
Delta H CS 6	0,300010245	0,299973389	-3,68559E-05	m
Delta H CS 7	0,5	0,499966302	-3,36985E-05	m

Verification Flow Model Svasek With retaining structure
Time 5:00

Evaluating Cross Section 1

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	1,6	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,015	[m/s]
Hydraulic Radius	R	3,627906977	[m]
Wetted Area	A	124,8	[m^2]
Wetter Perimeter	P	34,4	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (maps)		24	m
Water level (Svasek)		1,7	[mNAP]
Bottom level harbor (Svasek)		-3,5	[mNAP]
Water depth		5,2	m
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 2

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	3,2	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,05	[m/s]
Hydraulic Radius	R	2,512871287	[m]
Wetted Area	A	50,76	[m^2]
Wetter Perimeter	P	20,2	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		10,8	m
Water level (Svasek)		1,7	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		4,7	m
*Assume square harbor bottom			
celcius and salt water)	v	0,00141	[m^2/s]

Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 4 because of riptide

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-0,22	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,005	[m/s]
Hydraulic Radius	R	2,497607656	[m]
Wetted Area	A	104,4	[m^2]
Wetter Perimeter	P	41,8	[m]
Mannings roughness coefficient	n	0,028	[s/$m^{1/3}$]
Width harbor (drawing Leo Kaan)		36	m
Water level (Svasek)		1,7	[mNAP]
Bottom level harbor (Svasek)		-1,2	[mNAP]
Water depth		2,9	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 6

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	2,4	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,017	[m/s]
Hydraulic Radius	R	3,693467337	[m]
Wetted Area	A	147	[m^2]
Wetter Perimeter	P	39,8	[m]
Mannings roughness coefficient	n	0,028	[s/$m^{1/3}$]
Width harbor (drawing Leo Kaan)		30	m
Water level (Svasek)		1,7	[mNAP]
Bottom level harbor (Svasek)		-3,2	[mNAP]
waterdepth		4,9	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 7

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	1,8	[m3/s]
Mean Fluid Velocity (Svasek)	V	0,018	[m/s]
Hydraulic Radius	R	3,451977401	[m]
Wetted Area	A	122,2	[m^2]
Wetter Perimeter	P	35,4	[m]

Mannings roughness coefficient	n	0,028	[s/m$^{1/3}$]
Width harbor (drawing Leo Kaan)		26	m
Water level (Svasek)		1,7	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		4,7	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Calculating the difference Balance of mass

Mass Balance formula	Q=A1*V1=A2*V2=A3*V3....

The A is set and is not able to change, therefore only the Q and V are evaluated

Velocity

	V According to Mass balance calculation	V according to Svasek	Differences model and mass balance	Unit
CS 1	0,012820513	0,015	-0,002179487	m/s
CS 2	0,063041765	0,05	0,013041765	m/s
CS 4	-0,00210728	0,005	-0,00710728	m/s
CS 6	0,016326531	0,017	-0,000673469	m/s
CS 7	0,014729951	0,018	-0,003270049	m/s

Discharge

	Q According to Mass balance calculation	Q according to Svasek model	Differences model and mass balance	Unit
CS 1	1,872	1,6	0,272	m3/s
CS 2	2,538	3,2	-0,662	m3/s
CS 4	0,522	-0,22	0,742	m3/s
CS 6	2,499	2,4	0,099	m3/s
CS 7	2,1996	1,8	0,3996	m3/s

Bernoulli check

Formula used

$$y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$$

Check Delta H

	Delta H with info from model	Delta H with V according to mass balance	Differences model and mass balance	Unit
H CS1	5,200011468	5,200008377	-3,09044E-06	m
Delta H CS 2	0,499884047	0,499805816	-7,82313E-05	m
Delta H CS 4	2,300010194	2,300008151	-2,04256E-06	m
Delta H CS 6	0,299996738	0,299994792	-1,94649E-06	m
Delta H CS 7	0,499994954	0,499997319	2,36463E-06	m

Verification Flow Model Svasek With retaining structure
Time 6:00

Evaluating Cross Section 1

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-2,2	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,02	[m/s]
Hydraulic Radius	R	3,771428571	[m]
Wetted Area	A	132	[m^2]
Wetter Perimeter	P	35	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (maps)		24	m
Water level (Svasek)		2	[mNAP]
Bottom level harbor (Svasek)		-3,5	[mNAP]
Water depth		5,5	m
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 2

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-2,4	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,02	[m/s]
Hydraulic Radius	R	2,596153846	[m]
Wetted Area	A	54	[m^2]
Wetter Perimeter	P	20,8	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		10,8	m
Water level (Svasek)		2	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		5	m
*Assume square harbor bottom celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]

Density of liquid (assume salt water)	ρ	1025	[kg/m³]

Evaluating Cross Section 4 because of riptide

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	0,23	[m3/s]
Mean Fluid Velocity (Svasek)	V	0	[m/s]
Hydraulic Radius	R	2,716981132	[m]
Wetted Area	A	115,2	[m^2]
Wetter Perimeter	P	42,4	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		36	m
Water level (Svasek)		2	[mNAP]
Bottom level harbor (Svasek)		-1,2	[mNAP]
Water depth		3,2	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	ν	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	ν	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 6

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-1,1	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,01	[m/s]
Hydraulic Radius	R	3,861386139	[m]
Wetted Area	A	156	[m^2]
Wetter Perimeter	P	40,4	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		30	m
Water level (Svasek)		2	[mNAP]
Bottom level harbor (Svasek)		-3,2	[mNAP]
waterdepth		5,2	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	ν	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	ν	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 7

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-0,2	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,01	[m/s]
Hydraulic Radius	R	3,611111111	[m]
Wetted Area	A	130	[m^2]
Wetter Perimeter	P	36	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		26	m

Water level (Svasek)		2	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		5	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Calculating the difference Balance of mass

Mass Balance formula	Q=A1*V1=A2*V2=A3*V3....

The A is set and is not able to change, therefore only the Q and V are evaluated

Velocity

	V According to Mass balance	V according to Svasek	Differences model and	Unit
CS 1	-0,016666667	-0,02	0,003333333	m/s
CS 2	-0,044444444	-0,02	-0,024444444	m/s
CS 4	0,001996528	0	0,001996528	m/s
CS 6	-0,007051282	-0,01	0,002948718	m/s
CS 7	-0,001538462	-0,01	0,008461538	m/s

Discharge

	Q According to Mass balance calculation	Q according to Svasek model	Differences model and mass balance	Unit
CS 1	-2,64	-2,2	-0,44	m3/s
CS 2	-1,08	-2,4	1,32	m3/s
CS 4	0	0,23	-0,23	m3/s
CS 6	-1,56	-1,1	-0,46	m3/s
CS 7	-1,3	-0,2	-1,1	m3/s

Bernoulli check

Formula used $$y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$$

Check Delta H

	Delta H with info from model	Delta H with V according to mass balance	Differences model and mass balance	Unit
H CS1	5,500020387	5,500014158	-6,22947E-06	m
Delta H CS 2	0,5	0,49991348	-8,65204E-05	m
Delta H CS 4	2,300020387	2,300013955	-6,43264E-06	m
Delta H CS 6	0,300015291	0,300011624	-3,66681E-06	m
Delta H CS 7	0,500015291	0,500014037	-1,25327E-06	m

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Verification Flow Model Svasek With retaining structure
Time 7:00

Evaluating Cross Section 1

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-5	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,03	[m/s]
Hydraulic Radius	R	3,529411765	[m]
Wetted Area	A	120	[m^2]
Wetter Perimeter	P	34	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (maps)		24	m
Water level (Svasek)		1,5	[mNAP]
Bottom level harbor (Svasek)		-3,5	[mNAP]
Water depth		5	m
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 2

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-4,4	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,04	[m/s]
Hydraulic Radius	R	2,454545455	[m]
Wetted Area	A	48,6	[m^2]
Wetter Perimeter	P	19,8	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		10,8	m
Water level (Svasek)		1,5	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		4,5	m
*Assume square harbor bottom celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 4 because of riptide

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	0,32	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,005	[m/s]
Hydraulic Radius	R	2,347826087	[m]
Wetted Area	A	97,2	[m^2]
Wetter Perimeter	P	41,4	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		36	m
Water level (Svasek)		1,5	[mNAP]
Bottom level harbor (Svasek)		-1,2	[mNAP]
Water depth		2,7	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 6

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-1,8	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,015	[m/s]
Hydraulic Radius	R	3,578680203	[m]
Wetted Area	A	141	[m^2]
Wetter Perimeter	P	39,4	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		30	m
Water level (Svasek)		1,5	[mNAP]
Bottom level harbor (Svasek)		-3,2	[mNAP]
waterdepth		4,7	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 7

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-1,7	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,015	[m/s]
Hydraulic Radius	R	3,342857143	[m]
Wetted Area	A	117	[m^2]
Wetter Perimeter	P	35	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		26	m
Water level (Svasek)		1,5	[mNAP]

Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		4,5	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Calculating the difference Balance of mass

Mass Balance formula	Q=A1*V1=A2*V2=A3*V3....

The A is set and is not able to change, therefore only the Q and V are evaluated

Velocity

	V According to Mass balance	V according to Svasek	Differences model and	Unit
CS 1	-0,041666667	-0,03	-0,011666667	m/s
CS 2	-0,090534979	-0,04	-0,050534979	m/s
CS 4	0,003292181	-0,005	0,008292181	m/s
CS 6	-0,012765957	-0,015	0,002234043	m/s
CS 7	-0,014529915	-0,015	0,000470085	m/s

Discharge

	Q According to Mass balance calculation	Q according to Svasek model	Differences model and mass balance	Unit
CS 1	-3,6	-5	1,4	m3/s
CS 2	-1,944	-4,4	2,456	m3/s
CS 4	-0,486	0,32	-0,806	m3/s
CS 6	-2,115	-1,8	-0,315	m3/s
CS 7	-1,755	-1,7	-0,055	m3/s

Bernoulli check

Formula used $y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$

Check Delta H

	Delta H with info from model	Delta H with V according to mass balance	Differences model and mass balance	Unit
H CS1	5,000045872	5,000088487	4,26152E-05	m
Delta H CS 2	0,499964322	0,49967072	-0,000293602	m
Delta H CS 4	2,300044597	2,300087934	4,3337E-05	m
Delta H CS 6	0,300034404	0,300080181	4,57768E-05	m
Delta H CS 7	0,500034404	0,500077726	4,33228E-05	m

Verification Flow Model Svasek With retaining structure
Time 8:00

Evaluating Cross Section 1

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-7,5	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,05	[m/s]
Hydraulic Radius	R	3,138461538	[m]
Wetted Area	A	102	[m^2]
Wetter Perimeter	P	32,5	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (maps)		24	m
Water level (Svasek)		0,75	[mNAP]
Bottom level harbor (Svasek)		-3,5	[mNAP]
Water depth		4,25	m
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 2

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-0,1	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,05	[m/s]
Hydraulic Radius	R	2,213114754	[m]
Wetted Area	A	40,5	[m^2]
Wetter Perimeter	P	18,3	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		10,8	m
Water level (Svasek)		0,75	[mNAP]
Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		3,75	m
*Assume square harbor bottom			
celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

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Evaluating Cross Section 4 because of riptide

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-0,48	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,01	[m/s]
Hydraulic Radius	R	1,759398496	[m]
Wetted Area	A	70,2	[m^2]
Wetter Perimeter	P	39,9	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		36	m
Water level (Svasek)		0,75	[mNAP]
Bottom level harbor (Svasek)		-1,2	[mNAP]
Water depth		1,95	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	ν	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	ν	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 6

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	-3,2	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,025	[m/s]
Hydraulic Radius	R	3,126649077	[m]
Wetted Area	A	118,5	[m^2]
Wetter Perimeter	P	37,9	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		30	m
Water level (Svasek)		0,75	[mNAP]
Bottom level harbor (Svasek)		-3,2	[mNAP]
waterdepth		3,95	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	ν	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	ν	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Evaluating Cross Section 7

Discription	Symbol	Value	Unit
Discharge (Svasek)	Q	0,1	[m3/s]
Mean Fluid Velocity (Svasek)	V	-0,035	[m/s]
Hydraulic Radius	R	2,910447761	[m]
Wetted Area	A	97,5	[m^2]
Wetter Perimeter	P	33,5	[m]
Mannings roughness coefficient	n	0,028	[$s/m^{1/3}$]
Width harbor (drawing Leo Kaan)		26	m
Water level (Svasek)		0,75	[mNAP]

Bottom level harbor (Svasek)		-3	[mNAP]
Waterdepth		3,75	
*Assume square harbor bottom			
Kinematic viscosity (10 degrees celcius and salt water)	v	0,00141	[m^2/s]
Kinematic viscosity (20 degrees celcius and salt water)	v	0,00108	[m^2/s]
Density of liquid (assume salt water)	ρ	1025	[kg/m^3]

Calculating the difference Balance of mass

Mass Balance formula	Q=A1*V1=A2*V2=A3*V3....

