Civil Design of a Tidal Power Plant

Case Brouwersdam

Iv-Infra b.v.

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Table of contents

1 Introduction

1.1 Context

In 1971 the Brouwersdam was completed, separating Lake Grevelingen from the North Sea. Despite the culvert Brouwerssluis, built in 1978, the ecological quality of Lake Grevelingen decreased due to lack of tidal movement. If no measures are taken, the ecological quality is expected to get worse. As a reaction to this threat, it is proposed to reintroduce a tidal movement of approximately 0.5 m on Lake Grevelingen by building a sluice in the dam with a discharge capacity of approximately 4,000 m^3/s.

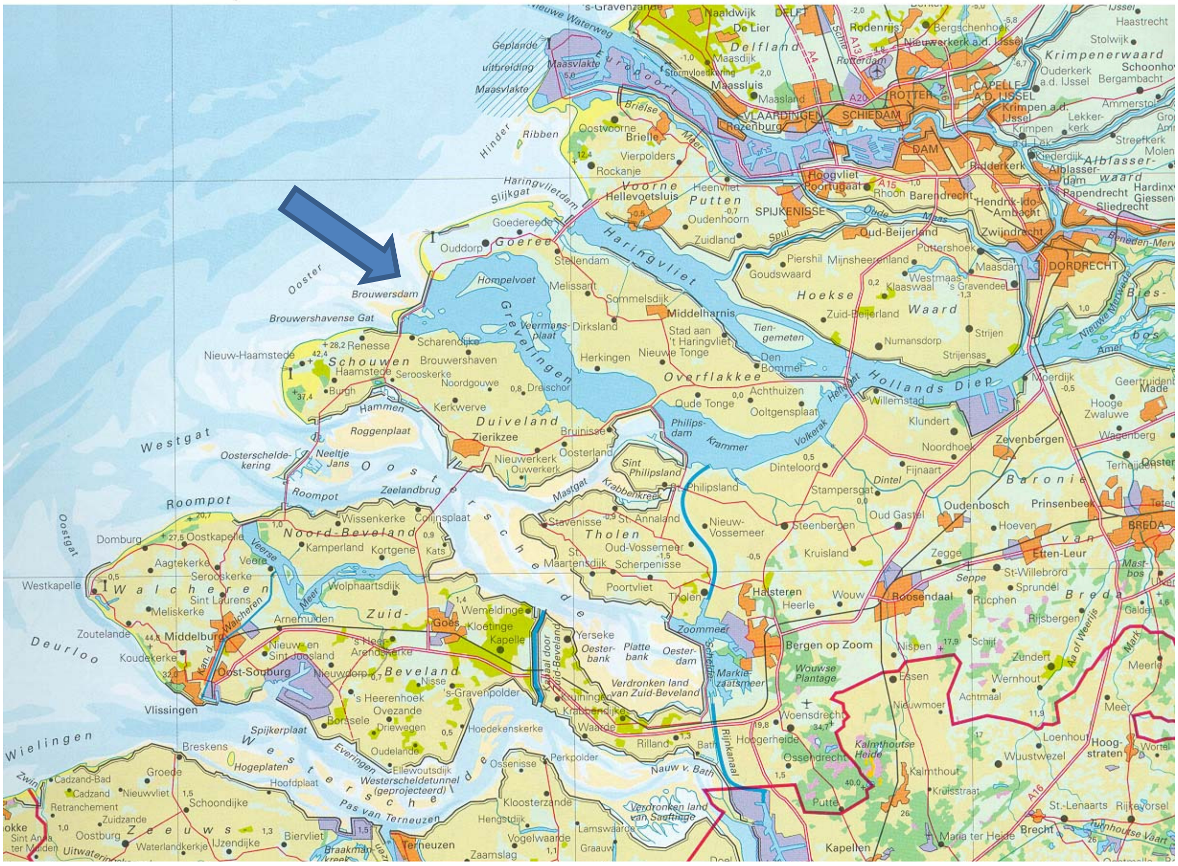

Figure 1 Location of lake Grevelingen and Brouwersdam

From a sustainability point of view it seems interesting to investigate whether or not it would be beneficial to equip the new sluice (or culvert) with turbines for the generation of tidal energy, a so-called tidal power plant.

Several (feasibility) studies to sluices and tidal power plants have been completed. At this stage it is uncertain if a tidal power plant would be economically beneficial. So far, all proposed designs of power plants are financially unattractive. A state of the art design, innovation and a smart construction method are required to move the cost-benefit-analysis from negative to positive.

1.2 Problem description

The reintroduction of tidal movement on Lake Grevelingen requires the construction of an expensive sluice. Building a tidal power plant instead of a sluice might be economically interesting if innovation in both turbines and the civil structure is moving forward. In existing studies to tidal power plants [Boon et al., 2008], [Mooyaart et al., 2010], [Welsink et al., 2014] building costs of the civil structure represent approximately 50 % of the total building costs and exceed available budget. At this stage, the cost-benefit-analysis of a tidal power plant in the Brouwersdam is negative.

1.3 Objective

Develop a state-of-the-art civil structure and construction method for a tidal power plant such that all design requirements (see chapter 2) are met, building costs are reduced significantly compared to existing quotations and total costs in relation to energy production is optimal. Create three designs of the civil structure based on:

- a diffuser type structure;
- a ducted type structure and
- a Venturi type structure.

1.4 Scope of work

Pro-Tide is a European partnership between France, Belgium, United Kingdom and The Netherlands, promoting research and development in the field of tidal energy and low head energy production. Iv-Infra is contracted by Pro-Tide-NL to find and draw up an optimal design of the civil structure and a smart building method, reducing building costs significantly.

The scope of work is limited to the design of the civil structure and its construction method. No research or engineering on the mechanical and turbine elements is expected. Pro-Tide-NL delivers all information on (research on new) types of turbines. Quotations only include the design and construction of the civil structure. Pro-Tide-NL does not expect a quotation of maintenance and operations costs, neither a quotation of turbines.

1.5 Note by quotations

The designs presented in this study are twofold: sketches (chapter 5) and preliminary designs (chapter 7). The corresponding quotations are either 'global cost estimates' (one for each sketch in chapter 5) or 'quotations according to SSK standard' (one for each preliminary design in chapter 7).

Both types of quotations include:
- civil building costs;
- design costs of the civil structure and
- VAT.

Quotations according to SSK standard represent expected building and design costs plus or minus 30%. The margin of 30% includes:
- variations in cost price;
- changes in estimated quantities;
- unforeseen costs within the design scope, boundary conditions and assumptions on which the designs are based.

1.6 Reader

In order to create optimal designs of the civil structure, five design steps will be followed.

Design step	Activities	Chapter
1. Examine the records	➢ Analyze existing studies ➢ Summarize results and design performances	2
2. Define reference design of a sluice	➢ Choose reference design of a sluice ➢ Deduce building costs of a sluice	3
3. Set up design requirements	➢ Define functions and functional requirements ➢ Determine hydraulic loads ➢ Determine geotechnical parameters	4
4. Investigate and assess alternative solutions	➢ Brainstorm sessions to generate solutions ➢ Analyze feasibility of solutions ➢ Define promising alternatives ➢ Assessment of alternatives to multi criteria ➢ Define three preferred alternatives	5, 6
5. Set up preliminary design	➢ Determine dimensions of civil structure ➢ Define and sketch building method and phases ➢ Create 3D design of civil structure ➢ Quote building costs	7

2 Existing studies

In the last decade several studies [Boon et al., 2008], [Mooyaart et al., 2010], [Vrijling et al., 2008], [Welsink et al., 2014] have been completed in search of a design that is both technically and economically attractive.

In order to avoid double work, the results of these studies have been analyzed and summarized. In Appendix A an overview is given of all studied alternatives/designs, in terms of location, type of structure, costs, energy production and more.

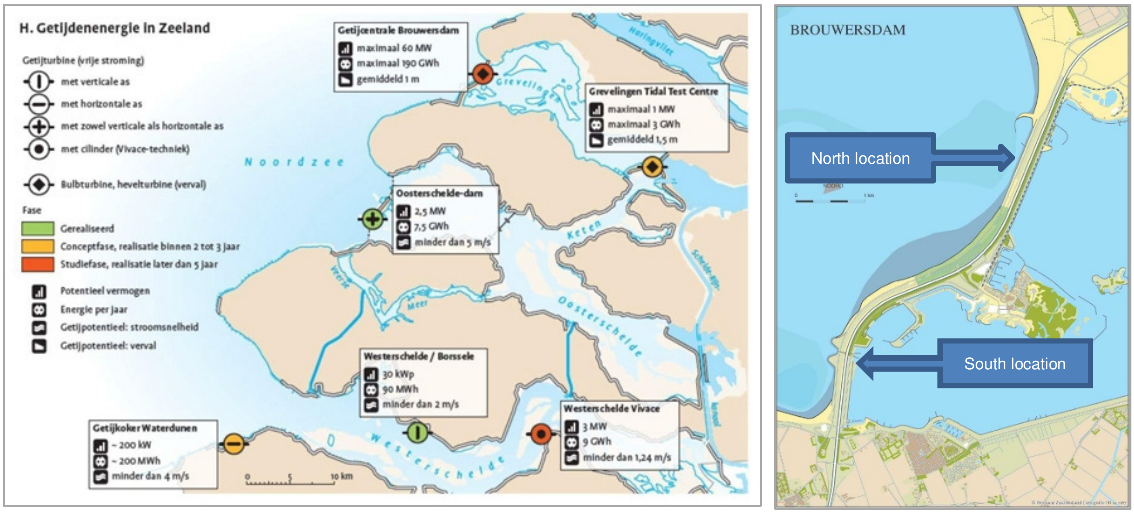

Figure 2 (left) Potential locations for Tidal Energy in Zeeland [www.duurzamgeproduceerd.nl] and (right) Potential locations for a plant in the Brouwersdam [Vrijling et al., 2008]

Some general conclusions can be drawn from existing studies:

- Across the Brouwersdam two potential locations can be identified to build a sluice and/or tidal power plant, see Figure 2;
  - The Southern location is relatively small, has deep (former) channels and is 'reserved' for the construction of 'Jachthaven van de Toekomst';
  - The Northern location is preferred, due to available length, presence of caissons and shallow (former) channels;
- Designs and quotations are not fully comparable, due to differences in boundary conditions, requirements, assumptions and definitions of costs;
- It is advised to set up a unambiguous set of requirements;

For more information on the existing studies, one is referred to Appendix A.

3 Reference design of a sluice

As a consequence of the actual inferior environmental quality of Lake Grevelingen and EU policy ‘Kaderrichtlijn Water’, reintroduction of tidal movement is required. The construction of a sluice in the Brouwersdam is technical feasible and would reintroduce tidal movement. ‘Projectbureau Getijdencentrale Brouwersdam’ (www.getijdencentralebrouwersdam.nl) is using such a sluice as a reference (level) to compare additional building costs of a tidal power plant (or alternative structure) with the benefits of the production of (green tidal) energy.

3.1 Reference structure

Figure 3 shows one of many possible designs of a sluice, which is able to carry ’ducted free stream’ turbines. The structure is known as the Eastern Scheldt storm surge barrier and has sufficient flow capacity to create a tidal movement at Lake Grevelingen of 0.5 m.

Figure 3 Reference design, Eastern Scheldt storm surge barrier [source: www.beeldbank.rws.nl]

3.2 Quotation of reference structure

The building costs of a civil structure strongly depend of the length of the structure.

Based on [Nieuwkamer, 2012] and [Vries, 2014], Projectbureau Getijdencentrale Brouwersdam assigned a sluice with a length of 98 m as a reference level.

Civil building costs are estimated at € 138 million, design costs included.

4 Design requirements tidal power plant

The civil structure for the tidal power plant needs to fulfill four primary functions:

- protecting hinterland against storm surges (primary flood defense n° 14);
- regulating water level (tidal movement on lake Grevelingen of 0.5 m);
- facilitating traffic (N57, parallel roads and cycle path) and
- generating energy.

4.1 Functional and technical requirements [MIRT Grevelingen, 2014]

Table 1: Functional requirements

	Functional requirements
Water passage	Water should be able to flow from the North Sea to lake Grevelingen and vice versa.
Flow rates	The Tidal Power Plant should be able to: o facilitate passage of minimal 3,500 m3/s (time average) of water in ebb-mode; o facilitate passage of minimal 3,500 m3/s (time average) of water in flood-mode.
Water barrier	The system should be able to function as a flood defense at all times. The incorporation in the Brouwersdam should have no negative influence on the flood defense capacity of the Brouwersdam itself, known as connecting water barrier no 14. The system should be able to resist high water levels and storm surges, up to the norm-frequency of 1/4,000 per year.
Level control	During normal operation, no storm surge, the system should be able to control water levels in lake Grevelingen: o targeted water level at lake Grevelingen on average NAP -0.20 m with variation between -0.55 and +0.15 NAP; o mean water level at North Sea LW-level NAP -1.06 m and HW-level NAP +1.44 m.
Traffic	The tidal power plant needs to facilitate road traffic on the Brouwersdam, also from the N57 and parallel road, at least with today's traffic quality.

Table 2: Aspect requirements

	Aspect requirements
Safety	The tidal power plant is to be considered as a machine that complies with "Machinerichtlijn".
Safe usage	Operators, visitors and others related to control, operation and

	maintenance must be able to safely stay in and around and make uses of the tidal power plant facility.
Fish friendliness	The tidal power plant fish mortality rate must be lower than 0.1 %.
Safety for sea mammals	Mortality rate for sea mammals must be lower than 0.01 %
Availability water passage	Non-availability of the tidal power plant, in relation to water passage, must be less than 0.5 %. Non-availability includes: o Foreseeable non-availability (maintenance). o Non foreseeable, non-availability as a result of closure of the gates due to malfunctioning).
Max. period of non-availability	The maximum time-interval of non-availability in relation to water passage must be less than 12 hours.
Discharge capacity during maintenance	Reduction of water passage capacity due to planned maintenance must be less than 50 %.
Vandalism effect on availability	The tidal power plant must be designed and constructed in a way that vandalism does not affect availability and reliability of the water passage function and water barrier functions.
Availability traffic connection	Non-availability of the tidal power plant in relation to road traffic must be equal or less than 0.5 %.
Life time tidal power plant	The tidal power plant must be constructed with a lifetime for functional use of at least 100 years.
Life time components	Components must have a life time: o Civil works: 100 years o Steel construction components: 50 years o Mechanical engineering components: 50 years.
Max. overtopping flow rate	Maximum overtopping flow rate must be less than 0.01 l/s/m for a highway immediately located after flood barrier.
Reliability of closure	The tidal power plant must have a chance of failure for closure, less than 2.5E-5 per year.
Re-establish closure after failure	After failure of closure procedure, closure must be restored within 1 day.
Reliability of mechanical parts	The chance of structural failure of the tidal power plant as a flood defense should be below 1/400,000 per year (0.01 x norm).
Structural safety/reliability	Reliability of the tidal power plant, in relation to structural safety, must comply with safety class RC3, according to Euro Code.
Air pollution, hindrance	Regarding air pollution, vibrations and noise, the tidal power plant needs to comply with relevant laws and legislation rules.
Environmental effect	The tidal power plant needs to fulfill the respective conditions in the governing environmental legislation.
Vibration during construction	The chance that vibrations lead to damage of objects must be minimized within the framework of SBR guidance A.
Water safety during	During construction, the flood defense capacity of the

construction	Brouwersdam should meet the rules according to Waterwet.
Temporary barrier function	Temporary measures for flood defense during construction should be designated as primary water barriers within the framework of the Waterwet.
Control	The tidal power plant needs to be controllable on-site and remote.
Dismantling	Moving parts should be demountable with reasonable effort.

Table 3: External interface requirements

	External interface requirements
Interface inlet and outlet on ambient	The inlet and outlets need to connect to adjacent streams (outside system boundary) in a way that water passage under free fall conditions is guaranteed.
Flow velocity at end sea bed protection	Maximum flow velocity at the bottom interface between tidal power plant and surrounding water system needs to be less than 0.5 m/s.
Cables and conduits	Functions of existing cables and pipe work on the Brouwersdam must be maintained.
Interface traffic roads	Roads inside the tidal power plant system boundary need to connect to surrounding roads.

4.2 Hydraulic boundary conditions

According to the periodical assessment of flood defenses in the Netherlands, the prevailing hydraulic boundary conditions for the northern part of the Brouwersdam are as given in Table 4.

Table 4: Hydraulic boundary conditions Brouwersdam, frequency = 1/4,000 per year

Location	Description	Control water level (Toetspeil) [m + NAP]	H_s [m]	$T_{m-1.0}$ [s]	β [°]
	Damvak Goeree	5.0	2.6	7.5	10

H_s, $T_{m-1.0}$ and β are wave characteristics. The tidal power plant should be designed with a lifetime expectancy of at least 100 years. Due to climate change, additional surcharges should be added to these assessment conditions in order to define design conditions. Sea level rise has been estimated at 1.0 m in 2100. In combination with a rising level of high water of 0.1 m and a robustness level equal to 0.1 m, this results in a design water level of +6.2 m NAP, see also [Mooyaart et al., 2010].

5 Alternatives and variants of a tidal power plant

Pro-Tide-NL wants an optimal design of the civil structure for three basic alternatives:

- Diffusor
- Gate/Ducted
- Venturi/VETT

These basic alternatives differ in type of turbine, level of ongoing research in turbine, civil costs, efficiency in energy production, flow capacity and required length of the structure.

A tidal power plant with a diffusor is built to optimize energy production. It includes a traditional bulb turbine or more advanced bi-directional turbines. Both are relatively efficient, but expensive. Due to the diffusors and optimal energy production flow capacity is relatively low. As a consequence the civil structure becomes relatively big and large, if a flow capacity of 4,000 m3/s should be guaranteed.

A gate / ducted type of tidal power plant is characterized by minimal civil costs. Flow capacity is relatively high, but energy production relatively low. The structure is able to carry varies types of turbines, including bulb and ducted free stream turbines, which are cheaper than bulb turbines. As research to ducted free stream turbines continues, efficiency of energy production will increase in future.

A tidal power plant with a Venturi or VETT system is the most innovative one. Intensive research to increase efficiency even more is expected. The turbines are relatively cheap, compared to bulb turbines and free flow turbines, but efficiency is lower due to extra energy conversion steps. Applying this type results in a bigger (and longer) civil structure compared to the gate/ducted type.

The challenge in this design process lies in the combination of (ambivalent) requirements, as presented in chapter 4. In two work sessions, all kind of solutions have been investigated, presented, discussed and analyzed. For each alternative, mentioned above, at least three variants of civil structures (feasible solutions) are analyzed. A comprehensive overview of these promising variants is given in Appendix C, including dimensions and construction method.

Mapping the design requirements to the presented solutions, the differences between solutions can be found in:

- Construction method
- Temporary flood defense
- Traffic diversion / detour
- Use of existing caissons

Appendix D contains all stability and dimensional calculations. Appendix E contains calculations to determine the required length of a structure in order to create sufficient tidal movement.

5.1 Diffuser

When applying a diffuser, the civil structure exists of a so called power house, see Figure 4. The design of the civil structure itself is more or less defined by the power house. Hence, an optimal variant should be found in an innovative construction method. Several methods were conceived during the two working sessions, eventually three were chosen as the most promising variants:

- 1A ’Building in the dry’
- 1B ’Building in the wet’
- 1C ’Pneumatic caisson’

Every variant will be described briefly. For every design the water retaining function is fulfilled by a set of vertical valves, assuming that the turbines cannot retain water by itself. Traffic (N57 and parallel road) will be relocated on top of the structure.

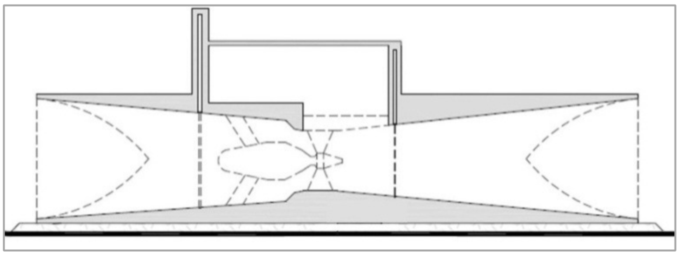

Figure 4: Powerhouse design for a bulb turbine with diffusers [Welsink et al., 2014]

5.1.1 1A ‘Building in the dry’

The structure will be placed at the Grevelingen side of the existing caissons, as can be seen in Figure 5. In addition to the benefits of the design in [Mooyaart et al., 2010] this location has three advantages:

- The old caissons together with the remaining part of the dam can guarantee the water safety during construction, so no temporary barrier has to be built.
- Using the old caissons as soil retaining structure, the available space for a building pit will be increased.
- The road N57 will stay at its present position so no extra bends are needed for this road.

The stability of the existing caissons as retaining structure was checked and can be found in Appendix D. During construction, parts of the Brouwersdam will stay intact at the sea side as well as the Grevelingen side, to accommodate traffic. The building pit will be pumped dry, after which high strength prefab elements will be placed. After constructing the powerhouse and relocating the roads, the existing caissons will be removed together with the remaining parts of the dam. At the location of the tidal power plant, the dam will be constricted.

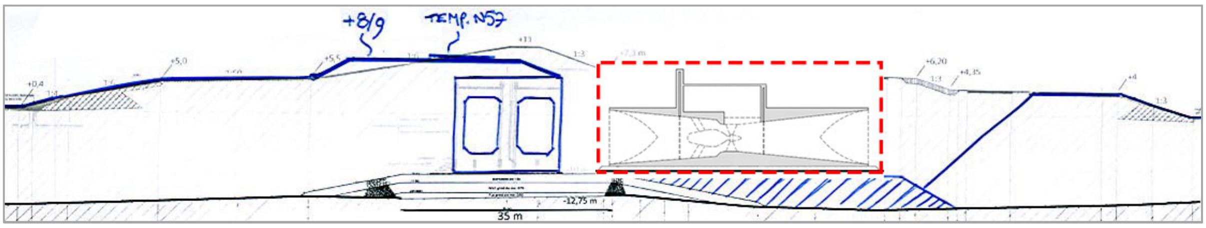

Figure 5: Variant 1A 'Building in the dry' cross-section during construction

The stability of the Diffuser structure is already calculated in a former study [Welsink et al., 2014], in which the horizontal stability for a bulb turbine of 3.5 m was not sufficient. By increasing the dimensions of the structure, for example the total height or the thickness of the floor elements, the structure becomes stable. Increasing the diameter of the turbine will also increase the required length and width, resulting in a stable structure.

The main dimensions are the length (perpendicular to the dam) which is 35 m and the required width which will be 7.7 m per turbine element. Based on a first estimation, the total length (needed parallel to the dam) is approximately 625 m, equal to 86 elements.

5.1.2 1B 'Building in the wet'

This variant is placed at the same location as variant 1A for the same reasons as mentioned above Also in this variant the existing caissons are used as retaining structure, but no building pit is constructed.

A cross-section of the structure during construction can be seen in Figure 6. Part of the dam, located at the Grevelingen side of the caissons, will be excavated which makes it possible to ship prefab units to location. For construction of the prefab units an external building dock is needed. Possibly the dock used during the construction of the Brouwersdam, named Bommenende, can be used.

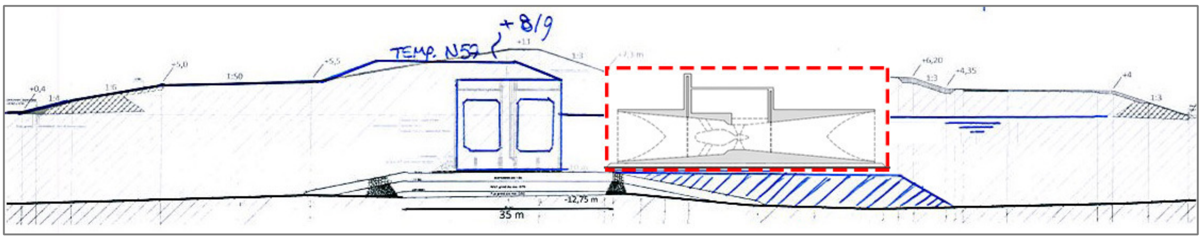

Figure 6: Variant 1B 'Building in the wet' cross-section during construction

The dimensions are almost the same as for variant 1A; likewise it is the case for this structure that some extra weight is needed to reach horizontal stability. The stability of the old caissons is checked for this specific situation. Also for this variant a larger diameter of the turbine is a possibility.

5.1.3 1C 'Pneumatic caissons'

The location and design of the structure is not different compared to variants 1A and 1B, but in order to place the caisson to its location a pneumatic caisson method is used, see Figure 7. After immersing the caissons into the ground, the ground around the caissons will be excavated and the existing caissons will be removed.

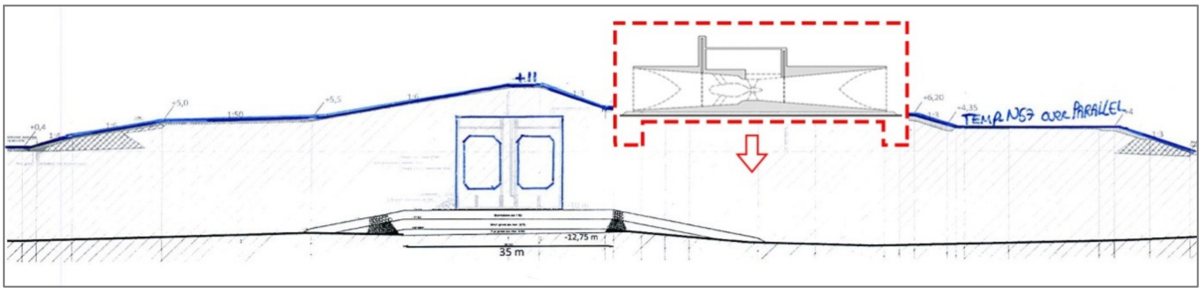

Figure 7: Variant 1C 'Pneumatic caisson' cross-section during construction

Also for this variant the dimensions are used which were calculated in [Welsink et al., 2014]. It is advised to construct caisson elements, existing of several turbines that can be sunk to its required position as a whole. The caissons will not be sunken precisely next to each other, a space of approximately 5 – 10 m is needed in-between the caissons. These spaces need to be filled in order to guarantee water safety during the operational phase.

5.2 Gate/Ducted

For the Gate type of structure a lot of different options are possible for the structure itself as well as for the turbine. The two work sessions resulted in four promising variants.

- 2A 'Eastern Scheldt barrier like structure, dry construction'
- 2B 'Eastern Scheldt barrier like structure, wet construction'
- 2C 'Slender structure'
- 2D 'Floatable pillar containers'

5.2.1 2A 'Eastern Scheldt barrier like structure, dry construction'

This variant consists of pillars with a bridge deck on top, vertical closure valves and a turbine in-between the pillars, see Figure 8. A dry construction method will be used, in which the existing caissons will be used as retaining structure as well as part of the dam at the Grevelingen side, see Figure 5.

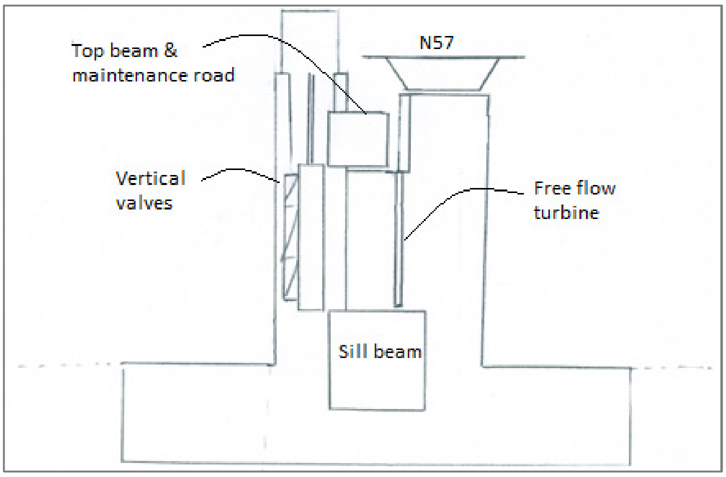

Figure 8: Variant 2A/2B Cross-section of 'Eastern Scheldt barrier' like structure

To reach overall stability, the foot of the pillars must be expanded 7.5 m to each side. The pillar itself will be 35 m long (perpendicular to the dam), 10 m width (parallel to the dam) and 18.75 m high. A total length of approximately 150 m, equal to 4 or 5 pillars, is needed to get the required flow area and desired tidal range.

5.2.2 2B 'Eastern Scheldt barrier like structure, wet construction'

The wet construction method can be done in different ways, for instance by building the whole pillar in an external building dock and then float it to its position. This method has been used during the construction of the Eastern Scheldt barrier. For the Eastern Scheldt barrier special ships were built to place the pillars. For this method the existing caissons are again used as retaining structures.

The dimensions of this variant are significantly larger than variant 2A which will be built in the dry. This is because a smaller friction coefficient applies in case of a wet construction method, which influences the horizontal stability. To reach stability the length (perpendicular to the dam) has to be increased to 40 m (instead of the 35 m needed in the dry method) and the top of the pillar needs to be heightened with an extra 5 m to NAP + 11 m. The required length (parallel) of these variants is the same as for variant 2A, approximately 150 m.

5.2.3 2C 'Slender structure, wet and dry construction'

In order to decrease the dimensions of the structure, in this variant is chosen for a small span of approximately 8 m, see Figure 9. A floor will be constructed over the total length and width of the structure. At every 8 meters a wall/pillar will be constructed which functions as the casing for the valves and turbines. On top of this structure a roof will be constructed with added soil for extra mass, needed to achieve stability. The road can be located on top of the soil layer and a maintenance road can be located on top of the maintenance room. For this structure a dry construction method can be used as well as a wet construction method. For both methods the use of a large amount of prefab units is preferable. In case of a wet construction it is preferable to sink only one element, which can be made floatable. For a dry construction method, the same method as for variant 1A and 2A can be used.

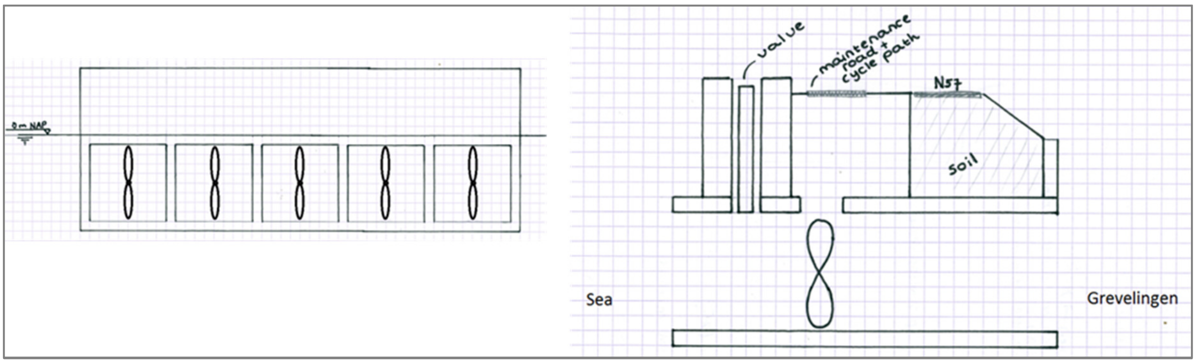

Figure 9 Variant 2C,'Slender ducted structure' front and cross-section

One of the possible designs which is stable has the following dimensions: the length (perpendicular to the dam) is equal to 28 m, the wet surface will be 8 x 8 m^2 in which one large turbine can be placed and the floor will be embedded 2 m below ground level (-12 m NAP) in order to reach stability. A total length of 135 m, equal to 12 or 13 units, is needed to get the requirement flow area and required tidal range.

5.2.4 *2D 'Floatable pillar containers'*

This variant has the same principle as the Eastern Scheldt barrier, with pillars and a large valve in-between. The difference can be found in reduced structure length by using a pile foundation. In order to build these pillars, first large piles will be driven into the underground, next prefab containers will be placed on top of those piles and filled with sand or concrete. A connection between the piles and container is already present in the prefab containers. For the foundation of one pillar 12 steel piles with a diameter of 2 m are needed. The other dimensions of this structure are smaller than the Eastern Scheldt like structure, because the piles will increase the overall stability of the structure. A top view and front with dimensions are given in Figure 10 and Figure 11.

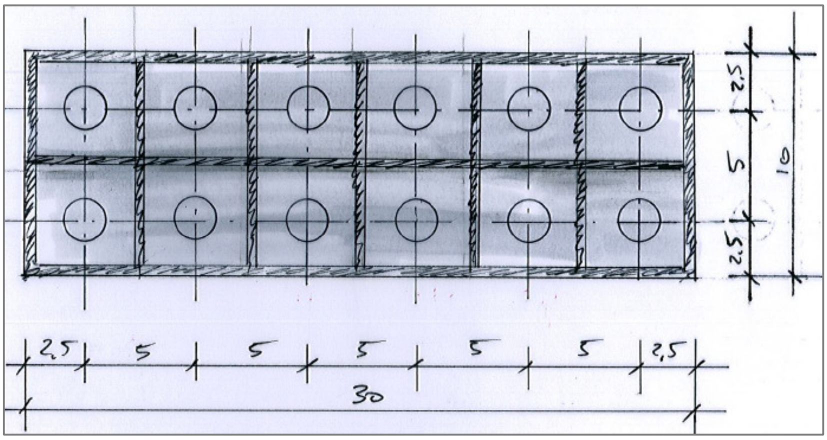

Figure 10: Variant 2D 'Floatable container with piles', top view

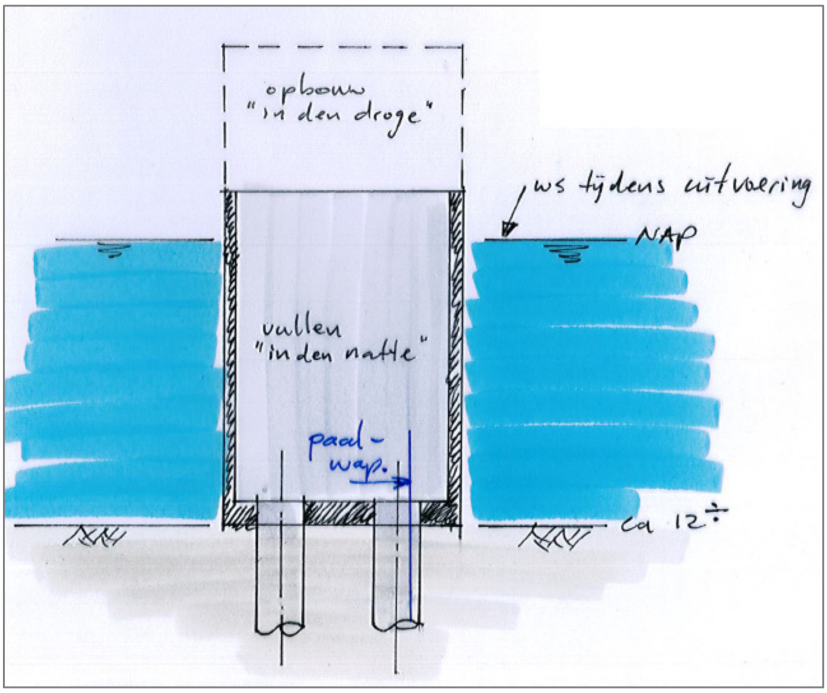

Figure 11: Variant 2D 'Floatable container with piles', front

5.3 Siphon/VETT

Similar to the previous types of turbines, also for the Siphon/VETT four variants are chosen during the two work sessions. The siphon is a structure with diffusers which are outside the structure itself.

- 3A 'Building pit dry construction'
- 3B 'Wet construction'
- 3C 'Siphon inside powerhouse'
- 3D 'Venturi in slender structure'

For the first three variants the water retaining function will be fulfilled by an overpressure pump, which has lower estimated costs than any mechanical structure. In variant 3D a separate valve will be constructed to retain high water pressure.

5.3.1 3A 'Building pit dry construction'

In this variant two rows of sheet piling are used which will be installed through the present bottom protection. Next a dry building pit can be constructed in which the structure can be built. To a large extend, the dam will have the same appearance as the present dam, only a constriction is needed at the location of the siphons. This also means that the roads need to be relocated to the top of the dam. The turbines and generators are located at the Grevelingen side of the old caissons, see Figure 12.