The A is set and is not able to change, therefore only the Q and V are evaluated

Velocity

	V According to Mass balance	V according to Svasek	Differences model and	Unit
CS 1	-0,073529412	-0,05	-0,023529412	m/s
CS 2	-0,002469136	-0,05	0,047530864	m/s
CS 4	-0,006837607	-0,01	0,003162393	m/s
CS 6	-0,027004219	-0,025	-0,002004219	m/s
CS 7	0,001025641	-0,035	0,036025641	m/s

Discharge

	Q According to Mass balance calculation	Q according to Svasek model	Differences model and mass balance	Unit
CS 1	-5,1	-7,5	2,4	m3/s
CS 2	-2,025	-0,1	-1,925	m3/s
CS 4	-0,702	-0,48	-0,222	m3/s
CS 6	-2,9625	-3,2	0,2375	m3/s
CS 7	-3,4125	0,1	-3,5125	m3/s

Bernoulli check

Formula used $$y_1 + z_1 + \frac{u_1^2}{2g} = y_2 + z_2 + \frac{u_2^2}{2g} + \Delta H_{1-2}$$

Check Delta H

	Delta H with info from model	Delta H with V according to mass balance	Differences model and mass balance	Unit
H CS1	4,250127421	4,250275564	0,000148143	m
Delta H CS 2	0,5	0,500275254	0,000275254	m
Delta H CS 4	2,300122324	2,300273182	0,000150857	m
Delta H CS 6	0,300095566	0,300238397	0,000142831	m
Delta H CS 7	0,500064985	0,500275511	0,000210526	m

Combining the findings

Velocity V According to Mass balance calculation

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	0,021317829	0,012820513	-0,016666667	-0,041666667	-0,073529
CS 2	0,14619883	0,063041765	-0,044444444	-0,090534979	-0,002469
CS 4	-0,006388889	-0,00210728	0,001996528	0,003292181	-0,006838
CS 6	0,03125	0,016326531	-0,007051282	-0,012765957	-0,027004
CS 7	0,03340081	0,014729951	-0,001538462	-0,014529915	0,0010256

Velocity V according to Svasek [m/s]

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	0,035	0,015	-0,02	-0,03	-0,05
CS 2	0,05	0,05	-0,02	-0,04	-0,05
CS 4	0,01	0,005	0	-0,005	-0,01
CS 6	0,032	0,017	-0,01	-0,015	-0,025
CS 7	0,035	0,018	-0,01	-0,015	-0,035

Difference V mass balance and Svasek [m/s]

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	0,013682171	0,002179487	-0,003333333	0,011666667	0,0235294
CS 2	-0,09619883	-0,013041765	0,024444444	0,050534979	-0,047531
CS 4	0,016388889	0,00710728	-0,001996528	-0,008292181	-0,003162
CS 6	0,00075	0,000673469	-0,002948718	-0,002234043	0,0020042
CS 7	0,00159919	0,003270049	-0,008461538	-0,000470085	-0,036026

Combining the findings

Discharge According to Mass balance calculation

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	3,612	1,872	-2,64	-3,6	-5,1
CS 2	2,052	2,538	-1,08	-1,944	-2,025
CS 4	0,72	0,522	0	-0,486	-0,702
CS 6	3,84	2,499	-1,56	-2,115	-2,9625
CS 7	3,458	2,1996	-1,3	-1,755	-3,4125

Discharge according to Svasek [m3/s]

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	2,2	1,6	-2,2	-5	-7,5
CS 2	6	3,2	-2,4	-4,4	-0,1
CS 4	-0,46	-0,22	0,23	0,32	-0,48
CS 6	3,75	2,4	-1,1	-1,8	-3,2
CS 7	3,3	1,8	-0,2	-1,7	0,1

Difference Q mass balance and Svasek [m3/s]

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	-1,412	-0,272	0,44	-1,4	-2,4
CS 2	3,948	0,662	-1,32	-2,456	1,925
CS 4	-1,18	-0,742	0,23	0,806	0,222
CS 6	-0,09	-0,099	0,46	0,315	-0,2375
CS 7	-0,158	-0,3996	1,1	0,055	3,5125

Combining the findings

Delta H According to Mass balance calculation

	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	4,3000232	5,200008377	5,500014158	5,000088487	4,2502756
CS 2	0,4989338	0,499805816	0,49991348	0,49967072	0,5002753
CS 4	2,3000211	2,300008151	2,300013955	2,300087934	2,3002732
CS 6	0,2999734	0,299994792	0,300011624	0,300080181	0,3002384
CS 7	0,4999663	0,499997319	0,500014037	0,500077726	0,5002755

Delta H According to Svasek

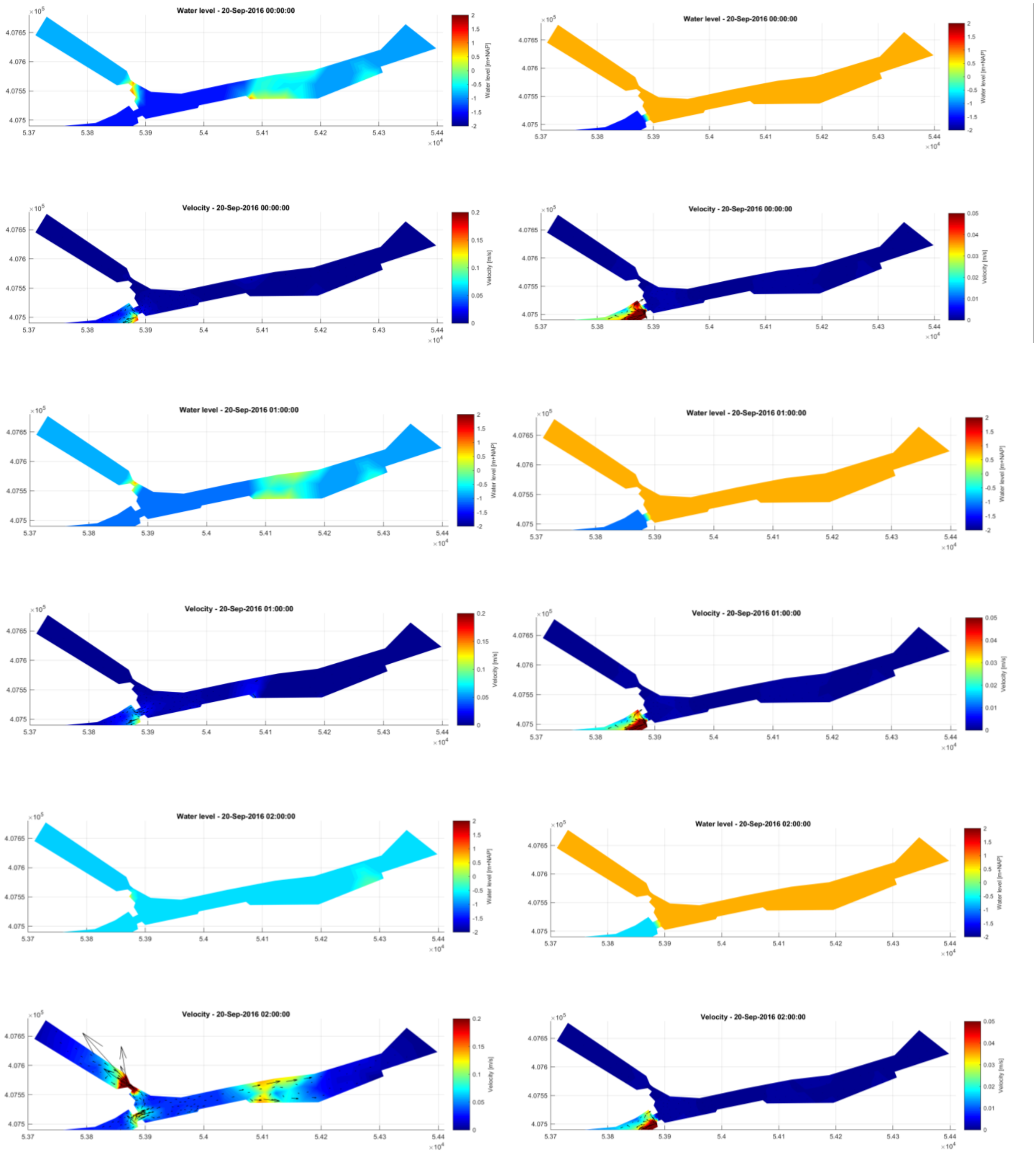
	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	4,3000624	5,200011468	5,500020387	5,000045872	4,2501274
CS 2	0,499935	0,499884047	0,5	0,499964322	0,5
CS 4	2,3000573	2,300010194	2,300020387	2,300044597	2,3001223
CS 6	0,3000102	0,299996738	0,300015291	0,300034404	0,3000956
CS 7	0,5	0,499994954	0,500015291	0,500034404	0,500065

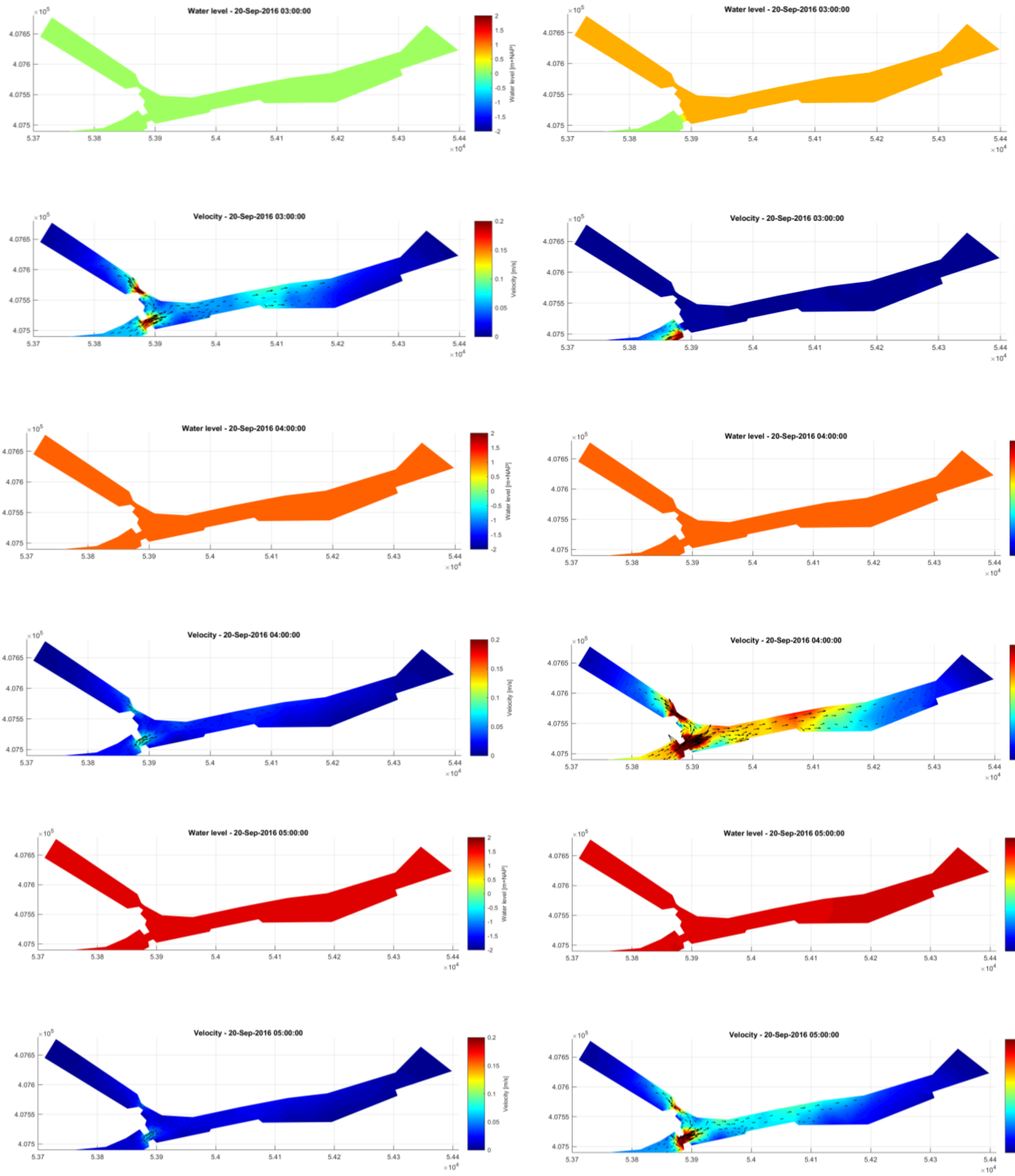
Difference Delta H mass balance and Svasek

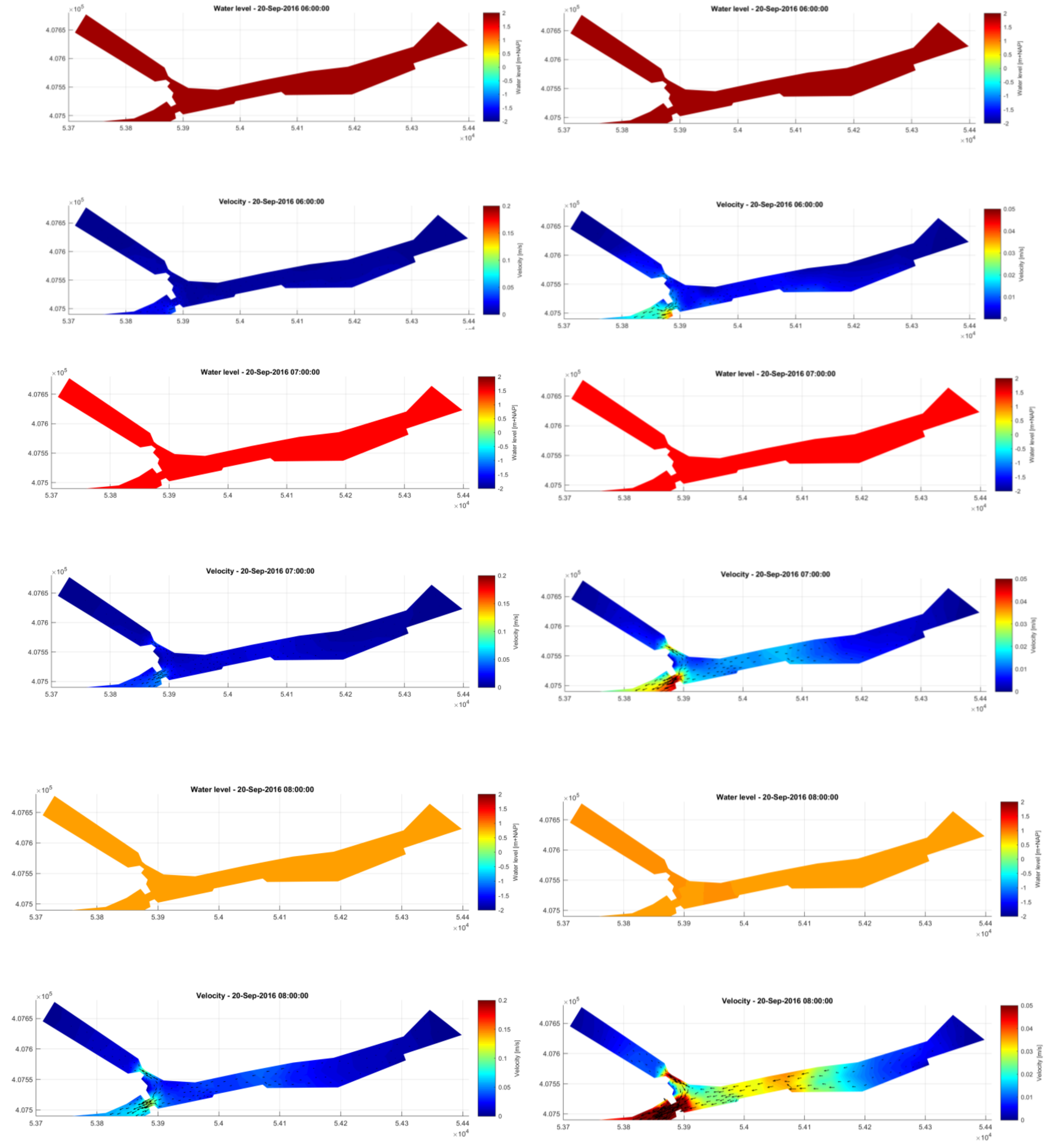
	Time 4:00	Time 5:00	Time 6:00	Time 7:00	Time 8:00
CS 1	3,927E-05	3,09044E-06	6,22947E-06	-4,2615E-05	-0,000148
CS 2	0,0010013	7,82313E-05	8,65204E-05	0,000293602	-0,000275
CS 4	3,626E-05	2,04256E-06	6,43264E-06	-4,3337E-05	-0,000151
CS 6	3,686E-05	1,94649E-06	3,66681E-06	-4,5777E-05	-0,000143
CS 7	3,37E-05	-2,36463E-06	1,25327E-06	-4,3323E-05	-0,000211