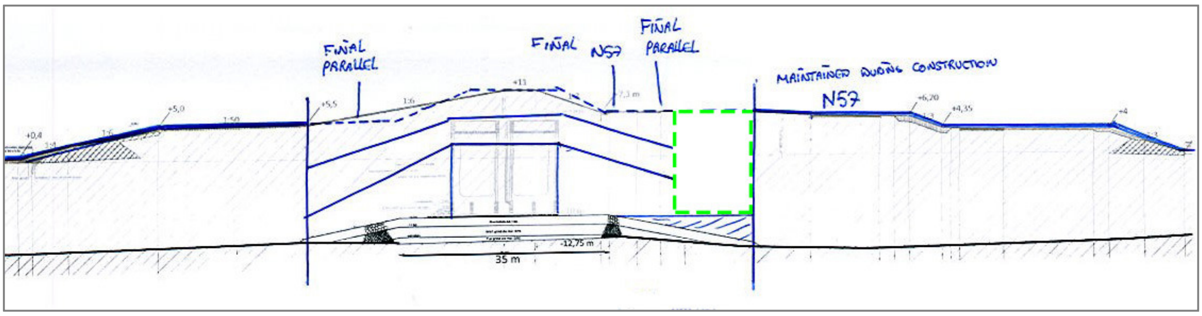

Figure 12: Variant 3A 'Siphon, built in the dry', cross-section during construction

For stability reasons the sheet piles need to be anchored, during construction as well as in the operational phase. In this variant the structure for the turbine and generator has no structural function. The stability is guaranteed by the sheet piles and part of the original dam. This means that the dimensions of this structure can be as small as possible. For the siphon the diameter is estimated at 3.5 m, which is the same as for the Diffuser variants. The in- and outflow must be diffusing in order to create a smooth entry and exit minimizing hydraulic losses. The total width of one element is estimated at 7.7 m, equal to the Diffuser structure. A total length of 750 m is requires, equal to 96 siphons.

5.3.2 3B 'Wet construction'

For this variant a separate caisson-like prefab element is constructed in an external building dock. This element contains turbines, generators, one outflow and facilities to construct a road on top. At the other side of the outflow a connection can be made to the part of the siphon that goes over the old caissons. An overview of the location of this variant is given in Figure 13; this location is favorable because the N57 can be maintained at the present location. During construction the existing caissons and part of the dam will be used as water barrier and soil retaining structure. After construction the dam will be excavated and the roads will be located on top of the new caissons.

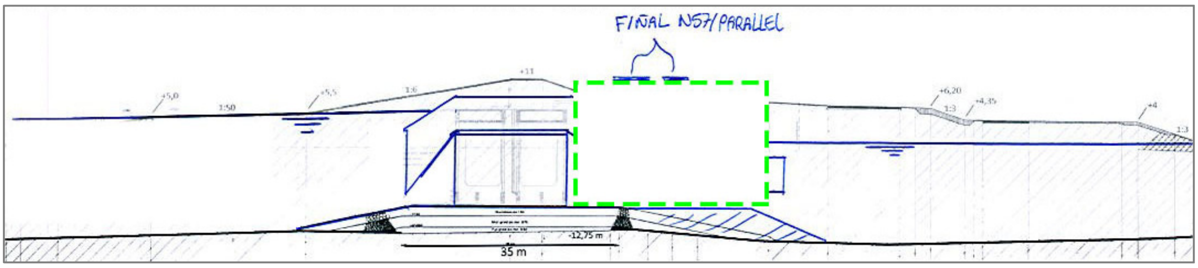

Figure 13: Variant 3B cross-section during construction

The dimensions of this prefab structure are equal to the Diffuser structure, a length (perpendicular to the dam) of approximately 35 m and a width of 7.7 m. This is necessary because this element is almost completely responsible for the overall stability. At this stage it is not certain if the in- and outflows are stable without an additional supporting structure.

5.3.3 *3C 'Siphon inside powerhouse'*

In this design the siphon 'powerhouse' is fully constructed in the dry around the existing caissons. The sea resistent shell forms the main water barrier. The siphon is integrated in this structure. Because the new structure is built around the old caissons, a wider building pit is needed. This means that a temporary soil body at the sea side is needed to fulfill the funtions of the primary water barrier during construction. An impresion of such a powerhouse is shown in Figure 14.

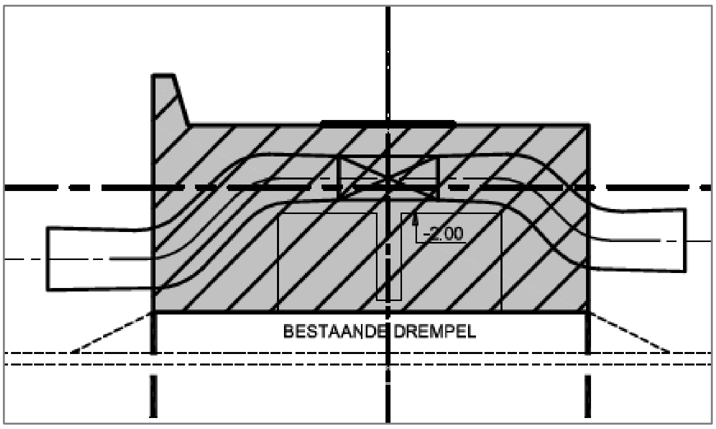

Figure 14: Variant 3C Siphon inside powerhouse [Mooyaart et al., 2010]

As a first approximation the dimensions are equal to the Diffuser powerhouse, thus a length of approximately 35 m and a width of 7.7 m per element. This guarantees overall stability.

5.3.4 *3D 'Venturi in slender structure'*

This variant is a combination of structure 2C (Slender gate structure) and a Venturi. The structure will be placed behind the old caisson with a dry or wet construction method. The old caissons will be used as soil retaining structures during construction, and removed after construction. An impression of this variant is given in Figure 15. The casing of the valves together with the valves will fulfill the water retaining function. All extra soil added to this structure will provide sufficient stability.

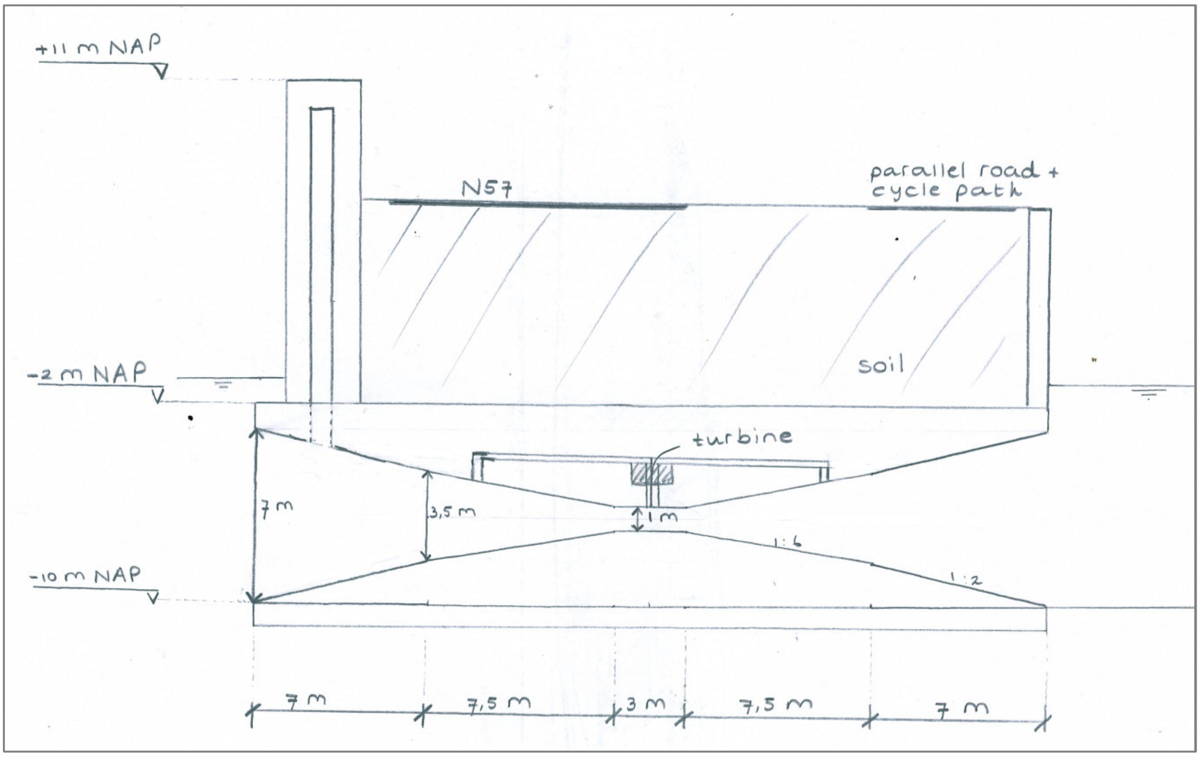

Figure 15: Variant 3D 'Venturi in slender structure', cross-section

5.4 Use of alternative materials

The use of alternative materials, instead of concrete and steel, has been investigated. One should keep in mind that from a structural point of view the Brouwersdam is an aggressive environment: salt water, salty wind, high head difference over the structure and wave attack. Moreover, the structure should be designed and built with a lifespan expectancy of at least 100 years. Given potential head differences over the structure, it should be able to meet all rules of stability, including vertical and horizontal balance. Sufficient weight and ballast is needed to meet there rules.

For above mentioned reasons, it is advised to use (armored) concrete as construction material. The valves, on the other hand, can be built of steel or alternative material, such as high strength concrete with fibers.

The use of alternative materials would rather be applicable to structural elements such as valves and not to the main civil structure.

The sand of sand as ballast material, though, is deviating from existing designs, call it innovative.

6 Assessment of feasible solutions

For each different type of structure a multi criteria analysis is carried out. The scores of each variant are explained per criterion.

6.1 Preferred Diffusor type

For the diffuser structure, three different variants are compared by using a multi criteria analysis, shown in Table 5.

Table 5: MCA Diffuser

	1A Bulb turbine, built in the dry	1B Bulb turbine, built in the wet	1C Bulb turbine, built with a pneumatic caisson
Construction cost	0	0	-
Risks (design and execution)	-	0	--
Performance	0	0	0
Maintenance	0	0	0
Innovation	0	0	0
Hindrance of execution	0	0	+
Flexibility (type of turbine)	-	-	-

<u>Construction costs</u>

For the wet construction method an external building site is needed, which will increase the costs. For the dry method the dry building pit and pumping installation will lead to extra costs.

The pneumatic caisson has extra costs concerning the structure, including entrances for the transit of materials and people. Another point is that the caissons will not be constructed next to each other, but a certain space is needed in-between two caissons. This space needs to be filled up to maintain the water retaining function of the dam. This extra space will increase the length needed in the dam, which will also influence the costs.

<u>Risks</u>

For all variants the stability of the existing caissons as part of the primary water barrier is a risk. The feasibility of a building pit, in terms of drainage, is a risk of the dry construction method. It is not certain if it is possible to pump the building pit dry, because of the dimensions (very deep) and its location (close to the sea and a lake). Another risk for the dry method is the stability of the levee at the Grevelingen side during construction.

For all variants the reliability of the foundation is not known. This risk is relatively small for the dry construction method, because after building a dry building pit the foundation can be checked and improved when needed. When constructing in the wet, the foundation can also be adapted when needed. This is not true for the pneumatic caissons, which results in a high risk. Another aspect concerning the soil characteristics is that for the pneumatic caissons, obstacles will cause problems when immersing the caissons.

The accuracy of placing the elements is much more precisely when building in the dry. For building in the wet and for the pneumatic caissons this results in an additional risk. The pneumatic caissons will not be placed close to each other, as mentioned before, additional risks occur in order to create a water tight connection between the elements.

For the wet construction method and the pneumatic caisson more difficult methods need to be executed in order to create a connection between the structure and the sill or bottom protection. Another risk for the pneumatic caisson is that during immersion of the caisson an overpressure machine will be used. Working in these circumstances and the machines itself result in extra risks.

Performance
For the three variants the same turbine can be used and there are no differences in the turbine dimensions. A larger length might result in some additional hydraulic resistance; this however has a very small influence. This means that the performance will not differ significantly between the variants.

Maintenance
When using two valves, the room in which the turbine is placed can be closed. In this way the turbine can be pumped dry and be maintained. This is probably the same for each variant.

Innovation
All construction methods used for these variants are no new or innovative methods, resulting in an equal score for all variants.

Hindrance of execution
For all variants the roads (N57, parallel roads and cycle paths) need to be relocated, which will cause some hindrance. For the dry method a building pit is needed, which will require more space than for the pneumatic caisson method. For the wet method the entire part at the Grevelingen side of the dam will be excavated, which means that even more space is needed for this method.

Flexibility
This type of structure with diffusers is not very flexible in relation to different types of turbines, it is ideal for a bulb type of turbine. The dimensions of the turbine are flexible, but to a certain extent.

6.2 Preferred Ducted/Gate type

The five variants with a gate type of structure are compared by using a multi criteria analysis, see Table 6. The score of each variant is explained per criterion.

Table 6: MCA Ducted/Gate type

	2A ESB like structure, in the dry	2B ESB like structure, in the wet	2C Slender structure,		2D Floatable pillar containers
			Dry	Wet	
Construction cost	0	--	+	+	-
Risks (design and execution)	-	0	-	+	-
Performance	0	0	+	+	0
Maintenance	0	0	+	+	0
Innovation	0	0	0	0	+
Hindrance of execution	0	0	0	0	0
Flexibility (turbine)	+	+	++	++	0

<u>Construction costs</u>

The main differences between the variants are the dimension and thus the amount of material needed. Compared to the most slender structure (2C), the dry build ESB like structure becomes relatively large in order to be stable and the wet build ESB like structure even larger. This results in high cost for the construction. The gates that should retain storm surge, in variant 2A and 2B are very expensive.

The dimensions of the structure on piles are relatively small, because this structure uses piles for stability. These piles have a large diameter and need to be constructed deep into the underground which will also lead to high construction costs.

A concern for variant 2A and 2B is the placing of a prefab sill beam in-between the pillars, which will increase the total costs. For the wet construction the costs of an external building dock needs to be taken into account. As for the dry method the costs for a dry building pit and the pump installations needs to be taken into account.

<u>Risks</u>

The risks for this type of structure are similar to the risk of the Diffuser type structures. For all variants the stability of the old caissons as part of the primary water barrier is a risk.

The feasibility of a building pit, in terms of drainage, is a risk of the dry construction method. It is not certain if it is possible to pump the building pit dry, because of the dimensions and its location.

Another risk for the dry method is the stability of the levee at the Grevelingen side during construction.

For all variants the reliability of the foundation and the soil characteristics are not known precisely. This is a large risk because settlements and tolerances can be an issue due to the concentrated forces below the pillars. Variant 2C does not have a pillar structure which leads to a lower risk. For the pile structure the piles will have a length of approximately 30 m; it results in risks of construction and the risk that the bearing capacity of the ground is not sufficient.

Another risk for the floatable containers is related to the feasibility (and amount of material needed) to fill the containers.

<u>Performance</u>
Variant 2C is a slender structure which means that less length is needed parallel to the dam. This means that the performance per meter increases for variant 2C. The performance is dependent on the type of turbine, which is not yet defined.

<u>Maintenance</u>
In order to maintain the turbines in the pillar structure a maintenance road will be constructed. However, no separate room is available to execute maintenance which is a disadvantage compared to variant 2C. In the design of variant 2C a separate room is designed for maintenance.

<u>Innovation</u>
No significantly difference is present between the variants in this design phase.

<u>Hindrance of execution</u>
For all variants the roads need to be located temporarily to the top of the dam. Also no difference occurs in use of the dam, the same part will be excavated for all variants.

<u>Flexibility</u>
The Ducted/Gate structures are more flexible than the Diffuser structures, which means that more different type of turbines can be chosen in combination with these structures. In the ESB like structure several turbines are possible, even an axial propeller turbine or an orthogonal turbine.

6.3 Preferred Venturi type

The four different variants for a siphon structure are compared by using a multi criteria analysis, given in Table 7. The score of each variant is explained per criterion.

Table 7: MCA siphon

Variants: Criteria:	3A Siphon, built in the dry	3B Siphon, built in the wet	3C Siphon inside powerhouse	3D Venturi in slender structure	
				dry	wet
Construction cost	-	+	0	+	-
Risks (design and execution)	--	-	-	-	+
Performance	0	+	0	+	+
Maintenance	-	0	0	+	+
Innovation	0	0	0	0	0

Hindrance of execution	0	0	-	0	0
Flexibility (type of turbine)	0	0	0	+	+

Construction costs

In the first three variants it is chosen maintain partly the existing caisson, but still the top 7 meters must be removed in order to decrease the level of the siphons and the required under pressure. Variant 3A is designed with retaining walls at two sides with anchors; these walls must be installed through the bottom protection. This will lead to extra costs. Variant 3C will be built on top of the existing caisson in the dry; this can only be executed by using a temporary water barrier at the sea side. This soil body needs to be provides with bed protection which is costly.

Risks

Variants 3A, 3B and 3C reuse the existing caissons. This entails uncertainties and risks. For instance, is the caisson still stable when removing the top part of the caissons and the steel valve? Can it act as a foundation for the new structure? When removing the soil around the caissons, will they be stable as part of the permanent water barrier?

A risk is the connection from the caisson to the siphons. This does not apply to variant 3D in which a completely new structure will be built. A risk is the foundation of the in- and outflow structures of variant 3A and 3B and their strength. Variant 3A needs to carry a lot of added soil, which can cause problems. A risk for variant 3A is the construction of the rows of sheet piling through the bottom protection.

Performance

The length of the siphons plays a dominant role in relation to hydraulic losses. Variant 3B and 3D are the shortest variants and therefore have the lowest hydraulic losses.

Maintenance

On top of the siphon in variant 3A, a lot of soil will be added, creating difficulties in assessment and maintenance of the installations. For variant 3B and 3C, no extra soil is added which makes it easier to maintain the structure and for variant 3D even a separate room is designed for maintenance of the turbines and generators.

Innovation

No significantly difference is present between the variants in this design phase.

Hindrance of execution

Variant 3C will be built in the center of the dam, which will lead to extra hindrance during execution. The other variants also need to build the siphon over the old caissons, but this can be done in a shorter time period to decrease the hindrance of execution.

Flexibility
For the siphon type of structure the dimensions are not flexible which means that the type of turbine is also not very flexible. A turbine which uses a Venturi can be applied to all siphon solutions.

6.4 Overview of building costs

Based on the quotations, see Appendix G, Table 8 gives an overview of the building costs per variant, VAT excluded. The most cost effective variants, in terms of civil costs all-in, are marked red. As building costs are of great importance, Pro-Tide-NL indicated the marked variants (1B, 2C2 and 3D) as preferred solutions to be investigated in depth. The preliminary design of these three solutions is reported in Chapter 7.

Table 8 Overview building costs

Construction method	Length [m]	Civil costs All-in [M€]	Costs/m [M€/m]	Added costs closure [M€/m]	Total Civil costs [M€/m]
1A Bulb dry	625	268	0,43	0,03	0,46
1B Bulb wet	625	263	0,42	0,03	0,45
1C Bulb pneumatic	625	320	0,51	0,03	0,54
2A ESB, dry	150	101	0,67		0,67
2B ESB, wet	150	TBD			
2C1, Ducted, dry	150	63	0,42		0,42
2C2, Ducted, wet	150	60	0,40		0,40
2D Ducted, piles	150	98	0,65		0,65
3A Siphon, dry	625	370	0,59		0,59
3B Siphon, wet	625	400	0,64		0,64
3C Siphon, top, dry	625	308	0,49		0,49
3D Venturi					
3E Linear VETT	200	138	0,69		0,69

Note: Variant 3D 'Venturi in slender structure' has no quotation. In the process of indicating three preferred alternatives, a new variant originated: variant 3E 'Linear VETT'. Pro-Tide-NL indicated variant 3E as one of three preferred solutions.

7 Preliminary design of three preferred solutions

The best variant within each alternative/type, see chapter 6, will be analyzed in depth, optimized and evolved into a preliminary design. Due to optimization, the preliminary designs might differ slightly compared to the solutions as presented in chapter 5.

Appendix D contains all stability and dimensional calculations, upon which the preliminary designs in this chapter are based. Appendix G contains quotations according to SSK standard.

Appendix H contains all drawings / 3D visualizations of the presented alternatives.

7.1 Alternative 1: diffusor type structure

7.1.1 Design presentation

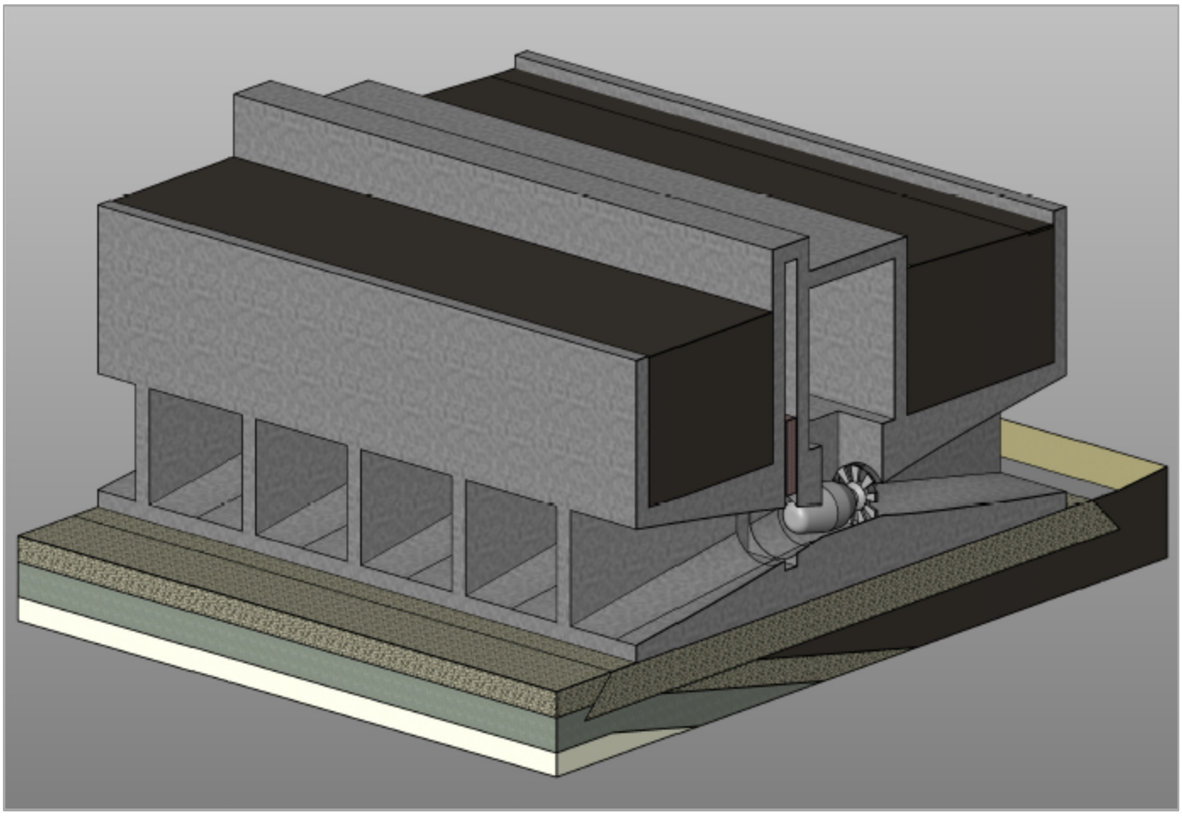

Figure 16 Visualization 3D Diffusor type structure

The design of this variant is mostly determined by the structure of the diffuser, which forces water to flow through a converging structure in which the turbine will be placed. Next the water will flow through a diverging outflow structure. The design has only minor changes compared to the variant 1A and 1B, mostly concerning the dimensions.

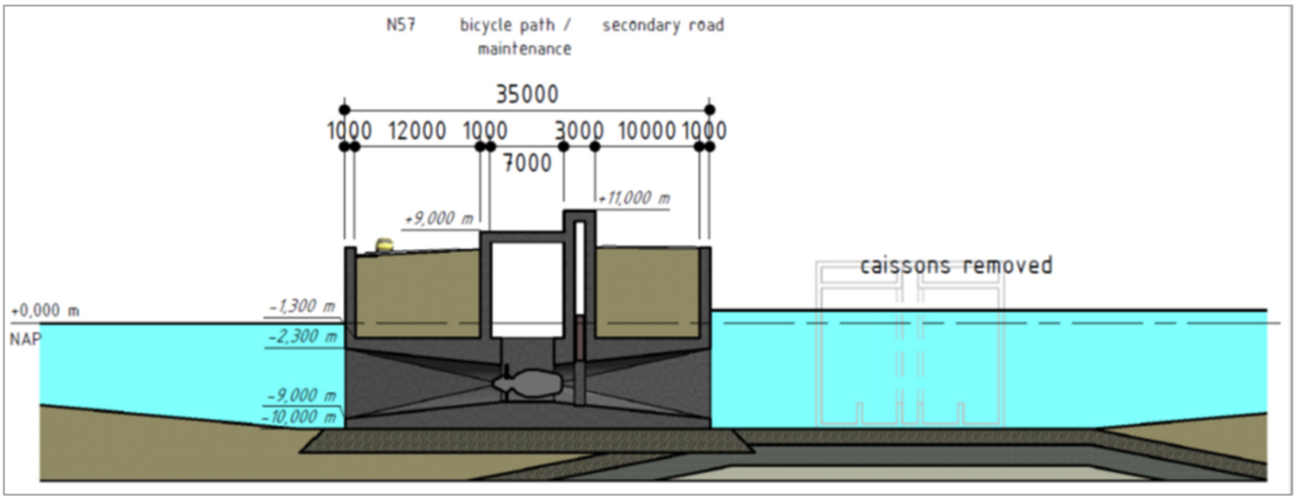

Figure 17 Cross section Diffusor type structure

The location of the turbine is mostly fixed, in the middle of the structure. As a consequence the technical room is also located in the middle of the structure. The turbine can be hoist up into the technical room for maintenance. In order to combine the technical room with a room for maintenance of the valves, the valves are located at the sea side of the turbine but still in the middle of the structure. At both sides of the technical room soil bodies are constructed, which form the basis for the N57 and a parallel road. A cycle path and maintenance road is located on top of the technical room. In extreme conditions, the parallel road needs to be closed, because it is located at the sea side of the primary water barrier.

The total length of this structure (perpendicular to the dam) is 35 m, which is the minimum diffuser length for turbines with a diameter of 3.5 m. In total 86 turbines are needed to create a tidal range of 0.5 m in Lake Grevelingen, this leads to a total length (parallel to the dam) of 662 m.

The connection between the structure and the present dam consists of a combi-wall, which is space efficient comparing to an asphalt slope. In order to reach an optimal design of this connection further research is recommended.

The structure itself will be built on top of the present bottom protection and part of the present sill. The sill needs to be checked and must be extended to the required length. It is assumed that the present bottom protection, consisting of a layer of mastic asphalt and rubble, still fulfills the requirements.

7.1.2 *Construction method, in the wet*

The diffuser variant consists of a lot of concrete, which means that this structure is difficult to make floatable. In total 86 diffusers are needed with a total length of 662 m. An option is to create in total

6 elements of approximately 100 m long and 35 m wide. In order to let these elements float, head walls can be used or other floatable elements. Still, this will not give enough buoyancy for one element, which means that external floatable units are needed. Both the structure elements and the external floating units need to have a draught of approximately 8 m, which is at least 1 m above the final construction depth.
An option to place the elements is by using phasing, in which elements with a lower mass can be floated to its location. This mass reduction is done my making openings in the diffuser structure, which can be filled with concrete once the elements are at its final location. The casing of the valves and the technical room can also be built after floating the elements to their location; this also reduces the total weight of the elements during transport.

7.1.3 Quotation

Building costs of the civil structure, design included, have been quoted in Appendix G. Building costs are estimated at € 318.500.000 +/- 30 % (VAT included).

7.2 Alternative 2: ducted type turbine

7.2.1 Design presentation

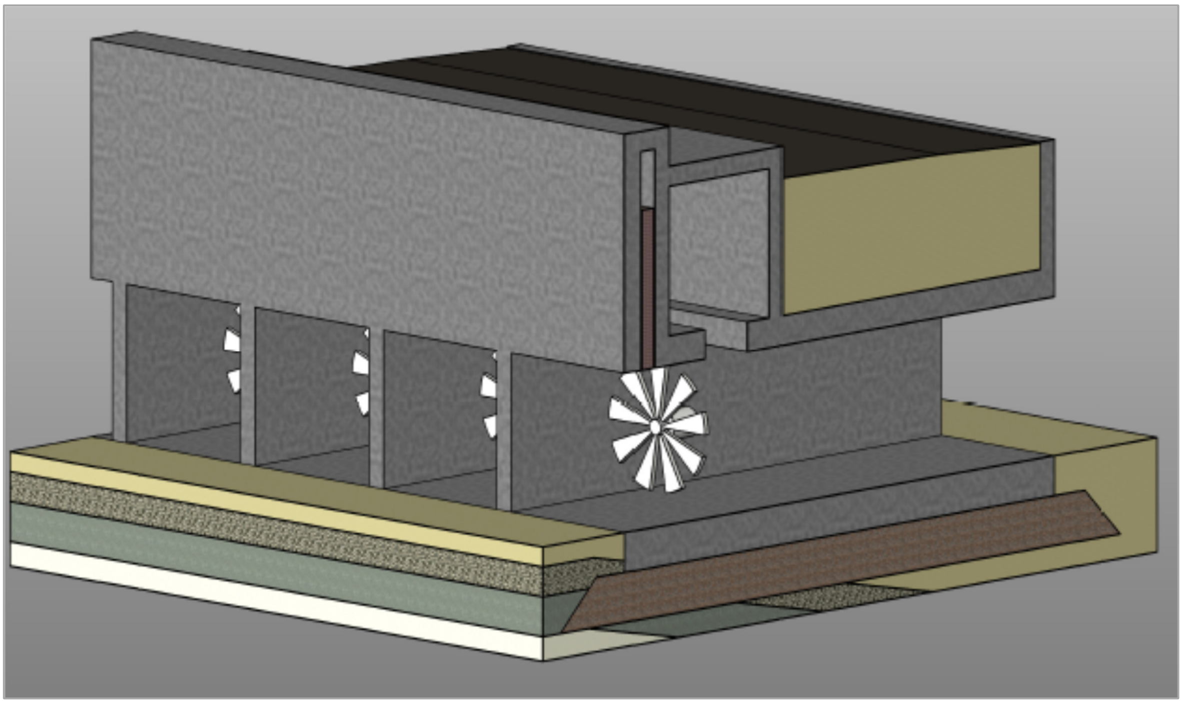

Figure 18 Visualization 3D Ducted type structure

A ducted structure contains a larger flow area, increasing flow capacity significantly. Therefor it influences the total length needed in the dam (parallel to the dam).

A floor will be constructed over the whole width of the structure and at every 8 m walls will be built on which a roof element can be constructed. The wet area of one unit is 8x8 m2, in which one large turbine can be placed.

The valve and water barrier are located at the sea side of the structure. Behind the valves a technical room is located in which the turbines and the valves can be maintained. On top of the technical room a cycle path/maintenance road can be constructed. At the Grevelingen side of the structure soil will be added on top of which the parallel road and N57 will be located.

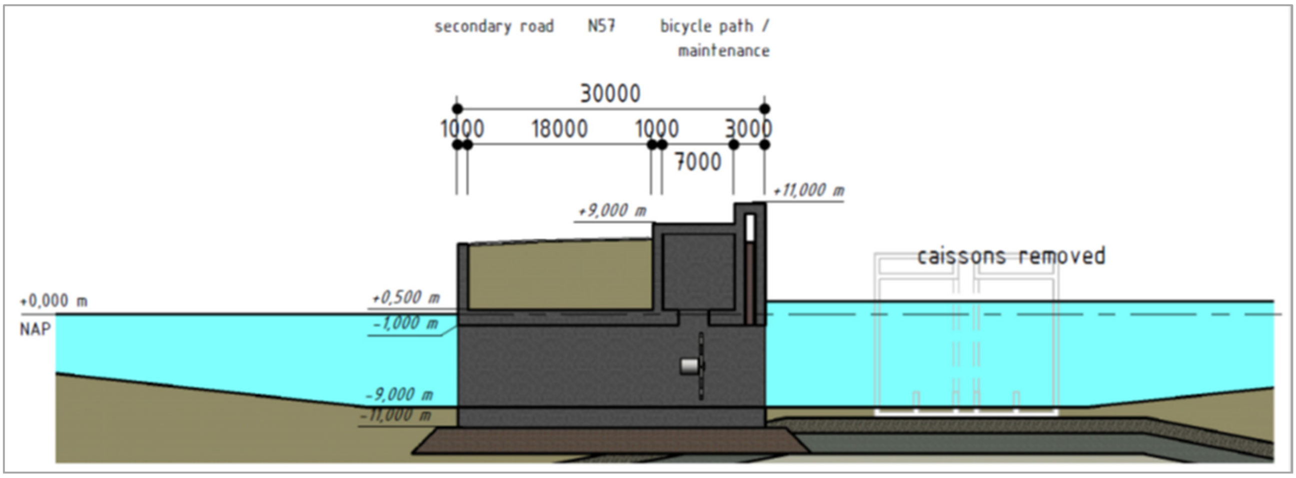

Figure 19 Cross section Ducted type structure

For stability reasons an extra thick floor element of 2 m is designed, which brings the total depth of this structure to a level at NAP-11 m. The structure will be located on top of the present bottom protection and the adjacent sill structure.

The connection between the structure and the dam, again, consist of a combi-wall.

In this variant a safe connection is made between the valves, water barrier and the combi-wall, because the structure of the barrier is placed at the sea side and hence creates a continuous barrier.

7.2.2 Construction method, in the wet

The ducted variant has a length of 135 m and a width of 30 m. Each element can be placed in one piece. This has the advantage of not having any (underwater) connections. Moreover the operation has to be executed only once. This element has more buoyancy force than the diffuser, because less concrete is used. Also for this element a draught of 8 m is preferred, which means that probably extra floating capacity must be added. This can be done by using sponsons, hollow elements with high buoyancy. The maximal draught for these elements is also 8 m. The extra width of the sponsons, needed at each side of the element, must be available in the dry dock.

7.2.3 Quotation

Building costs of the civil structure, design included, have been quoted in Appendix G. Building costs are estimated at € 75.000.000 +/- 30 % (VAT included).

7.3 Alternative 3: linear VETT

7.3.1 Design presentation

The linear Vett structure has been evolved in the process to choose the best Venturi variant. It has not been presented in chapter 5. This Venturi Enhanced Turbine Technology (Vett) is designed by VerdErg and will be applied into a slender type of structure. In the linear Vett, the water flow is converged into a Venturi in which the water will accelerate, entailing a drop of pressure compared to the incoming flow, see Figure 20.

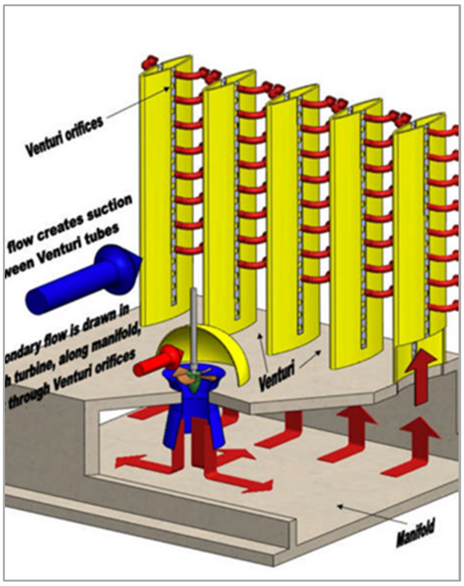

Figure 20 Linear VETT

In order to use this pressure difference, a separate opening is constructed through which 20 % of the total water volume will flow. Because of the lower pressure water will flow through a turbine, along a manifold into a basement structure after which the water will flow through the Venturi vanes (VerdErg, 2014).

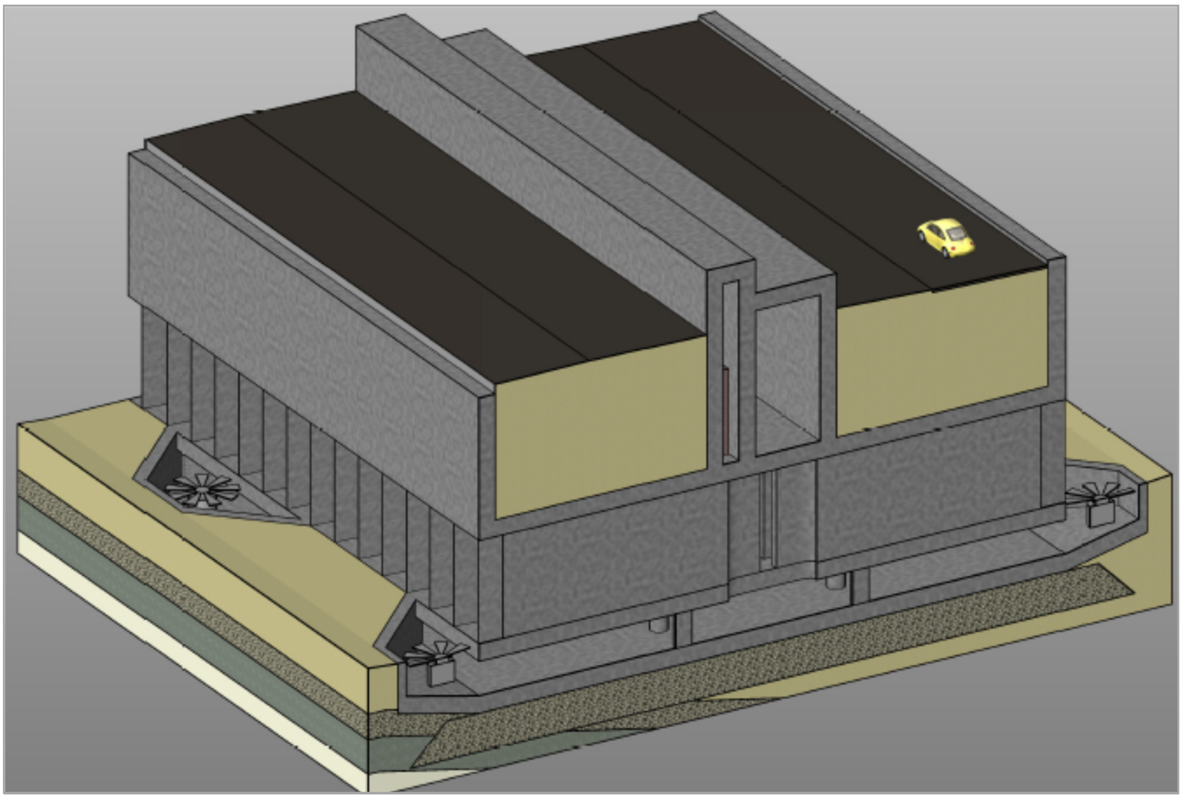

Figure 21 Visualization 3E 'Linear VETT' structure

The dimensions are fixed for this Venturi, in total a length of 200 m (parallel to the dam) is needed to achieve the 0.5 m tidal range. The whole structure consists of 8 units. In front of every 10 Venturi openings a turbine will be placed, on both sides (sea and Grevelingen). One unit has a length of 25 m (parallel to the dam). This means that overall 8x2 turbines will be placed. These turbines can be hoist up from an external pontoon for maintenance.

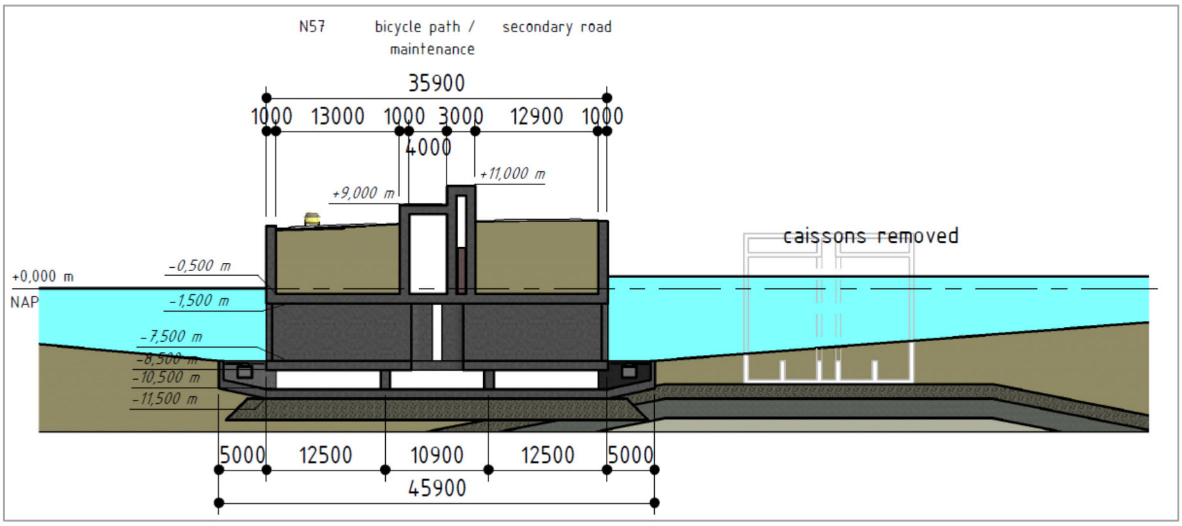

Figure 22 Cross section VETT type structure

Many small valves are installed instead of a few large valves. The valves will be placed at the narrowest point of the Venturi, to keep the valves as small as possible. The valves are connected to a technical room from which the valves can be maintained.

At both sides of the valve a soil body is present to guarantee stability. It also creates a smooth connection to the present dam. In order to decrease the soil pressure below the structure, underneath the N57 EPS blocks can be used to reduce the weight.

At the sea side a parallel road and cycle path will be constructed and at the other side the N57 will be located. During extreme water levels, the parallel road and cycle path need to be closed, because they are located at the sea side of the primary water barrier.

7.3.2 Construction method, in the wet

The Venturi variant will have a length of 200 m and a width of 38.5 m. The structure exists of several concrete elements. One element has a width of 50 m, in which 4X2 turbines can be placed. Like the diffuser variant, this variant also needs extensive external buoyancy. As an alternative the structure can be installed in different phases. For example, the basement structure can be placed first by floating this part and immersing it. Next the Venturi vanes can be constructed and the prefab elements can be connected to the basement structure. As last step, the roof structure can be constructed together with the valves and other structures above water level.

7.3.3 Quotation

Building costs of the civil structure, design included, have been quoted in Appendix G. Building costs are estimated at € 138.500.000 +/- 30 % (VAT included).

8 Conclusions and recommendations

The **objective** of this study was to develop a state-of-the-art civil structure and construction method for a tidal power plant in the Brouwersdam, reducing building costs significantly compared to quotations of sluices in [MIRT Grevelingen, 2014] and following studies.

The structure should meet all requirements mentioned in [MIRT Grevelingen, 2014], based on its four functions, see chapter 4 in this report:

- protecting hinterland against storm surges (primary flood defense n° 14);
- regulating water level (tidal movement on lake Grevelingen of 0.5 m);
- facilitating traffic (N57, parallel roads and cycle path) and
- generating energy.

The result of this study contains, amongst others, **three technically feasible designs** for a tidal power plant, of which two are competing with the quotation of the reference design, see chapter 3, € 138.000.000 +/- 30 %, VAT included:

1. A diffusor structure;
   - is able to carry (rather expensive) bulb turbines and bi-directional turbines;
   - is built to optimize energy production;
   - has relatively low flow capacity;
   - results in a relatively large structure, 662 m in length;
   - is quoted at € 318.000.000 +/- 30 %, including VAT, if built in the wet;
2. A slender ducted structure able to carry varies types of turbines, including free stream turbines
   - is able to carry varies types of turbines, including free stream turbines;
   - has relatively high flow capacity;
   - results in a relatively short structure, 136 m in length;
   - is quoted at € 75.000.000 +/- 30 %, including VAT, if built in the wet;
3. A Linear VETT structure
   - is equipped with innovative (relatively cheap) Venturi Enhanced Turbine Technology;
   - has lower energy production due to extra energy conversion steps;
   - results in a structure of 200 m length;
   - is quoted at € 138.000.000 +/- 30 %, including VAT, if built in the wet.

These quotations are based on SSK standard and include civil building costs, design costs of the civil structure and VAT. The margin of 30% includes risks and uncertainties within the scope, boundary conditions and assumptions upon which the designs are based, as well as variations in cost price and changes in estimated quantities.

The reduction in building costs (related to the reference design) of the civil structure is achieved due to:

- comprehensive engineering and design, resulting in in-depth understanding of required dimensions;

- using existing caissons as soil retaining structure during construction. This means that a temporary flood defense is no longer needed, roads are only detoured during construction time and building pit is smaller;
- building in the wet.

Based on the gained knowledge within this study, further reduction in building costs is expected and would benefit Pro-Tide, if the following recommendations are followed up:

a) Invest in detailed engineering and design;
b) Invest in research and/or design of an integrated civil, turbine and mechanical structure;
c) Invest in geotechnical survey, in order to define more accurate (non-conservative) soil parameters;
d) Invest in advanced hydraulic analyses (numerical or physical scale modeling), in order to forecast more accurate flow capacity and energy production, as structure length is of great importance for building costs and performance.

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Welsink, M., and Yazici, S., *Innovatieve civiele technieken voor de getijcentrale Brouwersdam.* TU Delft, 2014.

Appendix A: Results existing studies

Iv-Infra

Report B: Notitie civiele aspecten doorlaatmiddel Brouwersdam (Ministerie van Verkeer en Waterstaat, Witteveen+Bos, 2008)

Variant	Investment [x10^6 euro]**	Energy yield [GWh/y]	Tide [m]***	cent/kwh (NPV=0 in 60 year)	Type	Location	Location in lateral direction	Dock type	Turbine	Dturbine [m]	n turbines	Average discharge [m3/s]	Stability checked?
B. 1	314	0	0,5	-	Sluice	South	Inner side dam	Dry dock, with the help of temporary dam	-	-	-	2500	No
B. 2	314	0	0,5	-	Sluice	North	Inner side dam	Dry dock, with the help of temporary dam	-	-	-	2500	No
B. 3	1549	344	1,0-1,1	-	Power plant, Bi-D	South and North	Inner side dam	Dry dock, with the help of temporary dam	Bulb	3,5	106+70	7600	No

"Full costs"

*** Characteristics tidal power plant variant 3 based on TU Delft 2008 variant 7**
**** Determined investment costs have a bandwidth of +/- 50% for reports B, C, and D. For report A a bandwidth was not stated.**
*****Tide is defined as two times the tidal amplitude**

Report A: Getijcentrale in de Brouwersdam, een verkennende studie (TU Delft, 2008)

Variant	Investment [x10^6 euro]	Energy yield [GWh/y]	Tide [m]**	cent/kwh (NPV=0 in 60 year)	Type	Location	Location in lateral direction	Dock type	Turbine	Dturbine [m]	n turbines	Discharge during operation [m3/s]	Stability checked?
A. 1a	291,2	226	1,0-1,1	7,17	Ebb	North	Orgininal caissons	Dry dock	Bulb	3,5	106	5100	No
A. 1b	291,2	203	1,1-1,2	7,98	Flood	North	Orgininal caissons	Dry dock	Bulb	3,5	106	5100	No
A. 2a	279,2	226	1,0-1,1	6,88	Ebb	North	Orgininal caissons	Dry dock	Bulb	3,5	106	5100	No
A. 2b	279,2	203	1,1-1,2	7,66	Flood	North	Orgininal caissons	Dry dock	Bulb	3,5	106	5100	No
A. 3a	457,6	392	1,5	6,48	Ebb	North and South	Orgininal caissons / block dam	Dry dock	Bulb	3,5	106+52	7600	No
A. 3b	457,6	280	1,5	9,07	Flood	North and South	Orgininal caissons / block dam	Dry dock	Bulb	3,5	106+52	7600	No
A. 4	228,5	213	0,7	6	Bi-directional	North	Orgininal caissons	Dry dock	Bulb	3,5	106	2x4560	No
A. 5	167,5	145	0,4	6,43	Bi-directional	South	Orgininal block dam	Dry dock	Bulb	3,5	70	2x3010	No
A. 6	188,1	162	0,5	6,47	Bi-directional	South (2 layers)	Orgininal block dam	Dry dock	Bulb	3,5	2x40	2x3440	No
A. 7	395,95	344	1,0-1,1	6,43	Bi-directional	South and North	Orgininal caissons / block dam	Dry dock	Bulb	3,5	106+70	2x7570	No
A. 8	416,55	353	1,1	6,59	Bi-directional	South and North	Orgininal caissons / block dam	Dry dock	Bulb	3,5	106+2x40	2x8000	No

Without costs for dock, etc.!

Report C: Getijcentrale in de Brouwersdam, variantenstudie (Groenservice Zuid-Holland, Royal Haskoning, 2010)

Variant	Investment [x10^6 euro]	Energy yield [GWh/y]	Tide [m]**	cent/kwh (NPV=0 in 60 year)	Type	Location	Location in lateral direction	Dock type	Turbine	Dturbine [m]	n turbines	Average discharge [m3/s]	Stability checked?
C. 1a	499	193	0,57	-	Bi-directional	North	Orginінal caissons	Dry dock	Bulb	3,5	106	-	No
C. 1b	315	30	1,6	-	Bi-directional	North	Orgininal caissons	Dry dock	Free flow turbine	6	20x4	-	No
C. 1b*	158	10	0,5	-	Bi-directional	North	Orgininal caissons	Dry dock	Free flow turbine	6	20x4	-	No
C. 2a	534	193	0,57	-	Bi-directional	North	Inner side dam	Dry dock, with the help of temporary dam	Bulb	3,5	106	-	No
C. 2b	350	30	1,6	-	Bi-directional	North	Inner side dam	Dry dock, with the help of temporary dam	Free flow turbine	6	20x4	-	No
C. b*	175	10	0,5	-	Bi-directional	North	Inner side dam	Dry dock, with the help of temporary dam	Free flow turbine	6	20x4	-	No
C. 3a	562	193	0,57	-	Bi-directional	North	In Lake Grevelingen inner side dam	External dock, submersed + building in the wet	Bulb	3,5	106	-	No
C. 3b	379	30	1,6	-	Bi-directional	North	In Lake Grevelingen inner side dam	External dock, submersed + building in the wet	Free flow turbine	6	20x4	-	No
C. 3b*	190	10	0,5	-	Bi-directional	North	In Lake Grevelingen inner side dam	External dock, submersed + building in the wet	Free flow turbine	6	20x4	-	No
C. 4a	497	174	0,56	-	Bi-directional	North	Siphon partially over original caissons	Dry dock	Waterpower/(tube-) turbine	≈ 3,5	≈ 106	-	No
C. 4b**	301	118	0,56	-	Bi-directional	North	Siphon partially over original caissons	Dry dock	Pneumatic	-	-	-	No

"Full costs"

Report D: Innovatieve civiele technieken voor de Getijcentrale Brouwersdam (TU Delft, 2014)

Variant	Investment [x10^6 euro]	Energy yield [GWh/y]	Tide [m]**	cent/kwh (NPV=0 in 60 year)	Type	Location	Location in lateral direction	Dock type	Turbine	Dturbine [m]	n turbines	Average discharge [m3/s]	Stability checked?
D. 1: Base variant	468	Same as haskoning 1a?*	Same as haskoning 1a?*	-	Bi-directional	North	Orgininal caissons	Dry dock	Bulb	3,5	106	Same as haskoning 1a?*	Yes
D. 2: MKV1: Larger D	434	Same as haskoning 1a?*	Same as haskoning 1a?*	-	Bi-directional	North	Orgininal caissons	Dry dock, with the help of temporary dam	Bulb	7	26	Same as haskoning 1a?*	Yes
D. 3: MKV2: VLH turbine	475	Lower efficiency	-	-	Bi-directional	North	Orgininal caissons	Dry dock	VLH Turbine	5,5	152	4520	Yes

"Full costs"
***Same turbine surface chosen for base variant and MKV1 as with Royal Haskoning 1a**

Iv-Infra

Report B: Notitie civiele

Variant	Stab. sufficient?	Remarks	Basic assumptions	Assumptions	Boundary conditions	Recommended further research
B. 1	-		- Location sluices at old tidal closures. In the southern part as far as possible from the Schouwense Bank. - Maintenance dredging is to be avoided, which can be expected upto a bottom height of -10 m NAP. -Lowest possible cost over a lifetime of 100 years except for considerations of sustainable building and health & safety.	- Discharge coëfficiënt 0.6 (conservative)	- Indicative design water level NAP +6,00 m - North: Upto -40 m NAP subsoil medium to very fine sand. - South: Upto -50 m NAP mainly coarse sand, local clay layer.	- Additional costs by reintroducing tide (adjusting banks, ports, etc.) - Maintenance costs - Optimization dimensions sluice - Flow through and streamlining sluice - Geotechnical investigation in purpose of foundation - Reliability closure sluice / tidal power station
B. 2	-					
B. 3	-					

Report A: Getijcentrale i

Variant	Stab. complies?	Remarks	Basic assumptions	Assumptions	Boundary conditions	Recommended further research
A. 1a	-		- Maximum water level variation: 1.50 meter. - Costs that would been made to achieve a tide for ecological reasons, are not included in the economic calculation.	- System efficiency: 85% - Constant water surface Lake Grevelingenr: 117 km2	-Measured water level Brouwershavensche Gat-08 over a few years.	- Further specifications and operation of low head turbines (e.g., the ability to pump and sluice). - Technical aspects of a tidal power station annex sluice. - A financial and economic analysis, in which it becomes clear what the total costs and benefits will be and how these should be distributed to the involved parties.
A. 1b	-					
A. 2a	-					
A. 2b	-					
A. 3a	-					
A. 3b	-					
A. 4	-					
A. 5	-					
A. 6	-					
A. 7	-					
A. 8	-					

Report C: Getijcentrale i

Variant	Stab. complies?	Remarks	Basic assumptions	Assumptions	Boundary conditions	Recommended further research
C. 1a	Same as TU Delft 2014 base?	-	- Bi-directional power plant - Northern part Brouwersdam. - Available length northern part, 812.5 meters, is fully exploited. - Height of top sea-defense construction at design water level (+6.2 m NAP), height road should be discussed. - Traffic capacity of N57 must be equal to current capacity after completion. Necessity and location parallel roads and tourist railways should be reconsidered. - Considered the large scale of the project, dimensions turbines not dependent on standards. - For reasons of fish-friendliness for siphon-like solutions, a maximum pressure of 4 m water column. - No conduits or large cables that must be removed or replaced. - Harbor dams at northern side are no obstacle for connecting structures.	- Sill and bottom protection used for closure of the Brouwerdam are in good condition and are possibly useful during construction or operational phase. - A bulbturbine can be closed with sufficient reliability. Both the guide vanes and turbine blades are adjustable and can be used for closure. - System efficiency bulb: 80%, siphon: 72%, pneumatic: 50% - Constant surface Lake Grevelingen: 117 km2 - Discharge coefficient 0.6 for variants 123b	Waterstand / Waarde: Huidige toetswaterstand [HR 2006]: NAP + 5,00 m Ontwerpwaterstand (100 jaar): NAP + 6,20 m Laagwaterstand: NAP – 1,50 m Hoogwaterstand Grevelingenmeer[8]: NAP + 1 m Laagwaterstand Grevelingenmeer: NAP – 1 m MIddenwaterstand Grevelingenmeer: NAP - Measured water level Brouwershavensche Gat-08 of the year 2009.	- Stability - Drainage discharge dock (1,2,4) - Fish-friendly measures (a) - Discharge coefficient (123b, 123b *) - Wether a parapet meets the safety requirements (1.4) - Whether the mastic layer reduces underflow (1,2,4) - Dimensions and performance hydro turbines (a) - Strength properties / stability design (123a) - Stability temporary dam (2) - Cost external dock, larger turbine, soil composition lake side (3) - Minimization hydraulic losses, costs sea-defense construction (4) - Cavitation (4a) - Performance full-scale pneumatic turbines (4b)
C. 1b	-	-				
C. 1b*	-	Rough cost estimate base on 1b				
C. 2a	-	-				
C. 2b	-	-				
C. b*	-	Rough cost estimate base on 2b				
C. 3a	-	-				
C. 3b	-	-				
C. 3b*	-	Rough cost estimate base on 3b				
C. 4a	-	-				
C. 4b**	-	Turbine only tested on lab. scale				

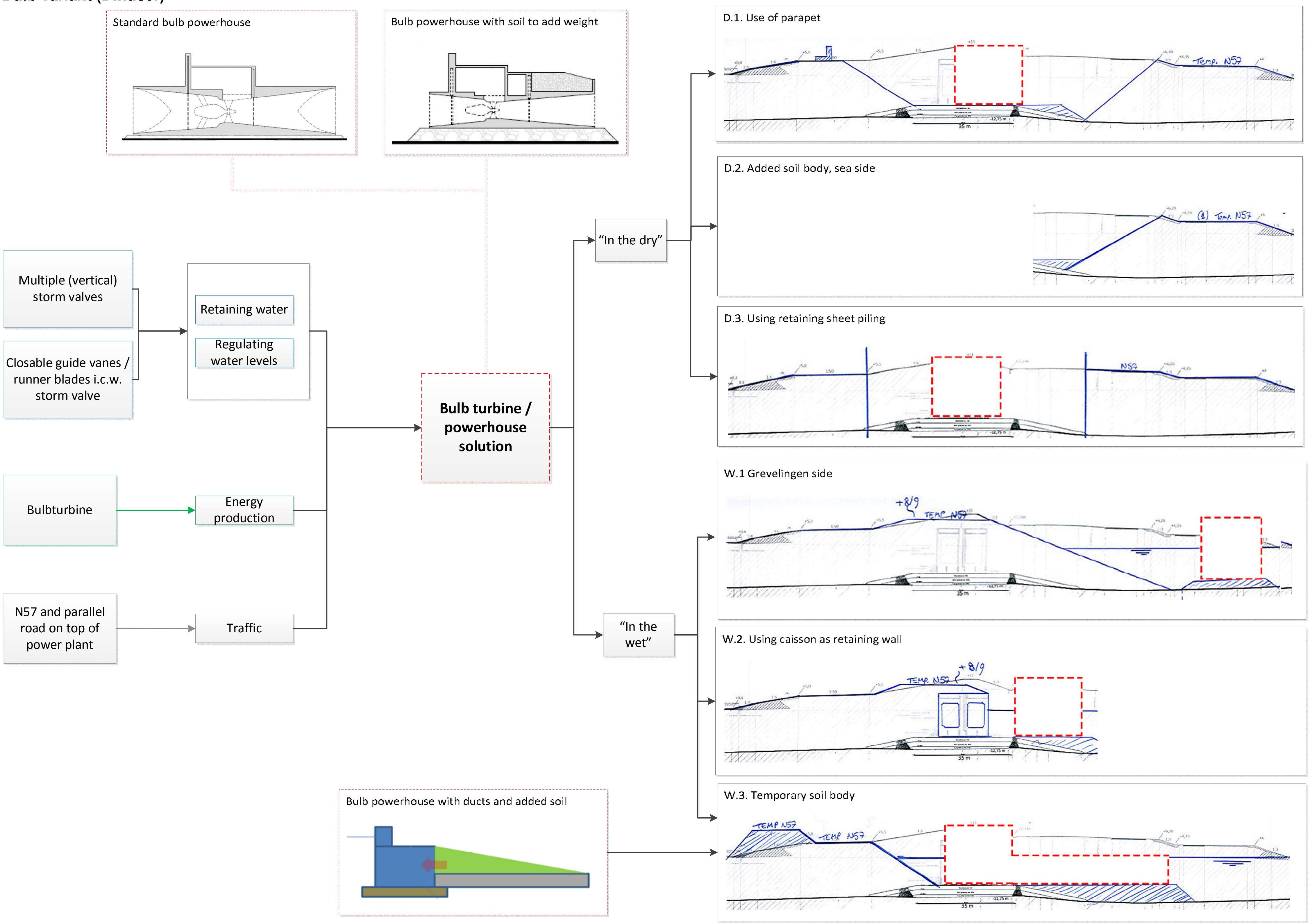
Report D: Innovatieve ci

Variant	Stab. complies?	Remarks	Basic assumptions	Assumptions	Boundary conditions	Recommended further research
D. 1: Base variant	No, horizontal equilibrium	Base variant based on previous reports	- Bi-directional power plant - Northern part Brouwersdam. - Only damped tidal variation permitted - Available length norther part: 812.5 meter - Retaining height equal to Oosterscheldekering (+5,80 m NAP) - Traffic capacity of N57 must be equal to current capacity after completion. - No conduits or large cables that must be removed or replaced. - Harbor dams at northern side are no obstacle for connecting structures.	- Sill and bottom protection used for closure of the Brouwerdam are in good condition and are possibly useful during construction or operational phase. - Soil protection calculated based on heads of 2.5 to 3 meterr. - A bulbturbine can be closed with sufficient reliability. Both the guide vanes and turbine blades are adjustable and can be used for closure.	- Hydraulic boundary conditions from report Royal Haskoning. - North: Upto -40 m NAP subsoil medium to very fine sand.	- Upto which dimensions the VLH turbine can be scaled - Influence resonance ib external diffuser - Cost of removing bottom protection and sill - Potential reduction of concrete by using sand as ballast - Design primary flood defense - Safety against flooding during construction - Road free of waves - Reliability of closure - Efficiency turbines - State of bottom protection and sill - Dewatering or impermeable layer
D. 2: MKV1: Larger D	Yes					
D. 3: MKV2: VLH turbine	Yes					

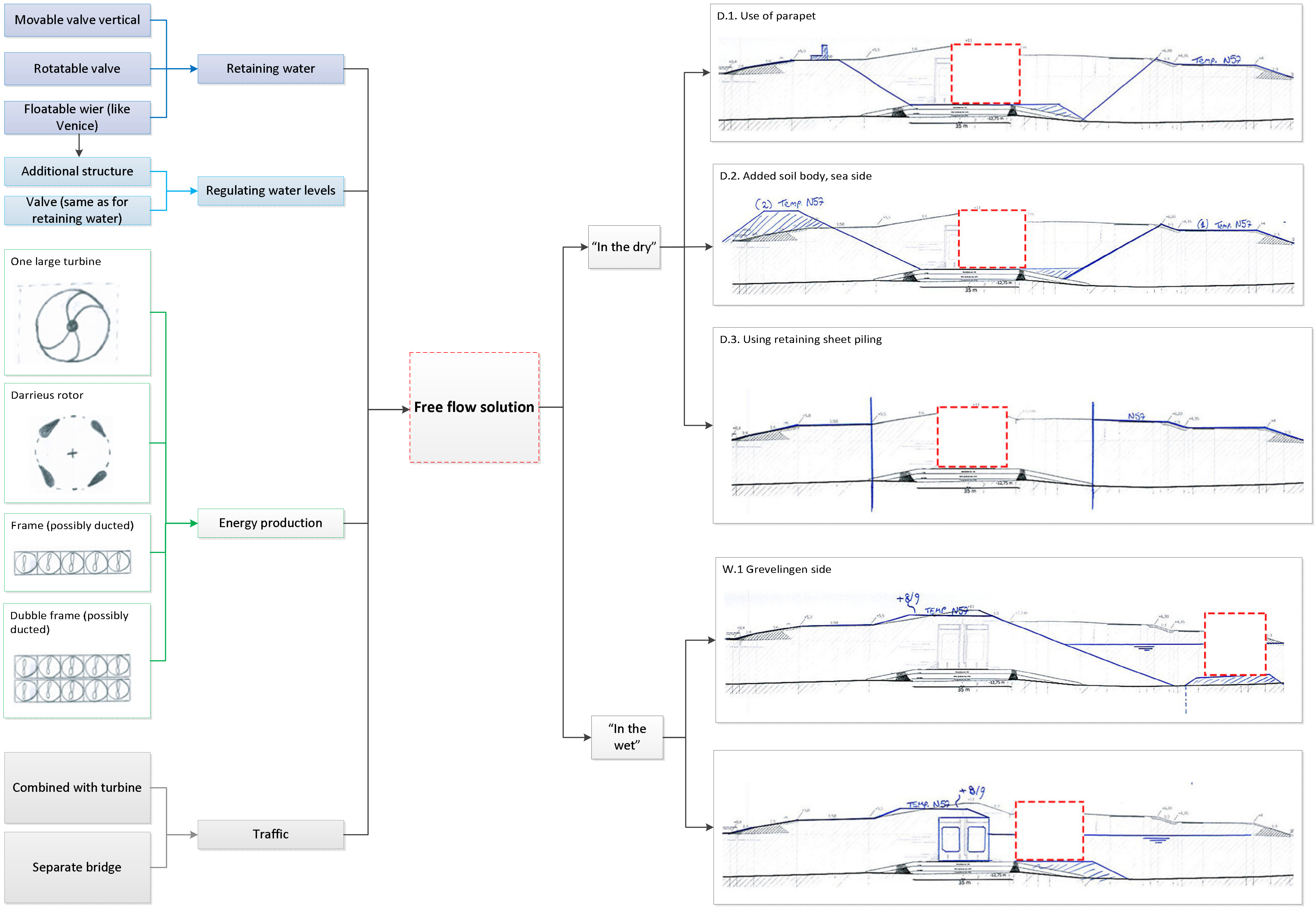
Appendix B: Work session 1. Flow diagrams

APPENDIX B: FLOW DIAGRAMS

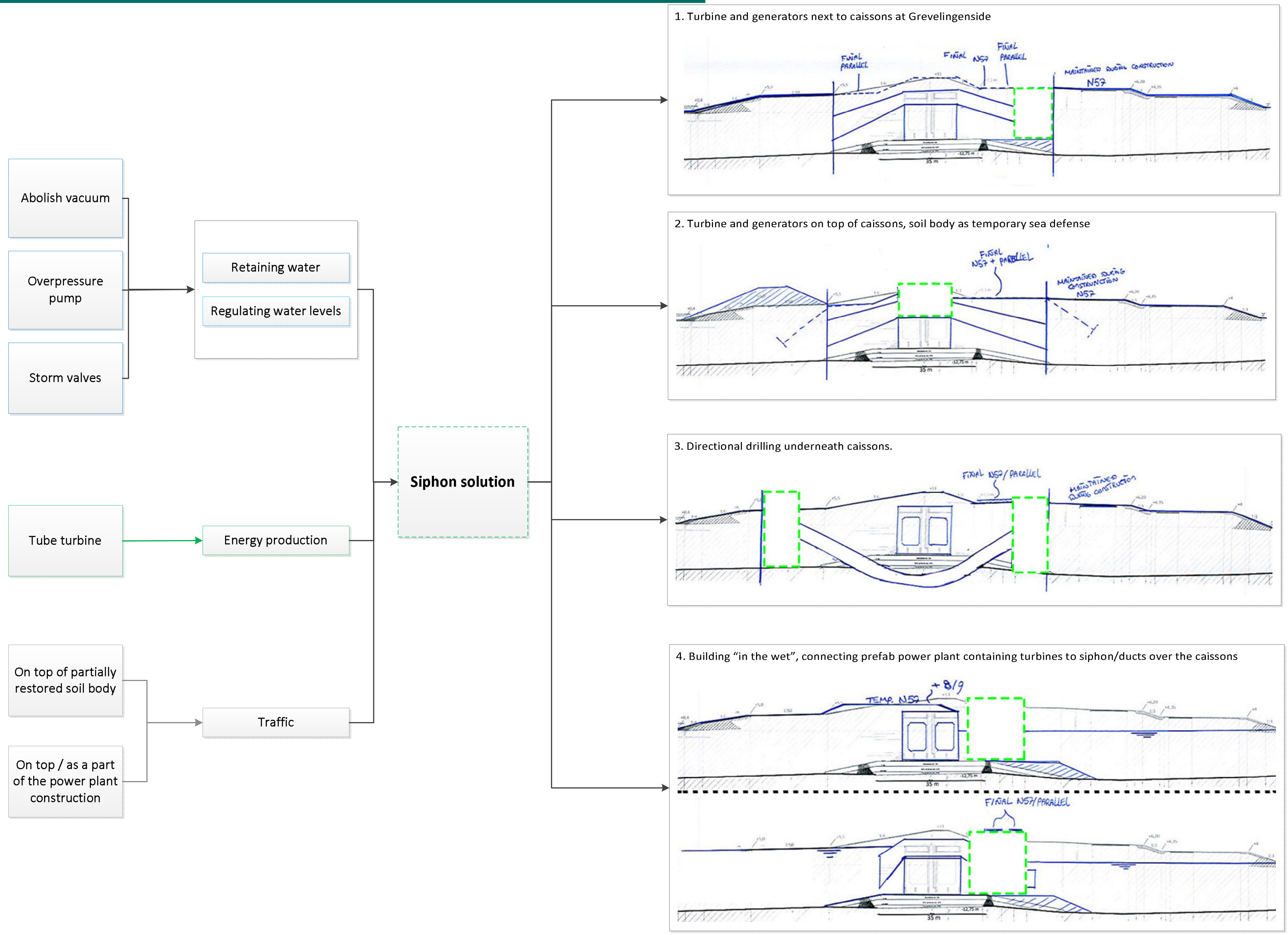
Bulb variant (Diffuser)



Flow diagram type Free flow (Gate)



Flow diagram type Siphon



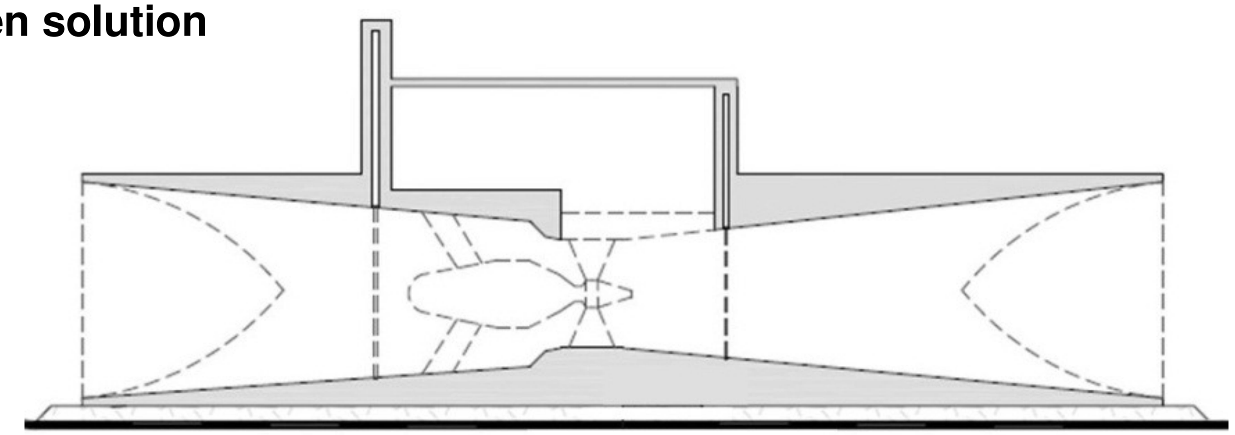
Appendix C: Work session 2. Overview promising variants

APPENDIX C1: OVERVIEW PROMISING VARIANTS

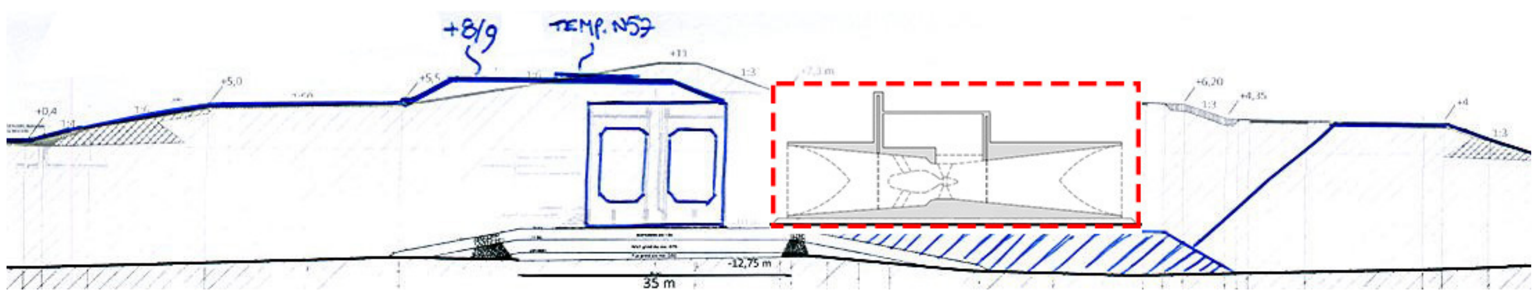
Type turbine: Diffuser
ID: Variant 1A. Building in the dry

Explanation design:
The ‘standard’ bulbturbine powerhouse design is chosen, see figure below, possibly using soil to add weight to this structure if necessary.
The water retaining function is most likely fulfilled by a set of multiple vertical valves, since the type of turbine will probably not be able to close and retain water itself. If this is the case, it is possible to reduce the number of storm valves for water retaining and regulation.
The traffic connection (N57 and parallel road) runs over the power plant, most likely above the location of the turbines.