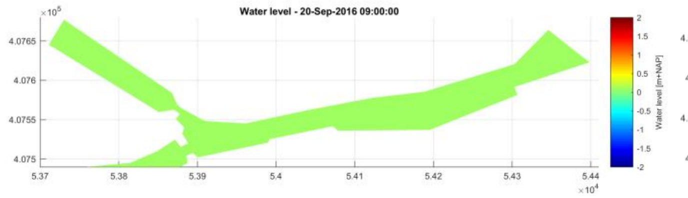
8.6.3 Figures water velocity and water levels in the harbor

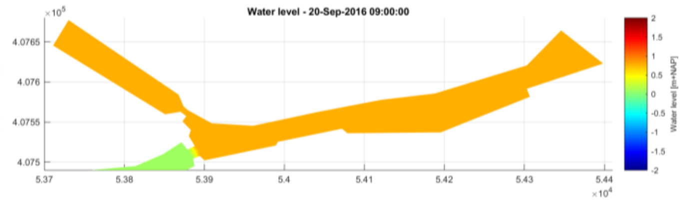
These maps were derived from the research of Sam Bom. (Bom, 2016)




Water level - 20-Sep-2016 03:00:00
Water level - 20-Sep-2016 03:00:00
Velocity - 20-Sep-2016 03:00:00
Velocity - 20-Sep-2016 03:00:00
Water level - 20-Sep-2016 04:00:00
Water level - 20-Sep-2016 04:00:00
Velocity - 20-Sep-2016 04:00:00
Velocity - 20-Sep-2016 04:00:00
Water level - 20-Sep-2016 05:00:00
Water level - 20-Sep-2016 05:00:00
Velocity - 20-Sep-2016 05:00:00
Velocity - 20-Sep-2016 05:00:00
Water level [m+NAP]
Velocity [m/s]


Water level - 20-Sep-2016 06:00:00
Water level - 20-Sep-2016 06:00:00
Velocity - 20-Sep-2016 06:00:00
Velocity - 20-Sep-2016 06:00:00
Water level - 20-Sep-2016 07:00:00
Water level - 20-Sep-2016 07:00:00
Velocity - 20-Sep-2016 07:00:00
Velocity - 20-Sep-2016 07:00:00
Water level - 20-Sep-2016 08:00:00
Water level - 20-Sep-2016 08:00:00
Velocity - 20-Sep-2016 08:00:00
Velocity - 20-Sep-2016 08:00:00
Water level [m+NAP]
Velocity [m/s]


Water level - 20-Sep-2016 09:00:00
Water level [m+NAP]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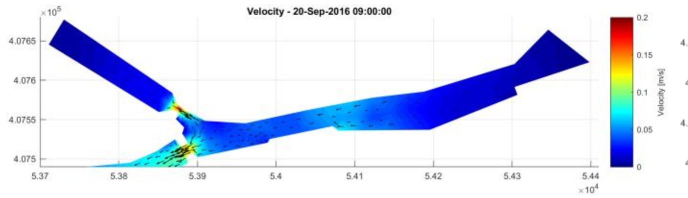
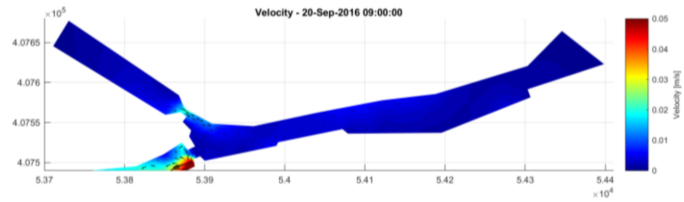
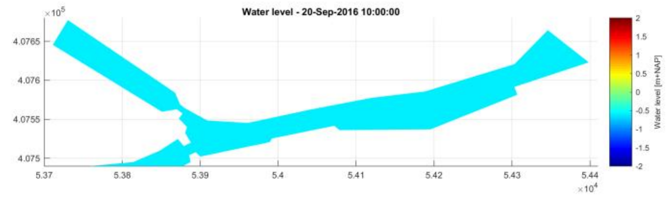
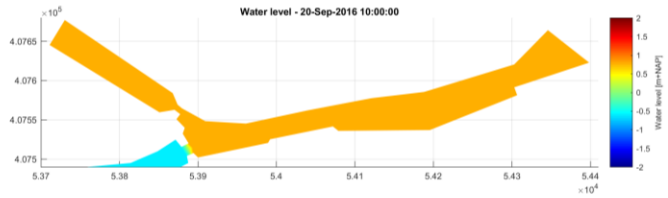
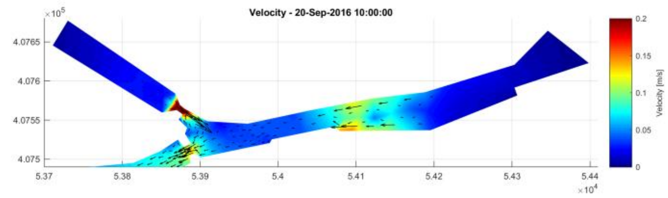
Water level [m+NAP]

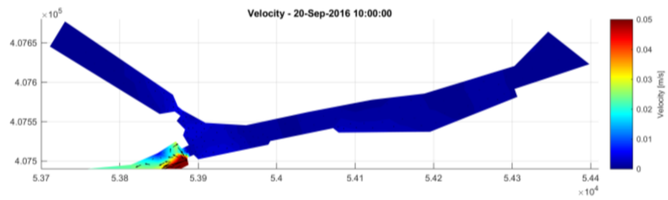

Velocity - 20-Sep-2016 09:00:00
Velocity [m/s]

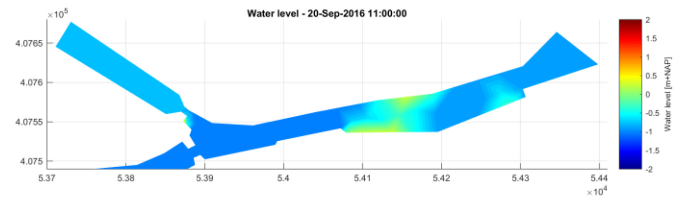

Velocity - 20-Sep-2016 09:00:00
Velocity [m/s]

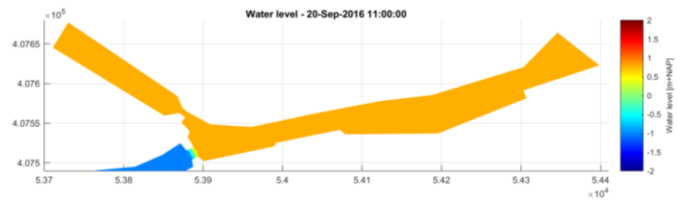

Water level - 20-Sep-2016 10:00:00
Water level [m+NAP]

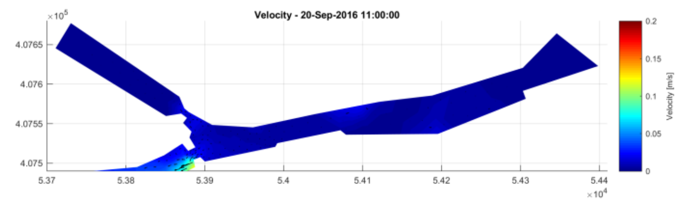

Water level - 20-Sep-2016 10:00:00
Water level [m+NAP]

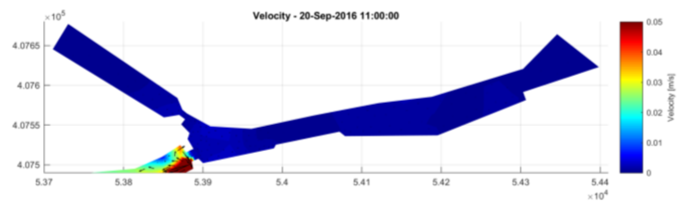

Velocity - 20-Sep-2016 10:00:00
Velocity [m/s]

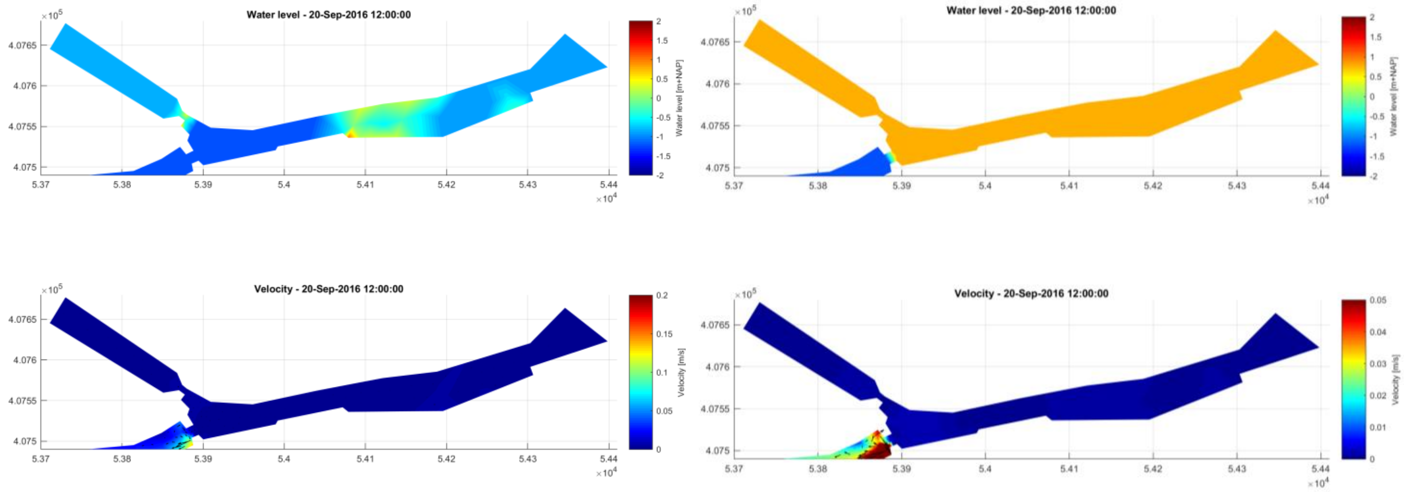

Velocity - 20-Sep-2016 10:00:00
Velocity [m/s]


Water level - 20-Sep-2016 11:00:00
Water level [m+NAP]


Water level - 20-Sep-2016 11:00:00
Water level [m+NAP]


Velocity - 20-Sep-2016 11:00:00
Velocity [m/s]


Velocity - 20-Sep-2016 11:00:00
Velocity [m/s]



8.6.4 Estimation water flow with pumping station ‘t Sas

This is a rough estimation, there was no data available on the exact inflow from the pumping station, the discharges differ largely per day and season. This estimation shows that there is water movement on the east side of ‘t Sas.

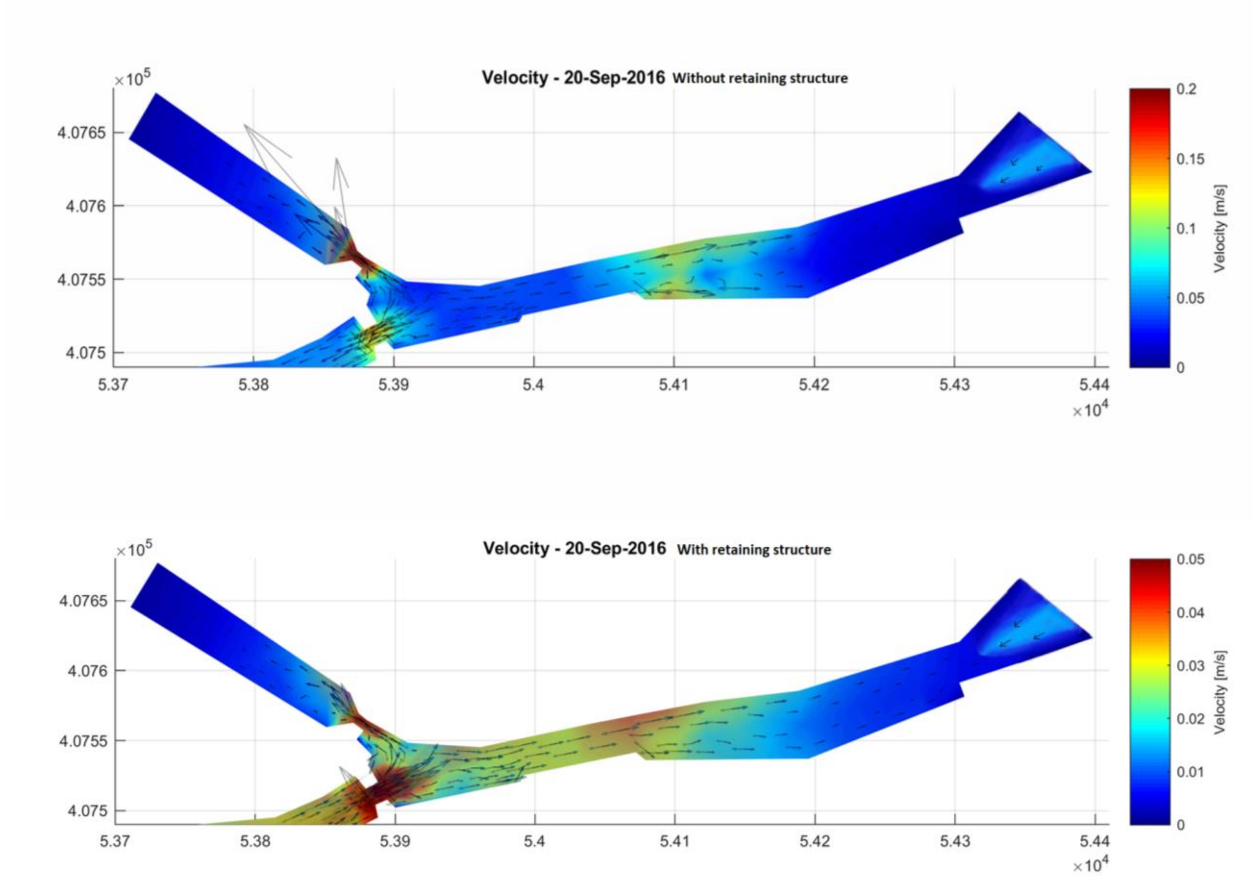


Figure 92 Estimation water flow including pumping station ‘t Sas.

8.6.5 Calculation Residence time

Data harbor Zierikzee		
Agerage chloride concentration	7420	mg Cl/L
Surface area harbor	24800	m2
Surface area Oude Haven	6950	m2
High tide	1,55	mNAP
Low tide	-1,3	mNAP
Average water level (old)	0,6	mNAP
Average water level (new)	0,8	mNAP
Average bottom level harbor	-1,85	mNAP
Current situation harbor Zierikzee		
Minimal water depth	0,55	m
Maximal water depth	3,4	m
Average water depth	1,975	m
Minimal volume	13640	m3
Maximal volume	84320	m3
Average volume	48980	m3
Current situation Oude Haven		
Water depth max Oude haven	4	m
Water depth min Oude haven	2,8	m
Water depth average Oude haven	3,4	m
Volume max Oude haven	27800	m3
Volume min Oude haven	19460	m3
Volume average Oude haven	23630	m3
Future situation with a minimal water level of +0,80mNAP harbor		
Minimal water depth	2,65	m
Maximal water depth	3,4	m
Average water depth	3,025	m
Minimal volume	65720	m3
Maximal volume	84320	m3
Average volume	72695	m3
Future situation with a minimal water level of +0,80mNAP Oude haven		
Minimal water depth	3,2	m
Maximal water depth	4	m
Average water depth	3,6	m
Minimal volume	22240	m3
Maximal volume	27800	m3
Average volume	24325	m3

Residence time		
Formula residence time	$T_f = \frac{VT}{(1-b)P}$	
Current residence time harbor		
R	2,85	m
P	70680	mr
T	12	hrs
b	0,2	[-]
Tf	**10,39474**	hrs
Current residence time Oude haven		
R	2,85	m
P	19807,5	m3
T	12	hrs
b	0,2	[-]
Tf	**17,89474**	**hrs**
Future residence time harbor		
R	0,75	m
P	18600	m3
T	4,5	hrs
b	0,2	[-]
Tf	**21,98438**	hrs
Future residence time Oude haven		
R	0,75	m
P	5212,5	m3
T	4,5	hrs
b	0,2	[-]
Tf	**26,25**	hrs
Differences in residence time		
Residence time entire harbor	**11,58964**	**[h]**
Residence time Oude haven	**8,355263**	**[h]**

8.6.6 Evaluation potential options to tackle the water quality problems

In the theoretical framework potential options are explained to improve the water quality. All optional options are discussed below with an argumentation whether the option would be suited for the harbor of Zierikzee.

8.6.6.1 *Reducing nutrient influx*

One way of dealing with the water quality problem is the reduction of the nutrient influx by means of water treatment. A treatment installation requires space and money. Because the city center of Zierikzee is small and has historical sights the water treatment installation does not fit into this picture. Furthermore, the costs of water treatment facilities are very costly and the water in the harbor remains stratified. Reducing the nutrient flux is not seen as a suitable manner to solve the water quality problem in the harbor of Zierikzee.

Oysters to filter the water

One oyster can filter up to 5 liters of water per hour. The oysters are of sufficient size at the age of 3 for consumption. The average oyster that is consumed has a length of 100 mm and 50 mm in length. (Oetser koning, 2017) In the present situation the total harbor water is refreshed in 13 hours. 384.923 oysters are needed to filter that 25.020 m^3 of water in 13 hours. 25.020*10^3 / (5*13) = 384.923 oysters.

When the oysters are used to filter the water, they will take up 1.926m^3. 384.923 *(0,1*0,05) =1.926 m^3. This is 1/13th of the total harbor.

Oysters are very sharp and reproduce fast, the seeds attach to hard substrate (Oetser koning, 2017). Boats are positioned in De Oude Haven. Sharp oysters might not be the most practical considering the function of the harbor.

The large volume the oysters will need and the physical characteristics of the oyster are negative characteristics for the water quality improvement measure.

Floating Treatment Wetlands (FTWs)

The FTWs have a positive effect on the total phosphor concentration (TP), the total nitrogen concentration (TN) and the pH. The result can be seen in Table 3. The bacterial and plant efficient to remove nutrients was substantially enhanced during the performance period. In the control period the nutrients were still being removed, this was due to some bacterial activity and solids that were settling down. The net removal rate by the FTW of the TN was 1,7 lb/yr/f3 and 0,54 1,7 lb/yr/f3 for the TP. (Floating Island International Inc., 2014)

The water is being filtered from TP and TN by the FTW's. This results in a decrease in eutrophication. However, the water is not moved. The water in the harbor will remain stratified. Another aspect of the FTW is that they have to be removed to remove the nutrients truly from the water system. If the FTW's are not removed the nutrients are only temporarily stored, when the plants die the nutrients are retrieved into the water system. Due to the fact that the water remains stratified, the water quality problem is only solved partially. Furthermore, De Oude Haven is a historical area where a lot of tourists come. The FTWs may look neglected and deteriorated. To maintain the FTW looking nurtures regular maintenance activities are needed.

Pontoon hula's and pole hula's

After nine months from the start of the experiment with the pole hula's the wet biomass of the Blue mussel varied between the 9 kg and the 203 kg. The reference poles without hulas had an average wet biomass of Blue mussels of 100 kg. (Paalvast P. , 2015) On average the biomass on the pole hulas was 4,4 to 11,4 times larger than compared to the reference poles.

The colonization on the ropes of the pontoon hulas was similar to that of the pole hula's. The density of the ropes related to the optimal biomass production was estimated at 4 to 8 ropes pet m2. (Paalvast, Wesenbeeck, Velde, & Vries, 2012)

Due to the experiments the conclusion could be made that the hulas enhance sessile biological production and biodiversity. This effect is likely to result in an increase in the water quality locally. (Paalvast P. , Application of string and rope structures, pole and pontoon hulas, to increase production and biodiversity in man-made hardsubstrate aquatic environments., 2015) However, the water remains stratified and the nutrients remain in the water system. The nutrients are only removed when the biomass on the ropes is removed and excluded from the system. The pontoon hula's and pole hula's do not cope with the all problem of the water quality.

8.6.6.2 *Destratification*

Aeration
The aeration methods used when there is a lack of oxygen. Aeration only influences the oxygen content, the nutrient content and the algae blooms are not influenced by the aeration. (Lorenzo, 1977)

The problem in De Oude Haven considers algae blooms in the summer, therefore aeration is not a suitable solution for the particular situation.

Mixing with water
With a high energy system, the lake can be de-stratified in order to control algal blooms. The algae will be redistributed throughout the water column, this limits the amount of light available for photosynthesis with as a result a reduction in productivity of the algae. The nutrients are less available in the water system. (Lorenzo, 1977)

In the harbor the eutrophication and algae blooms in the summer are problematic. Mixing the water column using water tackles both problems. The nutrient in the water system are not removed.

Flushing
In Amsterdam free discharge has been used for the refreshment of the water in the canals, When the water from the Ijmeer was 20 to 25 cm higher than that of the city the canals could be refreshed by using the pressure of the water, no pump was needed. (Baaren, 2010)

When there is a minimal water level in the harbor of Zierikzee the sluice doors are open when the water level in De Nieuwe Haven is higher than +0,80 mNAP. There is not sufficient water pressure to flush the water from the harbor. The harbor has to be flushed by means of a pump.

The flushing of the system removes the nutrients. The water is moved but that is no guarantee for the water to destratify. The flushing of the water reduces the algae blooms due to a reduction in nutrient availability.

8.6.6.3 *Conclusion*

By using arguments in the prior chapter whether the options are suited for improving the water quality in Zierikzee, the following was concluded.

There are three types of options that could be applied into the harbor:

- Destratification
  Destratification with water jets would tackle the eutrophication and algae blooms in the harbor.
- Flushing

The flushing of the system removes the nutrients. The flushing of the water reduces the algae blooms due to a reduction in nutrient availability.

- Combination of flushing the water and destratification

8.6.7 Alternatives to improve the water quality

Four alternatives were designed to safeguard the water quality in the Oude Haven. The alternatives are not technically developed into detail, it is about the type of alternative and how that would contribute to the water quality.

To restore the water quality four alternatives were designed. Each alternative contains a turbine. The turbine is a pump that helps the water in the harbor mix by producing an increase in water velocity. The increase in water velocity will make the water more turbulent, mixing the water.

Because of the historical environment, all the pipes of the different alternatives are designed out of side, underneath the road. The alternatives are similar but have their own way of functioning. The name of the alternatives indicate how the alternatives function and makes them more rememberable. Each alternative is discussed, in the end of the chapter the argumentation is given for the choice of the alternative.

8.6.7.1 *Alternative 1: XL Garden hose*

The first alternative entails the principle of a large garden hose. A pipe is positioned underneath the road, connecting the water from the Nieuwe haven with the water in the Oude haven. A turbine is installed within the pipe. The pipe in the Oude haven is connected to the quay wall and contains multiple holes that can be closed and two larger valves. A top view of the pipe is shown on Figure 93. Figure 94 shows more details of the pipe with the valves.

The XL garden hose will function in cycles, containing three phases. The turbine generates a powerful water flow through the pipe, from the Nieuwe haven to the Oude haven. The holes in the first part of the pipe are open and the first valve is closed. The water is flowing out of the pipe on the left side of the harbor. The second phase of the cycle is that the holes on the first part of the pipe are closed and the holes on the second part of the pipe are opened. The first valve is open and the second valve it closed. When the turbine is on, the water now flows from the end of the Oude haven toward the small bascule bridge. The third phase considers the last part of the pipe. The holes in the third part of the pipe are open and the holes of the first and second part of the pipe are closed, and all the valves are open. The water flow from the right side of the harbor. After the third stage the cycle starts from the beginning. The cycles are shown in Figure 95.

Due to the different cycles the construction creates the opportunity to mix the water due to multiple water movements. The valves that generate the cycles are however sensitive to maintenance, just as the 460 m long pipe.

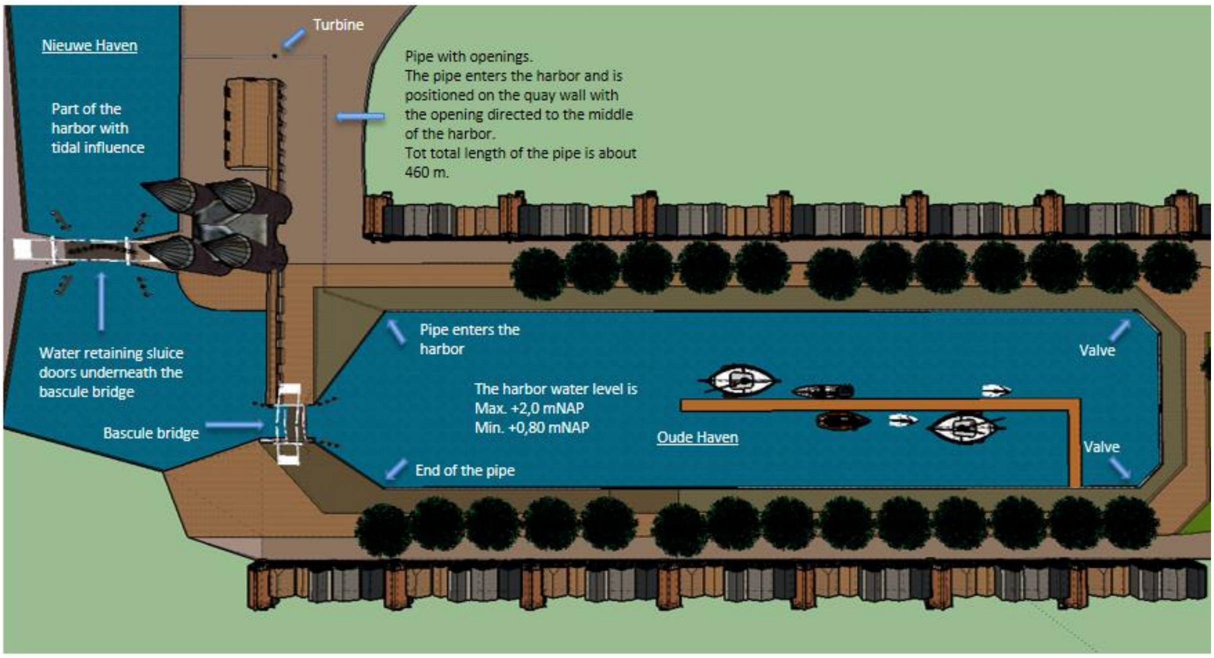


Figure 93 Top view alternative 1: Pipe with openings

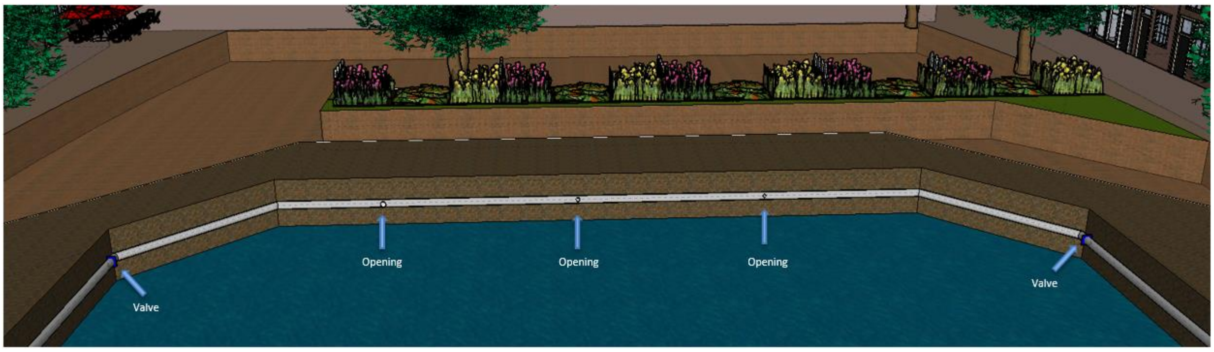


Figure 94 The valves and openings on the east side of alternative 1: Pipe with openings