Chosen solution form



Cross-section during



Construction method:
In this variant during construction the caissons are remained intact and used as retaining wall. The execution is done “in the dry”.
A number of prefab high strength concrete (HSC) shells can be placed and then ‘glued’ together by a lower strength concrete (like B45). This lower strength concrete adds the necessary weight to stabilize the structure.
In short, the construction method of variant A is as follows:

1. Lowering the crest of the dam to about +8/9 m NAP to create space for the temporary N57;
2. The N57 will be relocated to the crest of the dam;
3. Excavation of building pit between caissons and the remaining of soil body at the Lake Grevelingen side and pump this building pit dry. In order to pump it dry, also below the bottom protection water needs to be pumped away in order to avoid uplifting of the bottom protection;
4. Construction of the additional sill (and bed protection if necessary);
5. Construction of the tidal power plant and N57 and parallel road on top “in the dry”;
6. Connecting N57 and parallel roads to power plant;
7. Excavation remaining soil and demolition of the old caissons;
8. Finish the construction of the dam.

Questions per MCA criterion:

- Construction cost
  - What is the available width inside the dam and what width is needed during construction?
  - How much reliability is needed, given the large hinterland lake to store water? So is a double set of storm valves needed, or is a ‘weaker’ regulation valve in combination with a storm valve a possibility. Does the turbine have any regulation and/or retaining function?
- Risks
  - Feasibility building pit in terms of drainage. (Uplifting bottom of building pit, too much seepage)
  - Reliability of the foundation (and its behavior in the dry)
  - Stability of the caisson and the primary water barrier

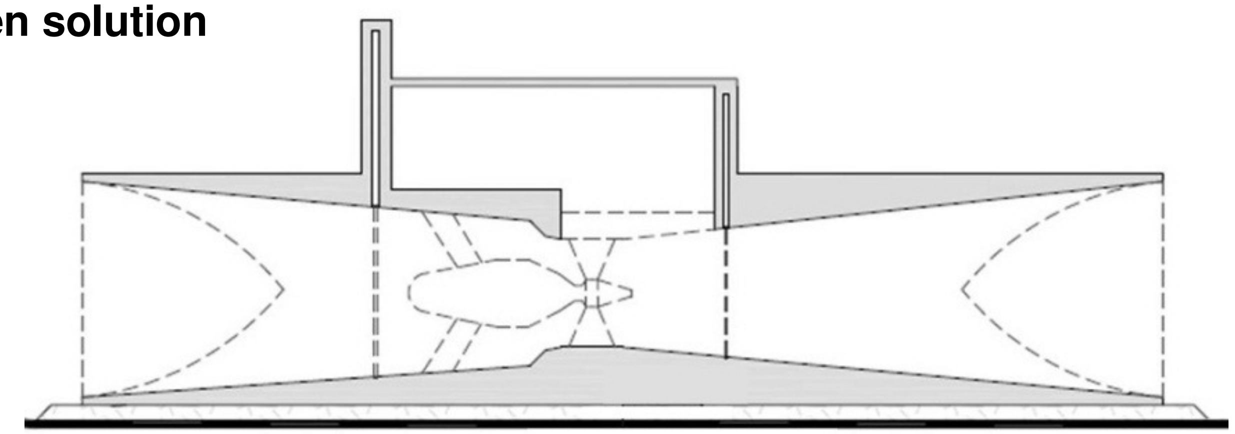
Remarks

- Building “in the dry” in this variant results in more control than with building in the wet.

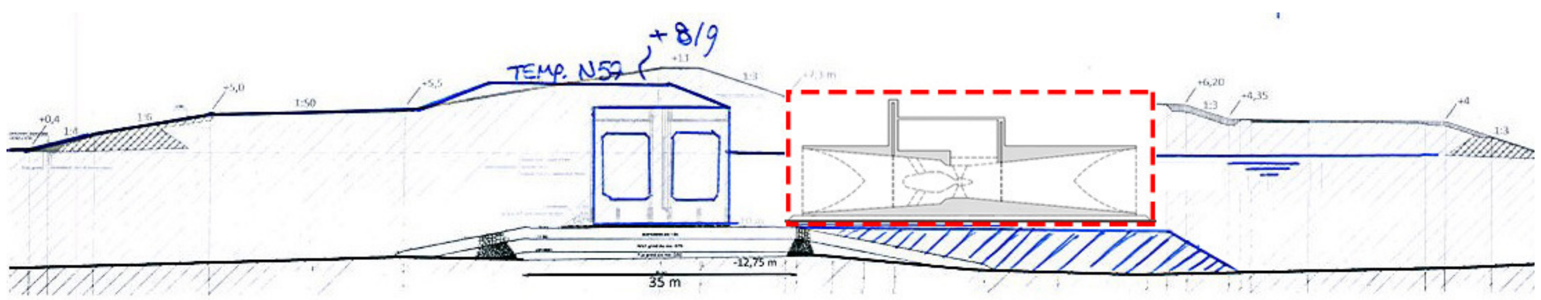
Type turbine: Diffuser
ID: Variant 1B. Building in the wet

Explanation design:
The 'standard' bulbturbine powerhouse design is chosen, see figure below, possibly using soil to add weight to this structure if necessary.
The water retaining function is most likely fulfilled by a set of multiple vertical valves, since the type of turbine will probably not be able to close and retain water itself. If this is the case, it is possible to reduce the number of storm valves for water retaining and regulation.
The traffic connection (N57 and parallel road) runs over the power plant, most likely above the location of the turbines.

Chosen solution form



Cross-section during



Construction method:
In this variant during construction the caissons are remained intact and used as retaining wall as well The execution of this variant is however "in the wet".
In this case larger prefab units, with the HSC cores on the inner surfaces, are built somewhere around Lake Grevelingen and can be floated to the location.
In short, the construction method of variant B is as follows:

1. Preparation of the external building dock (somewhere around Lake Grevelingen);
2. Construction of the floatable prefab elements in the building dock;
3. Lowering the crest of the dam to about +8/9 m NAP to create space for the temporary N57;
4. The N57 will be relocated to the crest of the dam;
5. Excavation the full dam between the caissons and Lake Grevelingen;
6. Construction of the additional sill (and bed protection if necessary);
7. Placing the prefab structures;
8. Finish construction of the elements, turbines;
9. Relocating and connecting N57 and parallel roads over power plant;
10. Excavate the dam at the seaside and demolition of the old caissons;
11. Finish the construction of the dam.

Questions per MCA criterion:

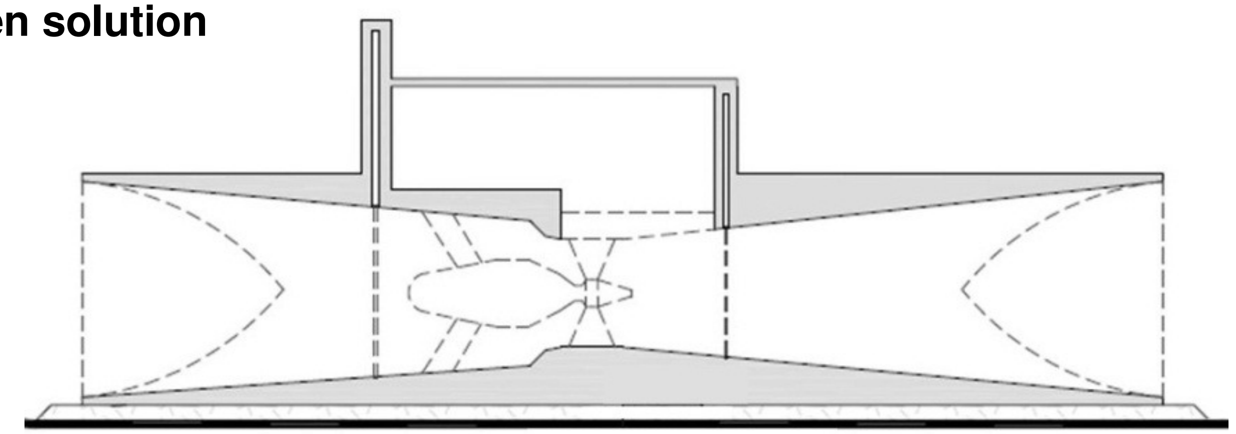
- Construction cost
  - What are the costs of an external building site? Where is such a dock available? Can future reuse of the building dock reduce costs?
  - How much reliability is needed, given the large hinterland lake to store water? So is a double set of storm valves needed, or is a 'weaker' regulation valve in combination with a storm valve a possibility. Does the turbine have any regulation and/or retaining function?
- Risks
  - Reliability of the foundation
  - Stability of the caisson and the primary water barrier
  - Accuracy of dimensions, placing the elements, ensure water tight connection

Remarks

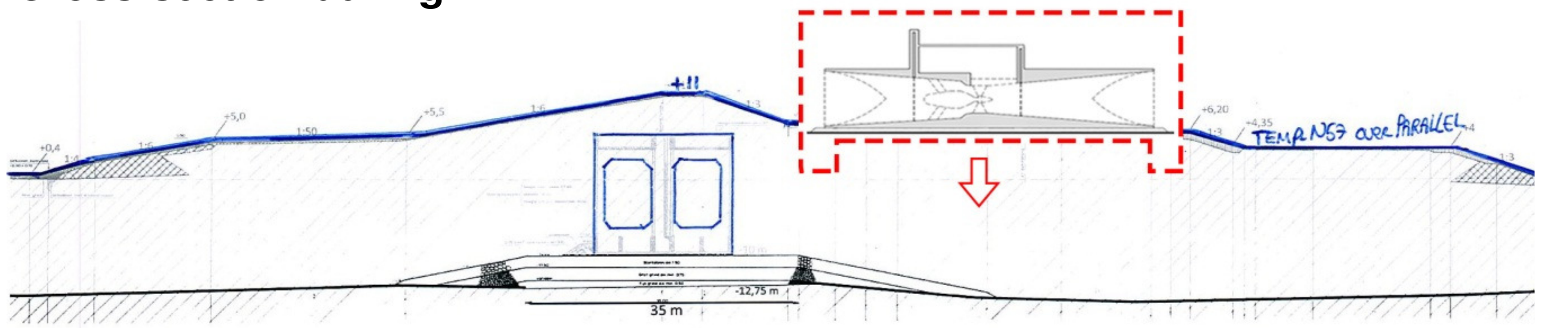
Type turbine: Diffuser
ID: Variant 1C. Pneumatic caissons

Explanation design:
The 'standard' bulbturbine powerhouse design is chosen, see figure below, possibly using soil to add weight to this structure if necessary. Due to the use of a pneumatic caisson as building method, the shape might be altered however.
The water retaining function is most likely fulfilled by a set of multiple vertical valves, since the type of turbine will probably not be able to close and retain water itself. If this is the case, it is possible to reduce the number of storm valves for water retaining and regulation.
The traffic connection (N57 and parallel road) runs over the power plant, most likely above the location of the turbines.

Chosen solution form



Cross-section during



Construction method:
The third variant uses the "pneumatic caisson method" to lower the tidal power plant to its final location. In this way the plant can be constructed in the dry on top of the dam. The N57 could be relocated to the current parallel road at the Grevelingen side.

1. The N57 will be relocated to the crest of the dam or at the seaside of the dam;
2. Create space for constructing the caissons and other material;
3. Construction of the caissons in which entrances need to be constructed to enable immersion into the soil. Entrances for the transit of materials, water and people are needed;
4. Create space for the storage of soil, which originates from beneath the caissons;
5. Immersion of the caissons;
6. Relocate the roads to the caissons;
7. Excavation remaining soil of the existing dam and demolition of the old caissons.

Questions per MCA criterion:

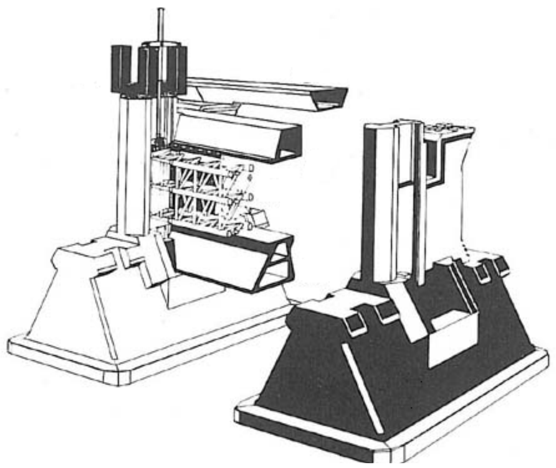
- Construction cost
    - What facilities are needed for a pneumatic caisson?
    - How much space is needed in order to immerse the caissons to their required location?
- Risks
    - Obstacles in the soil below the pneumatic caisson
    - Connection with the existing bottom protection and present sill
    - Accuracy of dimensions, placing the elements next to each other, ensure water tight connection
    - Working in compressed air in order to excavate the soil beneath the caissons

Remarks

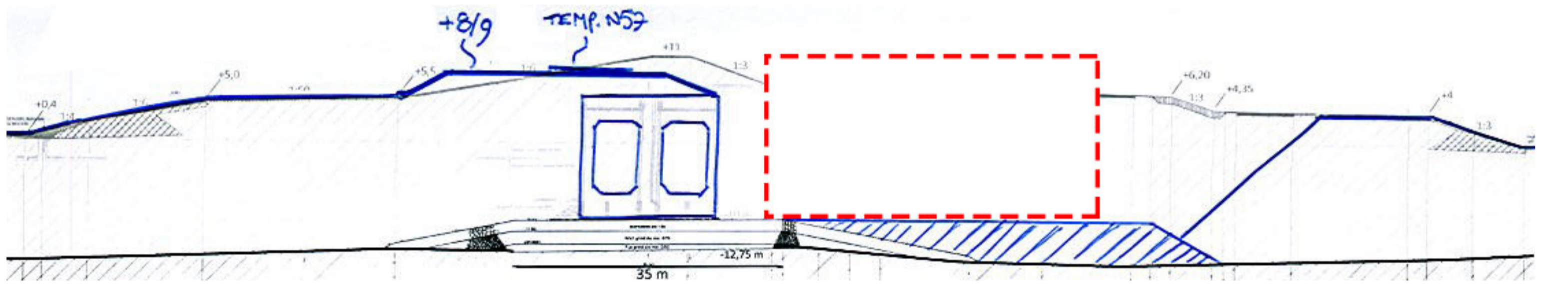
Type turbine: Gate
ID: Variant 2A. Eastern Scheldt barrier like structure “in the dry”

Explanation design:
As the most promising ‘shape’ an Easter Scheldt Barrier like structure is chosen. Since the closure valves must both regulate and retain the water level in two directions, a vertical sliding valve or a sector gate was chosen. The structure consists of pillars with a bridge deck on top, the mentioned closure valves, turbines and most likely a sill beam between them. In the figure below a cross section of the Easter Scheldt Barrier is shown as an example to the shape of the gate structure solution.
What shape or type of turbine is placed is not yet decided. A vertically movable frame containing multiple turbines is a possibility, but also the more ‘windmill’ type turbines, which are each founded separately.

Example solution form
(Rijkswaterstaat, 2014)



Cross-section during



Construction method:
In this variant during construction the caissons are remained intact and used as retaining wall. The execution is done “in the dry”. One continuous building pit will be used.
In short, the construction method of variant A is as follows:
12. Lowering the crest of the dam to about +8/9 m NAP to create space for the temporary N57;
13. The N57 will be relocated to the crest of the dam;
14. Excavation of the building pit between caissons and the remaining of soil body at the Lake Grevelingen side and pump the building pit dry. Also below the bottom protection in order to prevent uplifting;
15. Construction of the additional sill (and bed protection if necessary);
16. Construction of the pillars and placing of sill beam;
17. Construction of the storm valves, turbines and bridge deck for N57 and parallel road;
18. Connecting N57 and parallel roads to power plant / bridge deck;
19. Excavation remaining soil and demolition of the old caissons;
20. Finish the construction of the dam.

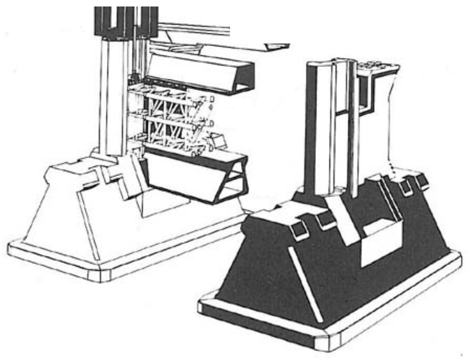
Questions per MCA criterion:
- Construction cost
  - What are the global dimensions of the pillars to ensure the stability of the structure?
- Risks
  - Feasibility building pit in terms of drainage. (Uplifting bottom of building pit, too much seepage)
  - Settlements and tolerances could be an issue due to concentrated forces at pillars
  - What is the quality of the current foundation?

Remarks

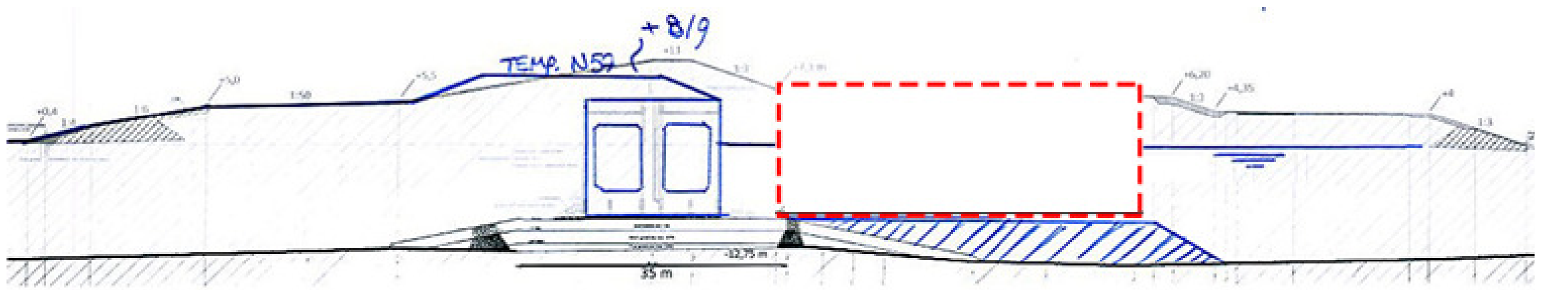
Type turbine: Gate
ID: Variant 2B. Eastern Scheldt barrier like structure “in the wet”

Explanation design:
As the most promising ‘shape’ an Easter Scheldt Barrier like structure is chosen. Since the closure valves must both regulate and retain the water level in two directions, a vertical sliding valve or a sector gate was chosen. The structure consists of pillars with a bridge deck on top, the mentioned closure valves, turbines and most likely a sill beam between them. In the figure below a cross section of the Easter Scheldt Barrier is shown as an example to the shape of the gate solution.
What shape or type of turbine is placed is not yet decided. A vertically movable frame containing multiple turbines is a possibility, but also the more ‘windmill’ type turbines, each founded separately.

Example solution form (Rijkswaterstaat,



Cross-section during



Construction method:
In this variant large prefab floating containers are constructed in an external building dock and then floated in. These containers will be filled with concrete or sand and then function as pillars. The prefab sill beam must be placed between the pillars.
During construction the caissons are remained intact and used as retaining wall as well. The execution of this variant is thus “in the wet”.
In short, the construction method of variant B is as follows:

21. Preparation of the external building dock (somewhere around Lake Grevelingen);
22. Construction of the floatable prefab elements in the building dock;
23. Lowering the crest of the dam to about +8/9 m NAP to create space for the temporary N57;
24. The N57 will be relocated to the crest of the dam;
25. Excavation the full dam between the caissons and Lake Grevelingen;
26. Construction of the additional sill (and bed protection if necessary);
27. Placing the prefab pillar structures and the prefab sill beam
28. Construction of the storm valves, turbines and bridge deck for N57 and parallel road;
29. Relocating and connecting N57 and parallel roads over power plant;
30. Excavate the dam at the seaside and demolition of the old caissons;
31. Finish the construction of the dam

Questions per MCA criterion:

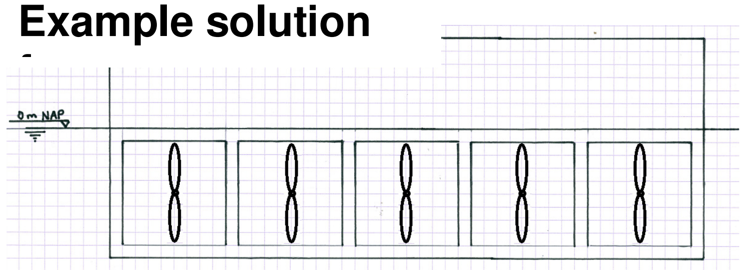
- Construction cost
  - What are the global dimensions of the pillars to ensure the stability of the structure?
  - Placing of the prefab sill beam
  - Ensuring the water tightness of the structure
- Risks
  - Settlements and tolerances could be an issue due to concentrated forces at pillars
  - What is the quality of the current foundation?
  - Is the amount of material needed, to fill the floatable containers realistic?

Remarks

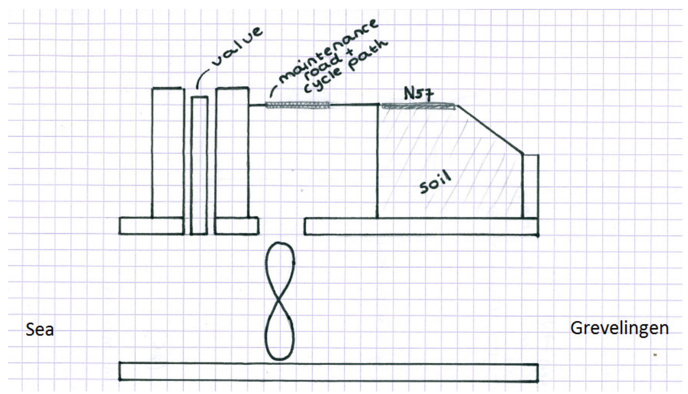
Type turbine: Gate
ID: Variant 2C Slender structure, wet and dry construction

Explanation design:
In this design the most important aspect is that it must be easy to construct and be as small as possible. At the bottom protection and sill a floor will be constructed over the full length of the structure with connections to walls at each 8 or 10 meters. The walls can be prefab elements to make the construction even easier. Above the walls a roof like structure will be constructed also with prefab elements. In every square a separate valve and turbine will be constructed. In this way a smaller structure is needed for the valve. Above the structure extra soil can be added to increase stability. The N57 and maintenance road can be constructed on top of the soil layer or house with turbine and generator.

Example solution

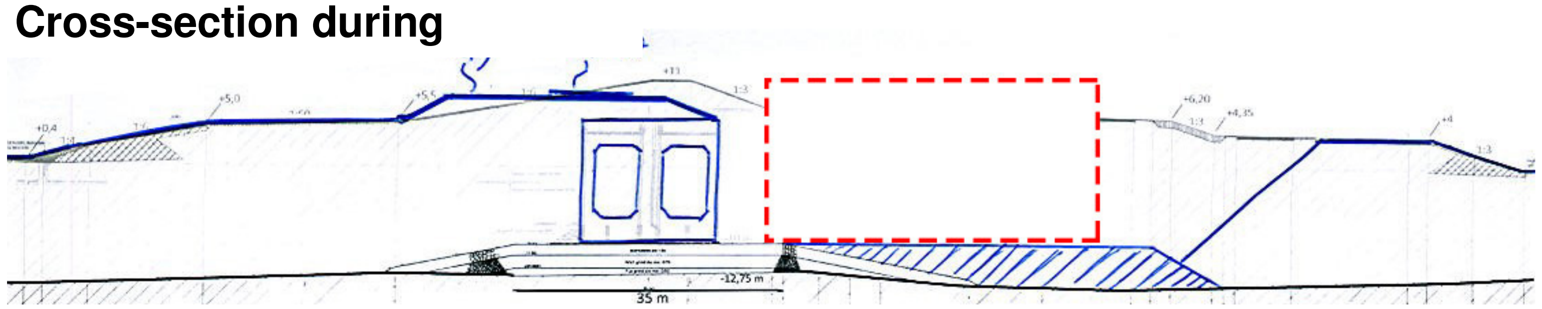


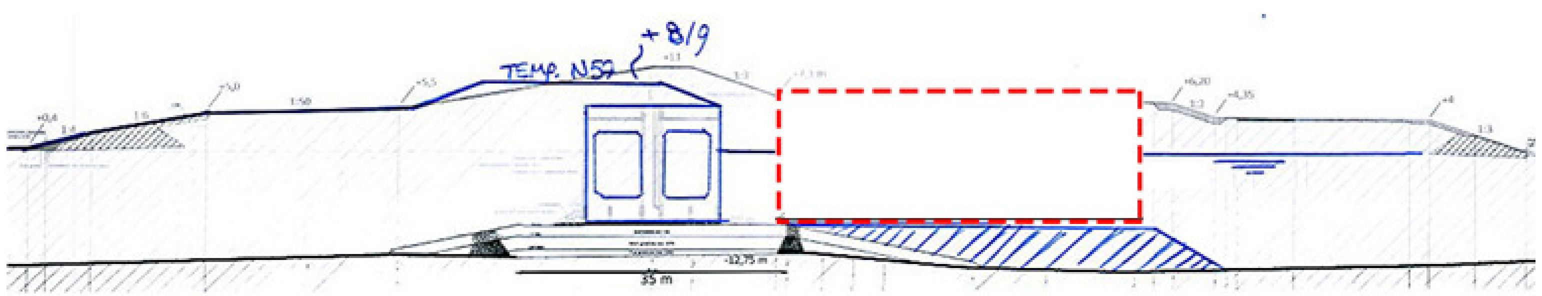
Front view



Side view

Cross-section during





Construction method:
This structure can be constructed as well in the dry as in the wet. When constructing in the wet, blocks can be formed of 4 or 5 turbines with structure which can be floated to its position. The method used is almost the same is for the wet construction of the diffuser variant (variant 1B.). By using a dry method a building pit needs to be constructed, the method used is the same as for the diffuser variant 1A.

Questions per MCA criterion:
The questions are the same as for the diffuser variants and are written below.

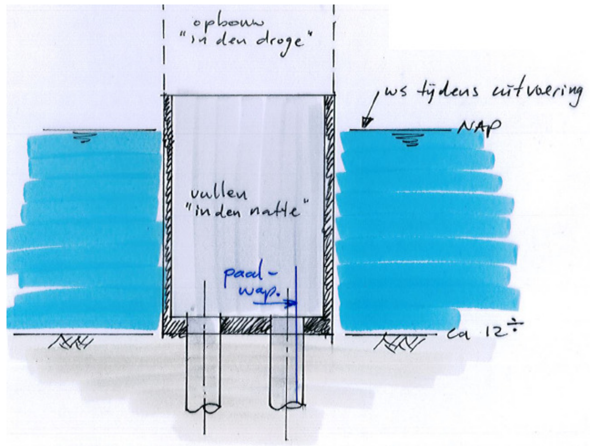
- Construction cost
  - What are the global dimensions for a stable structure?
  - What is the available width inside the dam and what width is needed during construction? (dry construction)
  - How much reliability is needed, given the large hinterland lake to store water? So is a double set of storm valves needed, or is a ‘weaker’ regulation valve in combination with a storm valve a possibility. Does the turbine have any regulation and/or retaining function?
  - What are the costs of an external building site? Where is such a dock available? Can future reuse of the building dock reduce costs? (wet construction)
- Risks
  - Feasibility building pit in terms of drainage. (Uplifting bottom of building pit, too much seepage for dry constructing method)
  - Reliability of the foundation (and its behavior in the dry)
  - Stability of the structure and the primary water barrier
  - Stability of the levee at the Grevelingen side (dry construction)
  - Accuracy of dimensions, placing the elements, ensure water tight connection (wet construction)

Remarks

Type turbine: Gate
ID: Variant 2D. Floatable pillar containers

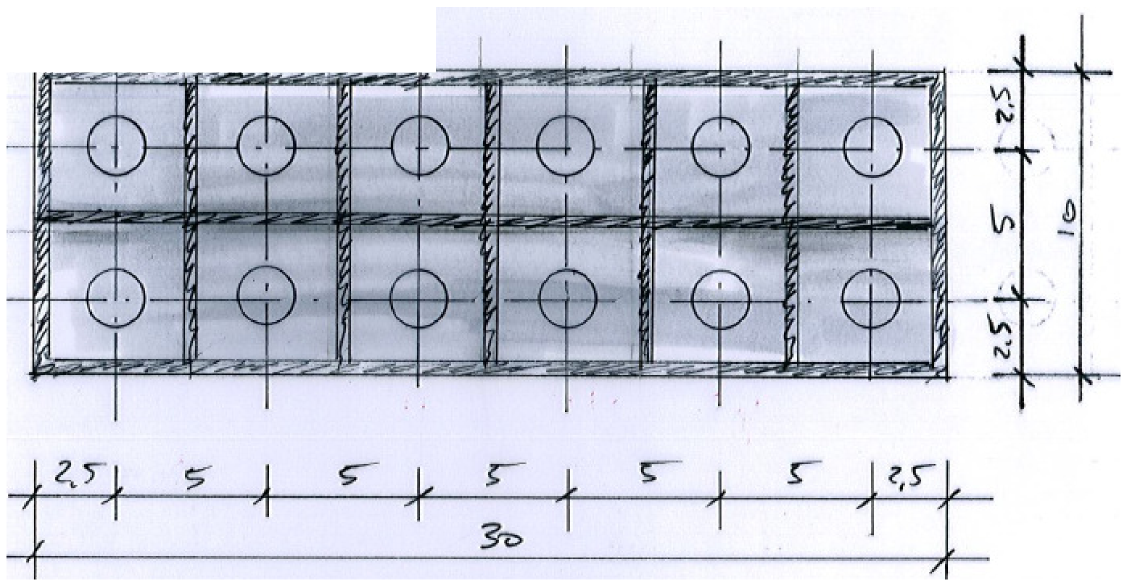
Explanation design:
This variant has the 'shape' of an Easter Scheldt Barrier like structure, but constructed on piles. Since the closure valves must both regulate and retain the water level in two directions, a vertical sliding valve or a sector gate was chosen. The structure consists of pillars with a bridge deck on top, the mentioned closure valves, turbines and most likely a sill beam between them. The pillars are constructed as pad footing on 12 piles of steel with a diameter of approximately 2 m. These piles will be filled with a concrete mixture (reinforced).
What shape or type of turbine is placed is not yet decided. A vertically movable frame containing multiple turbines is a possibility, but also the more 'windmill' type turbines, each founded separately.

Example solution form (front view)



Example floatable pillar container

Top view



Construction method:
In this variant large prefab floating containers are constructed in an external building dock and then floated in and placed on top of the piles. These containers will be filled with concrete and function as pillars. The prefab sill beam must be placed between the pillars.
During construction the caissons are remained intact and used as retaining wall as well. The execution of this variant is thus "in the wet".
In short, the construction method of variant D is as follows:
1. Preparation of the external building dock (somewhere around Lake Grevelingen);
2. Construction of the floatable prefab elements in the building dock;
3. Lowering the crest of the dam to about +8/9 m NAP to create space for the temporary N57;
4. The N57 will be relocated to the crest of the dam;
5. Excavation the full dam between the caissons and Lake Grevelingen;
6. Construct the 12 piles from a pontoon;
7. Empty the piles and fill them with reinforced concrete;
8. Preparation of the ground around the piles;
9. Float in the caissons with a reinforced connection for the piles;
10. Fill the caissons with concrete in the wet;
11. Construction of the bottom protection;
12. Construction of the storm valves, turbines and bridge deck for N57 and parallel road (in the dry);
13. Relocating and connecting N57 and parallel roads over power plant;
14. Excavate the dam at the seaside and demolition of the old caissons;
15. Finish the construction of the dam.

Questions per MCA criterion:
- Construction cost
  - What are the global dimensions of the pillars to ensure the stability of the structure? And of the piles?
  - Placing of the prefab sill beam
- Risks
  - Settlements and tolerances could be an issue due to concentrated forces at pillars
  - Is the amount of material needed, to fill the floatable containers realistic?
  - What type of soil is available, is the required bearing capacity available and it is it possible to construct the piles at a required depth?

Remarks

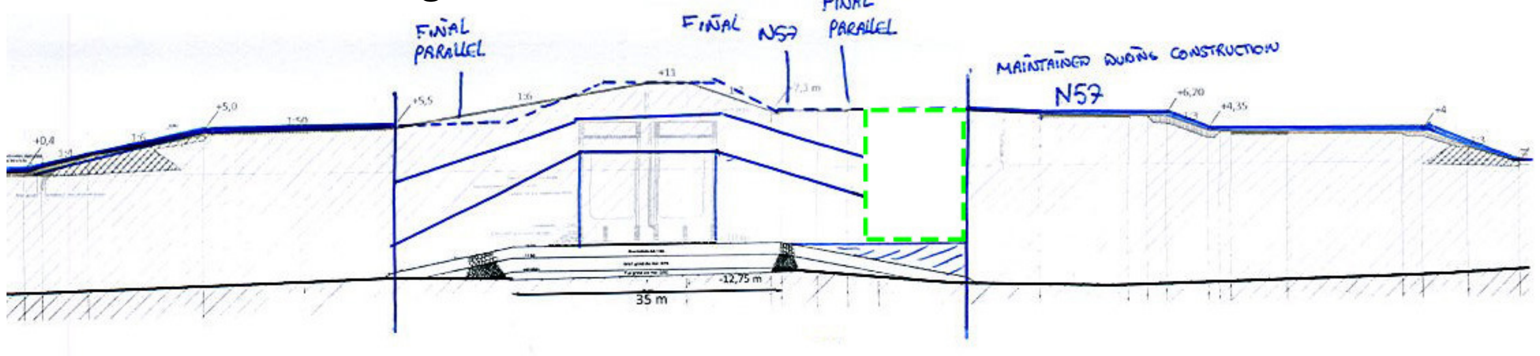
Accuracy of dimensions, placing the elements, ensure water tight connection (wet construction)

Type turbine: Siphon
ID: Variant 3A. Building pit dry construction

Explanation design:
The shape of the turbines and their housing itself is not detailed yet. It is decided however that the turbines will be placed next to the caissons instead of on top, to enhance performance. The water retaining function is fulfilled by an overpressure pump.
In this variant part of the dam is restored after construction, resulting in a continuous connection of the traffic function: both parallel roads, the N57 and the cycle path.

Chosen solution

Cross-section during



Construction method:
A dry construction method will be used, which means that the building pit needs to be pumped dry. In short, the construction method of variant A is as follows:

1. Relocate the cycle path to the parallel road at the seaside;
2. Sheet pile at location next to the N57 at the seaside, with anchoring;
3. HW sheet pile at location where the current berm starts (seaside), with anchoring;
4. Excavate;
5. Install tubes and connections;
6. Refill ground and construct the roads (N57, parallel road and cycle path) an anchors for the sheet piles;
7. Relocate parallel road seaside;
8. Constrict at the seaside: walls/piles, connections and excavate;
9. Constrict at the Grevelingen side: walls/piles, connections and excavate.

Questions per MCA criterion:

- Construction cost
  - Are the retaining walls at the ends of the siphon structure necessary?
- Risks
  - Feasibility building pit in terms of drainage. (Uplifting bottom of building pit, too much seepage)
  - The quality of the present foundation and old caissons
  - Construct the sheet piles through the bottom protection
- General/Performance
  - The (added) hydraulic resistance of the siphon

Remarks

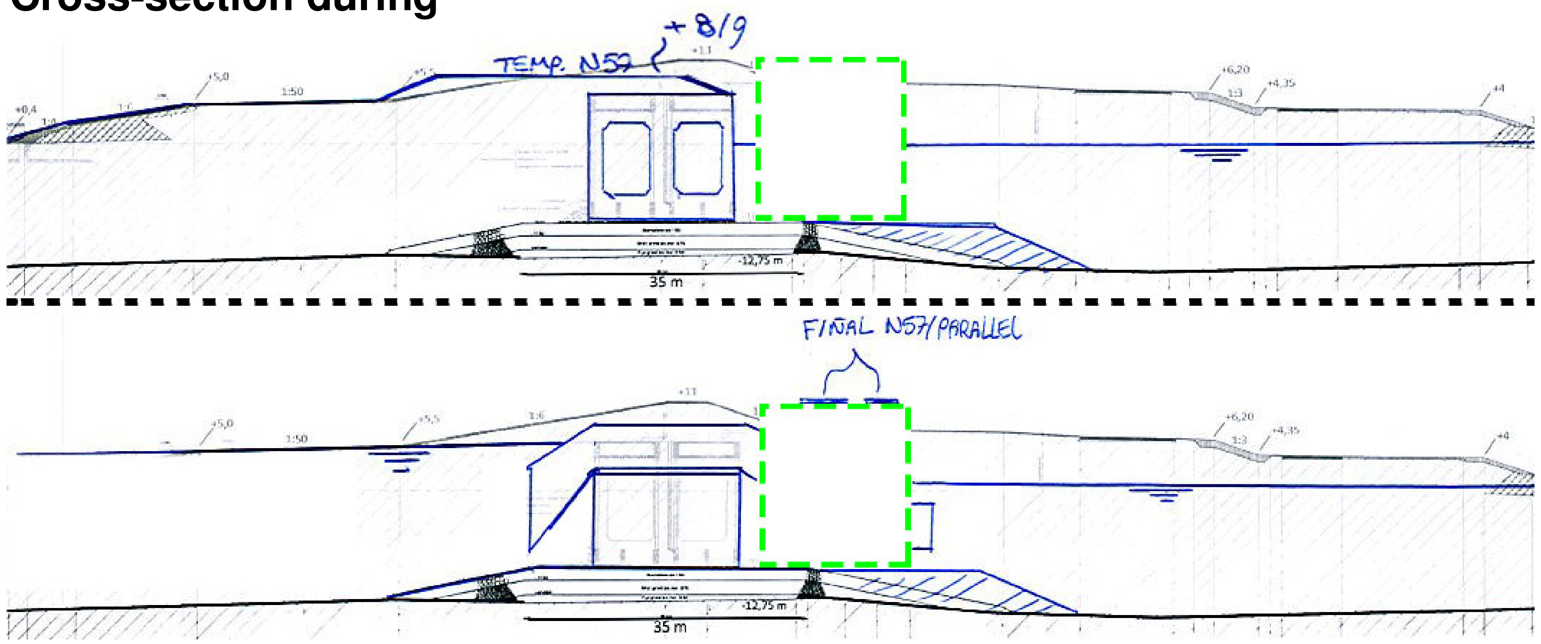
- Retaining wall / sheet piling is expensive, also anchors are needed in the construction phase as well as the operational phase
- Smaller building pit in comparison to diffuser variants

Type turbine: Siphon
ID: Variant 3B. Wet construction

Explanation design:
A sea resistant caisson-like prefab element is constructed in an external building dock, containing the turbines, generators and facilities to construct the road upon. This element already contains one outflow, but on the other side will be connected to the siphon that goes over the caissons. The prefab ducts can be made of several materials.
The water retaining function is fulfilled by an overpressure pump, also installed inside the power plant element. The remainder of the caissons, the siphon and power plant element as a whole can be connected create a stable structure.

Chosen solution

Cross-section during



Construction method:
In short, the construction method of variant B is as follows:
1. Preparation of the external building dock (somewhere around Lake Grevelingen);
2. Construction of the floatable prefab elements containing the turbines, etc. in the building dock;
3. Lowering the crest of the dam to about +8/9 m NAP to create space for the temporary N57;
4. The N57 will be relocated to the crest of the dam;
5. Excavation the full dam between the caissons and Lake Grevelingen;
6. Construction of the additional sill (and bed protection if necessary);
7. Placing the prefab elements and connecting the prefab elements
8. Relocating and connecting N57 and parallel roads over power plant;
9. Excavate the dam at the seaside;
10. Reduce height caissons by partially demolishing top caisson
11. Place prefab ducts on top of caissons;
12. Connect caissons, power plant element, ducts/siphon.

Questions per MCA criterion:
- Construction cost
  - The needed support of the in- and outflow ends of the siphon
- Risks
  - Reliability of the caisson as part of the permanent retaining barrier

- General /Performance
  - The (added) hydraulic resistance of the siphon

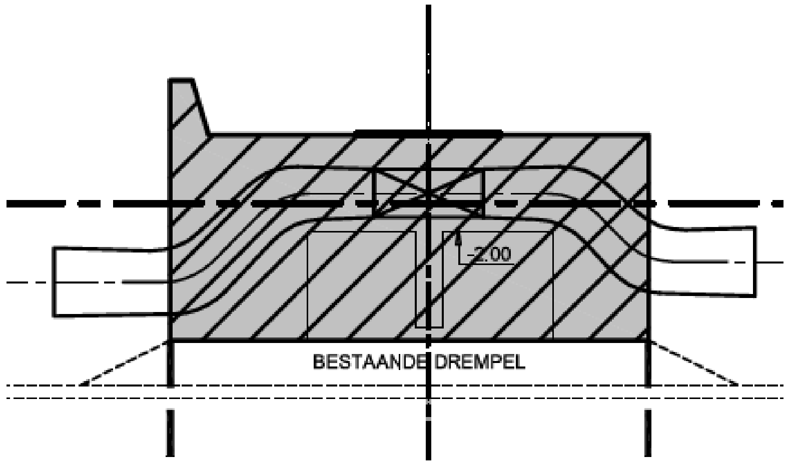
Remarks

- Stability of the prefab in and outflows

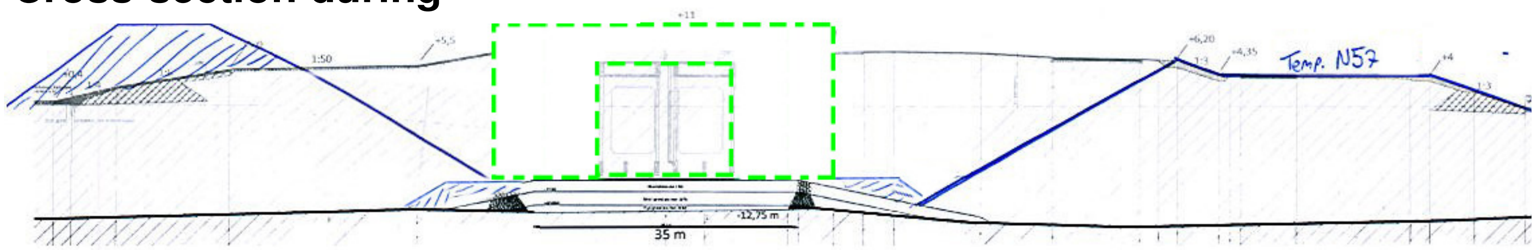
Type turbine: Siphon
ID: Variant 3C. Siphon inside powerhouse (built "in the dry" using temporary soil body)

Explanation design:
In this design the siphon 'powerhouse' is fully constructed in the dry around the existing caissons. The sea resistent shell is the main water barrier. The siphon is integrated in this structure.
The water retaining function is fulfilled by an overpressure pump, also installed inside the power plant element.
As no sheet piling is used in this variant, the building pit has to be wider and a temporary soil body is needed to fulfill the functions of the primary water barrier during construction.

Chosen solution form



Cross-section during



Construction method:
In short, the construction method of variant C is as follows:
32. Construction of the temporary soil body as water barrier;
33. Relocating N57 and parallel roads to the parallel road at the Lake Grevelingen side;
34. Excavation of the building pit and pump it dry;
35. Reducing the height of the caissons by partially demolishing them;
36. Addition of sill and bottom protection if necessary;
37. Construction of the tidal power plant including the siphon;
38. Relocation of the N57 and parallel roads to the top of the tidal power plant;
39. Excavation of the remaining dam and temporary soil body.

Questions per MCA criterion:
- General /Performance
  - The (added) hydraulic resistance of the siphon

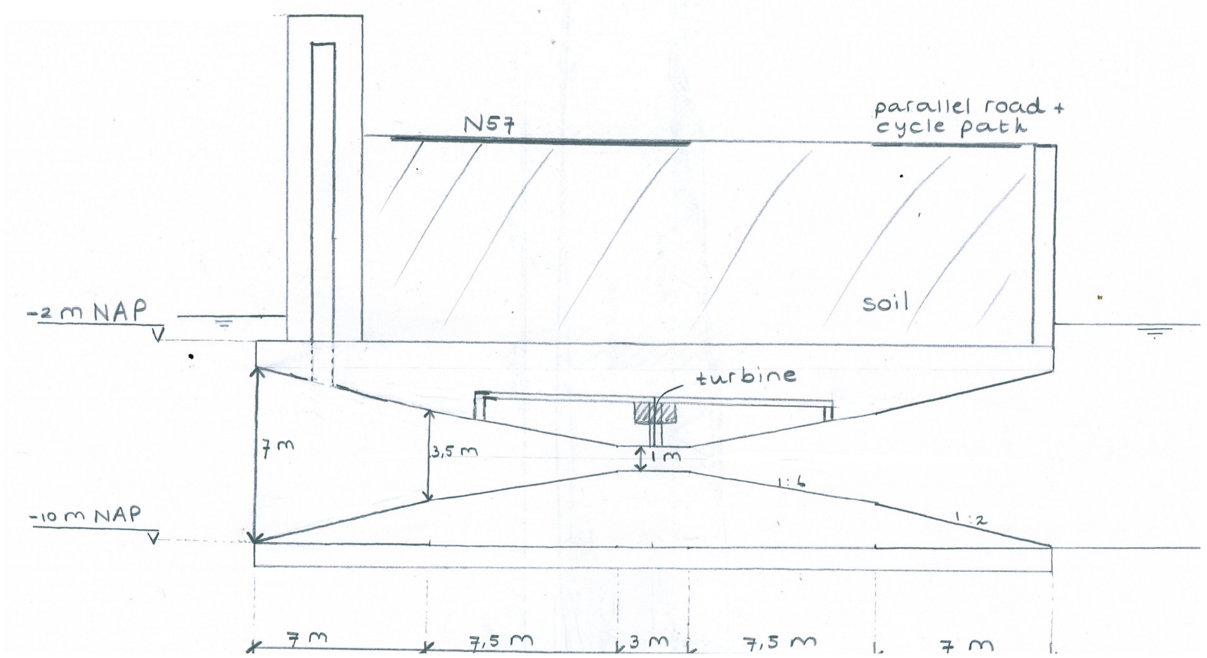
Remarks

- For stability, the old caissons need to be part of the whole structure.
- The road needs to be relocated and connected to the roads located at the dam, this will lead to some curves.

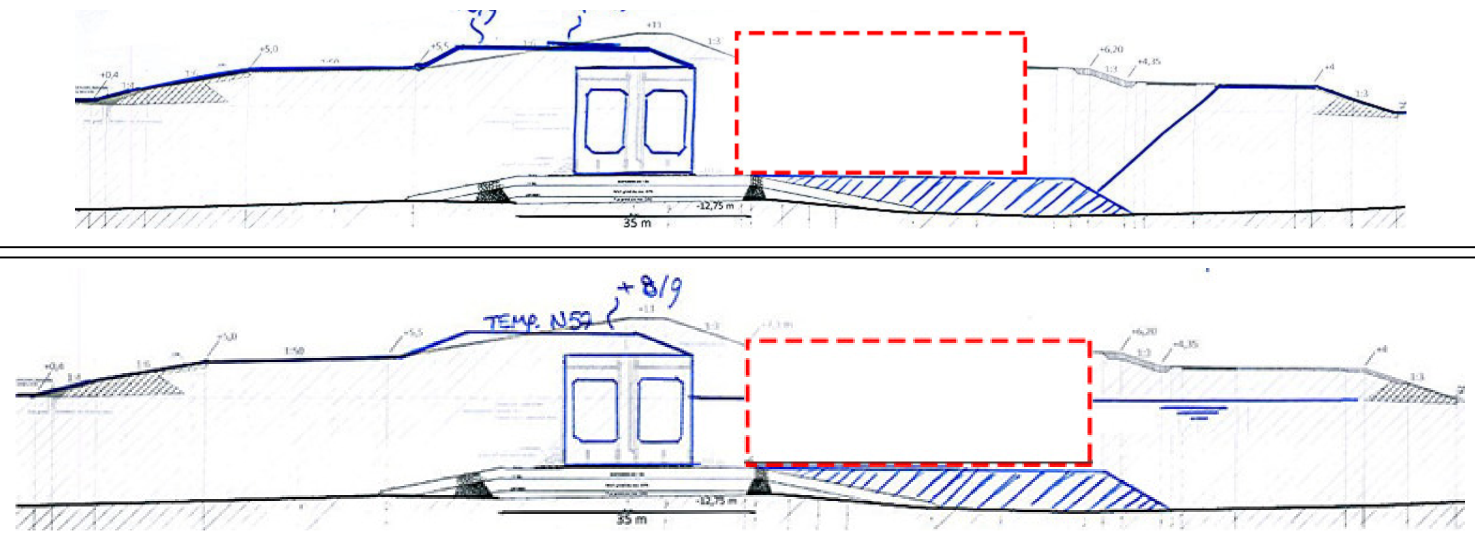
Type turbine: Siphon
ID: Variant 3D. Venturi in a slender structure

Explanation design:
This variant is a combination of 2C and a venture structure. An explanation of the civil structure can be found below variant 2C. The only difference is that this is combined with a venturi structure. The inflow area will have the dimensions of 7x7 m^2 and will go to a 3.5 m diameter and a venturi diameter of 1 m, as shown in the figure below.

Example solution



Cross-section during construction (dry and wet)



Construction method:
This structure can be constructed as well in the dry as in the wet. When constructing in the wet, blocks can be formed of 4 or 5 turbines with structure which can be floated to its position. The method used is almost the same is for the wet construction of the diffuser variant (variant 1B.). By using a dry method a building pit needs to be constructed, the method used is the same as for the diffuser variant 1A.

Questions per MCA criterion:
The questions are the same as for the diffuser variants and are written below.

- Construction cost
  - What are the global dimensions for a stable structure?
  - What is the available width inside the dam and what width is needed during construction? (dry construction)
  - How much reliability is needed, given the large hinterland lake to store water? So is a double set of storm valves needed, or is a 'weaker' regulation valve in combination with a storm valve a possibility. Does the turbine have any regulation and/or retaining function?
  - What are the costs of an external building site? Where is such a dock available? Can future reuse of the building dock reduce costs? (wet construction)
- Risks
  - Feasibility building pit in terms of drainage. (Uplifting bottom of building pit, too much seepage for dry constructing method)
  - Reliability of the foundation (and its behavior in the dry)
  - Stability of the structure and the primary water barrier
  - Stability of the levee at the Grevelingen side (dry construction)
  - Accuracy of dimensions, placing the elements, ensure water tight connection (wet construction)

Remarks

The structure will be placed at the location of the present N57, this means that this road can have the same location in the

APPENDIX C2: MINUTES WORK SESSION 2

In the first work session a lot of different alternatives were developed for three different types of turbines, namely bulb, free flow and siphon. The aim of the second work session was to create two variants per type of turbine which are most promising. These promising variants can originate from variants created in the first work session, can be completely new ones or combined solutions.

MCA criteria

Before selecting the most promising variants, first criteria must be selected for which the variants will be tested. The following criteria are selected: (written in order of importance)

1. Construction cost
2. Risk and reliability
3. Performance (GWh/year)
4. Maintenance
5. Innovation
6. Hindrance of execution
7. Fish friendliness
8. Environmental disturbance (landscape integration)
9. Sustainability

The first 6 criteria are most important for designing the civil structure for the tidal power plant. The other criteria are also important, but do not apply (or to a lesser extent) to the civil structure. The innovation criterion is important for the Ministry of Economic Affairs, who likes to stimulate innovative ideas.

Some question were asked concerning the criterion construction cost. It was not completely clear to what the construction cost of the tidal power plant will be compared. Jacob van Berkel explained that the costs will be compared to the base variant in which only the structure for water passage is designed. It must be said that in this variant the costs of regulating the water levels is not yet taken into account. These costs must be added to the 138/158 million euro. Concluding the construction costs for the power plant minus the costs of the base variant should be lower than the benefits of the power plant.

Main functions / table of requirements

The importance of the main functions was stated in this order:

1. Water passage (water level management)
2. Retain water (primary flood defense & daily)
3. Traffic
4. Generate energy

Additional to the second function is was mentioned to split the retaining water function into daily conditions and extreme conditions. This means that two separate structures can be designed for the different conditions, or one structure is needed which can fulfill both functions. For instance a turbine which changes its resistance, in this way it can control water levels.
No additional requirements were given, so the existing table of requirements (2011) is used.

Discussion variants

Next the different variants were discussed per type of turbine.

Bulb (now named Diffuser)

The structure, in which the bulb is placed, is for every variant more or less the same. Differences can be made in the use of materials and the amount of materials used for the structure (for example the diffuser which can be made of steel). On the other hand, a lot of different construction methods are possible for this type of structure.
The most promising construction method is the method in which the old caissons are used as soil retaining structure. The caissons and part of the existing dam are used as primary flood defense, therefore no temporary structure is needed. This method can be used as well in the dry as in the wet. By using a soil body at the Grevelingen side of the dam a construction pit can be constructed. Bulb turbines of which the turbine can also retain water, are possible as the primary water defense when it is proved that it is safe. Until now, the safety is not yet guaranteed. However, it is used as primary defense in river power plants and in tidal power plants in France. When this type of turbine is used, only a single closure structure will be sufficient.

Free flow (now named Gate)

For the flee flow turbine all variants converge to a slender structure with or without an integrated water barrier. Most variants have a pillars like structure with in between turbines.
The water retaining structure can be executed in different ways for this type of turbine. For instance an integrated, vertical moving gate; a rotatable gate; a sector gate or a floatable gate (like Venice). It is preferable that these gates can also manage water levels during daily conditions. The gates of the Eastern Scheldt barrier would probably not suffice for daily regulation. It was said that gates like in the Afsluitdijk but in opposite direction is possible. Another option that was given was two vertical moving gates from which the upper one can open en creates a flow through the gates. An advantage of these gates is that less bed protection is needed, because the flow velocities are much lower at the bottom.
Questions for a small structure for a free flow turbine are:

- Is it possible to re-use the foundation of the old caissons?

Menno Rikkers said that the foundation can only be reused if the forces on the foundation will have the same order of magnitude and distribution as the old caissons. Otherwise a new foundation needs to be designed. So when pillars are used, new high forces will occur for which a foundation needs to be designed.

- Is it possible to improve the existing foundation?

  This is probably a lot of work, which is not very easy to achieve, but it is only needed locally.
- What length is needed for horizontal and rotational stability?

  This need to be checked, keeping in mind that the answer must be smaller than the dimensions of a caisson structure. Otherwise it is more suitable to use a 'powerhouse' structure instead of a slender structure.
  For horizontal stability the use of buttresses (steunberen) can be used, to support the pillars. Or the option of monopiles can be used, which are used for off-shore wind turbines. A negative aspect of monopiles is that a separate structure is needed which can retain water.
- What should be the height of the road?

  It is possible to build the road as high as the Eastern Scheldt barrier (+11 m NAP) or the road can be located more to the Grevelingen side with enough space for overtopping water, which means that the height can be reduced.

Remark: Is was said that it is not preferable when the net operator is depended of the water management over the barrier. A part of this problem is solved, because the tide is easy to predict. Much more difficult to predict is the set up by the wind or low pressure. Another remark was that the power plant is relatively small, which results in a low impact on the net.

Siphon

The structure for a siphon solution should be as small as possible, to decrease the hydraulic losses. At the same time, it should not be too small because it has to be stable.
In all variants the old caisson is partly reused, which is one of the advantages of this type of structure. This means that it needs to be checked whether the old caisson are stable.
One variant, which can be applied to every other variant and is not specific for one type of turbine, is the possibility to build a (temporary) bridge. This can be done in order to create space, which can be used for construction.

Determine promising variants

In the next phase, per type of structure two promising variants were chosen. Before starting, Jacob van Berkel asked to think also about a solution for the situation in which no dam exists. In this way, the solution is more general and can be applied to other similar projects. Everybody agreed that if no dam is present the construction method should be in the wet, which means that immersion is the best option. However, in this case the Brouwersdam exists, which means that it cannot be said which construction method is best in advance.

Bulb (Diffuser)

For the bulb turbine the construction method needs to be chosen, because the structure is more or less the same for each variant. The structure looks like a powerhouse, with integrated gates. This structure can be seen as a caisson, as much prefab elements as possible are preferable. A caisson can be placed in different ways, namely dry, wet or by using a pneumatic caisson.

Option 'dry' is favorable by contractors. It is less costly to construct, because the quality of the structure (required for the 100 year life time) is easier to guarantee when building in the dry.

Questions which arose for the dry construction method:

- Concerning the stability of the construction pit. Is it possible to pomp out the water? Is the asphalt layer thick enough to withstand the forces? Is the water safety guaranteed?

Next each variant was discusses which eventually led to the two promising variants, which can be found in the document: "A3 overview promising variants.doc". The existing variants were discussed with the help of the document: "Flowchart_variants.pdf".

Option D.3 has a lot of negative aspects, for instance that sheet piles need to go through the present bottom protection. This is difficult, costly and will damage the bottom protection. Furthermore the sheet piles probably need to be anchored, which is also costly.

Option D.4. (see 'addition' at the end of the document) and W.2. are promising according to Jan-Dirk Reijneveld, because the old caissons and part of the dam will act as the primary flood defense. An estimation was made by Ed van der Blom and Gerard Kraaijeveld about the construction time, it will be at least 1.5 – 2 years. This means that the water barrier should be strong enough to survive the storm season. In these options a large part of the dam will remain the same, which is probably strong enough and is much cheaper than building a temporary barrier. A question was asked if it is safe to relocate the N57 to the seaside of the dam. Menno Rikkers told that it is possible if the road will be constructed at +8/+9 m NAP. Furthermore, these options create a lot of space. The old caissons are used as soil retaining wall, so next to the caissons the construction pit can be build.

Option W.1. is not preferable because it is costly to divert the N57, extra dam is needed to connect the original road to the new road. In addition, this diversion is not aesthetically desirable especially when looking from a bird's-eye view. Another negative aspect is that a new bottom protection need to be build, because this is not yet present at the Grevelingen side of option W.1.

The advances of option W.3. are that the final location of the N57 is the same as in the present situation, also the location for the water barrier is at the same location as in the present situation. One negative aspect is that a temporary water barrier needs to be constructed with bank protection.

Menno Rikkers suggested another construction option, namely using a pneumatic caisson. It is possible to build single elements in this way, unknown in this option is if it is possible to immerse the caissons next to each other. Positive aspects of this option are that no temporary water barrier needs to be constructed and enough space is available for construction.
Conclusion: The negative aspects of building a temporary water barrier and bank protection is costly. That is why is chosen for options were no temporary barrier needs to be build. So option D.4. and W.2. are chosen, together with the pneumatic caisson. These options will be elaborated.

Free flow (Gate)
The structure for the free flow turbines will be a slender structure, this means a structure like the Eastern Scheldt barrier in which a water retaining structure is integrated. This water retaining structure, a gate, can be an obstruction for choosing the location of the roads, this must be taken into account.
Stability is the main issue of this structure. As already discussed, a lot of question arose concerning the foundation and stability, these can be found in chapter 3 about the discussion.
For a slender structure pillars will be used. To create a stable foundation, multiple solutions are possible. For instance a big slap (vloerplaat) beneath the pillars or a pile foundation with a canoe like structure on top. The pile foundation is very difficult to combine with a water retaining structure because below water level, the piles will not retain water. A lot discussion was about the dimensions of the pillars and foundation. Mentioned reference projects were the Eastern Scheldt barrier, the Afsluitdijk, Haringvliet and the Ramspol bridge.
For the construction method Ed van der Blom suggested that it is possible to use a combination of a dry and wet method. First build the pillars somewhere else and place them in the wet. Then, the structure between the pillars can possibly be built in the dry. One of the questions was how to place the pillars in the wet, for the Eastern Scheldt barrier a special ship was built for this task.
Another possibility is to construct the foundation and bottom protection in the dry, in a construction pit in the existing dam. This pit can be located at the Grevelingen side next to the old caissons (like option D.4. of Bulb).
Concluding: both a dry and wet construction method will be considered in the next phase. For the location of the structure the preference goes to the place next to the old caissons. Both for the dry as for the wet method.
The type of gate will be a vertical lift gate or possibly a sector gate. The rotatable valve is not chosen because it cannot manage water levels and is not suitable for retaining water in two directions.
No type of turbine is chosen for the promising variants. For every type also the ducted option is possible.

Siphon
For the siphon option all variants were deliberated briefly.
The bored variant (3) will have high costs for the executions. For every tube a new starting point with foundation needs to be built. Another negative aspects is that it is not very easy to ore through the bottom protection. And last, it is not easy to let this structure act as a water barrier. A separate structure or gates are needed in this solution.

The variant in which the turbines and generators are located above the old caissons (variant 2) is not preferable, because turbines need to be placed as low as possible to avoid cavitation. That is why the variant with the turbines located at the Grevelingen side (variant 1) of the old caissons is more preferable. Negative aspects of variant 1 are the sheet piles which need to go through the bottom protection and probably need anchoring.
Variant 4, which is located close to the old caissons, is also a promising variant. This is because no temporary water barrier needs to be built and because the tubes of the siphons are as small as possible. It needs to be checked whether this variant is stable, if the old caissons can be used as a part of the water retaining structure and if a small tube is possible.
One remark was made concerning the water retaining function of the siphon, for all siphons it is much cheaper to close the siphons with an overpressure system compared to any mechanic system.
Concluding: variant 1 and 4 are chosen, mainly because the other options are much more expensive or not feasible.

Appendix D: Stability calculations

Appendix D1: Stability variant *Diffuser*

The design of the Diffuser variant is almost the same as the design in the variants nota (R-04), except for some added details. The design of this variant is shown in the figure below.

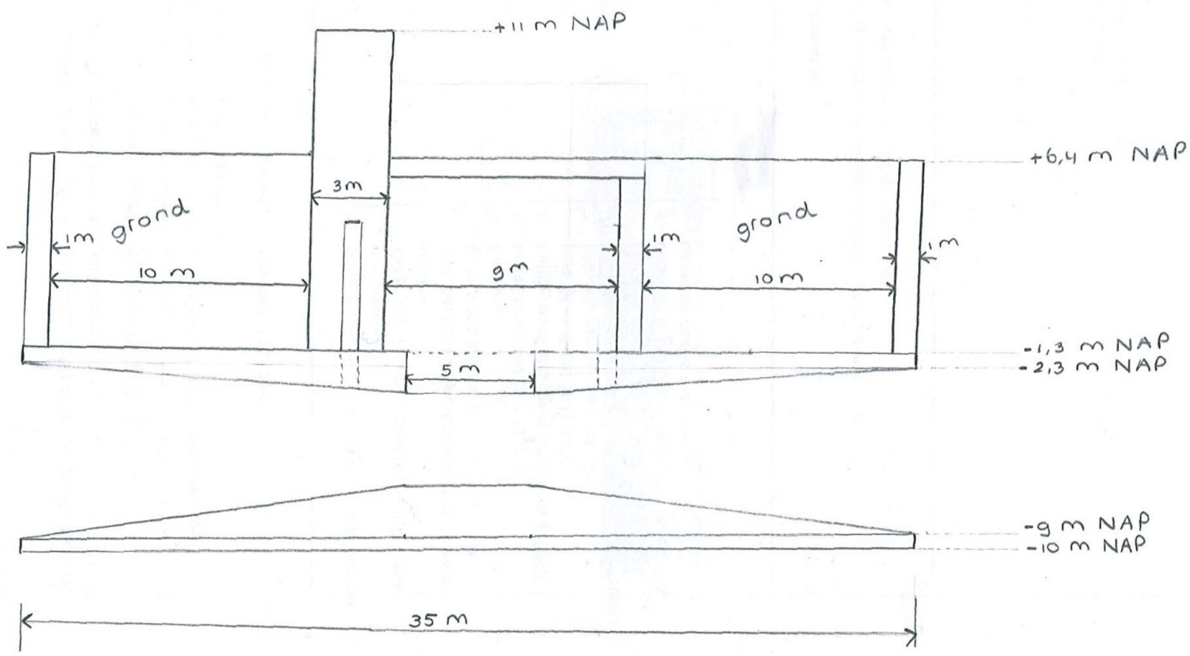


Figure 1: Cross-section variant Diffuser

The water flow will enter the structure through square openings, which will become a circle when going to the turbine. It is possible to hoist the turbine up to a maintenance room. On top of this maintenance room a cycle path/maintenance road will be located. At the seaside of the valves, so outside the high water barrier, a parallel road will be located. The N57 will stay at its present location, at the Grevelingen side of the valves at a top of a soil body to obtain the required height.

Forces

The forces acting on the structure are shown in de figure below:

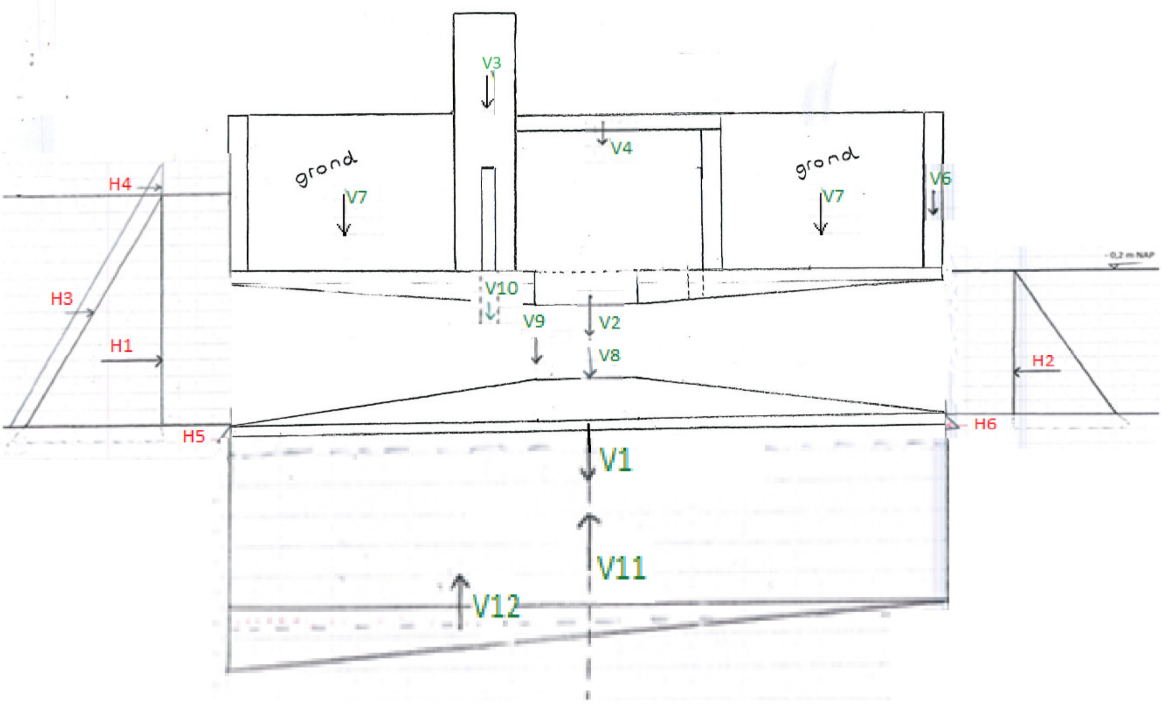


Figure 2: Forces acting on the structure

Horizontal

- H1: Due to hydrostatic pressure of water at the North sea side;
- H2: Due to hydrostatic pressure of water at the Grevelingen side;
- H3: Due to waves below design level;
- H4: Due to waves above design level;
- H5: Due to active soil pressure;
- H6: Due to passive soil pressure.

Vertical

- V1: Weight of floor element (concrete);
- V2: Weight of second floor element (concrete);
- V3: Weight casing valves (concrete);
- V4: Weight roof of maintenance room (concrete);
- V6: Weight soil retaining wall (concrete);
- V7,1: Weight soil body seaside;
- V7,2: Weight soil body Grevelingen side;
- V8: Water pressure at the top of the floor;
- V9: Weight turbine;
- V10: Weight of valve (steel);
- V11: Constant upward water pressure;
- V12: Variable upward water pressure;
- V13: Traffic load;
- V14: Weight walls between the elements (concrete);
- V15: Weight diffuser structure (concrete).

For the calculation of the stability a few assumptions were made:

- The design water level at North Sea is taken to be +6.2 m NAP;

- The lowest water level at Lake Grevelingen will be -1 m NAP;
- The wave load is taken into account hydrostatically and fully reflecting. The wave pressure continues hydrostatically in the subsoil till the bottom of the structure. It has no effect on the water pressure beneath the structure;
- All soil around the structure is sand, which has a volumetric weight of 18 kN/m^3 dry and 20 kN/m^3 wet;
- The friction coefficient between structure and sill is equal to 0.56, assuming that a connection wil be made by means of 'undergrouting';
- The neutral horizontal pressure coefficient K,neutral is equal to 0.5.
- The passive horizontal pressure coefficient K,passive Is equal to 2.
- The maximum allowable soil pressure beneath the structure is 250 kN/m2;
- The weight of the turbines and installation is assumed 200 kN per meter wet width and founded on the structure and is thus taken into account.

Stability calculations

The structure must withstand the horizontal forces during extreme conditions, without sliding aside or rotating. Moments are calculated around the midpoint of the bottom of the structure. Furthermore the maximum bearing capacity of the soil should not be exceeded.

Safety factors are used confirm Leidraad kunstwerken (2003), this means for the horizontal stability the following factors: $0.9 * Permanent + 1.25 * Variable$. And for the bearing capacity of the subsoil, the following factors are used: $1.2 * Permanent + 1.25 * Variable$. Comparing the both combinations leads to an overall factor of 3.2, while much lower factor is expected. This influences the dimensions significantly, that is why is chosen for the safety factor of 1, only for the vertical water loads, which also influences the dimensions but to a lesser extent. This assumption is safe because the maximum upward water level will probably be smaller than assumed during a storm, because it takes some time for the water to react into the ground.

This design is relatively heavy, caused by the concrete structure of the diffuser. It is chosen to reduce the amount of concrete by creating hollow spaces in the diffuser structure. In the stability calculation this is modelled by using a lower volumetric mass, of 20 kN/m^3 instead of the normal 25 kN/m^3. Another way to reduce the mass is by reducing the amount of soil, this can be done by using EPS blocks or using light weight soil. This is applied below the N57 in order to stay below the maximum bearing capacity of the soil.

The results of the calculations are given in the table below, the calculations can be found at the end of this appendix.

Table 1: Stability checks variant Diffuser

Stability checks			Stability factor
Horizontal stability		STABLE	**1,24**
Rotational stability		STABLE	**1,11**
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,03**

Overall, this structure is still very stable at the stability checks. To reduce the cost, the dimensions could be chosen smaller, only the dimension are depended of the characteristics of the turbine and its diffusers which means that no further reductions can take place. Only optimisations in concrete design and in the soil bodies can be executed.

Excel calculations

First the general dimensions of the structure and its location will be given, after which a stability calculation is made, last the bearing capacities is checked.