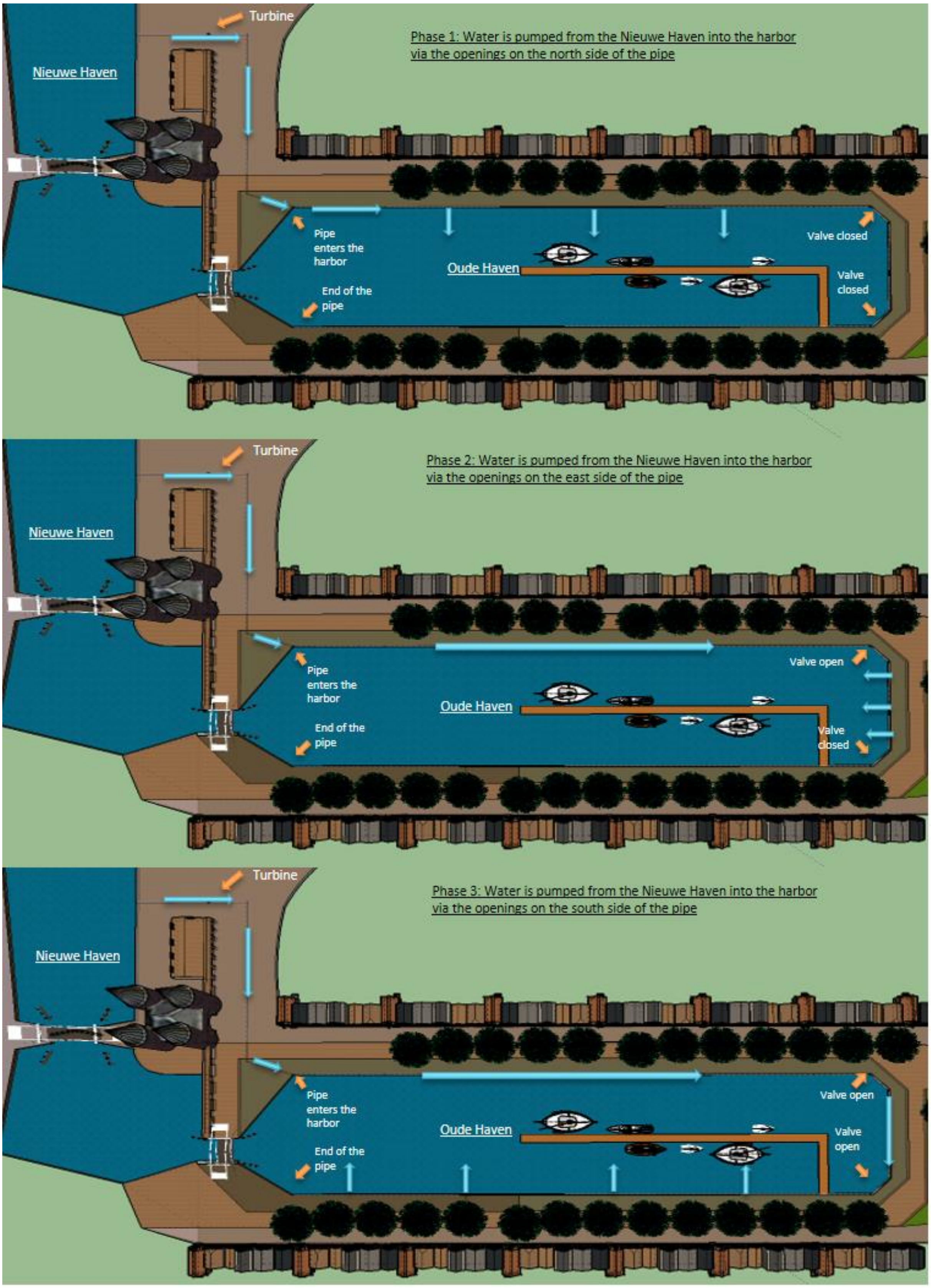


Figure 95 Schematization of how Alternative 1: Pipe with openings functions

8.6.7.2 *Alternative 2: Fountain*

With the thought in mind that the municipality would like to improve the city and make it more attractive, a fountain was designed. The fountain is placed on the end of De Oude Haven. The fountain consists of four frogs that sit on the side of the harbor, on the quay wall. A central fountain shaped like a “Zeeuwse knoop” is positioned in the water. In the part behind De Oude Haven there is a fountain with frogs on it, to make the area more cohesive the frogs were chosen to be placed in the fountain in the harbor. The Zeeuwse knoop a characteristic item for the history of Zeeland. To make the fountain the shape of the Zeeuwse knoop would remind people of the historical background of the area.

The fountain is connected to a pipe that leads to the Nieuwe Haven, the part of the harbor that is influenced by the tide. A turbine will produce a water flow through the pipe and make the fountain functional. The total length of the pipe from the Nieuwe Haven to the place where the pipe is split is approximately 290 meters. On Figure 96 a top view is shown of the construction. Figure 98 shows how the fountain would function.

The physical appearance of the fountain would improve the image of Zierikzee and reconnect the city to the water, as said to be a goal in the Masterplan. On Figure 97 the physical appearance of the fountain is shown. Because the water is “rain bowed” into the harbor the fountain would be likely only to refresh the upper layer of water in the harbor.

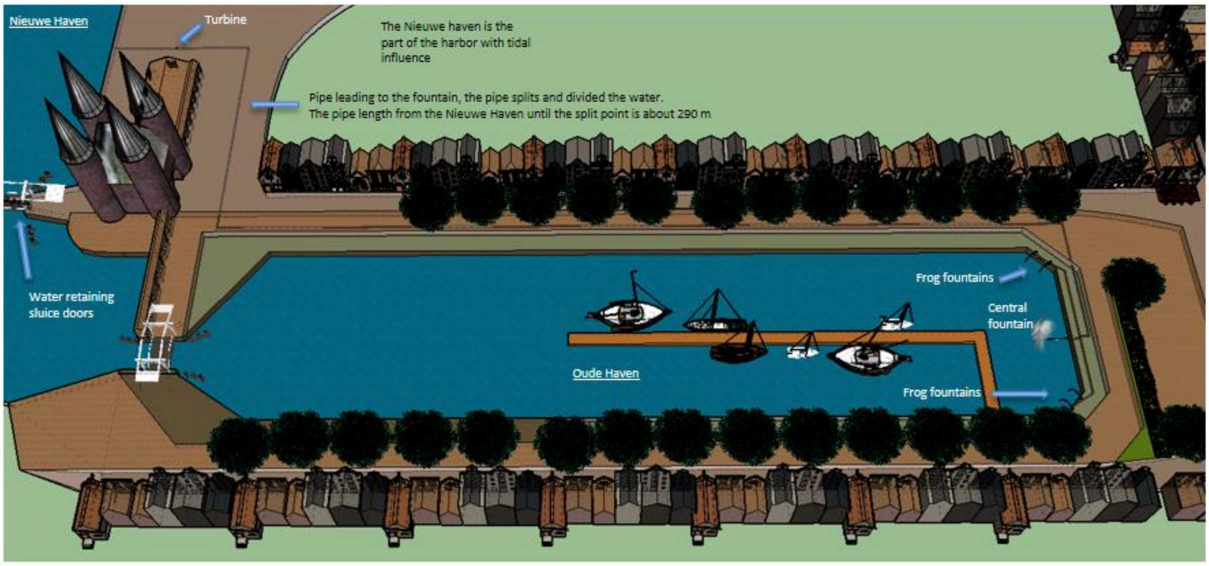


Figure 96 Top view Alternative 2: Fountain

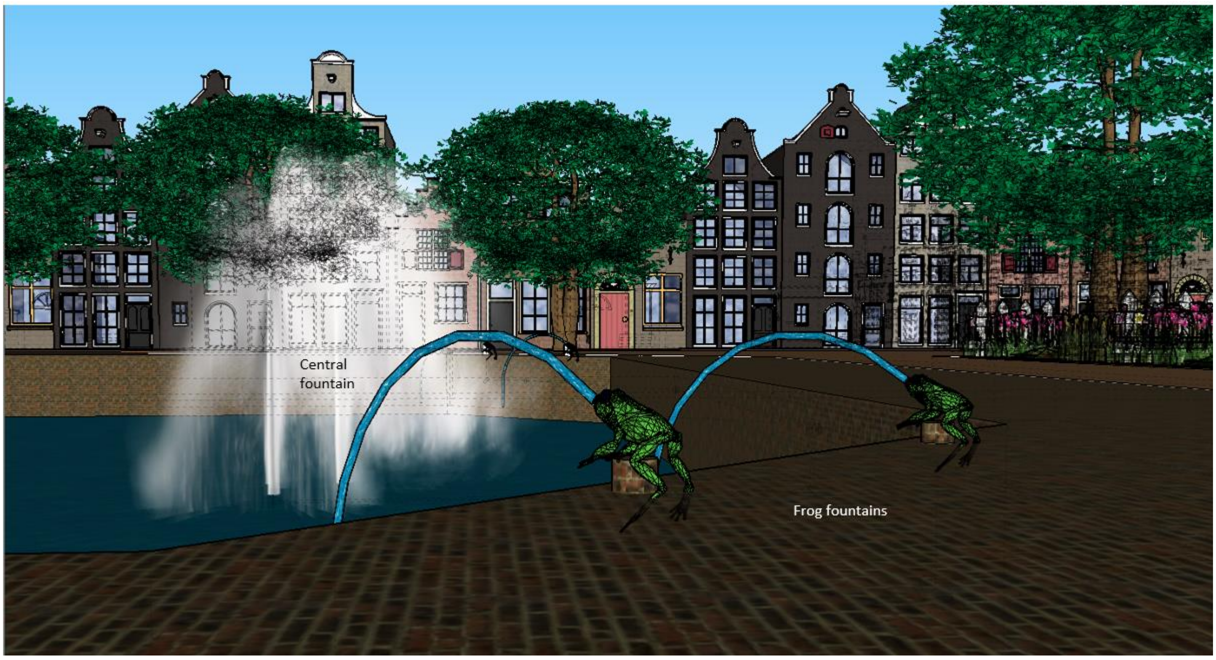


Figure 97 Alternative 2: Fountain vision

Figure 98 Schematization of how Alternative 2: Fountain functions

8.6.7.3 *Alternative 3: A short pipe*

Just in front of the sluice doors the pipe is connected to the tidal zone. The pipe is constructed underneath the road and enters De Oude Haven. When the pipe has entered De Oude Haven it makes a bend in the direction of the park, the pipe has an adjustable nozzle. The nozzle is meant to optimize the angle at which the water flows into the harbor. The angle influenced the mixing efficiency. To make the layout of alternative 3 more clear Figure 99 is given, the circle on the figure indicates the location of Figure 100. Figure 100 shows the inlet of the pipe into the harbor. Figure 101 shows a schematization of how alternative 3 functions.

The turbine pumps the water through the pipe, pushing the new water toward the back of De Oude Haven. The water flow into the harbor will power a circular water flow through De Oude Haven. The total length of the pipe is approximately 95 meters.

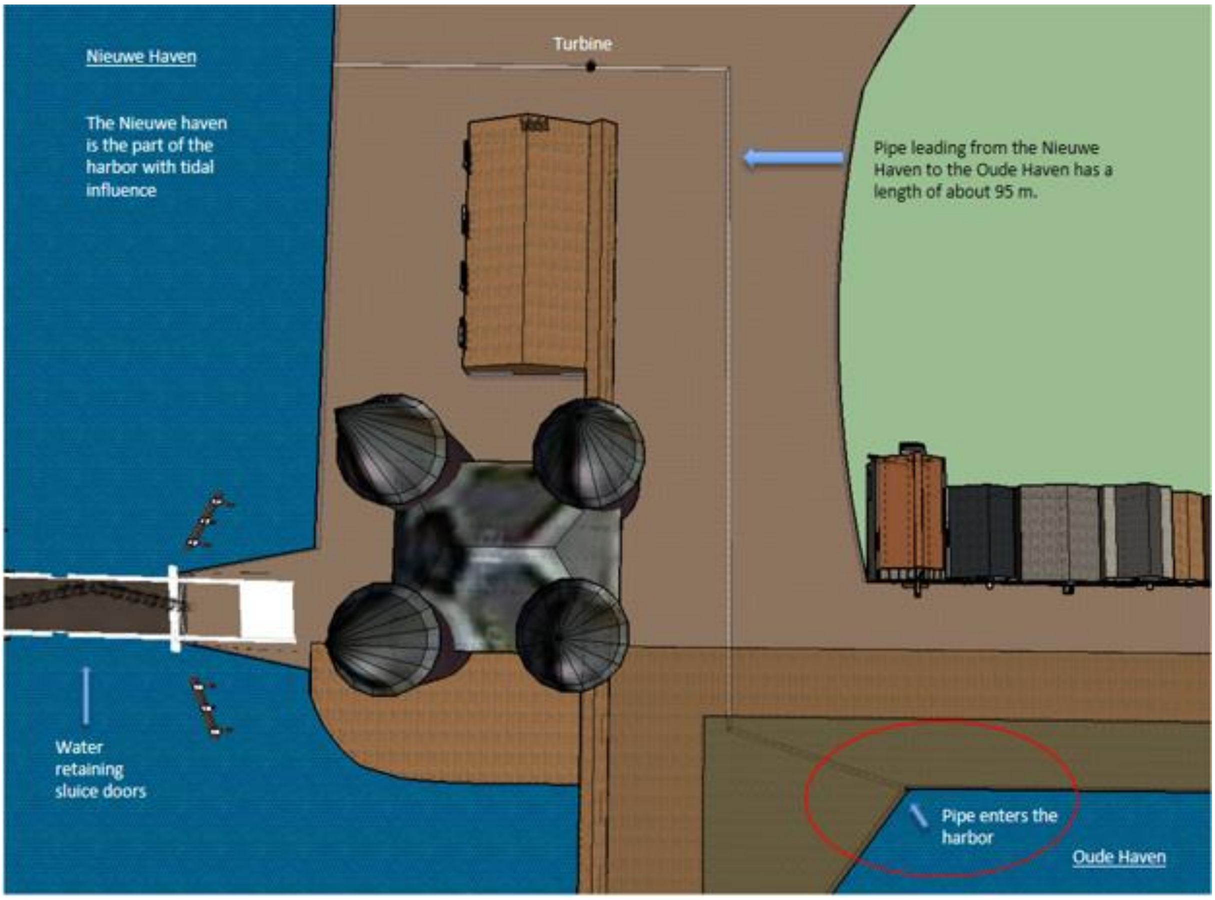


Figure 99 Top view Alternative 3: A short pipe

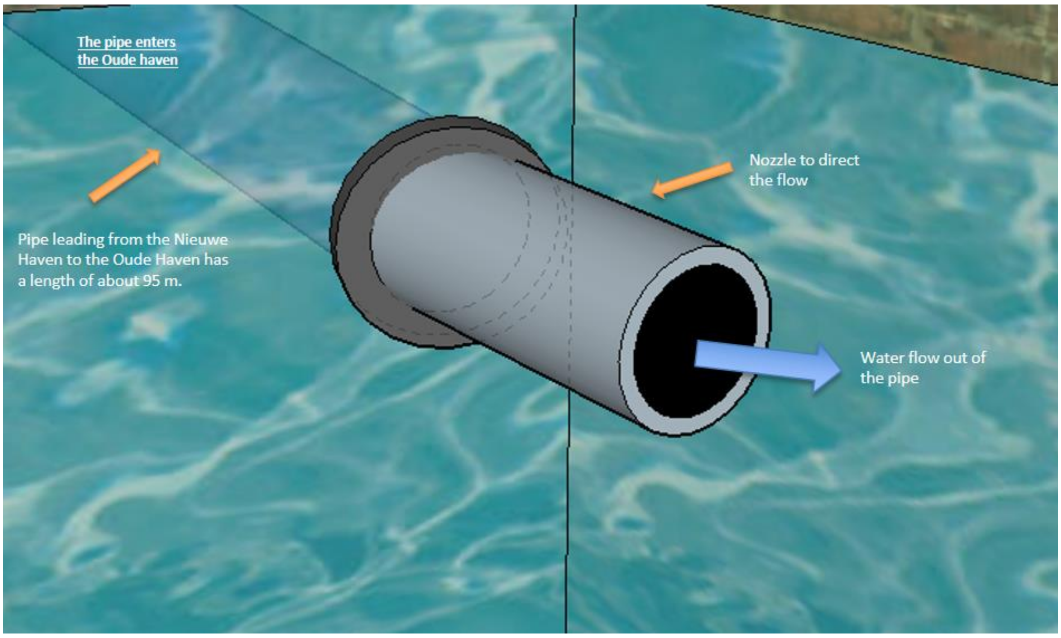


Figure 100 Alternative 3: short pipe, inlet into the harbor

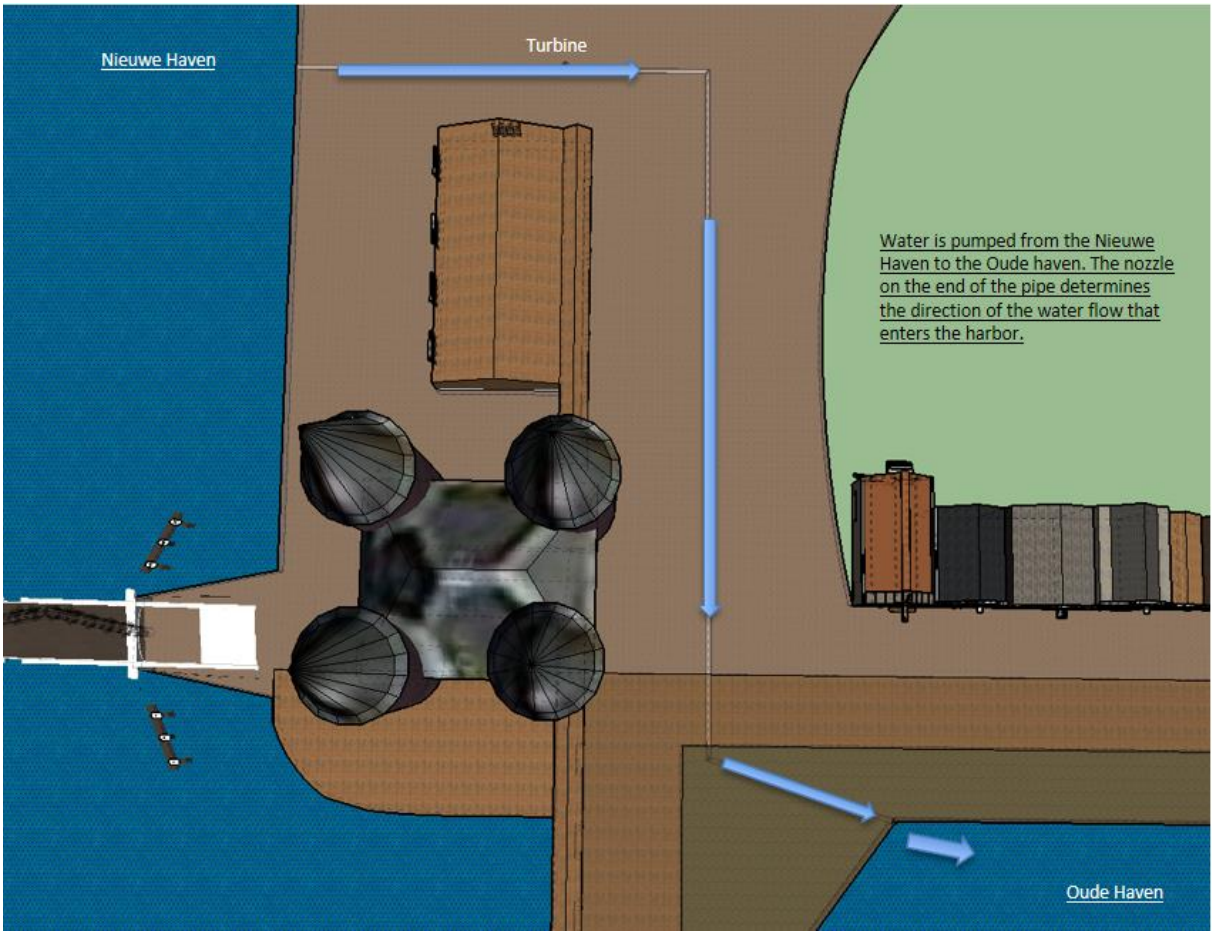


Figure 101 Schematization of how Alternative 3: A short pipe functions

8.6.7.4 *Alternative 4: Turbine*

A turbine within the harbor is positioned to generate a water flow. The water will be mixed due to the turbine. Water from the harbor flows into the turbine via the lowest pipe, the turbine adds power to the water and provides an increase in water velocity, the water exits the turbine into the harbor via the top pipe. A nozzle will be placed on the inlet and outlet of the turbine to change the angle of the water flow, optimizing the mixing of the water. The water in the harbor is mixed by means of turbulent flow produced by a turbine.

Figure 102 provides insight on where the turbine would be positioned.

Figure 103 Provides a better understanding of how the turbine would function.

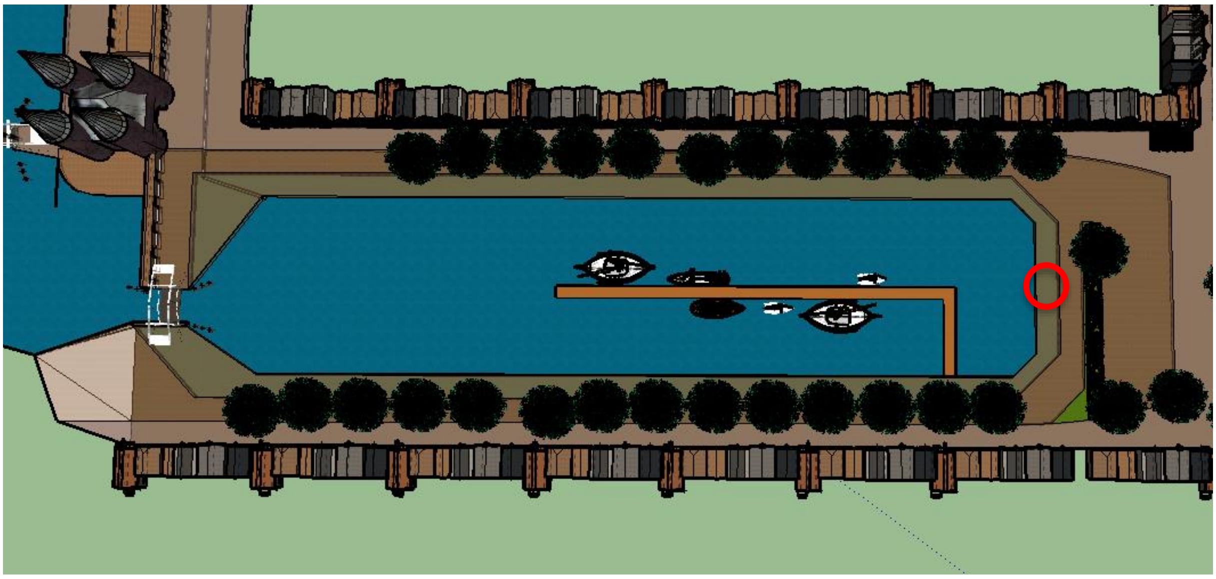


Figure 102 Alternative 4: Turbine, Perspective of the location indicated by the red circle

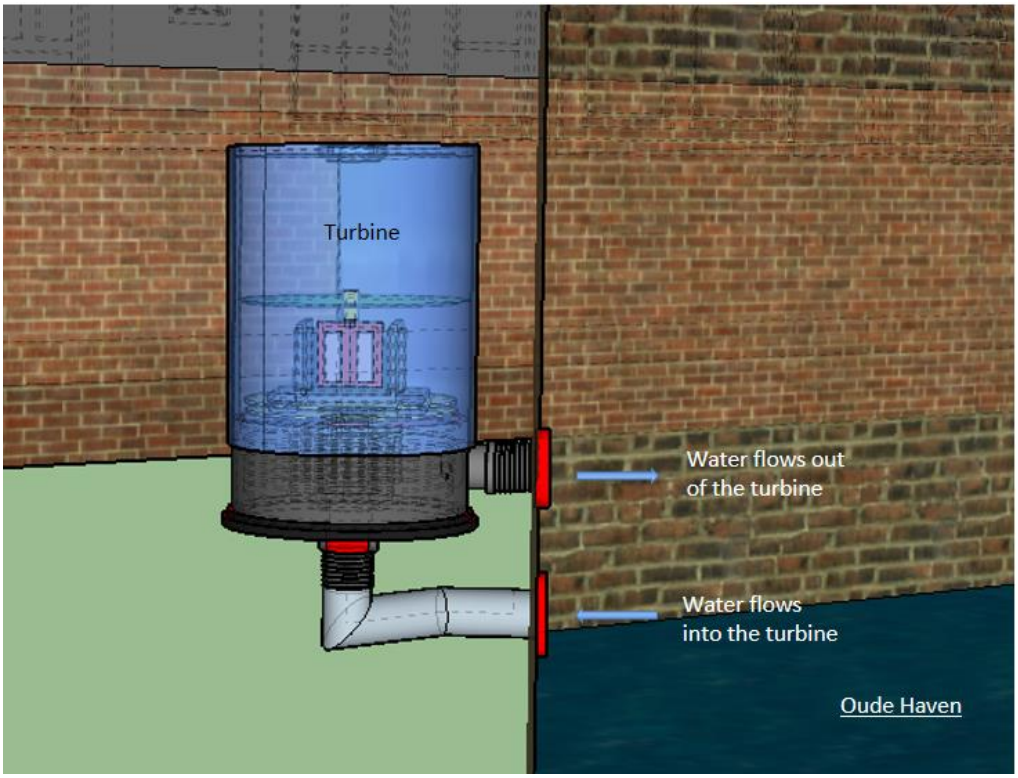


Figure 103 Side view alternative 4: Turbine

8.6.8 Argumentation alternative

In order to make a choice in which alternative is found most suitable for the situation two aspects were considered. The way how the alternative mixes the water is considered and the mix efficiency. The way the water is mixed influences the efficiency of the construction. The other aspect is the length of the pipe. The longer the pipe, the higher the construction costs, maintenance and the disruption to the environment.

8.6.8.1 *Alternative 1: XL garden hose*

The pipe with three outlet areas has the ability to mix the water by pumping water from different directions. The pipe has multiple valves. These valves cause an increase in maintenance activities and costs. Also, the pipe is approximately 460 m long, this would result in an increase in construction costs.

8.6.8.2 *Alternative 2: Fountain*

The pipe that leads from the Nieuwe Haven to the fountain has a length of 290m. The fountain will likely only refresh the top layer of the water. The lower layers remain the same. The water refreshment would not be executed over the total water column. This alternative will not be chosen for this reason.

8.6.8.3 *Alternative 3: A short pipe*

The short pipe has no valves, this reduces the maintenance activities. The pipe length is approximately 95 m. Compared to the fountain and the xl garden hose this alternative has the least long pipe. The water that is pumped in the harbor will generate a circulation of the water, resulting in mixing. The angle of the water flow can easily be optimized by changing the nozzle.

8.6.8.4 *Alternative 4: Turbine*

Alternative 4 has no pipe. This reduces the costs, disruptions and maintenance activities. The water is mixed due to the flow that is created. Making the nutrient less available and preventing stratification of the water.

8.7 Minutes of the meetings

8.7.1 Minutes 07-02-2017, M. de Bruine, L. Kaan, E. Zaman

Subject: Research proposal
Location: Gemeente Schouwen-Duivenland, Zierikzee
Date: 07-02-2017
Time: 9.00 – 10.30
Present: Marco de Bruine, Leo Kaan, Eddy Zaman and Iris Zijlstra

Research Leo Kaan
Leo has done research on what the new minimal water level should be. To achieve a minimal water level, he designed a set of sluice doors. The water retaining sluice doors will be located under the bascule bridge.
From this research a minimal water level of +0,80 mNAP has been derived.
The water depth was calculated with a 2,70 m immersion of the ships. During high tide the water will flow over the sluice doors. At high tide 62 cm of water will flow over the doors and will be refreshed 12 hours and 54 minutes a day.
The quay walls next to the sluice doors have valves as an option. This is to enable fish migration and more refreshment of water if needed.

Research TU Delft
A student of the TU Delft has done research on creating a minimal water level in the Oude haven. This could be a useful report.

Pumping station
There are two pumps that have a capacity of 110m3/s. The pumps can lift the water up to 2,5 m. It is not efficient to pump larger elevations than 2,5 m. The pumping station will not be adjusted due to high costs. The pumps undergo regular maintenance.

Main-question: ***"How can the chemical water quality, focusing on oxygen, and the ecological water quality, focusing on fish migration, in the harbors "De Oude Haven" and "'t Sas" in Zierikzee be secured when a minimal water level is created by a water retaining structure on the location***
of the double bascule bridge?"

- The main-question now exists of two separate questions.
- Use instead of water quality the requirements for the water quality (water kwalitatieve randvoorwaarden). The requirements will be explained in the sub-questions.
- Say harbors instead of the harbors "De Oude Haven" and "'t Sas".

Sub-question:
Connect sub-questions to the main-question. Create 3 sub-questions:

- In relation to the current situation
- In relation to the oxygen concentration
- In relation to the fish migration

Scope
Use Leo's research as a basis for the research project. In the foreword this has to be clear, so you don't have to include it in the main and sub-questions.

Stakeholders

- The proper water quality status when a minimal water level is created in the harbors has to be proven to Rijkswaterstaat in order to obtain permits.
- The province of Zeeland will be concerned with the water quality in the harbors, they might also have information about the harbor in relation to the water quality.
- The water board Scheldestromen finds fish migration an important issue in this project.
- People in the region notice the harbors fall dry, this is not a pleasant sight. When the pump discharges its water into the harbor at low tide the water becomes very turbid.

Possible solution
The rainwater is being collected separately. This water could be used to create more water refreshment.

Actions Iris:

- Rewrite main and sub-questions
- Write a clear scope
- Ask TU Delft research report on the Oude haven
- Contact the province of Zeeland
- Contact Rijkswaterstaat (Jan Boot)

8.7.2 Minutes 17-02-2017, J. Heringa

Subject: Water quality simulation
Location: HZ University of Applied Science
Date: 17-02-2017
Time: 13:00
Present: I. Zijlstra and J. Heringa

Question: What would be the most suitable program to simulate the harbors?
Sobek would be the most suitable program to simulate the harbors in because of the salt water, also because of the water quality aspect of the project.

Question: What data is needed to make a simulation?
The surface area of the harbors, the water depth, the structures and the tidal influence is the first data that can be put in. Salt concentration and nutrient concentration can be added later.

Question: What would be the first step in making the model?
The first thing to do is make a simple stream model of the harbor. The salinity has to be measures in the harbor at different placed. This is to see how the salt dynamics goes. This data could be calibrated based on the data of Rijkswaterstaat from the Oosterschelde. The salt data needs to be put in the basic model.
From that basis the model can be made more complex.

Actions:

- Start to collect data about the harbor
- Measure the salt content in the harbor
- Build a simple Sobek model

- Contact Alco Nijssen for further in-depth Sobek information

8.7.3 Minutes 20-04-2017, M. de Bruine, L. Kaan

-
Subject: MCA fish passages
Location: Zierikzee
Date: 20-04-2017
Time: 10:00
Present: M. de Bruine, L. Kaan and I. Zijlstra

Iris has explained all the eight alternative fish passages to help Marco and Leo understand them, the criteria and the process of how the alternative fish passages were judged.

The indicators for the aesthetics criteria were discussed. The size of the construction is according the municipality of the most importance.

The term “continuity” was not clear enough. The term did not express the total content of the criteria. The term “accessibility” would be more suited for the criteria.