Dimensions structure & situation		
Length	35	m
Top structure (maintenance room)	9	m NAP
Top of casing for valves	11	m NAP
Width of casing for valves	3	m
Top floor element	-9	m NAP
Bottom floor element	-10	m NAP
Top soil (bottom)	-10	m NAP
Bottom wall	-9	m NAP
Height wall	6,7	m
Width wall	1	m
bottom second floor element	-2,3	m NAP
Top second floor element	-1,3	m NAP
Wet width	6,7	m
Total width one unit (h.t.h.)	7,7	m
Width walls on top of structure	1	m
Bottom maintenance room roof	8	m NAP
Length maintenance room	7	m
Height maintenance room wall	10,3	m
Height soil retaining wall	7,5	m
Top valve	-2	m NAP
Top bottom protection	-12,75	m NAP
Average concrete surface diffuser structure	32,03	m2
Weight steel valve	9,81	kN/m2
Width steel valve	1	m
Width N57	11	m
Height added soil	7,5	m
Length added soil	23	m

Parameters water load		
Design water level North Sea	6,2	m NAP
Lowest water level Grevelingen	-1	m NAP
Wave amplitude	1,3	m
Reflection parameter r	2	-
Wave period	7,5	s
Material		
ρ*g , concrete	25	kN/m3/m1
ρ*g , concrete with openings	20	kN/m3/m1
Parameters soil		
K,neutral	0,5	-
K,passive	2	-
ρ*g , dry sand	10	kN/m3
ρ*g , dry sand (with weight reduction)	10	kN/m3
ρ*g , wet sand	20	kN/m3
ρ*g , salty water	10,25	kN/m3
ρ*g , sand-saltwater	9,75	kN/m3
Present height N57 at Brouwersdam	6,2	m NAP
Parameters loads		
Traffic line load	13,333	kN/m /m1
Turbines (total installation)	200	kN/m1
Parameters stability checks		
Safety factor permanent(fav. forces)	0,9	-
Safety factor permanent (unfav. forces)	1,2	-
Safety factor variable (fav. forces)	1,25	-
Safety factor variable (unfav. Forces)	1,25	-
f,dry building	0,56	-
f,in the wet (with grouting)	0,56	-
σ',bearing cap. soil	250	kN/m2
σ',currently	157,5	kN/m2

Calculation 1: Horizontal and rotational stability

Forces	Resultant/m1	Width unit	Resultant o	Safety factor	Resultant o	arm [m] to Mb	Moment (
Horizontally							
H1 (hydrostat. Sea on valve + floor)	1345	7,7	10357	1,25	12946	5,4	69907
H2 (hydrostat. Grev on valve + floor)	-415	7,7	-3196	1,25	-3996	3,0	-11987
H3 (wave below design level)	432	7,7	3324	1,25	4155	8,1	33659
H4 (wave above design level)	35	7,7	267	1,25	333	17,1	5691
H5 (active soil press.)	0	7,7	0	1,20	0	0,0	0
H6 (passive soil press.)	0	7,7	0	0,90	0	0,0	0
subtotal	1396		10751		13439		97270
Vertically							
V1 (weight concrete floor element)	875	7,7	6738	0,90	6064	0,0	0
V2 (weight concrete second floor element)	750	7,7	5775	0,90	5198	0,0	0
V3 (weight concrete casing valves)	615	7,7	4736	0,90	4262	-3,5	-14917
V4 (weight concrete roof element maintenance	175	7,7	1348	0,90	1213	0,0	0
V6 (weight concrete wall retaining soil x2)	375	7,7	2888	0,90	2599	0,0	0
V7,1 (weight soil seaside side)	750	7,7	5775	0,90	5198	-10,8	-55873
V7,2 (weight soil Grevelingen side)	975	7,7	7508	0,90	6757	10,0	67568
V8 (water pressure at the top of the floor)			4612	1,00	4612	0,0	0
V9 (weight turbine)	200	6,7	1340	0,90	1206	-2,5	-3015
V10 (steel valve)	76	6,7	506	0,90	455	-3,5	-1594
V11 (const. upward water)	-3229	7,7	-24861	1,00	-24861	0,0	0
V12 (var. upward water)	-1292	7,7	-9945	1,00	-9945	-5,8	58010
V14 (weight concrete wall between elements)			5863	0,90	5276	0,0	0
V15 (weight concrete diffuser structure)			24026	0,90	21623	0,0	0
subtotal	270		36306		29656		50178
Additional - Vertically							
V13 (traffic load)	147	7,7	1129	1,25	1412	10,8	15175
subtotal	147		1129		1412		15175

Resultants with traffic force	Total units		Total (rounded)	
ΣM	162622,92	kNm	163	MNm
ΣH	13438,95	kN	13	MN
ΣV	31067,57	kN	31	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	147447,89	kNm	147	MNm
ΣH	13438,95	kN	13	MN
ΣV	29655,94	kN	30	MN

Stability checks			Stability factor
Horizontal stability		STABLE	**1,24**
f	0,56		
f*ΣV	>	ΣH	
16607,327	>	13438,9544	
Rotational stability		STABLE	**1,11**
ΣM/ΣV	<	1/6*B	
5,234490833	<	5,83333333	

Calculation 2: Bearing capacity

Forces	Resultant/m1	Width unit	Resultant o	Safety factor	Resultant o	arm [m] to Mb	Moment (
Valves, etc - Horizontally							
H1 (hydrostat. Sea on valve + floor)	1345	7,7	10357	1,25	12946	5,4	69907
H2 (hydrostat. Grev on valve + floor)	-415	7,7	-3196	1,25	-3996	3,0	-11987
H3 (wave below design level)	432	7,7	3324	1,25	4155	8,1	33659
H4 (wave above design level)	35	7,7	267	1,25	333	17,1	5691
H5 (active soil press.)	0	7,7	0	1,25	0	0,0	0
H6 (passive soil press.)	0	7,7	0	0,90	0	0,0	0
subtotal	1396		10751		13439		97270
Vertically							
V1 (weight concrete floor element)	875	7,7	6738	1,25	8422	0,0	0
V2 (weight concrete second floor element)	750	7,7	5775	1,25	7219	0,0	0
V3,1 (weight concrete casing valves)	615	7,7	4736	1,25	5919	-3,5	-20718
V4 (weight concrete roof element maintenance room)	175	7,7	1348	1,25	1684	0,0	0
V6 (weight concrete wall retaining soil x2)	375	7,7	2888	1,25	3609	0,0	0
V7,1 (weight soil seaside side)	750	7,7	5775	1,25	7219	-10,8	-77602
V7,2 (weight soil Grevelingen side)	975	7,7	7508	1,25	9384	10,0	93844
V8 (water pressure at the top of the floor)			4612	1,00	4612	0,0	0
V9 (weight turbine)	200	6,7	1340	1,25	1675	-2,5	-4188
V10,1 (steel valve)	76	6,7	506	1,25	633	-3,5	-2214
V11 (const. upward water)	-3229	7,7	-24861	1,00	-24861	0,0	0
V12 (var. upward water)	-1292	7,7	-9945	1,00	-9945	-5,8	58010
V14 (weight concrete wall between elements)			5863	1,25	7328	0,0	0
V15 (weight concrete diffuser structure)			24026	1,25	30032	0,0	0
subtotal	270		36306		52931		47133
Additional - Vertically							
V13 (traffic load)	147	7,7	1129	1,25	1412	10,8	15175
subtotal	147		1129		1412		15175

Resultants with traffic force	Total units		Total (rounded)	
ΣM	159577,28	kNm	160	MNm
ΣH	13438,95	kN	13	MN
ΣV	54342,55	kN	54	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	144402,24	kNm	144	MNm
ΣH	13438,95	kN	13	MN
ΣV	52930,91	kN	53	MN

Stability checks			Stability factor
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,03**
Virtual excentricity ΣV (from Grev. side) w. traffic	14,5635	m	
Virtual excentricity ΣV (from Grev. side) w/o. traffic	14,7719	m	
σ',d	<	σ',bearing cap. soil	
242,3	<	250	

Appendix D2: Stability variant *Ducted*

The design of the Ducted variant has some minor differences compared to the design in the variants nota (R-04). Changes are concerning the overall dimensions, this is because of the change in safety factor usages. In the first phase a stability factor of 1.3 was required, in this phase safety factors are taken into account which influence the dimensions. The safety factor of TAW Leidraad Kunstwerken (2003) are used, per type of check the safety factor used will be explained.

The design of this variant is shown in the figure below.

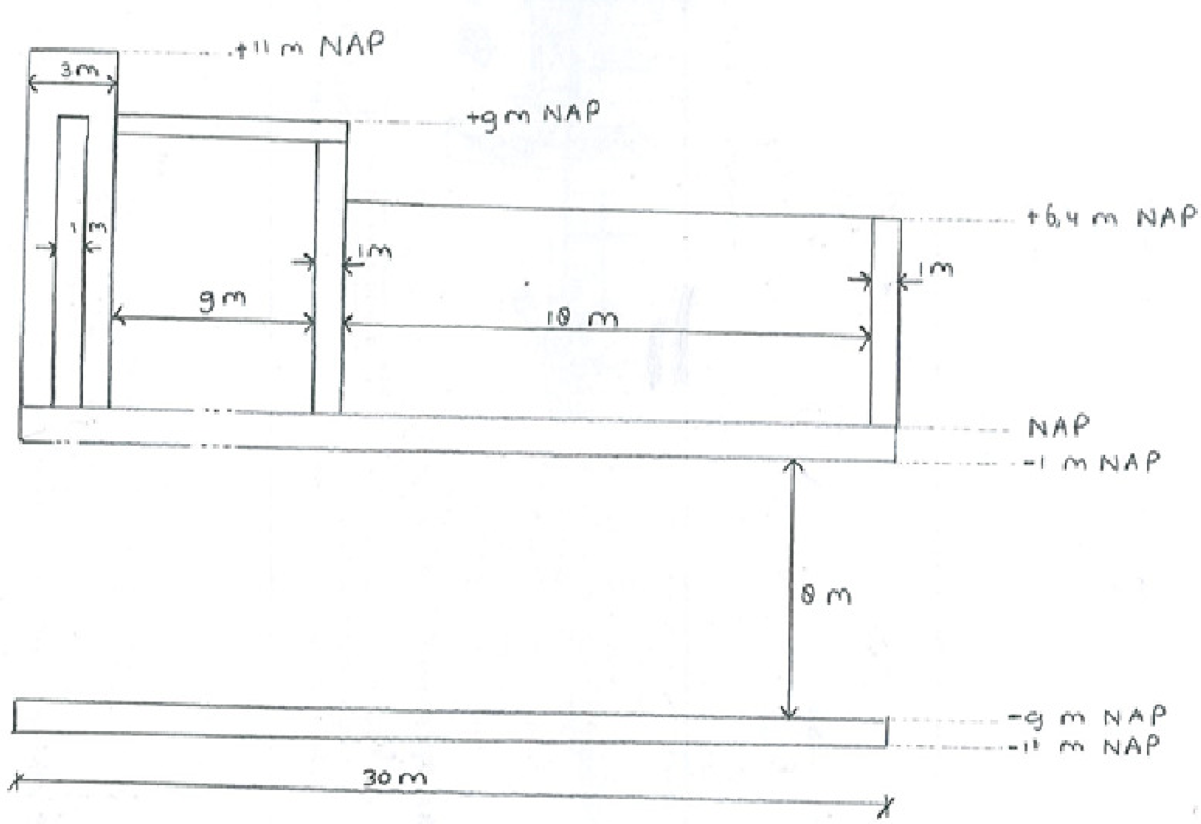


Figure 1: Cross-section variant Ducted with dimensions

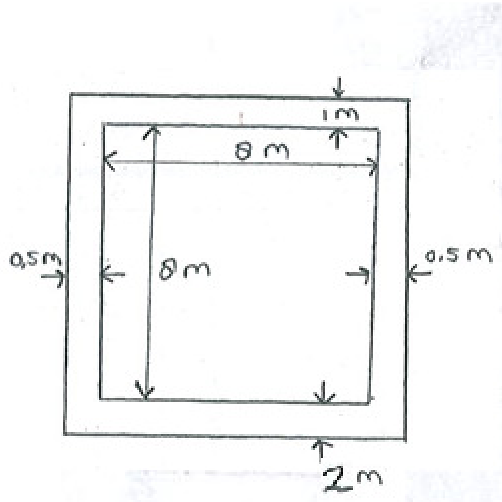


Figure 2: Front view flow area

At the seaside a valve is located, which will be closed in case of extreme conditions and can be used to regulate water levels when needed. Next to the valves and on top of the turbines a maintenance room will be constructed. The turbine can be hoist up to the maintenance room, which means that the structure does not have to be pumped dry for maintenance. On top of the maintenance room a cycle path will be located which can also be used as maintenance road, parking spaces will be created on top of the maintenance room. At the Grevelingen side a large amount of soil is used for stability, on top of this soil body the N57 and a parallel road will be located.

First, the horizontal and rotational stability were checked after which the soil pressure is checked.

Forces

The forces acting on the structure are shown in de figure below:

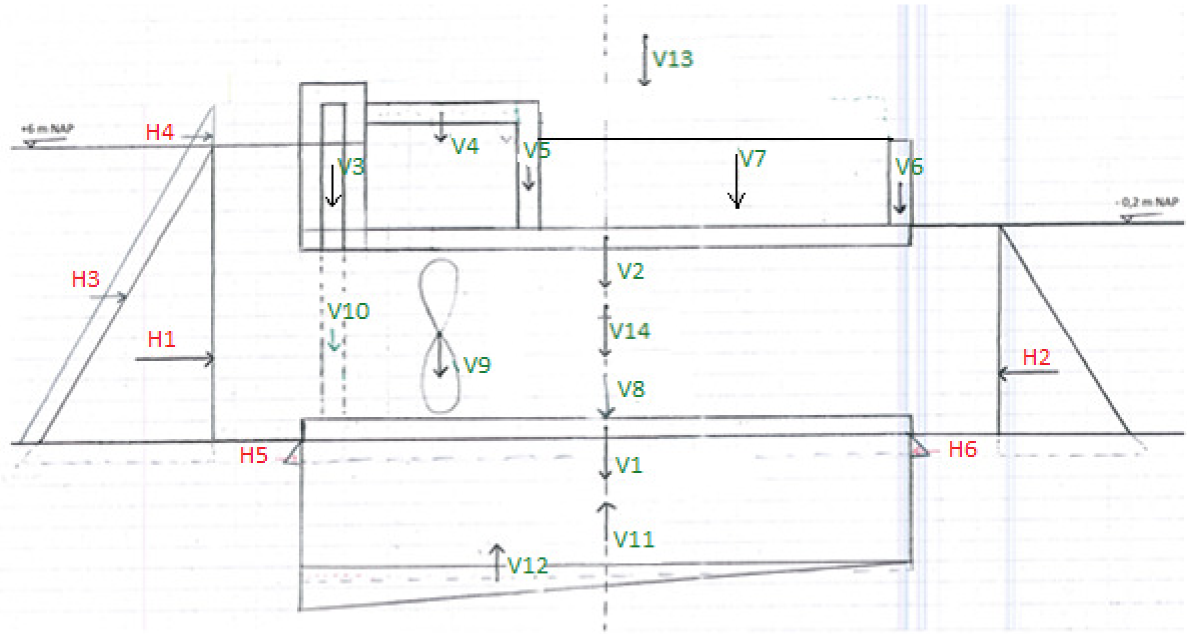


Figure 3: Forces acting on the structure

Horizontal

- H1: Due to hydrostatic pressure of water at the North sea side;
- H2: Due to hydrostatic pressure of water at the Grevelingen side;
- H3: Due to waves below design level;
- H4: Due to waves above design level;
- H5: Due to active soil pressure;
- H6: Due to passive soil pressure.

Vertical

- V1: Weight of floor element (concrete);
- V2: Weight of second floor element (concrete);
- V3: Weight casing valves (concrete);
- V4: Weight roof of maintenance room (concrete);
- V5: Weight wall of maintenance room (concrete);
- V6: Weight soil retaining wall (concrete);
- V7: Weight soil body;

- V8: Water pressure at the top of the floor;
- V9: Weight turbine;
- V10: Weight of valve (steel);
- V11: Constant upward water pressure;
- V12: Variable upward water pressure;
- V13: Traffic load;
- V14: Weight walls between the elements (concrete).

For the calculation of the stability a few assumptions were made:

- The design water level at North Sea is taken to be +6.2 m NAP;
- The lowest water level at Lake Grevelingen will be -1 m NAP;
- The wave load is taken into account hydrostatically and fully reflecting. The wave pressure continues hydrostatically in the subsoil till the bottom of the structure. It has no effect on the water pressure beneath the structure;
- All soil around the structure is sand, which has a volumetric weight of 18 kN/m^3 dry and 20 kN/m^3 wet;
- The friction coefficient between structure and sill is equal to 0.56, assuming that a connection wil be made by means of 'undergrouting';
- The neutral horizontal pressure coefficient K,neutral is equal to 0.5.
- The passive horizontal pressure coefficient K,passive Is equal to 2.
- The maximum allowable soil pressure beneath the structure is 250 kN/m2;
- The weight of the turbines and installation is assumed 200 kN per meter wet width and founded on the structure and is thus taken into account.

Stability calculations

The structure must withstand the horizontal forces during extreme conditions, without sliding aside or rotating. Moments are calculated around the midpoint of the bottom of the structure. Furthermore the maximum bearing capacity of the soil should not be exceeded.

Safety factors are used confirm Leidraad kunstwerken (2003), this means for the horizontal stability the following factors: $0.9 * Permanent + 1.25 * Variable$. And for the bearing capacity of the subsoil, the following factors are used: $1.2 * Permanent + 1.25 * Variable$. Comparing the both combinations leads to an overall factor of 3.2, while much lower factor is expected. This influences the dimensions significantly, that is why is chosen for the safety factor of 1, only for the vertical water loads, which also influences the dimensions but to a lesser extent. This assumption is safe because the maximum upward water level will probably be smaller than assumed during a storm, because it takes some time for the water to react into the ground.

will probably be smaller than assumed during a storm, because it takes some time for the water to react into the ground.

The results of the calculations are given in the table below, the calculations can be found at the end of this appendix.

Table 1: Stability checks variant Ducted

Stability checks			Stability factor
Horizontal stability		STABLE	**1,06**
Rotational stability		STABLE	**1,13**
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,08**

Excel calculations

BUILDING IN THE WET - Dimensions structure & situation		
Length	30	m
Top structure (maintenance room)	9	m NAP
Top of casing for valves (sea side)	11	m NAP
Top of casing for valves (Grevelingen side)	9	m NAP
Width of casing for valves	3	m
Top floor element	-9	m NAP
Bottom floor element	-11	m NAP
Top soil (bottom)	-10	m NAP
Bottom wall	-9	m NAP
Height wall	8	m
Width wall	1	m
bottom second floor element	-1	m NAP
Top second floor element	0,5	m NAP
Wet width	8	m
Total width one unit (h.t.h.)	9	m
Width walls on top of structure	1	m
Bottom maintenance room roof	8	m NAP
Length maintenance room	7	m
Height maintenance room wall	8,5	m
Height soil retaining wall	5,7	m
Top valve	0	m NAP
Top bottom protection	-12,75	m NAP
Weight steel valve	9,81	kN/m2
Location valve (from sea)	1,5	m
Width steel valve	1	
Width N57	11	m
Height added soil	5,7	m
Length added soil	18	m

Parameters waterbelasting		
Design water level North Sea	6,2	m NAP
Lowest water level Grevelingen	-1	m NAP
Wave amplitude	1,3	m
Reflection parameter r	2	-
Wave period	7,5	s
Material		
ρ*g , concrete	25	kN/m3/m1
Parameters soil		
K,neutral	0,5	
K,passive	2	
ρ*g , dry sand	18	kN/m3
ρ*g , dry sand (with weight reduction)	12	kN/m3
ρ*g , wet sand	20	kN/m3
ρ*g , salty water	10,25	kN/m3
ρ*g , sand-saltwater	9,75	kN/m3
Height location N57 in present dam	6,2	m NAP
Parameters loads		
Traffic line load	13,333	kN/m /m1
Turbines (total installation)	200	kN/m1
Parameters stability checks		
Safety factor permanent (fav. forces)	0,90	-
Safety factor permanent (unfav. forces)	1,20	-
Safety factor variable (fav. forces)	1,25	-
Safety factor variable (unfav. forces)	1,25	-
f,dry building	0,56	-
f,in the wet (with undergrouting)	0,56	-
σ',bearing cap. soil	250	kN/m2
σ',currently	215,25	kN/m2

Calculation 1: Horizontal and rotational stability

Forces	Resultant/m1	Width unit	Resultant o	Safety factor	Resultant o	arm [m] to Mb	Moment (
Pillars - Horizontally							
H1 (hydrostat. Sea)	1516	1	1516	1,25	1895	5,73	10866
H2 (hydrostat. Grev)	-513	1	-513	1,25	-641	3,00	-1922
H3 (wave below design level)	432	1	432	1,25	540	8,10	4371
H4 (wave above design level)	35	1	35	1,25	43	17,07	739
H5 (active soil press.)	2	1	2	1,20	3	0,33	1
H6 (passive soil press.)	-10	1	-10	0,90	-9	0,33	-3
subtotal	1463		1463		1832		14052
Valves, etc - Horizontally							
H1 (hydrostat. Sea on valve + floor)	1516	8	12129	1,25	15162	5,40	81874
H2 (hydrostat. Grev on valve + floor)	-513	8	-4100	1,25	-5125	3,00	-15375
H3 (wave below design level)	432	8	3454	1,25	4317	8,10	34970
H4 (wave above design level)	35	8	277	1,25	346	17,07	5913
H5 (active soil press.)	2	8	20	1,20	23	0,33	8
H6 (passive soil press.)	-10	8	-78	0,90	-70	0,33	-23
subtotal	1463		11702		14654		107366
Vertically							
V1 (weight concrete floor element)	1500	9	13500	0,90	12150	0,00	0
V2 (weight concrete second floor element)	1125	9	10125	0,90	9113	0,00	0
V3 (weight concrete casing valves)	525	9	4725	0,90	4253	-13,50	-57409
V4 (weight concrete roof element maintenance room)	175	9	1575	0,90	1418	-8,50	-12049
V5 (weight concrete wall maintenance room)	213	9	1913	0,90	1721	-4,50	-7746
V6 (weight concrete wall retaining soil)	143	9	1283	0,90	1154	14,50	16737
V7,1 (weight soil)	718	9	6464	0,90	5817	-0,50	-2909
V7,2 (weight soil below N57)	752	9	6772	0,90	6094	8,50	51803
V8 (water pressure at the top of the floor)	2460	8	19680	1,00	19680	0,00	0
V9 (weight turbine)	200	8	1600	0,90	1440	-8,50	-12240
V10 (steel valve)	93	8	746	0,90	671	-13,50	-9059
V11 (const. upward water)	-3075	9	-27675	1,00	-27675	0,00	0
V12 (var. upward water)	-1107	9	-9963	1,00	-9963	-5,00	49815
V14 (weight concrete wall between elements)			6000	0,90	5400	0,00	0
subtotal	3722		36743		31273		16944
Additional - Vertically							
V13 (traffic load)	147	9	1320	1,25	1650	4,50	7425
subtotal	147		1320		1650		7425

Resultants with traffic force	Total units		Total (rounded)	
ΣM	145787	kNm	146	MNm
ΣH	16485	kN	16	MN
ΣV	32923	kN	33	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	138362	kNm	138	MNm
ΣH	16485	kN	16	MN
ΣV	31273	kN	31	MN

Stability checks			Stability factor
Horizontal stability		**STABLE**	**1,06**
f	0,56		
f*ΣV	>	ΣH	
17512,80384	>	16485,4688	
Rotational stability		**STABLE**	**1,13**
ΣM/ΣV	<	1/6*B	
4,428152452	<	5	

Calculation 2: Bearing capacity soil

Forces	Resultant/m1	Width unit	Resultant o	Safety factor	Resultant o	arm [m] to Mb	Moment (
Pillars - Horizontally							
H1 (hydrostat. Sea)	1516	1	1516	1,25	1895	5,73	10866
H2 (hydrostat. Grev)	-513	1	-513	1,25	-641	3,00	-1922
H3 (wave below design level)	432	1	432	1,25	540	8,10	4371
H4 (wave above design level)	35	1	35	1,25	43	17,07	739
H5 (active soil press.)	2	1	2	0,90	2	0,33	1
H6 (passive soil press.)	-10	1	-10	1,25	-12	0,33	-4
subtotal	1463		1463		1828		14051
Valves, etc - Horizontally							
H1 (hydrostat. Sea on valve + floor)	1516	8	12129	1,25	15162	5,40	81874
H2 (hydrostat. Grev on valve + floor)	-513	8	-4100	1,25	-5125	3,00	-15375
H3 (wave below design level)	432	8	3454	1,25	4317	8,10	34970
H4 (wave above design level)	35	8	277	1,25	346	17,07	5913
H5 (active soil press.)	2	8	20	0,90	18	0,33	6
H6 (passive soil press.)	-10	8	-78	1,25	-98	0,33	-33
subtotal	1463		11702		14621		107355
Vertically							
V1 (weight concrete floor element)	1500	9	13500	1,25	16875	0,00	0
V2 (weight concrete second floor element)	1125	9	10125	1,25	12656	0,00	0
V3 (weight concrete casing valves)	525	9	4725	1,25	5906	-13,50	-79734
V4 (weight concrete roof element maintenance room)	175	9	1575	1,25	1969	-8,50	-16734
V5 (weight concrete wall maintenance room)	213	9	1913	1,25	2391	-4,50	-10758
V6 (weight concrete wall retaining soil)	143	9	1283	1,25	1603	14,50	23245
V7,1 (weight soil)	718	9	6464	1,25	8080	-0,50	-4040
V7,2 (weight soil below N57)	752	9	6772	1,25	8465	8,50	71948
V8 (water pressure at the top of the floor)	2460	8	19680	1,00	19680	0,00	0
V9 (weight turbine)	200	8	1600	1,25	2000	-8,50	-17000
V10 (steel valve)	93	8	746	1,25	932	-13,50	-12581
V11 (const. upward water)	-3075	9	-27675	1,00	-27675	0,00	0
V12 (var. upward water)	-1107	9	-9963	1,00	-9963	-5,00	49815
V14 (weight concrete wall between elements)			6000	1,25	7500	0,00	0
subtotal	3722		36743		50418		4161
Additional - Vertically							
V13 (traffic load)	147	9	1320	1,25	1650	4,50	7425
subtotal	147		1320		1650		7425

Resultants with traffic force	Total units		Total (rounded)	
ΣM	132992	kNm	133	MNm
ΣH	16448	kN	16	MN
ΣV	52068	kN	52	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	125567	kNm	126	MNm
ΣH	16448	kN	16	MN
ΣV	50418	kN	50	MN

Stability checks			Stability fac
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,08**
Virtual excentricity ΣV (from Grev. side) w. traffic	12,44582	m	
Virtual excentricity ΣV (from Grev. side) w/o. traffic	12,50949	m	
σ',d	<	σ',bearing cap. soil	
232,42	<	250	

Appendix D3: Stability variant *Venturi*

The design of the Venturi variant is new compared to the previous variant in the variant nota R-04. For this variant also a small structure is preferable, which means that the design is similar to the ducted variant. The dimensions for the Venturi are provided by VedErg, which conducts research on the design of this type of turbine. Together with these dimensions, the following design is made.

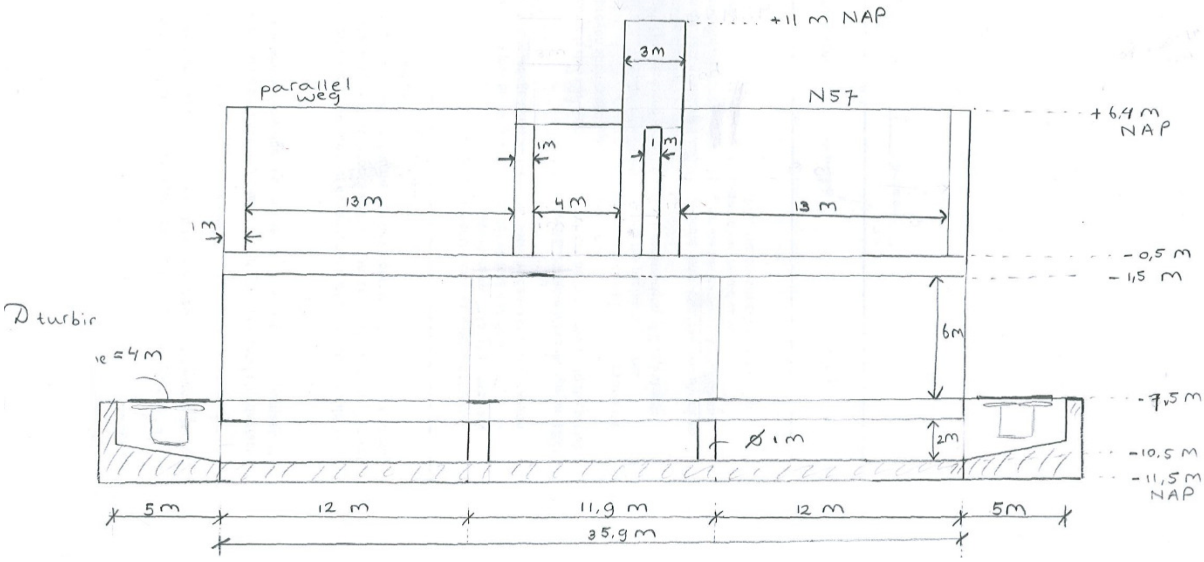


Figure 1: Cross-section variant Ducted with dimensions

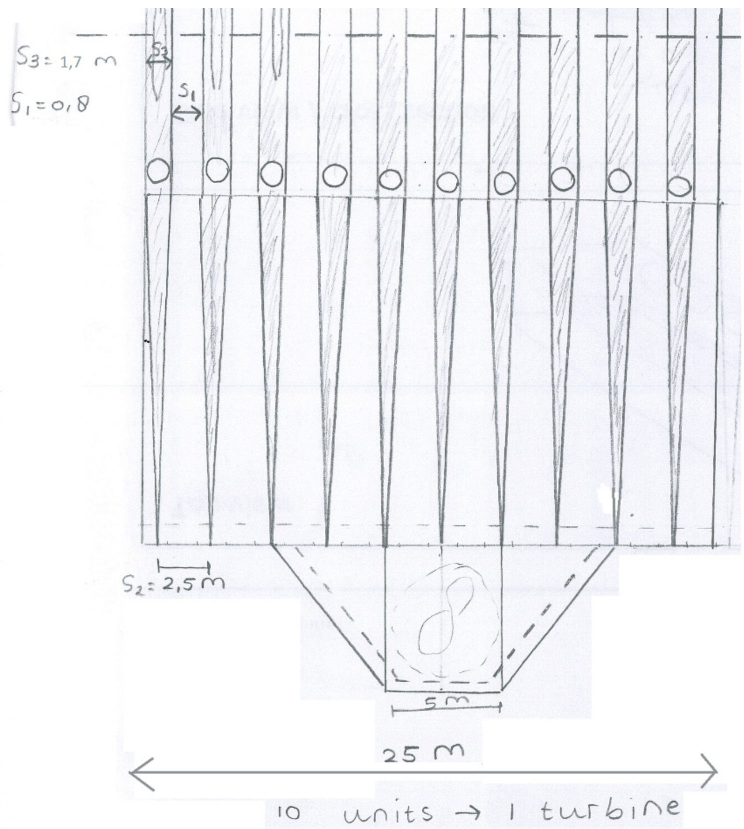


Figure 2: Top view with dimensions and turbine (not to scale)

The main difference between this variant and the ducted variant is the basement, located underneath the structure. Through this basement 1/5th of the total volume will flow, first through the turbine and then via openings through the narrowest part of the venturi. In front of every 10 venturi openings a turbine will be placed, on both sides (sea and Grevelingen). This means that in total 8x2 turbines will be placed. These turbines can be hoist up from an external pontoon for maintenance.

It is chosen to use a lot of small valves instead of a couple large valves, the valves will be placed at the narrowest point of the venturi, to keep the structure as small as possible. The valves are connected to a technical room from which the valves can be maintained.

At both sides of the valve a soil body is present to guarantee stability. At the sea side a parallel road will be constructed and at the other side the N57 will be located.

For the stability first, the horizontal and rotational stability were checked after which the soil pressure is checked.

Forces

The forces acting on the structure are written down below. The forces are defined in the same way as for variant Ducted, in which a picture is shown with the location of the forces.

Horizontal

- H1: Due to hydrostatic pressure of water at the North sea side;
- H2: Due to hydrostatic pressure of water at the Grevelingen side;
- H3: Due to waves below design level;
- H4: Due to waves above design level;
- H5: Due to active soil pressure;
- H6: Due to passive soil pressure.

Vertical

- V0: weight of the basement floor element (concrete)
- V1: Weight of floor element (concrete);
- V2: Weight of second floor element (concrete);
- V3: Weight casing valves (concrete);
- V4: Weight roof of maintenance room (concrete);
- V5: Weight wall of maintenance room (concrete);
- V6: Weight soil retaining wall (concrete);
- V7,1: Weight soil body (sea side);
- V7,2: Weight soil body (Grevelingen side);
- V8: Water pressure at the top of the floor;
- V9: Water pressure at top of the basement;
- V10: Weight of valve (steel);
- V11: Constant upward water pressure;
- V12: Variable upward water pressure;
- V13: Traffic load;
- V14: Weight concrete venture elements (concrete);
- V15: Weight concrete pillars in basement.

For the calculation of the stability a few assumptions were made:

- The design water level at North Sea is taken to be +6.2 m NAP;
- The lowest water level at Lake Grevelingen will be -1 m NAP;
- The wave load is taken into account hydrostatically and fully reflecting. The wave pressure continues hydrostatically in the subsoil till the bottom of the structure. It has no effect on the water pressure beneath the structure;
- All soil around the structure is sand, which has a volumetric weight of 18 kN/m^3 dry and 20 kN/m^3 wet;
- The friction coefficient between structure and sill is equal to 0.56, assuming that a connection wil be made by means of 'undergrouting';
- The neutral horizontal pressure coefficient K,neutral is equal to 0.5.
- The passive horizontal pressure coefficient K,passive Is equal to 2.
- The maximum allowable soil pressure beneath the structure is 250 kN/m2;

Stability calculations

The structure must withstand the horizontal forces during extreme conditions, without sliding aside or rotating. Moments are calculated around the midpoint of the bottom of the structure. Furthermore the maximum bearing capacity of the soil should not be exceeded. A cross-section without the turbines is chosen, because the stability with turbine is more stable because of its weight and extra length.

Safety factors are used confirm Leidraad kunstwerken (2003), this means for the horizontal stability the following factors: $0.9 * Permanent + 1.25 * Variable$. And for the bearing capacity of the subsoil, the following factors are used: $1.2 * Permanent + 1.25 * Variable$. Comparing the both combinations leads to an overall factor of 3.2, while much lower factor is expected. This influences the dimensions significantly, that is why is chosen for the safety factor of 1, only for the vertical water loads, which also influences the dimensions but to a lesser extent. This assumption is safe because the maximum upward water level will probably be smaller than assumed during a storm, because it takes some time for the water to react into the ground.

The results of the calculations are given in the table below, the calculations can be found at the end of this appendix.

Table 1: Stability checks variant Ducted

Stability checks			Stability factor
Horizontal stability		STABLE	1,22
Rotational stability		STABLE	1,67
Bearing capacity (i.r.t. max capacity value)		STABLE	1,13

The stability factors are still relative high, which means that this design could be optimised, however, dimensions from the venturi are given, which means that no mass reduction can be executed in the venturi structure. A reduction of mass is already applied below the N57 in order to reduce the forces on the subsoil.

Excel calculations

Venturi - Dimensions structure & situation		
Length	35,8	m
length basement	35,8	m
Top structure (maintenance room)	6,4	m NAP
Top of casing for valves (sea side)	11	m NAP
Width of casing for valves	3	m
Top basement floor element	-10,5	m NAP
Bottom basement floor element	-11,5	m NAP
Diameter pillars in basement	1	m
Top floor element	-7,5	m NAP
Bottom floor element	-8,5	m NAP
Top soil (bottom)	-10	m NAP
Bottom venturi	-7,5	m NAP
Height venturi	6	m
Width venturi (average)	1,13	m
bottom second floor element	-1,5	m NAP
Top second floor element	-0,5	m NAP
Wet width	0,8	m
Total width one unit (h.t.h.)	2,5	m
Width walls on top of structure	1	m
Bottom maintenance room roof	5,4	m NAP
Length maintenance room	4	m
Height maintenance room wall	6,9	m
Height soil retaining wall	6,9	m
Top valve	0	m NAP
Top bottom protection	-12,75	m NAP
Weight steel valve	9,81	kN/m2
Width steel valve	0,3	
Width N57	11	m
Height added soil	6,9	m
Length added soil	25,8	m

Parameters waterbelasting		
Design water level North Sea	6,2	m NAP
Lowest water level Grevelingen	-1	m NAP
Wave amplitude	1,3	m
Reflection parameter r	2	-
Wave period	7,5	s
Material		
ρ*g , concrete	25	kN/m3/m1
ρ*g , concrete with openings	20	kN/m3/m1
Parameters soil		
K,neutral	0,5	
K,passive	2	
ρ*g , dry sand	18	kN/m3
ρ*g , dry sand (with weight reduction)	12	kN/m3
ρ*g , wet sand	20	kN/m3
ρ*g , salty water	10,25	kN/m3
ρ*g , sand-saltwater	9,75	kN/m3
Height location N57 in present dam	6,4	m NAP
Parameters loads		
Traffic line load	13,333	kN/m /m1
Turbines (total installation)	200	kN/m1
Parameters stability checks		
Safety factor permanent (fav. forces)	0,90	-
Safety factor permanent (unfav. forces)	1,20	-
Safety factor variable (fav. forces)	1,25	-
Safety factor variable (unfav. forces)	1,25	-
f,dry building	0,56	-
f,in the wet (with undergrouting)	0,56	-
σ',bearing cap. soil	250	kN/m2
σ',currently	190,875	kN/m2

Calculation 1: Horizontal and rotational stability

Forces	Resultant/m1	Width unit	Resultant o	Safety factor	Resultant o	arm [m] to Mb	Moment (
Horizontally							
H1 (hydrostat. Sea)	1606	2,5	4014	1,25	5018	5,90	29603
H2 (hydrostat. Grev)	-565	2,5	-1413	1,25	-1766	3,50	-6180
H3 (wave below design level)	432	2,5	1079	1,25	1349	8,10	10928
H4 (wave above design level)	35	2,5	87	1,25	108	17,07	1848
H5 (active soil press.)	5	2,5	14	1,20	16	0,50	8
H6 (passive soil press.)	-22	2,5	-55	0,90	-49	0,50	-25
subtotal	1491		3726		4676		36183
Vertically							
V0 (weight concrete basement floor element)	895	2,5	2238	0,9	2014	0,00	0
V1 (weight concrete floor element)	895	2,5	2238	0,9	2014	0,00	0
V2 (weight concrete second floor element)	895	2,5	2238	0,9	2014	0,00	0
V3 (weight concrete casing valves)	776	2,5	1941	0,9	1747	2,50	4366
V4 (weight concrete roof element maintenance room)	100	2,5	250	0,9	225	-1,00	-225
V5 (weight concrete wall maintenance room)	173	2,5	431	0,9	388	-3,50	-1358
V6 (weight concrete wall retaining soil)	345	2,5	863	0,9	776	0,00	0
V7,1 (weight soil sea side)	1602	2,5	4005	0,9	3605	-28,35	-102199
V7,2 (weight soil Grevelingen side)	1068	2,5	2670	0,9	2403	28,35	68133
V8 (water pressure at the top of the floor)	2202	1,37	3016	1	3016	0,00	0
V9 (water pressure at the top of the basement)	734	2,5	1835	1	1835	0,00	0
V10 (steel valve)	21	0,8	16	0,9	15	2,50	37
V11 (const. upward water)	-3853	2,5	-9632	1	-9632	0,00	0
V12 (var. upward water)	-1871	2,5	-4679	1,00	-4679	-5,97	27916
V14 (weight concrete Venturi elements)	4296	1,13	4854	0,9	4369	0,00	0
V15 (weight concrete pillars in basement)			79	0,9	71	0,00	0
subtotal	8277		12362		10180		-3331
Additional - Vertically							
V13 (traffic load)	147	2,5	367	1,25	458	11,40	5225
subtotal	147		367		458		5225

Resultants with traffic force	Total units		Total (rounded)	
ΣM	38077	kNm	38	MNm
ΣH	4676	kN	5	MN
ΣV	10638	kN	11	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	32852	kNm	33	MNm
ΣH	4676	kN	5	MN
ΣV	10180	kN	10	MN

Stability checks			Stability factor
Horizontal stability		**STABLE**	**1,22**
f	0,56		
f*ΣV	>	ΣH	
5700,767551	>	4676,32813	
Rotational stability		**STABLE**	**1,67**
ΣM/ΣV	<	1/6*B	
3,579264731	<	5,96666667	

Calculation 2: Bearing capacity soil

Forces	Resultant/m1	Width unit	Resultant o	Safety factor	Resultant c	arm [m] to Mt	Moment (
Horizontally							
H1 (hydrostat. Sea)	1606	2,5	4014	1,25	5018	5,90	29603
H2 (hydrostat. Grev)	-565	2,5	-1413	1,25	-1766	3,50	-6180
H3 (wave below design level)	432	2,5	1079	1,25	1349	8,10	10928
H4 (wave above design level)	35	2,5	87	1,25	108	17,07	1848
H5 (active soil press.)	5	2,5	14	1,25	17	0,50	9
H6 (passive soil press.)	-22	2,5	-55	0,90	-49	0,50	-25
subtotal	1491		3726		4677		36183
Vertically							
V0 (weight concrete basement floor element)	895	2,5	2238	1,25	2797	0,00	0
V1 (weight concrete floor element)	895	2,5	2238	1,25	2797	0,00	0
V2 (weight concrete second floor element)	895	2,5	2238	1,25	2797	0,00	0
V3 (weight concrete casing valves)	776	2,5	1941	1,25	2426	2,50	6064
V4 (weight concrete roof element maintenance room)	100	2,5	250	1,25	313	-1,00	-313
V5 (weight concrete wall maintenance room)	173	2,5	431	1,25	539	-3,50	-1887
V6 (weight concrete wall retaining soil)	345	2,5	863	1,25	1078	0,00	0
V7,1 (weight soil sea side)	1602	2,5	4005	1,25	5007	-28,35	-141943
V7,2 (weight soil Grevelingen side)	1068	2,5	2670	1,25	3338	28,35	94629
V8 (water pressure at the top of the floor)	2202	1,37	3016	1,00	3016	0,00	0
V9 (water pressure at the top of the basement)	734	2,5	1835	1,00	1835	0,00	0
V10 (steel valve)	21	0,8	16	1,25	21	2,50	52
V11 (const. upward water)	-3853	2,5	-9632	1,00	-9632	0,00	0
V12 (var. upward water)	-1871	2,5	-4679	1,00	-4679	-5,97	27916
V14 (weight concrete Venturi elements)	4296	1,13	4854	1,25	6068	0,00	0
V15 (weight concrete pillars in basement)			79	1,25	98	0,00	0
subtotal	8277		12362		17818		-15482
Additional - Vertically							
V13 (traffic load)	147	2,5	367	1,25	458	11,40	5225
subtotal	147		367		458		5225

Resultants with traffic force	Total units		Total (rounded)	
ΣM	25926	kNm	26	MNm
ΣH	4677	kN	5	MN
ΣV	18276	kN	18	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	20701	kNm	21	MNm
ΣH	4677	kN	5	MN
ΣV	17818	kN	18	MN

Stability checks			Stability factor
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,13**
Virtual excentricity ΣV (from Grev. side) w. traffic	16,4814	m	
Virtual excentricity ΣV (from Grev. side) w/o. traffic	16,7382	m	
σ',d	<	σ',bearing cap. soil	
221,78	<	250	

APPENDIX D4: STABILITY CALCULATIONS OF CAISSONS AS SOIL RETAINING STRUCTURE

In both the dry and wet execution method of the bulb power plant and free flow solution, the caissons are used as temporary retaining wall as the border of the building pit.
A standard situation is chosen to calculate the stability of the caissons for. The crest will be lowered to +9 m NAP. At this level also the N57 will be located. This means the caissons will have to retain soil with a depth of around 19 meters, the difference in water level and the pressure by the N57.
To make the calculation a few assumptions were made:

- The governing sliding plane is between top sill and bottom caisson (an additional calculation might have to be made for the sliding plane between sill and bottom protection);
- The ground water level in the dam is taken to be + 1.5 m NAP in case of the wet variants, and -8 m NAP in case of a dry building pit due to drainage;
- The lowest water level at Lake Grevelingen will be -0.5 m NAP;
- The N57 is located next to the caissons (which is conservative);
- All soil around the caissons is sand, which has a volumetric weight of 18 kN/m^3 dry and 20 kN/m^3 wet;
- In the caisson, the soil left of the valve has the is dry above the left-side GWL and wet beneath. At the right side of the valve the same for the right-side water level.
- The friction coefficient between caisson and sill is equal to 0,4;
- The neutral horizontal pressure coefficient K,neutral is equal to 0,5.
- The passive horizontal pressure coefficient K,passive Is equal to 2.
- The maximum allowable soil pressure beneath the caissons is 300 kN/m2;

From the document “the closure of tidal basins” the following information is available:

- The wet weight of the empty caisson (with soil and assuming also without valves) is equal to 800 kN/m^1.
- Ballast material was used to weigh the caissons: 450 kN/m^1.

It is assumed that the dry weight of the caisson including ballast is 2160 kN/m3, which with a volumetric weight for both the concrete as the ballast material of25 kN/m^3, is 30% of the volume of the caisson. The volume of the steel valves is assumed negligible and this thus leaves 70% of ‘open’ space for the soil.

In the document "the closure of tidal basins" a coefficient of friction of 0.5 is assumed. It is mentioned that when the maximum horizontal force is exceeded, the ribs of the caissons will force their way into the stone sill which causes them to carry part of the load. As a result the coefficient of friction can rise to an estimated 0.85. In this calculation however initially a (conservative) coefficient of friction of 0.4 is used. If not sufficient further inquire could be done into the friction coefficients.
Although expected that the soil at the excavated side of the steel valve can, without additional measures, not be kept inside the caisson, the stability is calculated for the situation with all soil and with half of the soil 'lost'.
In the figure below all pressures and forces are shown, of which the dashed forces (H5 and V7) only act in the wet variant.

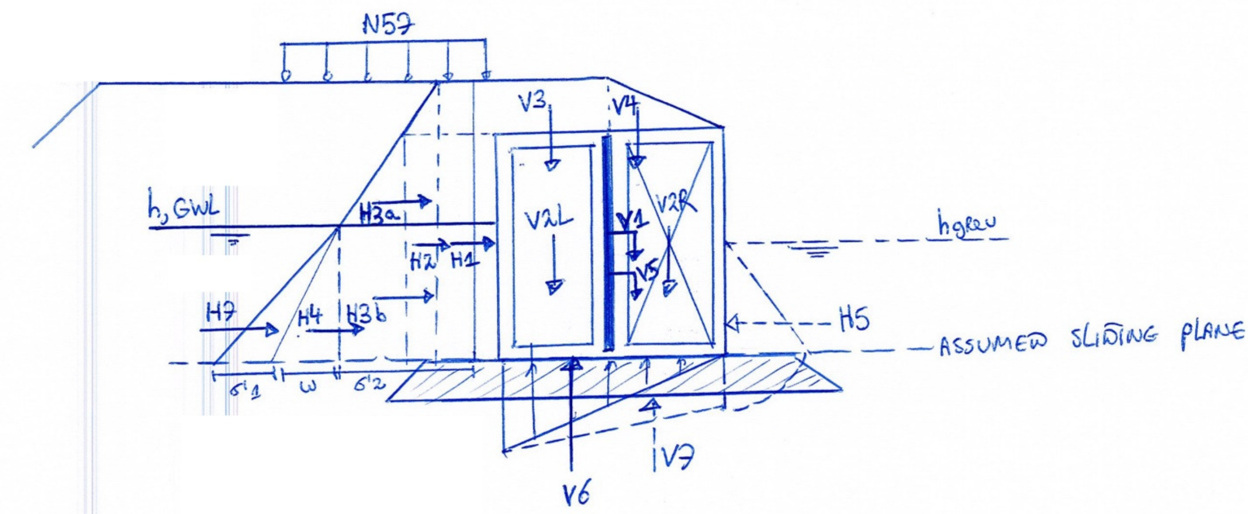


Figure 1: Pressures and forces on caisson

The separation of resultant forces is as follows:

Horizontal

- H1: Due to added horizontal soil pressure due to the top load of the N57;
- H2: Due to added horizontal soil pressure due to dry soil layer above the top of the caisson (+6 m NAP);
- H3a: Due to the soil pressure from +6 m NAP to GWL, resultant above GWL;
- H3b: Due to the soil pressure from +6 m NAP to GWL, resultant below GWL;
- H4: Due to ground water pressure ascending from GWL to bottom caisson;
- H5: Due to the water pressure from the lowest water level at Lake Grevelingen to -10 m NAP;
- H6: Optional/ if necessary: remaining soil pressure at the Grevelingen side
- H7: Due to the soil pressure beneath GWL;

Vertical

- V1: Weight of caisson concrete;
- V2L: Weight of soil at left-side in caisson, which is assumed totally wet;
- V2R: Weight of soil at right-side in caisson, which is assumed dry above lowest water level Grevelingen in case of building in the wet, and fully dry in case of a dry building pit;
- V3: Weight of unsloped part soil on top of caisson;

- V4: Weight of sloped part soil on top of caisson;
- V5: Weight steel valve;
- V6: Due to upward water pressure varying between left-side water pressure and zero at the right-side;
- V7: Due to added upward water pressure in case of a wet building pit and thus a water level at the Grevelingen side. (Pressure varying between right-side water pressure and zero at left-side);

Of course a lot of these forces result in moments. The moments are calculated around the midpoint of the bottom of the caisson.

Stability checks

The following stability checks were made:
- The horizontal stability (f*ΣV > ΣH);
- The rotational stability (ΣM/ΣV < 1/6*B);
- Bearing capacity (σ',virtual average < σ',capacity).

Additionally the following is informatively checked, but is not stability demand:
- Peak pressure i.r.t. current pressure.

The calculation is added at the end of this chapter. The current soil pressure beneath the caissons, with the crest at +11 m, is about:

$$\sigma' = \sigma tot - w = h,soilontop * \rho g,sand(dry) + \frac{W,concrete + ballast}{Width} + psoil * V * (\frac{h,gwl}{h,caisson} * \rho g,sand(wet) + \frac{h,caisson - h,gwl}{h,caisson} * \rho g,sand(wet) - h,gwl * \rho g,saltwater \leftrightarrow$$

$$\sigma' = 5 * 18 + \frac{2160}{18} + 0{,}7 * 288 * \frac{\left(\frac{10}{16} * 20 + \frac{6}{16} * 18\right)}{18} - 10 * 10{,}25 = 323{,}1\ kN/m^2$$

The groundwater level is taken at NAP in this calculation. The sand in the caissons beneath that level is wet.

Results

In the calculations no safety factors has been used. Although it is stated in the calculations that for any stability factor above 1 the structure is stable, a factor beneath 1.3 might still need additional measures to guarantee safety. As the use of the caissons as retaining wall is only temporary, the safety factor might be lower than with the stability checks of the final variants.

Dry

In case of a dry building pit, and the right side of the caisson empty, the caissons are stable for all checks.

D1E	Dry building pit, soil part caissons half empty			Stability factor
	Horizontal stability		STABLE	1,11
	Rotational stability		STABLE	8,81
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,1
	Peak pressure i.r.t. current pressure		LOWER	1,11

In case the caissons remain full with soil, the horizontal stability increases. Due to the added weight however, the stresses beneath the caisson exceed the current and the maximum allowable pressures.

D1F	Dry building pit, soil part caissons full			Stability factor
	Horizontal stability		STABLE	1,53
	Rotational stability		STABLE	2
	Bearing capacity (i.r.t. max capacity value)	UNSTABLE		0,69
	Peak pressure i.r.t. current pressure	HIGHER		0,59

If the caissons would be closed with for example the wooden beams which made the caissons floatable before placing, these could most likely be removed together with the soil in the Grevelingen-side of the caisson to 'restore' stability.

Wet

In case of building in the wet, the higher water levels at both sides of the caissons mainly increase the upward water pressures. In this case the horizontal stability is no longer secured, see below.

W1E	Building in the wet, soil part caissons half empty			Stability factor
	Horizontal stability	UNSTABLE		0,75
	Rotational stability		STABLE	8,06
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,69
	Peak pressure i.r.t. current pressure		LOWER	1,68

The same problem arises when the caissons are full with soil as with the dry building pit. It increases the horizontal stability, creating stability in that direction. The increased soil pressures are higher than allowed in that case however.

W1F	Building in the wet, soil part caissons full			Stability factor
	Horizontal stability		STABLE	1,1
	Rotational stability		STABLE	1,79
	Bearing capacity (i.r.t. max capacity value)	UNSTABLE		0,98
	Peak pressure i.r.t. current pressure	HIGHER		0,83

Possible alternate designs

A few possibilities would be available to increase stability, when deemed necessary.

Increasing horizontal stability:

A. Locating the road on top of the caissons instead of next to it;
B. Lowering the soil and road left of the caissons, but maintaining soil on top of the caissons to keep required crest level;
C. 'Leaving' soil at the Grevelingen side of the caisson, in case of the half empty caisson this also results in additional soil kept into the caisson;
D. A combination of A with B or C.

A higher coefficient of friction, of which is claimed that it may rise to 0.85, could also yield a largely increased horizontal stability. In that case, further inquiry into the coefficient of friction must be done. In the excel calculation the results of these options are shown as well.

Keeping 5 meter of soil from sill up on the Grevelingen-side of the caissons would for example ensure the stability in case of the wet variants and the half empty caissons, see below. This does however result in a loss of width for the building pit.

W1E	x2, Added soil right side:	5	m
	Lost width building pit (slope 1:2)	15,5	m

W1E	Building in the wet, soil part caissons half empty			Stability factor
	Horizontal stability		STABLE	1,07
	Rotational stability		STABLE	3,11
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,3
	Peak pressure i.r.t. current pressure		LOWER	1,19

Decreasing soil pressures:

A. Removing the soil on top of the caissons while maintaining the +9 next the caissons;
B. Removing the soil from the right side of the caissons (if this is not already the case).

Conclusion

Most likely the soil on the Grevelingen-side of the steel valve will be 'lost' from the caissons when excavating the building pit. In that case a dry building pit with drainage would be stable with the caissons as retaining wall. The wet variant might need some additional measures, like keeping a soil body of 5 meter height against the caissons at the Grevelingen-side. An possibly larger real coefficient of friction between caisson and sill than assumed, might mean that the caissons are already stable without additional measures for the wet variant as well.

Excel calculation

Dimensions caisson & situation		
Height caisson	16	m
Width caisson	18	m
x1, soil above top caisson	3	m
x2, soil next to caisson (from sill up)	0	m
slope sand from top caisson	0,5	-
Weight steel valve	80	kN/m1
Top ground water (dry variants)	-8	m NAP
Top ground water (wet variants)	1,5	m NAP
Top caisson	6	m NAP
Top sill	-10	m NAP
Top bottom protection	-12,75	m NAP
Lowest water level Grevelingen	-0,5	m NAP
Parameters bovenbelasting		
Normaal verkeer	13,33	kN/m1
Bouwverkeer? Kranen?	0	kN/m1
Materials caisson		
ρ*g , concrete	25	kN/m3/m1
Percentage concrete	30	%
Percentage soil	70	% *- of which sometimes half may be lost*
Parameters soil		
K,neutral	0,5	
K,passive	2	
ρ*g , dry sand	18	kN/m3
ρ*g , wet sand	20	kN/m3
ρ*g , salty water	10,25	kN/m3
Parameters stability checks		
f	0,4	-
σ',bearing capacity	300	kN/m2
σ',currently beneath caissons	323,1	kN/m2

Example calculation: situation D1E

Calculated weights and volumes		
Volume caisson	288	m3 / m1
Volume soil left	100,8	m3 / m2
Volume soil right	0	m3 / m3
Weight concrete	2160	kN /m1
Heigth caisson above WL sea side	14	m
Height caisson below WL sea side	2	m
Section modulus W	54	m3/m1

Forces	Resultant	arm [m] to Mbottom	Moment (clockw
Horizontally			
H1 (traffic)	106,64	8	853,12
H2 (due to soil above top caisson)	432	8	3456
H3a (due to soil betw top caiss. and GWL) (above GWL)	882	6,666666667	5880
H3b (due to soil betw top caiss. and GWL) (below GWL)	252	1	252
H7 (due to soil below GWL)	9,75	0,666666667	6,5
H4 (GW sea side)	20,5	0,666666667	13,66666667
H5 (water Grevelingen)	0	3,166666667	0
H6 (soil Grevelingen side)	0	0	0
Vertically			
V1 (concrete of caisson)	2160	0	0
V2L (soil in caisson, left)	1839,6	-4,5	-8278,2
V2R (soil in caisson, right)	0	4,5	0
V3 (soil on top of caisson, unsloped)	648	-3	-1944
V4 (soil on top of caisson, sloped)	162	5	810
V5 (steel valve)	80	0	0
V6 (uplifting water pressure, const.)	-184,5	-3	553,5
V7 (uplifting water pressure, var.)	0	0	0
V8 (maintaneid soil caisson, right, due to added soil)	0	4,5	0
Resultants			
ΣM	1602,586667		
ΣH	1702,89		
ΣV	4705,1		

Stability checks			Stability factor
Horizontal stability		STABLE	1,11
f*ΣV	>	ΣH	
1882,04	>	1702,89	
Rotational stability		STABLE	8,81
ΣM/ΣV	<	1/6*B	
0,340606292	<	3	
Bearing capacity (i.r.t. max capacity value)		STABLE	1,1
Virtual excentricity ΣV (from Grev. side)	8,659393708	m	
σ',rep	<	σ',bearing capacity	
271,68	<	300	
Peak pressure i.r.t. current pressure		LOWER	1,11
σ',max	<	σ',currently beneath caissons	
291,07	<	323,1	

Example calculation: situation W2F

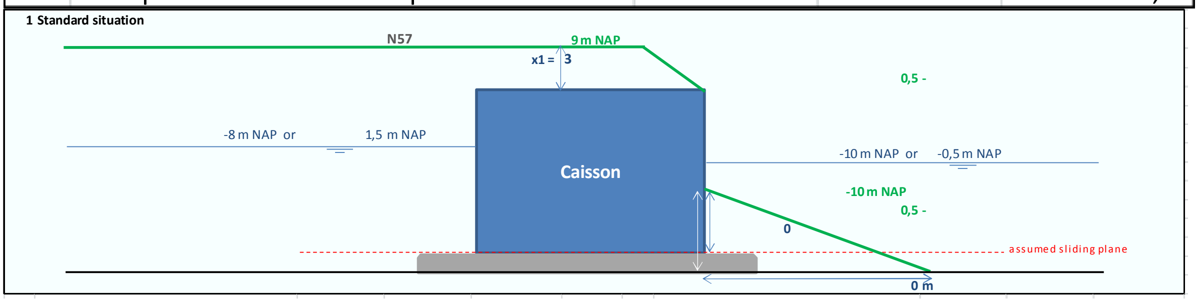
Calculated weights and volumes		
Volume caisson	288	m3 / m1
Volume soil left	100,8	m3 / m2
Volume soil right	100,8	m3 / m3
Weight concrete	2160	kN /m1
Heigth caisson above WL sea side	4,5	m
Height caisson below WL sea side	11,5	m
Section modulus W	54	m3/m1

Forces	Resultant	arm [m] to Mbottom	Moment (clockwise positi
Horizontally			
H1 (traffic)	106,64	8	853,12
H2 (due to soil above top caisson)	432	8	3456
H3a (due to soil betw top caiss. and GWL) (above GWL)	91,125	13	1184,625
H3b (due to soil betw top caiss. and GWL) (below GWL)	465,75	5,75	2678,0625
H7 (due to soil below GWL)	322,35938	3,833333333	1235,710938
H4 (GW sea side)	677,78125	3,833333333	2598,161458
H5 (water Grevelingen)	-462,5313	3,166666667	-1464,682292
H6 (soil Grevelingen side)	0	0	0
Vertically			
V1 (concrete of caisson)	2160	0	0
V2L (soil in caisson, left)	1959,3	-4,5	-8816,85
V2R (soil in caisson, right)	1423,8	4,5	6407,1
V3 (soil on top of caisson, unsloped)	648	-3	-1944
V4 (soil on top of caisson, sloped)	162	5	810
V5 (steel valve)	80	0	0
V6 (uplifting water pressure, const.)	-1060,875	-3	3182,625
V7 (uplifting water pressure, var.)	-876,375	3	-2629,125
V8 *(none, already full)*	0	4,5	0
Resultants			
ΣM	7550,7476		
ΣH	1633,1244		
ΣV	4495,85		

Stability checks			Stability factor
Horizontal stability		STABLE	**1,1**
f*ΣV	>	ΣH	
1798,34	>	1633,124375	
Rotational stability		STABLE	**1,79**
ΣM/ΣV	<	1/6*B	
1,679492778	<	3	
Bearing capacity (i.r.t. max capacity value)	UNSTABLE		**0,98**
Virtual excentricity ΣV (from Grev. side)	7,3205072	m	
σ',rep	<	σ',bearing capacity	
307,07	<	300	
Peak pressure i.r.t. current pressure	HIGHER		**0,83**
σ',max	<	σ',currently beneath caissons	
389,6	<	323,1	

Overview results

1	**Standard situation: N57 next to caisson, top caisson at +9 m NAP (can be altered)**			
Par	x2, Added soil right side:	0	m	
Res	Lost width building pit (slope 1:2)	0	m	
D1E	**Dry building pit, soil part caissons half empty**			**Stability factor**
	Horizontal stability		STABLE	1,11
	Rotational stability		STABLE	8,81
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,1
	Peak pressure i.r.t. current pressure		LOWER	1,11
W1E	**Building in the wet, soil part caissons half empty**			**Stability factor**
	Horizontal stability	UNSTABLE		0,75
	Rotational stability		STABLE	8,06
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,69
	Peak pressure i.r.t. current pressure		LOWER	1,68
D1F	**Dry building pit, soil part caissons full**			**Stability factor**
	Horizontal stability		STABLE	1,53
	Rotational stability		STABLE	2
	Bearing capacity (i.r.t. max capacity value)	UNSTABLE		0,69
	Peak pressure i.r.t. current pressure	HIGHER		0,59
W1F	**Building in the wet, soil part caissons full**			**Stability factor**
	Horizontal stability		STABLE	1,1
	Rotational stability		STABLE	1,79
	Bearing capacity (i.r.t. max capacity value)	UNSTABLE		0,98
	Peak pressure i.r.t. current pressure	HIGHER		0,83



2	**Locating the N57 on top of the caissons**			
Par	x2, Added soil right side:	0	m	
Res	Lost width building pit (slope 1:2)	0	m	
D2E	**Dry building pit, soil part caissons half empty**			**Stability factor**
	Horizontal stability		STABLE	1,18
	Rotational stability		STABLE	18,83
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,13
	Peak pressure i.r.t. current pressure		LOWER	1,17
W2E	**Building in the wet, soil part caissons half empty**			**Stability factor**
	Horizontal stability	UNSTABLE		0,81
	Rotational stability		STABLE	31,72
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,74
	Peak pressure i.r.t. current pressure		LOWER	1,84
D2F	**Dry building pit, soil part caissons full**			**Stability factor**
	Horizontal stability		STABLE	1,63
	Rotational stability		STABLE	2,19
	Bearing capacity (i.r.t. max capacity value)	UNSTABLE		0,7
	Peak pressure i.r.t. current pressure	HIGHER		0,61
W2F	**Building in the wet, soil part caissons full**			**Stability factor**
	Horizontal stability		STABLE	1,18
	Rotational stability		STABLE	2,01
	Bearing capacity (i.r.t. max capacity value)			1
	Peak pressure i.r.t. current pressure	HIGHER		0,86

3	**Additional lowering of dam next to caisson, soil on top caisson sloped from both sides**			
Var	Soil above caisson left-side	0	m	
Var	Crest level on top caison	9	m NAP	
Par	Slope on caisson	0,5	-	
Par	x2, Added soil right side:	0	m	
Res	Lost width building pit (slope 1:2)	0	m	

D3E	**Dry building pit, soil part caissons half empty**			**Stability factor**
	Horizontal stability		STABLE	1,43
	Rotational stability		STABLE	18,95
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,21
	Peak pressure i.r.t. current pressure		LOWER	1,35

W3E	**Building in the wet, soil part caissons half empty**			**Stability factor**
	Horizontal stability	UNSTABLE		0,97
	Rotational stability		STABLE	7,41
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,94
	Peak pressure i.r.t. current pressure		LOWER	2,31

D3F	**Dry building pit, soil part caissons full**			**Stability factor**
	Horizontal stability		STABLE	2
	Rotational stability		STABLE	2,56
	Bearing capacity (i.r.t. max capacity value)	UNSTABLE		0,74
	Peak pressure i.r.t. current pressure	HIGHER		0,66

W3F	**Building in the wet, soil part caissons full**			**Stability factor**
	Horizontal stability		STABLE	1,44
	Rotational stability		STABLE	2,49
	Bearing capacity (i.r.t. max capacity value)		STABLE	1,08
	Peak pressure i.r.t. current pressure	HIGHER		0,96

APPENDIX D5: STABILITY GATE VARIANT: ESB-LIKE STRUCTURE

It must be checked whether a slender structure is a possible alternative for a tidal power plant. A stable structure needs to be designed, for which the dimensions needs to be calculated. In order to find the required dimension, different assumption are taken which will be explained in the section below.

Design

For a first estimation to investigate whether a slender structure is a possible solution, a simplified structure is chosen. The pillars are designed to be solid and rectangular shaped, with the height, the length and the width as variables. Beneath the pillars is an embedded widened foot with its top at soil level.

The pillars are founded on the present bottom protection, but if necessary can also founded deeper into the soil.

The I-shaped part of the pillar in which the valves are located is higher than the other part. Furthermore a sill beam is used as well as a top beam. At the Grevelingen side of the pillar a road girder is placed.

The free flow turbines (either in a frame or founded separately) are placed at the Grevelingen side of the maintenance road. An advantage of this location is that the maintenance road can be used for both the valve as the turbines. A disadvantage is that the N57 has to be located higher or more to the Grevelingen side, in order to create space for maintenance of the turbines. This width might already be necessary for stability however.

In the figures below the design is shown.

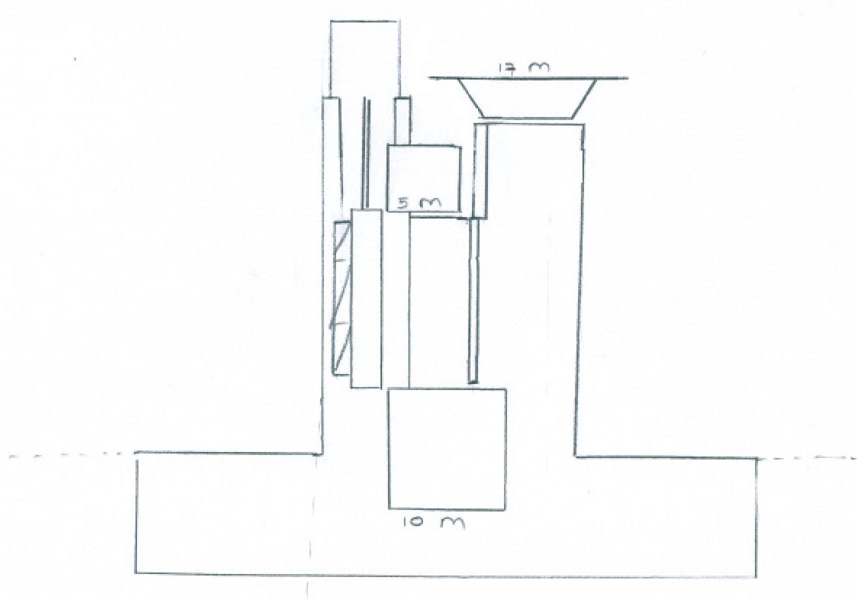


Figure 1: Cross section

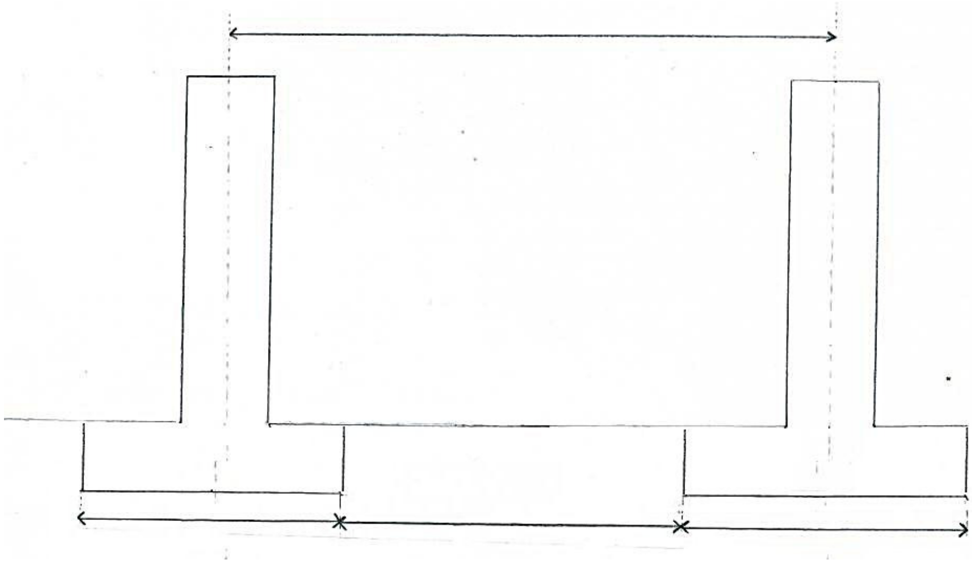


Figure 2: Front view of only the pillars

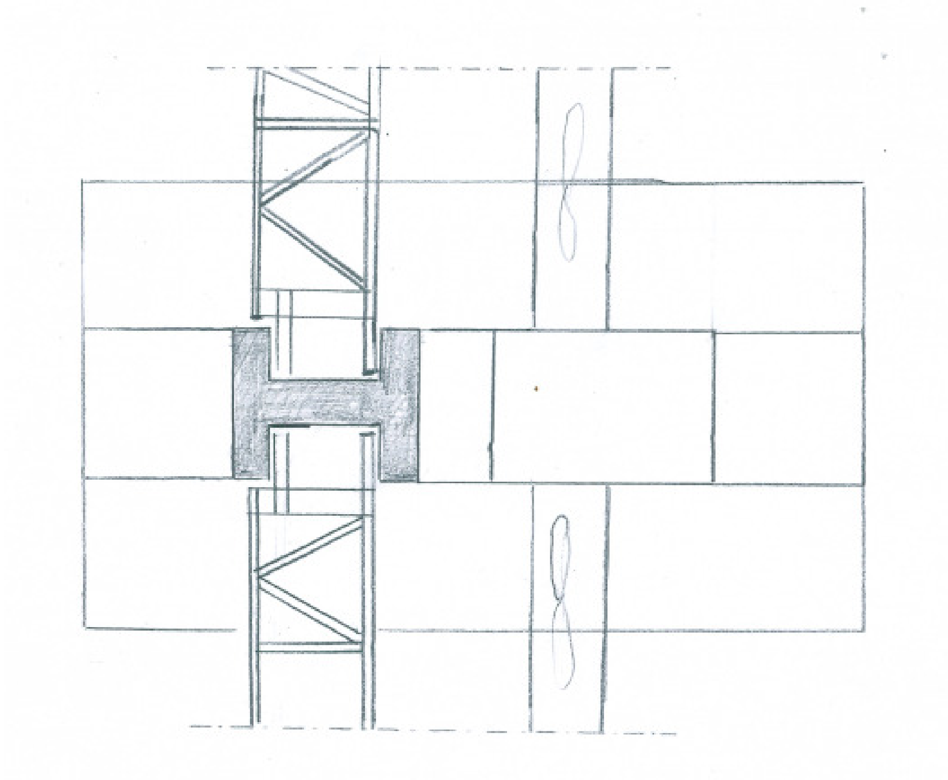


Figure 3: Top view

Forces

The used cross-section to calculate the resultant forces is shown below. The forces in red are horizontal, in black are vertical. In green are the forces added to calculate the effect of the widened pillar foot, either horizontal or vertical.

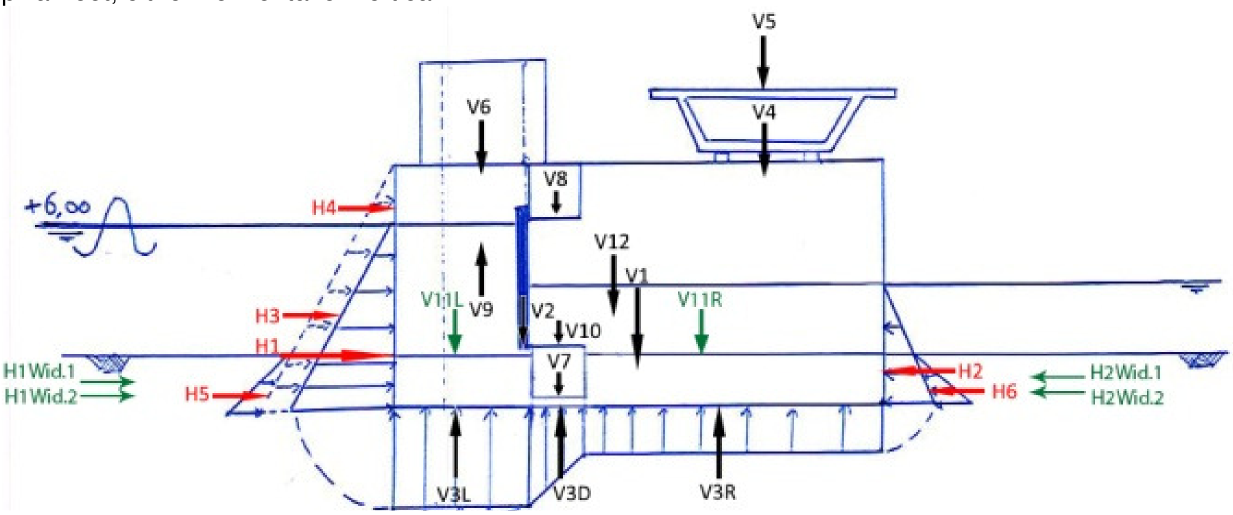


Figure 4: Forces on structure

For the calculation of the stability a few assumptions were made:

- The design water level at North Sea is taken to be +6 m NAP;
- The lowest water level at Lake Grevelingen will be -1 m NAP;
- The wave load is taken into account hydrostatically and fully reflecting. The wave pressure continues hydrostatically in the subsoil till the bottom of the structure. It has no effect on the water pressure beneath the pillars.
- All soil around the structure is sand, which has a volumetric weight of 18 kN/m^3 dry and 20 kN/m^3 wet;
- The friction coefficient between caisson and sill is equal to 0.4;
- The neutral horizontal pressure coefficient K,neutral is equal to 0.5.
- The passive horizontal pressure coefficient K,passive Is equal to 2.
- The maximum allowable soil pressure beneath the structure is 300 kN/m2;
- The weight of the top and sill beam is each 239.8 kN/m^1 (same as ESB) (Rijkswaterstaat, 2014);
- The weight of the road girder is 261.6 kN/m^1 (same as ESB) (Bouwdienst Rijkswaterstaat, 2002);
- The weight of the turbines and installation is assumed 200 kN per meter wet width and founded on the structure and is thus taken into account. The location of the turbines is right next to the sill beam and top beam / maintenance road.
- The sill beam is stable in itself, giving no additional stability to the structure and is thus excluded from the stability calculations. Forces V7 and V10 are thus not taken into account.