Marco asks, “Why were the costs not used as a criterion?”. Iris explains that the water board has advised to focus on the functionality of the construction. The reason for this is that the costs are very hard to calculate. The costs do not provide a good indicator because the unforeseen aspects reflect largely on the costs. It is therefore not accurate.

To the “neglected criteria” should be added why the costs are not a criterion and that the neglected criteria are not taken into account in the MCA.

In the conclusion of the MCA it would be nice to have a very distinct difference in total score of the alternatives. This reduces the chance of discussions. The total scores of the alternatives could be compared to the maximum score that can be achieved. This provides a clearer perspective on “how suitable” an alternative fish passage is.

Marco and Leo find the MCA clear and well explained. The 3D drawings make everything easily to understand.

Actions:

- Marco: Send ground research for the quay walls to Iris.
- Leo: Send the report of the presentation Leo has given last week to Iris.

8.7.4 Minutes 09-03-2017, P. Hopmans, B. Verkruysse

Subject: Intervision thesis
Location: HZ University Applied Science
Date: 09-03-2017
Time: 14:00
Present: Peter Hopmans, Bram Verkruysse, Iris Zijlstra

Iris tells about her progress in the project. Deltares has been contacted in order to assist with Sobek water quality. At the HZ there are no teacher that are familiar with Sobek water quality. Until Deltares has answered the questions the Sobek model cannot be made further.

Data from the Oosterschelde was collected from that Rijkswaterstaat database. The data from the pumping station and polder will be provided by the water board.

The past week the MCA and the options for the fish passage have been worked out in detail. There are four options to make the fish migration possible: a current situation, a De Wit fish passage, a Poppekinderen fish passage and a Maelstade fish passage. These options have been worked out in Sketchup drawings. One option has yet to be designed, this is the option in which the "leaking" pipe will be adjusted in the pumping station.

Bram advices to write the indicators for the criteria of the MCA. The indicators have to be clear so there is no doubt about the choice.

Two MCA's will be written, one for the fish passage and one for the improvement of the chemical water quality. The scores for the options of each MCA will be calculated. In a tree diagram the combination of the measures will be shown and a choice will be made for the best combination of measures.

Actions:
- Writing indicators for MCA criteria
- Thinking of a framework in which the two MCA's will be combined

8.7.5 Minutes 13-03-2017, M. Bil

Subject: The requirements and wishes of the Province of Zeeland
Location: Province of Zeeland, Middelburg
Date: 13-03-2017
Time: 14:00
Present: Michiel Bil (Province of Zeeland), I. Zijlstra

Contact information Michiel: 06-28904028 and ma.bil@zeeland.nl

What are your predictions for the water quality when a minimal water level is created?
Michiel expects water quality problems in the future. The water coming into the polder could contain the dinoflagellate Alexandrium Ostenfeldii. This dinoflagellate results in toxic waters. A dog died after being in the polder water that contained the Alexandrium Ostenfeldii dinoflagellate for less than a minute. Water board Scheldestromen has done research on the dinoflagellate. (Action)

The water will be less refreshed, this could result in algae blooms. The water in 't Sas will still be moving, the water in the Oude haven however will become stagnant. Michiel expects the worst water quality problems to appear in the Oude haven. At Rijkwaterstaat there are skilled people that continually work on modeling water quality. They could help with the Sobek model. (Action)

Michiel expects that the water in the harbors would remain brackish because of the incoming seepage. (Action)

Michiel asks if there are overflows of the sewers systems that are connected to the harbor. (Action)

The water quality will not meet the requirements for swimming water. This is because it is a harbor, boats discharge their tanks in this water. Michiel advices that the development of the harbor should not suggest the harbor contains swimming water. For example, in Middelburg there is a stairs into the harbor, making it very easy for people to enter the water, suggesting people can swim there. This will result in people swimming there. The consequence could be a large fine for the municipality.

For the fish migration there are two obstacles. Valves in the sluice door or in the wall of the harbor could function as by-pass for the fish.

How would the province like to see the harbors of Zierikzee develop in the future?
A maintained or improved water quality and sustainable development.

Has the province requirements for the development of the harbors?
The water quality has to meet the EFWD requirements by the year 2021. The fish have to be able to migrate, otherwise the requirements of the EFWD will not be met.

The harbor water falls under Rijkswaterstaat jurisdiction. Rijkwaterstaat considers the water quality and the water quantity of the harbors.

Has the province wishes for the design of a construction?
A sustainable, long-term construction. Allowing fish migration.

What would be a "No go" as a development for the harbors?
A no go for the project would be a decrease in water quality. The European Water Framework Directive aims at a good water quality for all water bodies by 2021, reducing the water quality this goal will not be met.

How would the province want to be included in the project in the future?
The province would like to be kept up to date on the project. An email to Michiel containing information with the status of the project would suffice. Michiel will be the contact person at the province for this project.

Actions:
- Ask the water board about the dinoflagellates in the polders. (Action Iris)
- Finding out if there are overflows of the sewers systems that are connected to the harbor. How often do they overflow and what substances will be discharged into the harbor? (Action Iris)
- Find out how much seepage will enter the harbors and what nutrients the seepage contains. (Action Michiel)
- Contact Thijs Poortvliet about who at Rijkswaterstaat could help with the Sobek water quality model. (Action Iris)

8.7.6 Minutes 15-03-2017, M. Schipper

Subject: Requirements and wishes Waterschap Schelderstromen
Location: Middelburg
Date: 15-03-2017
Time: 8:00
Present: Maurits Schipper, I. Zijlstra

Contact information Maurits: Maurits.Schipper@Scheldestromen.nl, 088-2461266

What are your predictions for the water quality when a minimal water level is created?
Because the nutrient rich water will continuously be discharged into the harbor and there will be less water movement, the water will decrease in water quality. In brackish waters it is more likely to achieve a "dead" water zone. This water is often black and smells. There is the risk of this happening in the Oude haven.

There will be costs in relation to the changes to the system. How high will the costs be and who is paying? Think about long and short-term costs. (ACTION)
The water board provided permits to construct in their jurisdiction area. The permits have consequences to Rijkswaterstaat so they will need to discuss the situation.

The catchment areas of the pumping stations are linked. If one falls out the others can step in when needed. There is an automatic check system for the pumping stations. There are also regular inspections of the pumping stations.

The long-term consequences of a minimal water level need to be researched, over the whole system. In the model the hinterland also needs to be considered.
During the winter periods the agricultural land may be flooded. In the polder there are some natural banks present. The quay walls do not have priority for Scheldestromen.

How would Scheldestromen like to see the harbors of Zierikzee develop in the future?
In the future water will be stored more in the ground. There will be a shift in water management strategy, from optimal technical control over the water to a more laid-back approach in which is dealt with what nature provides the system.

Has Scheldestromen requirements for the development of the harbors?
Scheldestromen has no specific requirement for the development of the harbor.

Has Scheldestromen wishes for the design of a construction?

- The banks of the harbors lie within the "waterstaatwerk" zone. This means it is preferred not to build new constructions there. However, this could be discussed with Scheldestromen and RWS.
- A sustainable construction.
- A solution could be to prevent a dead zone in the Oude haven is the flushing of the harbors by means of discharging the rain water into the harbor.
- For children and schools an open fish passage may be interesting.

What would be a "No go" as a development for the harbors?
A "dead zone" needs to be avoided.

How would Scheldestromen want to be included in the project in the future?
The water board would like to be kept up to date and involved when making decisions in the project. A hydrologist could take a look at the hydraulic model of the harbors. (ACTION)

Actions:

- Find out how high the costs will be. Also think about who is willing to pay what, consider long and short-term costs. (Action Iris)
- Contact hydrologist (Action Iris)

8.7.7 Minutes 20-03-2017, A. de Munnik, C. van der Linde

Subject:	Wishes Association Stad en Lande
Location:	Zierikzee, Café Concordia
Date:	20-03-2017
Time:	11:00
Present:	Anita de Munnik, Cor van der Linde, I. Zijlstra

Contact information Anita: ademunnik72@gmail.com
Contact information Cor: f2hclvanderlinde315@hetnet.nl

How would Stad en Lande like to see the harbors of Zierikzee develop in the future?
Stad en Lande wished to maintain the historical look and character of Zierikzee. Especially the eye catch objects have to be in the historical style.

In 1991 there was a plan to close off the Oude haven by means of a dam. However, this was unsuccessful because sediment was scoured away from underneath the dam.

Has Stad en Lande requirements for the development of the harbors?
Association Stad and Lande does not set requirements because it is an association. Stad en Lande only provides advice on projects.

Has Stad en Lande wishes for the design of a construction?
The construction has to match the environment. An idea could be to cover the construction with for example bricks identical to those of the quay wall. The bricks make the construction less noticeable, blending with the environment.

What would be a "No go" as a development for the harbors?
An object that does not match the environment and is an obstruction for the view. An example would be a huge futuristic construction.

How does Stad en Lande make decisions?
Stad en Lande consists of multiple commissions and the administrational body. Each commission deals with a certain theme. The commission discusses the matter and reports the outcome as an advice to the administrational body. The administrational body makes the final decision.

This project will be covered by the commission of monuments or the commission of spatial planning.

How would Stad en Lande want to be included in the project in the future?
Stad en Lande would like to be kept informed about the project.

8.7.8 Minutes 30-03-2017, M. van Wingerden

Subject:	Designing fish passages, water board Scheldestromen
Location:	Water board Scheldestromen, Middelburg
Date:	30-03-2017
Time:	11:00
Present:	Marius van Wingerden (Water board Scheldestromen), I. Zijlstra

Contact information Marius: 06-53848816 and Marius.vanWingerden@scheldestromen.nl

Is there a maximum flow velocity for free flow in order to reduce stress?
When using a free flow in a fish passage there is no set limit for the maximum flow velocity. However, Marius advices to keep the flow velocity under 4 m/s. It is not about reducing the stress level of the fish, what is important is that the fish will survive the fish passage. Important is that are gentle angles used for the bends of the pipes.

Write an explicit description of the current situation, what would change if there were a minimal water level and how a fish passage would influence the situation. (ACTION)

Describe the different obstacles that the fish have to overcome. (ACTION) The primary defense sluice is the first obstacle the fish have to overcome, the sluice doors will only slow the fish down.

Are there guidelines for the design of a fish passage?
It would be nice to consider the flounder larvae in addition to the three-thorned stickleback and eel.

The water board uses in a pipe diameter of 200 mm for the pipes in fish passages. This has proven to be working well. When a pipe is to small the reconstruction will cost much more than an over dimension.

The attraction flow needs to be positioned perpendicular to the overall water flow. The water velocity of the attraction flow is 0,1 or 0,2 m/s, the fish have to be able to swim against is. The most difficult part is to attract the fish to enter the fish passage.

Think about where the fish will gather. The entrance of the fish passage should be close to that area. The fish will gather in front of the pumping station because of the strong water flow.

The materials need to be able to cope with the salt in the water. Think about thick coatings and other protection measures. Moving objects are especially sensitive to the salt water.

Fish are being counted at ‘t Sas pumping station by Ravon. On Tellingen.Ravon.nl the fish counts are shown.

When the pumps from the pumping station need replacement or more capacity in the future a fish-friendly pump is advised.

The distance between the pumping station and the outlet of the fish passage needs to between 15 and 20 m. Otherwise the fish will be sucked into the pumping station.

The fish gather in the last layer of water. This should be kept in mind when designing the fish passage in relation to the efficiency.

The velocity of the attraction flow is known when the discharge of the pump is known.

What are your expectation the sluice doors will have on the fish migration?
Fish are attracted to the fresh water that is pumped from the polder into the harbor. This will not stop due to the additional sluice doors in the future situation. The sluice doors will likely not hinder the migrating fish, they will only be delayed. The fish will wait in front of the sluice doors, when they are closed and when the sluice doors are open the fish will swim to pumping station ‘t Sas.

Has water board Scheldestromen wishes for the design of a construction?
The fish passage should maintain the fish population or improve it. The fresh and salt species are valuable. Monitoring the fish passage after is has been constructed is useful in understanding the new situations and seeing the changes.

Discussion optional fish passages:

- **Present situation**
- **Fish sluice**
- **Free fall fish passage**
- **Maelstade fish passage**

In total there are six optional fish passages:

- Free fall fish passage
- Two fish friendly pumps fish passage
  The pump that pumps water into the container provides a constant attraction flow. The fish passage has the ability to work continuously or in phases.
- Free fall fish passage with the container on the downstream side (Maelstade)
  The distance the fish need to travel is large.
- Siphon fish passage
  The siphon fish passage could be working in phases or continuously.
- Fish sluice
  The fish sluice has a small operational timeframe. The water velocity is probably too large for the fish to swim through. Adjusting the doors in the pumping station in order to discharge on the basin could be an option. When opening the door in the pumping station controlled, the water will slowly flow into the harbor, allowing fish to swim against it. Another option is discharging the complete basin under free discharge into the polder, the fish are however in the last liters of water and the salt intrusion will be worse.
- Jack-screw fish passage
  The Jack-screw fish passage allows two-way migration and it adds capacity to the pumping station. If there is no increase in pump capacity needed this option is very expensive.

The difference between the Maelstede and the free fall fish passage is the location of the container. The container of the maelstede fish passage is on the downstream side compared to the free fall fish passage container. The positive this about this is that the container has to cope with less salt, the negative side the long travel distance.

Are there records of maintenance activities available for the different fish passages?
Because of the brackish water there is a lot of Palingbrood, the direct translation means Eel bread. This means the pipes need to be cleaned regularly.

Are there lists for construction costs available for the different fish passages?
Are the costs relevant for the decision for the fish passage? Marius tells that most fish passages cost between 500.000 euros and 1.000.000 euros. The costs that have been calculated based on a sketch will vary largely from the actual construction costs, the situations might change because unexpected events happen.

Is there a preferred construction method for the fish passage?

- **Using quay walls yes or no**
- **Time relation**

There is no preferred construction method. However, the safety and the dikes need to be considered in the process.

Actions:

- Actions Iris:
  - Describe the different obstacles that the fish have to overcome.
  - Write an explicit description of the current situation, what would change if there were a minimal water level and how a fish passage would influence the situation.

8.7.9 Minutes 18-04-2017, E. Zaman

Subject: Progress research

Location: KEN Engineering, Oud-Beijerland
Date: 18-04-2017
Time: 9:00
Present: E. Zaman and I. Zijlstra

Eddy tells about Leo Kaan's thesis defense presentation. During the presentation questions harsh were asked about why choices and assumptions were made and what they were based on. Eddy advices to make sure each assumption is supported.

- Read the management strategy of water board Scheldestromen considering fish passages in order to confirm the advice of Marius van Wingerden.(ACTION)
- Read reports on the efficiency of the different fish passages. (ACTION)
- Use Leo Kaan's report as a basis for this research report. (ACTION)

I informed Eddy on the progress of the research. The MCA of the fish passage is finished. The water board and municipality have the opportunity to comment on the MCA. After the MCA is finished and an official choice for a fish passage is made this will be worked out into detail. The question however is how detailed the fish passage needs to be worked out.

Willem Maan has worked at the water board in Utrecht. He could give information on how fish passages are constructed.

- Contact Willem Maan for information about constructing fish passages.(ACTION)

The data for the Sobek model is gathered. The nutrients of the polder need to be incorporated into the model. In order to calibrate the model a Sobek water quality expert is needed. The model still needs work.

Eddy advices to finish the MCA for the fish passage and start working on the Sobek model. He is concerned that if I do not continue working on the Sobek model in the end there will be a shortage in time. Eddy also advices Iris should already write the final report as far as possible.

Actions Iris Zijlstra:

- Read the management strategy of water board Scheldestromen considering fish passages in order to confirm the advice of Marius van Wingerden.
- Read reports on the efficiency of the different fish passages.
- Use Leo Kaan's report as a basis for this research report.
- Contact Willem Maan for information about constructing fish passages.

8.7.10 Minutes 18-04-2017, G. Schutgens

Subject: Calculation fish passage
Location: KEN, Oud-Beijerland
Date: 18-04-2017
Time: 13:00
Present: G. Schutgens and I. Zijlstra

Iris explained the thesis project to Gieljam. A decision has been made of which fish passage will be designed into detail: the fish passage with two fish friendly pumps.

There are three aspects that can be dimensioned and calculated: The foundation for the container, the container and the pipes.

Gieljam explains that Sigma is a nice program that calculate a ring cross-section of a pipe. This program helps determine a suitable material and strength for a pipe in the characteristic conditions. The NEN 3650 and NEN 3651 are needed to fill out the program correctly.

The pipes could be placed close to each other, this is easier for the construction. Besides each other is an option. It would be better that both pipes enter the fish passage from the side and not from the bottom of the container.

Most pipes are positioned 1 m under the ground surface. An HDD or an open slit construction are possible. PE, HPE or steel are materials that could be used.

Because of the brackish water the pipes have to be cleaned regularly. The deflection for the pipes is therefore maximum 5%.

Actions Iris:

- Making a Sigma calculation for the pipes in the fish passage with two fish friendly pumps.

8.7.11 Minutes 01-05-2017, P. Hopmans, B. Verkruysse, E. Zaman

Subject: Meeting with all mentors
Location: HZ University of Applied Science
Date: 01-05-2017
Time: 16:00
Present: P. Hopmans, B. Verkruysse, E. Zaman, I. Zijlstra

Calculation competence
Iris explains what the progress of the project is. Iris is performing a calculation on the pipe and on the piles of the foundation in order to determine their strength and characteristics. There is a struggle about what should and should not be calculated. The reason for this is that the research is very broad, calculating a very specific object could disturb the cohesion of the thesis.

Peter explains he want to discuss this with the second examiner on the second of May. To discuss what is sufficient for the calculations competence.

Bram and Peter advice to calculate the most critical part of the construction.

Water quality
For the analysis of the water quality Iris has made a model of the harbor of Zierikzee in Sobek Water quality. This model does not run jet; therefore experts are being found in order to discuss the model.

Bram states the refreshment of the water in the harbor could be studied. He would like to see the possible problems of the water quality addressed and an approach to deal with the different problems. Refreshment of the water solves almost all the water quality problems, therefor designing different alternatives to refresh the water would be logical.

Draft report
In order to receive feedback on the report form Bram and Peter the report will be send two weeks in advance of the GO/NO GO moment for the report. The GO/NO GO moment for the report is at the 29th of May. This means the report will be handed in for feedback on the 15th of May. Within one week Bram and Peter can send their feedback, this means before the 22nd of May. Iris has one week to improve the report before the GO/NO GO moment.

Actions:

- Discuss what calculations will need to be made on the 2nd of May. (Peter, Nicolas and Iris)

Appendix (phase 2): Evaluation of in-company performance

To be used by the in-company mentor

Student: Iris Zijlstra Evaluation period from: 01/02/2017 to: 24/04/2017

Organisation: KEN engineering In-company mentor: E. Zaman

Please evaluate the student in comparison to other recently graduated HBO-level employees in your organisation using the questions below

1. How do you evaluate the attitude of the student towards his/her work activities?

   Negative **Positive**
   1 2 3 4 5
   Explanation and suggestions:

2. Does the student show own initiative?

   No initiative **Pro-active**
   1 2 3 4 5
   Explanation and suggestions:

3. Is the work approach of the student practical?

   Not practical **Practical**
   1 2 3 4 5
   Explanation and suggestions:

4. How would you rate the social skills of the student?

   Insufficient **Sufficient**
   1 2 3 4 5
   Explanation and suggestions:

5. How would you rate the communicative skills of the student?

Not communicative **Very communicative**

1 2 3 4 5

Explanation and suggestions:

6. How do you rate the knowledge level of the student (in the field of his/her Bachelor program)?

Low level **High level**

1 2 3 4 5

Explanation and suggestions:

7. What is the performance level of the student?

Low level **High level**

1 2 3 4 5

Explanation and suggestions:

8. How much did the student contribute to your organisation?

A little **A lot**

1 2 3 4 5

Explanation and suggestions:

9. What is your overall evaluation of the student?

1 2 3 4 5 6 7 8 9 10

Explanation and suggestions:

Name: EZAAAH

Function: afdeling hoofd Infra

Date: 24/4/2017

Signature:

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8.7.12 Minutes 02-05-2017, P. Hopmans, N. Stanic

Subject: Calculations Civil Engineering
Location: HZ University of Applied Science
Date: 02-05-2017
Time: 14:30
Present: P.Hopmans, N. Stanic, I. Zijlstra

Research proposal
Nikola has read the research proposal and advices the following:

- Add references to the introduction.
- In the reading structure make the chapters bold. For example, **Chapter 2** contains etc.
- In the method an MCA is mentioned. Put the MCA framework in the research proposal along with some alternatives.
- The theoretical framework should contain more information then needed in the thesis. Use all the theory form the final report and copy it into the research proposal.

Calculations fish passage
For the pipe calculation the timespan of the settlement should be considered.
For the choice of pipe, a reinforced PE pipe can be used.

Nikola would like me to calculate the maximum and minimum velocity within the pipe that flows from the basin to the polder. The Bernoulli calculation would be used for this. Consider the different losses in the bends, at the inlet and at the outlet.

After calculating the velocity that flows through the pipe by gravitational force the amount of water that needs to be pumped will be calculated. Vpipe 2 in = Vpipe 1 out + V attraction flow out

The needed pressure and the overall head will be compared to the graph of a fish friendly pump. The work point of the pump would be determined.

To make the fish passage more interesting the force of the water that flows down due to gravitational force could be used. A turbine could be placed in the pipe to generate power. The energy could be used to power the fish friendly pump in the other pipe.

Figure 104 Notes about the calculation of the fish passage

Calculations water refreshment measure

The different alternatives were discussed:

- A pipe that connects to the tidal water with holes to distribute the water.
- A pipe that connects to the tidal water connected to a fountain into the harbor.
- A turbine in the harbor to mix the water.
- The rainwater sewer pipes that are discharging rainwater into the harbor.

Nikola comments the pressure in the pipes will not be high enough when they are connected to the tidal zone of the harbor. A turbine is needed to generate sufficient pressure to mix the water.

Nikola would like to see a calculation on the pipe and turbine that would be needed to mix the water. Also, a study about the movement of the water would be nice, how will the water mix.

- Think about the velocity that would be needed to mix the water.
- Think about flow patterns of the water.

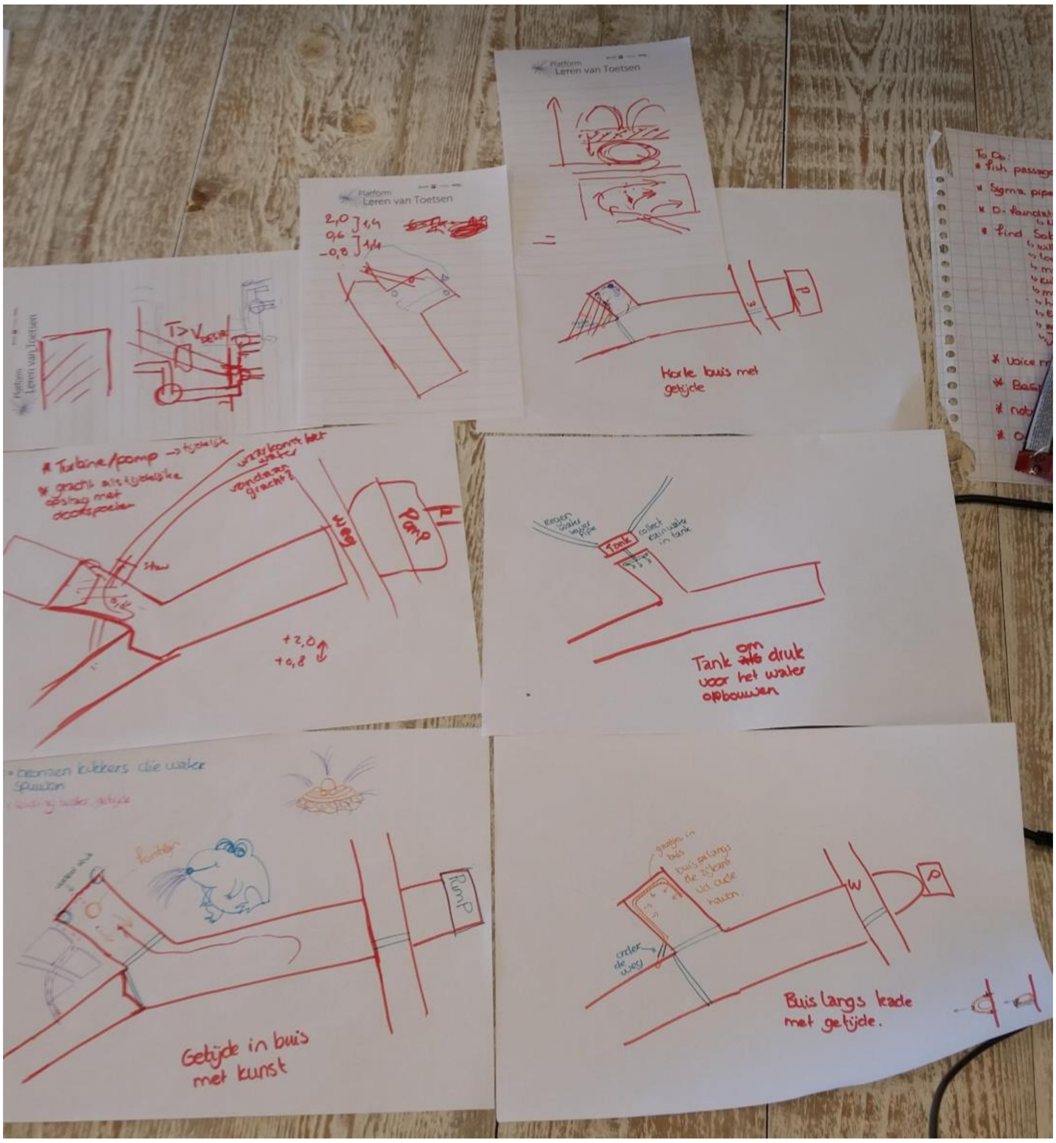

Figure 105 Notes on the alternative solutions for the water refreshment.

8.7.13 Minutes 24-05-2017, B. Verkruysse

Subject: Draft report 15-05-2017
Location: HZ University of Applied Science
Date: 24-05-2017
Time: 14:30
Present: B. Verkruysse and I. Zijlstra

Report improvements:

- Explain why some subjects have been zoomed in and discussed into detail.
- Compare the different water quality improvement possibilities and their efficiency with support from scientific articles.
- There are no preconditions for the water refreshment measure so explain that in the chapter "Program of requirements"
- Describe why the retention time formula was chosen and used.

- Think when evaluating the different possible water quality solutions about how practical they are.
- Move the “Oxygen in the water” chapter, 2,5 into the “water quality” chapter.
- Describe in the chapter 2.3.5. “Target image” also the ecological target image.
- Write a short conclusion about how brackish the water is in the water quality analysis.
- Explain why the focus lies on the fish migration in relation to the ecological water quality and the EWFD.
- Explain in the abstract the process of the method of the research.
- Explain that instead of oxygen in the water the focus lies on the refreshment of the water and why.

On Sunday, 28-05-2017 the second draft report will be uploaded into Onstage.

Bram comments that he is confident that the report will receive a **GO** on the GO/NO GO moments on the 29th of May.

8.7.14 Minutes 24-05-2017, P. Hopmans

Subject:	Draft report 15-05-2017
Location:	HZ University of Applied Science
Date:	24-05-2017
Time:	14:30
Present:	P. Hopmans and I. Zijlstra

Report improvements:

- Add in the introduction a figure that shows the fish migration problem. The picture of the water level difference and the arrows what direction the water and the fish have to go to.
- Link the polder water chemicals to the water quality analysis.
- Add the figure from chapter 7.1.19.2 in which the fish migration obstacles are shown to the “fish migration” chapter.
- Because the report is very large a flow chart with the different subjects that are discussed in the report would be a nice guide through the report.
- Place the Sobek chapters in the “water quality” chapter and describe what the possibilities are and what the Sobek model contains. Come back to the Sobek model in the recommendations.
- Add conclusions to the calculations of the pipe in Sigma. Explain that the calculations from Sigma are originated from the NEN and that that was carefully followed.
- For the MCA conclusion a table with the percentages could be added to make the score clearer.
- Make sure the APA style notes the last name and not the begin letters.
- When the report is complete, check whether all sub-questions are answered. In the conclusion all sub questions have to be answered.

On Sunday, 28-05-2017 the second draft report will be uploaded into Onstage.

Peter comments that he is confident that the report will receive a **GO** on the GO/NO GO moments on the 29th of May.

8.8 Email Hidrostal

Gmail

Iris Zijlstra <iriszijlstra2@gmail.com>

richtprijs visvriendelijke pomp gemaal

Leo Kaan <Leo.Kaan@schouwen-duiveland.nl> 9 januari 2018 om 09:56
Aan: Iris Zijlstra <iriszijlstra2@gmail.com>

Zie onderstaand ter info.

Gr Leo

Van: Hidrostal | Hatim Boulhriri [mailto:Hatim.Boulhriri@hidrostal.nl]
Verzonden: dinsdag 9 januari 2018 09:53
Aan: Leo Kaan
CC: Hidrostal | Wim van Dam; Hidrostal | Esther Vis
Onderwerp: FW: richtprijs visvriendelijke pomp gemaal

Goedemorgen Leo,

Zoals besproken:

Voor een Hidrostal F06K visvriendelijke pomp met voetbocht snelkoppel systeem moet u denken aan een geschatte investering van gemiddeld ergens tussen de 12 en 15duizend euro

e.e.a. afhankelijk van motorkeuze materiaalkeuze etc. etc.

Als er een werkpunt bekend wordt dan wil ik deze graag uitrekenen voor u!

Succes in de meeting straks!

Met vriendelijke groet, Meilleures salutations, Freundliche Grüsse, kind regards,

Hidrostal

Hatim Boulhriri
Inside Sales Coördinator

Hidrostal Benelux