The assumed dimensions can be found in the ‘dimensioning’ chapter.

A separation into resultant forces is made. There forces work over different structure width. Some of the forces work on both the valves and the pillars, like the horizontal water forces, others only on a specific part of the structure.
The separation of resultant forces is as follows:

Horizontal

- H1: Due to hydrostatic pressure of water at the North sea side;
- H2: Due to hydrostatic pressure of water at the Grevelingen side;
- H3: Due to waves below design level;
- H4: Due to waves above design level;
- H5: Due to active soil pressure;
- H6: Due to passive soil pressure.

Horizontal (widened foot)

- H1Wid.1: Due to hydrostatic pressure of water at the North sea side on the added foot width;
- H1Wid.2: Due to hydrostatic pressure of water at the North sea side on the added foot width;
- H2Wid.1: Due to hydrostatic pressure of water at the Grevelingen side on the added foot width;
- H2Wid.2: Due to hydrostatic pressure of water at the Grevelingen side on the added foot width;

Vertical (pillars)

- V1: Weight of pillar (concrete);
- V3L: Due to upward water pressure, left of the sill beam;
- V3D: Due to upward water pressure, next to the sill beam;
- V9: Upward force to compensate for the I-profile shaped pillar instead of a solid pillar.
- V3R: Due to upward water pressure, right to the sill beam.

Vertical (widened foot)

- V11L: Downward hydrostatic pressure of water at the North sea side on the added foot width;
- V11R: Downward hydrostatic pressure of water at the Grevelingen side on the added foot width;

Vertical (valves, etc)

- V2: Weight of the steel valve;
- V8: Weight of the top beam

Vertical (additional)

- V4: Weight of road girder;
- V5: Traffic load;
- V6: Weight of the casing which raises the valve.

Of course a lot of these forces result in moments. The moments are calculated around the midpoint of the bottom of the caisson.

Stability calculation

The following stability checks were made:

- The horizontal stability;
- The rotational stability;
- Bearing capacity.

Normally the safety factor must be higher than 1 to reach stability, but in this phase no use is made of safety factors that is why in these calculations a stability factor of 1.3 is required. In a next phase, this calculation needs to be more accurate which means that safety factors have to be taken into account and also different load combinations.

Additionally the following is informatively checked, but is not stability demand:

- Peak pressure i.r.t. current pressure.

The calculation is added at the end of this chapter.

Stable dimensions

The dimensions are altered in such a way that the stability requirements are fulfilled per type of construction method.

Dry construction

When constructing in the dry the connection of the soil and the concrete structure is better and can be checked more easily compared with the wet construction. This is why a higher friction coefficient can be used when building in a dry building dock. The friction coefficient which is used is equal to 0.56. The dimension for this case are shown below.

Table 1: Stability structure

Stability checks			Stability factor
Horizontal stability		STABLE	1,39
Rotational stability		STABLE	1,31
Bearing capacity (i.r.t. max capacity value)		STABLE	1,5
Peak soil pressure (i.r.t.. current pressure)	HIGHER		0,68

The dimensions can be seen in the figures below. To reach stability the foot of the pillar must be widened 7.5 m on each side. The wet width between two pillars is 30 meter. This means there is 15 meter left between two adjacent pillar feet.

On estimation, when ‘basic’ free flow turbines are used about 3 or 4 of these units would fulfill the minimum flow area to restore a tide of 0.5 meter. This would thus result in 4 or 5 of these large pillars with 3 or 4 valves in between.

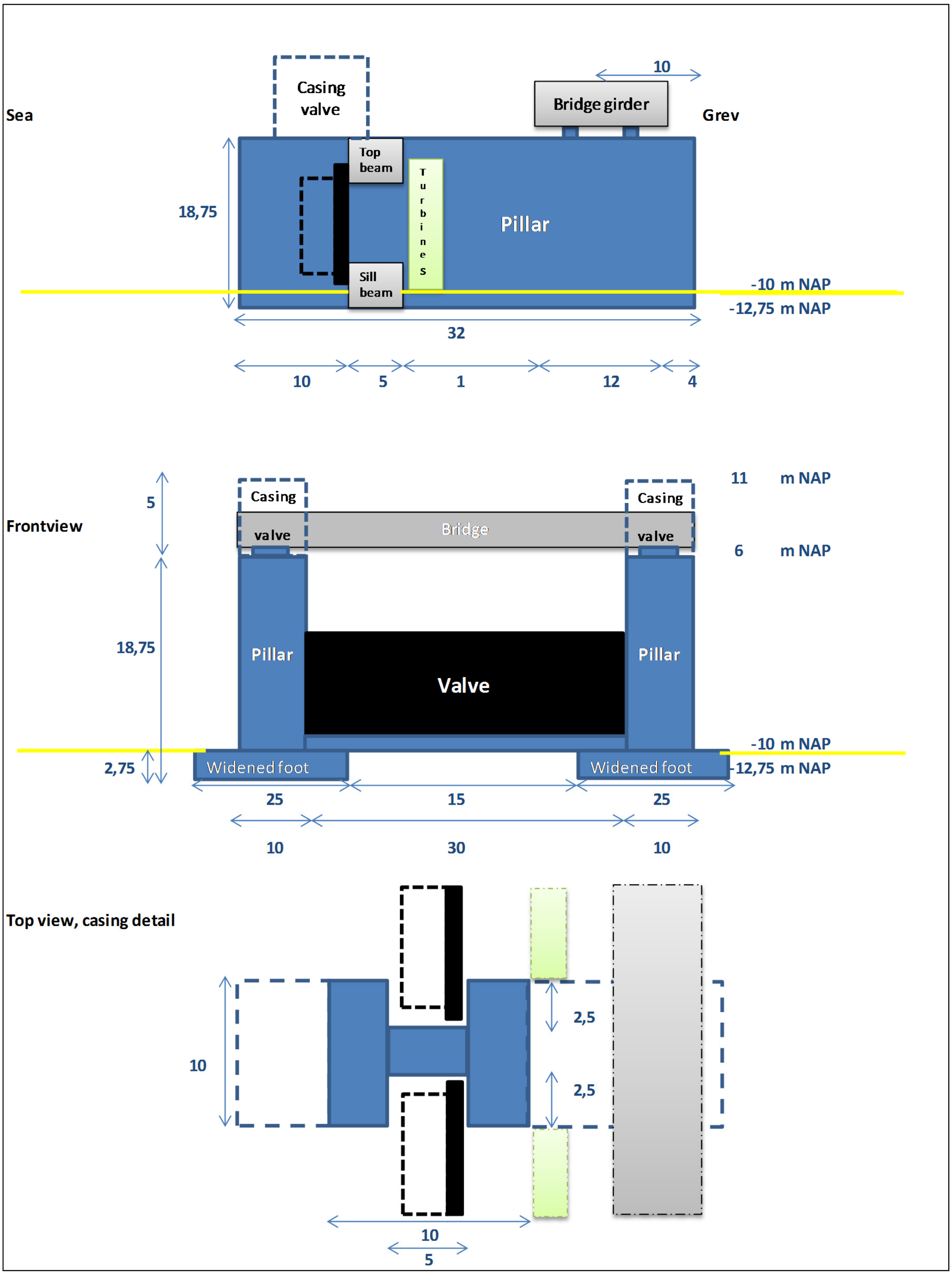


Figure 5: Stable dimensions

Wet construction

In the wet construction prefab elements will be placed upon the sill, this will have a smaller friction coefficient. The friction coefficient used for in case is equal to 0.35. This has a large influence on the horizontal stability.

In comparison to the variant which is built in the dry, the dimensions will have to increase in order to reach stability. For example the length (perpendicular to the dam) has to be increased to 50 m (instead of the 35 m needed in the dry method), or the top of the pillar needs to be increased with 5 m to + 11 m NAP in combination with a length increase to 40 m.

For the last mentioned dimensions the stability factors are given below.

Table 2: Stability factors of the free flow variant 2B

Stability checks			Stability factor
Horizontal stability		STABLE	**1,29**
Rotational stability		STABLE	**1,79**
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,76**
Peak soil pressure (i.r.t.. current pressure)	HIGHER		**0,66**

Due to the large wet surface for each unit and thus the large hydraulic radius, the effect of the added length in terms of discharge is negligible.

Excel calculations

Stability calculation

The calculations for the variant in the dry are given below. The calculations for the variant in the wet are similar, using different dimensions and a different f, namely 0.35 instead of 0.56.

Dimensions structure & situation		
Length pillar	32	m
Top pillar	6	m NAP
Top of I-shape casing for valves	11	m NAP
Top sill beam	-8,5	m NAP
Bottom sill beam	-12,75	m NAP
Top soil (bottom)	-10	m NAP
Bottom pillar	-12,75	m NAP
Height pillar	18,75	m
Width pillar	10	m
Width foot pillar	25	m
Width between two pillar feet	15	m
Wet width	30	m
Total width one unit (h.t.h.)	40	m
Width road girder	12	m
Width sill beam	5	m
Top valve	1,2	m
Top barrier betw. Pillars	5,8	m
Top bottom protection	-12,75	m
Weight steel valve	9,81	kN/m2
Location valve or left side of sill beam (from sea)	10	m
Length I-shape casing	10	m
Length "cut-in" for steel valve	5	m
Width "cut-in" for steel valve (at each side)	2,5	m
Width turbine installation	5	m
Parameters waterbelasting		
Design water level North Sea	6	m NAP
Lowest water level Grevelingen	-1	m NAP
Incoming wave amplitude	1,3	m
Reflection parameter r	2	-
Wave period	7,5	s

Material		
ρ*g , concrete	25	kN/m3/m1
Parameters soil		
K,active	0,5	
K,passive	2	
ρ*g , dry sand	18	kN/m3
ρ*g , wet sand	20	kN/m3
ρ*g , salty water	10,25	kN/m3
ρ*g , sand-saltwater	9,75	kN/m3
Parameters loads		
Box-girder road	261,6	kN/m1
Box-girder road, distance to Grev. border	10	m
Sill beam	239,8	kN/m1
Top beam	239,8	kN/m1
Traffic line load	13,333	kN/m /m1
Turbines (total installation)	200	kN/m1
Parameters stability checks		
Safety factor (fav. forces)	1	-
Safety factor (unfav. forces)	1	-
f,dry	0,56	-
σ',bearing cap. soil	300	kN/m2
σ',currently	232,3125	kN/m2

Forces	Resultant/m1	Width unit	Resultant one unit	arm [m] to M	Moment (clockwise
Pillars - Horizontally					
H1 (hydrostat. Sea)	1801,757813	10	18017,57813	6,25	112609,8633
H2 (hydrostat. Grev)	-707,5703125	10	-7075,703125	3,916666667	-27713,17057
H3 (wave below design level)	499,6875	10	4996,875	9,375	46845,70313
H4 (wave above design level)	34,645	10	346,45	19,61666667	6796,194167
H5 (active soil press.)	18,43359375	10	184,3359375	0,916666667	168,9746094
H6 (passive soil press.)	-73,734375	10	-737,34375	0,916666667	-675,8984375
subtotal	1573,219219		15732,19219		138031,6662
Valves, etc - Horizontally					
H1 (hydrostat. Sea on valve + beams)	1312	30	39360	5,333333333	209920
H2 (hydrostat. Grev on valve + beams)	-415,125	30	-12453,75	3	-37361,25
H3 (wave below design level)	426,4	30	12792	8	102336
H4 (wave above design level)	34,645	30	1039,35	16,86666667	17530,37
subtotal	1357,92		40737,6		292425,12
Pillar foot (only on added width) - Horizontally					
H5 (active soil press.)	18,43359375	15	276,5039063	0,916666667	253,4619141
H6 (passive soil press.)	-73,734375	15	-1106,015625	0,916666667	-1013,847656
H1Wid.1	451	15	6765	1,375	9301,875
H1Wid.2	38,7578125	15	581,3671875	0,916666667	532,9199219
H2Wid.1	-253,6875	15	-3805,3125	1,375	-5232,304688
H2Wid.2	-38,7578125	15	-581,3671875	0,916666667	-532,9199219
subtotal	142,0117188		2130,175781		3309,18457
Pillars - Vertically					
V1 (weight concrete)			150000	0	0
V3L (upward water, left of sill beam)	-1921,875	10	-19218,75	-11	211406,25
V3D1 (const. upward water, next to sill beam)	-179,375	10	-1793,75	-3,5	6278,125
V3D2 (var. upward water, next to sill beam)	-602,1875	10	-6021,875	-4,33333333	26094,79167
V3R (upward water, right of sill beam)	-2047,4375	10	-20474,375	7,5	-153557,8125
subtotal	-4750,875		102491,25		90221,35417
Pillar foot (only of added width) - Vertically					
V1 (weight concrete)			33000	0	0
V3L (upward water, left of sill beam)	-1921,875	15	-28828,125	-11	317109,375
V3D1 (const. upward water, next to sill beam)	-179,375	15	-2690,625	-3,5	9417,1875
V3D2 (var. upward water, next to sill beam)	-602,1875	15	-9032,8125	-4,33333333	39142,1875
V3R (upward water, right of sill beam)	-2047,4375	15	-30711,5625	7,5	-230336,7188
V11L (downwards water pressure)	1640	15	24600	-11	-270600
V11R (downwards water pressure)	2029,5	15	30442,5	5	152212,5
subtotal	-1081,375		16779,375		16944,53125
Valves, etc - Vertically					
V2 (steel valve)	95,157	30	2854,71	-6	-17128,26
V8 (top beam)	239,8	40	9592	-3,5	-33572
V9 ('cut-out' I-shaped part pillar)			-11718,75	-8,5	99609,375
subtotal	334,957		727,96		48909,115
Additional - Vertically					
V4 (weight road girder, concrete)	261,6	40	10464	6	62784
V5 (traffic load)	159,996	40	6399,84	6	38399,04
V6 ('casing' raised valve)			9375	-8,5	-79687,5
V12 (weight turbines	200	30	6000	1,5	9000
subtotal	621,596		32238,84		30495,54

Resultants with traffic force	Total units		Total (rounded)	
ΣM	620336,5112	kNm	620	MNm
ΣH	58599,96797	kN	59	MN
ΣV	152237,425	kN	152	MN

Resultants without traffic force	Total units		Total (rounded)	
ΣM	581937,4712	kNm	582	MNm
ΣH	58599,96797	kN	59	MN
ΣV	145837,585	kN	146	MN

Stability checks			Stability factor
Horizontal stability		STABLE	**1,39**
f*ΣV	>	ΣH	
81669,0476	>	58599,96797	
Rotational stability		STABLE	**1,31**
ΣM/ΣV	<	1/6*B	
4,074796399	<	5,333333333	
Bearing capacity (i.r.t. max capacity value)		STABLE	**1,5**
Virtual excentricity ΣV (from Grev. side) w. traffic	11,9252036	m	
Virtual excentricity ΣV (from Grev. side) w/o. traffic	12,00968796	m	
σ',rep	<	σ',currently	
199,47	<	300	
Peak soil pressure (i.r.t.. current pressure)	HIGHER		**0,68**
σ',max	<	σ',currently	
341,83	<	232,3125	

Discharge estimation

Number of elements v.s. tide		
n,elements [-]	1	3,7
A [m2]	255	943,5
L,tidal power plant [m]	40	148
Tide Grevelingen [m]		0,504

Parameters		
η*Cp	0,35	-
n,turbines per element	4	-
D,turbine	6	m
mu	0,9	-

From stability calculation		
Aunit	255	m2

Calculated		
A,turbine per element	113,0973355	m2
Ratio v2/v1	0,9453208	-
mu'	0,85	-

Calculation tide Lake Grevelingen					
Parameters					
<u>Getij</u>					
T	44700	s			
omega	0,000140563	rad/s			
Psiz	1,25	m	Amplitude getij op zee		
<u>Grevelingen</u>					
Ak	117000000	m2			
<u>Doorlaatmiddel</u>					
n	3,7	-			
b	30	m			
B	111	m			
d	8,5	m			
L	32	m			
cf	0,003	-			
mu'	0,85	-			
As	943,5	m2			
R	3,311688312	m			
Berekening					
<u>Weerstand doorlaatmiddel</u>					
chi	0,528988235				
gamma	24,06027751				
<u>Respons getij</u>					
r	0,201761102				
psik	0,252201378	Getijamplitude Grevelingen			
dH	0,504402755	Getijverschil Grevelingen			
<u>Debiet en stroomsnelheid</u>					
Qamp	4148	m3/s	Maximaal debiet		
Qgem	2641	m3/s	Gemiddeld debiet		

APPENDIX D6: STABILITY VARIANT 2D FLOATABLE CONTAINER PILLARS

This variant has pillars which use piles in order to reach stability. Below each pillar 12 piles are constructed with a diameter in the order of 2 m, for instance steel pipe piles can be used. An overview is given in the figures below.

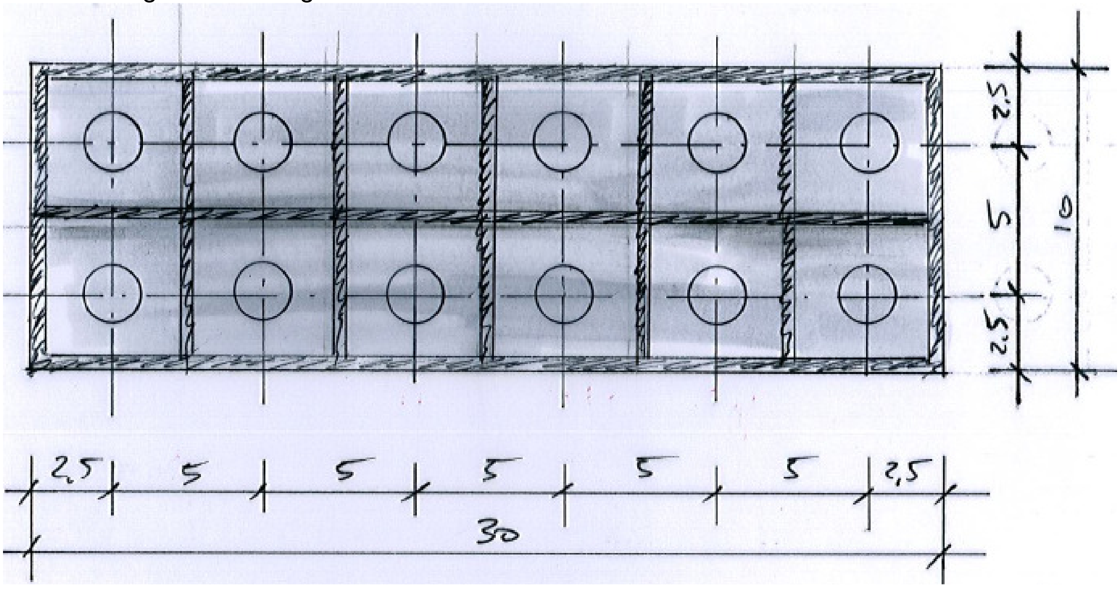


Figure 1: Overview dimensions variant 2D

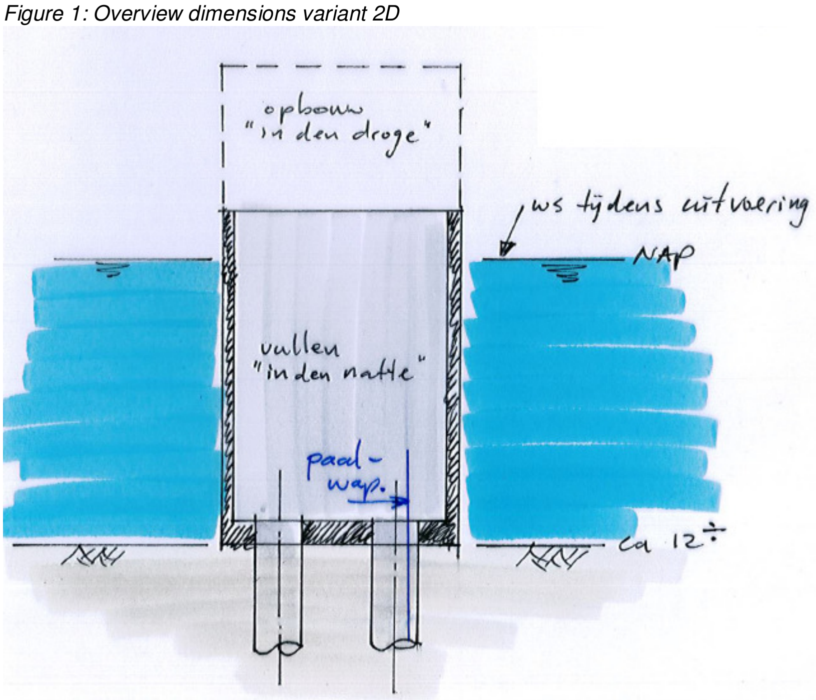


Figure 2: Front view

In order to calculate the force that acts on the piles, it is assumed that the forces on this structure are the same as for the Eastern Scheldt barrier structure with the same dimensions only without widened foot and a smaller length. The length can be shortened, because the piles help for stability, a length of 26 m is assumed and a width of 10 m is used. This gives the following forces on the structure (calculated with the EXCEL OSK v4, with length of 26 m and a foot width of 10 m).

Table 1: Forces acting on variant 2D

loads			
	ΣM	571000	kNm
	ΣH	56000	kN
	ΣV	115000	kN
	number of piles	12	

With these forces the total forces acting on the piles can be calculated, the weight of the piles is not taken into account.

Table 2: Calculation forces acting on the piles

Calculation			
	z	15	m
	I	875	m4
	e	12,5	m
Fmax			
M	v= (M*e)/I =	8143	kN
V	v =V/8 =	8333	kN
	Fmax =	16476	kN
Fmin			
M	v= (M*-e)/I =	-8143	kN
V	v =V/8 =	8333	kN
	Fmin =	190	kN

Concluding a maximal forces of Fs;druk;max,rep = 16500 kN will act at the piles, this is without safety factors. Furthermore the minimum force is larger than 0, which means that no tensile force will act on the piles. A first estimation of the dimensions of the piles is that a the thickness needs to be 25 mm and a length of 30 m is required in order to bear the forces. It is not certain if it is possible to construct the piles at this depth, this is a risk of this variant. Furthermore, it has to be investigated whether the available capacity of the ground is sufficient.

Appendix E: Required length of structure i.r.t. tidal movement

Appendix E: Required length in the dam of the promising solutions

Given the 0.5 m tide that has to be restored on Lake Grevelingen, a certain flow area is needed. In reality, the allowable minimum and maximum water level on Grevelingen have influence on the average tide, as well as the fact that the average water level on Grevelingen is lowered to -0.20 m NAP.

Besides that the dimensions, shape and materials of the tidal power plant influence the through flow.

Ducted variants

In the Witteveen+Bos report a calculation is made for their design. The same approached is used to calculate the needed amount of units or length of the ducted tidal power plant variants.

This approach does not take into account the real (measured) water level at the North Sea or the allowable water levels at Lake Grevelingen. It assumes a sinusoidal tide. The result of this calculation is therefore indicative and must be used as a minimum. In a later stage, when the energy yield will be calculated by using the measured water levels at the North Sea, a more accurate estimation could be acquired.

The calculation uses and assumes the following parameters:

- Tidal period T = 44700 s
- Average tidal amplitude North Sea ξ,sea = 1.25 m
- Surface Lake Grevelingen Ak = 117 * 10^6 m^2
- cf,concrete = 0.003

The discharge coefficient is estimated at 0.9 instead of the very conservative value of 0.6 used by Witteveen+Bos, as the design will be optimized for through flow.

Royal Haskoning made an estimation of the influence of ducted turbines on the discharge through the tidal power plant. The following equation is used:

$$\frac{v,2}{v,1} = \sqrt[3]{\frac{Atot - \eta * Cp * Aturb}{Atot}}$$

In this formulae v1 is the velocity in front of the turbine and v2 the velocity behind the turbine. This ratio is taken as the 'loss' in discharge coefficient due to the turbines. The efficiency $\eta * Cp$ is taken equal to 35%.

The friction of the structure is calculated by the following equation:

$$\chi = \tfrac{1}{2} + c_f \frac{L}{R}$$

The ½ represents the outflow loss (Carnot with U_2= 0 (Battjes & Labeur, 2009)). In the case of a closed duct the hydraulic radius of one element is $\frac{As}{2*d+2*wet\ width}$. In case of an open structure, like ducted variant 2A and 2B the wet width of the element should of course only be counted once.

The tidal response factor and thus the tide on Lake Grevelingen can then be calculated with the following equation:

$$r = \cos(\theta) = \frac{1}{\sqrt{2}\Gamma}\sqrt{-1+\sqrt{1+4\Gamma^2}} \quad \text{met:} \quad \Gamma \equiv \frac{8}{3\pi}\chi\left(\frac{A_k}{\mu \cdot A_s}\right)^2 \frac{\omega^2 \hat{\zeta}_z}{g}$$

Ducted variant 2A and 2B

The estimated global dimensions resulted in a wet width of 30 m and a water depth of 8.5 meter (beneath +0 m NAP). This is equal to the Royal Haskoning variants, in which per element four turbines of 6 m diameter are used. A ratio v2/v1 of 0.95 was calculated in that case. This results a new discharge coefficient μ' of $0.95 * 0.9 = 0.855$. The result of this calculation is given below. The full excel calculation is added to this document.

Table 1: Needed length ducted variant 2A and 2B

Ducted variant 2A & 2B	Single unit	Total
n,elements [-]	1	3,7
A,element [m²]	255	943,5
L,element [m]	40	148
Tide Grevelingen		0,501

Of course 3.7 elements is not a very realistic value, in this case either the dimensions could be altered or 4 elements could be placed.

Ducted variant 2C

In case of ducted variant 2C one unit has a flow surface of $Atot = 8 * 8 = 64\, m^2$. A turbine of 7 meter diameter is assumed, which has a surface of $\frac{1}{4} * \pi * 7^2 = 38.5\, m^2$. This ratio then becomes:

$$\frac{v,2}{v,1} = \sqrt[3]{\frac{64 - 0.35 * 38.5}{64}} = 0.924$$

The new discharge coefficient μ' then becomes $0{,}924 * 0.9 = 0{,}83$. When used in the calculation the number of needed elements, the flow surface and total length of the tidal power plant can be calculated. The result of this calculation is given below. The full excel calculation can be found below the table with outcomes. Due to the smaller elements and the roof this variant has relatively more friction influence per m^2 than variant 2A, even though the length of the tidal power plant is shorter. Even so, due to the larger pillar versus wet width ratio less length in the dam is needed.

Table 2: Needed length ducted variant 2C

Ducted variant 2C	Single unit	Total
n,elements [-]	1	15
A [m²]	64	960
L in dam [m]	9	135
Tide Grevelingen		0.495

Calculation 1: Ducted variant

Calculation tide Lake Grevelingen (Venturi)			
In de notitie 5 civiele aspecten doorlaatmiddel Brouwersdam is een soortgelijke			
kombergingsberekening gemaakt. De berekening gaat uit van een sinusoïde getij oppervlak.			
en berekent de getijrespons op het Grevelingenmeer als functie van doorlaatlengte en wrijvingsverliezen			
Toegevoegd:			
Zowel kom als verbinding zijn kort t.o.v. de getijgolflengte (ca. <1/20), deze eis leidt tot verwaarloosbare traagheid			
Genoemde aannamen:			
Traagheid in Grevelingen verwaarloosbaar			
Traagheid in verbinding verwaarloosbaar			
Getij is bij benadering sinusbeweging			
Parameters			
Getij			
T	44700	s	Periode getijdegolf
omega	0,000141	rad/s	Hoeksnelheid
Psiz	1,25	m	Amplitude getij op zee
Grevelingen			
Ak	1,17E+08	m2	Oppervlakte grevelingen
Doorlaatmiddel			
n	15	-	Aantal elementen
b	8	m	Breedte opening per element
B	120	m	Totale breedte
d	8	m	Hoogte opening
L	28	m	Lengte element (evenwijdig aan de dam)
cf	0,003	-	Wrijvingscoefficient
mu'	0,83	-	Contractiecoefficient
As	960	m2	Totale natte doorsnede
R	2	m	Hydraulische straal
Berekening			
Weerstand doorlaatmiddel			
chi	0,542		
gamma	24,97336		
Respons getij			
r	0,198114		
psik	0,247642	Getijamplitude Grevelingen	
dH	0,495284	Getijverschil Grevelingen	
Debiet en stroomsnelheid			
Qamp	4073	m3/s	Maximaal debiet
Qgem	2593	m3/s	Gemiddeld debiet

Diffuser variants

For the variants with bulb turbines the calculation is somewhat different. The discharge through the turbines is depended on the chosen turbine design head and design discharge. This determines in turn the installed power and the costs of the turbines.

Royal Haskoning used a turbine diameter of 3.5 meter. The length of each unit in the dam is then estimated by $2.2 * 3.5 = 7.7$ meter. The flow surface of one unit is $\frac{1}{4} * \pi * 3.5^2 = 9.62$ m^2. When the design discharge of 47 m^3 and the design head of 1.5 meter are compared to the flow surface, a 'virtual' discharge coefficient can be estimated: $m = \frac{Q}{At*\sqrt{2*g*H}} = \frac{47}{9.62*\sqrt{2*9.81*1.5}} = 0.9.$

For a continuous sinusoidal tide and a loss in hydraulic head of 10% this results in a needed flow surface of 822 m^2 to reach a tide of 0.5 meter.

This would mean a minimum of $\frac{822}{9.62} \approx 86$ units and thus 662 meter length of the tidal power plant. This length is very large in comparison to the ducted variants. This is mainly due to small flow surface in comparison to the length of one unit in the dam. The total needed flow surface is even smaller in this estimation than the case with the free flow turbines.

Table 3: Needed length diffuser variants

Diffuser variants	Single unit	Total
n,elements [-]	1	86
A [m^2]	9.62	827
L in dam [m]	7.7	662
Tide Grevelingen		0.5

It must be mentioned, that a new type of turbine might possibly be used resulting in a higher discharge.

Siphon variants

In the same way as with the ducted variants the tidal response factor could be calculated. The friction is now calculated by:

$$\chi = \frac{1}{2} + cf * \frac{L}{R} + \xi$$

In which ξ is a losses coefficient which takes into account head losses due to corners. From the received TU Delft excerpt the values, given in Table 4, are known. To calculate the loss in hydraulic head these values need to be multiplied with $\frac{u^2}{g}$ and not $\frac{u^2}{2g}$ as in the mentioned document, the values are thus halved.

Table 4: Losses coefficient

	Losses coefficient (ξ)
Entry in the siphon	0,04
90 degrees knee	0,125
45 degrees knee	0,075

The losses due to entry in the siphon are neglected as these are small and this has not been taken into account for the other alternatives either.

The dimensions of the siphon are not yet known. For now the same diameter of 3.5 m en length in the dam, 2.2D, are used. A length of 45 meter is used for the siphon, instead of the 35 for the diffuser variants. In that case 96 units are needed to reach a tide of 0.5 meter on Lake Grevelingen. This results in a total length of 739,2 meter in direction of the dam.

Table 5: Needed length siphon variants

Siphon variants		
n	1	96
A [m^2]	12.25	1167
L in dam [m]	7.7	739.2
Tide Grevelingen		0.50

Linear Venturi variant

In case of the linear Venturi variant one unit has a flow surface of $Aentry = 1200\ \ m^2\ and\ Aventuri\ =\ \ 400\ \ m^2$. No turbine is used in the main flow, which means that the loss of energy by the venture is assumed to be zero. A venture is designed in such a way that water will accelerate very efficiently. This is why not is chosen for the smallest flow surface area, but for the average area = (1200+400)/2 = 800 m^2.

The result of this calculation is given below. The full excel calculation is added to this document. The organization VedErg already calculated for the Brouwersdam that 200 m is sufficient to reach the 0.5 m tidal range. With the assumption made and safe chosen parameters, this calculation gives a needed length of 220 m. Assuming that VedErg has used more accurate values for the properties of the venture and turbines, the 200 m will be used in this phase of study.

Table 6: Needed length ducted variant 2C

Ducted variant 2C	Single unit	Total
n,elements [-]	1	1,1
A [m2]	400	440
L,tidal power plant [m]	200	220
Tide [m]		0,49

Calculation 2: Venturi variant

Calculation tide Lake Grevelingen (Venturi)			
In de notitie 5 civiele aspecten doorlaatmiddel Brouwersdam is een soortgelijke			
kombergingsberekening gemaakt. De berekening gaat uit van een sinusoïde getij oppervlak.			
en berekent de getijrespons op het Grevelingenmeer als functie van doorlaatlengte en wrijvingsverliezen			
Toegevoegd:			
Zowel kom als verbinding zijn kort t.o.v. de getijgolflengte (ca. <1/20), deze eis leidt tot verwaarloosbare traagheid			
Genoemde aannamen:			
Traagheid in Grevelingen verwaarloosbaar			
Traagheid in verbinding verwaarloosbaar			
Getij is bij benadering sinusbeweging			
Parameters			
<u>Getij</u>		m	
T	44700	s	Periode getijdegolf
omega	0,000141	rad/s	Hoeksnelheid
Psiz	1,25	m	Amplitude getij op zee
<u>Grevelingen</u>			
Ak	1,17E+08	m2	Oppervlakte grevelingen
<u>Doorlaatmiddel</u>			
n	1,1	-	Aantal elementen
b	133,3333	m	Breedte opening per element
B	146,6667	m	Totale breedte
d	6	m	Hoogte opening
L	35,8	m	Lengte element (evenwijdig aan de dam)
cf	0,003	-	Wrijvingscoefficient
mu'	0,9	-	Contractiecoefficient
As	880	m2	Totale natte doorsnede
R	2,882096	m	Hydraulische straal
Berekening			
<u>Weerstand doorlaatmiddel</u>			
chi	0,537265		
gamma	25,05614		
<u>Respons getij</u>			
r	0,197793		
psik	0,247241	Getijamplitude Grevelingen	
dH	0,494481	Getijverschil Grevelingen	
<u>Debiet en stroomsnelheid</u>			
Qamp	4066	m3/s	Maximaal debiet
Qgem	2588	m3/s	Gemiddeld debiet

Appendix F: Piping calculations

Appendix F: Piping

All three variants will be constructed at top of the existing bottom protection, which consist of a mastic asphalt layer with a thickness of 0.24 m with on top a layer of 200 kg/m^2 rubble. Assuming that this asphalt layer is still intact and that the rubble can be reused, piping can only occur beneath the asphalt layer.

For the check the method of Lane will be used, which is most suitable for a water retaining structure. Piping needs to be checked for the extreme conditions.

Lane:

$$L \geq \gamma * C_L * \Delta H$$

$$L = \sum L_{vert} + \sum \frac{1}{3} L_{hor} = 0 + \frac{1}{3} * 260 = 86.7\ m$$

$\gamma = 1.5\ (safety\ factor)$

$C_L = Lane's\ constant\ depended\ on\ soil\ type = 6.0\ for\ middle\ fine\ sand$

$\Delta H = differential\ head\ accros\ the\ structure = 6.2 - -0.2 = 6.4\ m$

$$L \geq 1.5 * 6 * 6.4 = 57.6\ m$$

Check: 86.7 > 57.6 which means that this design meets the requirements concerning the possibility of piping.

Appendix G: Quotations

Project	:	INPA140433
Kunstwerk	:	Getijdecentrale (incluus nivelleringsstuw)
Locatie	:	Brouwersdam
Soort	:	Bulb turbine
Variant 1a	:	In den droge gebouwd (deels prefab / deels in situ)

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	32500	m2	€	8,00	€	260.000,00
1.02	Afvlakken dijklichaam tbv ruimte omlegging N57	45500	m2	€	5,00	€	227.500,00
1.03	Bekleding aanbrengen / herstellen talud	16250	m2	€	55,00	€	893.750,00
2.01	Aanleg tijdelijke N57 over omgelegde dijk	15600	m2	€	50,00	€	780.000,00
2.02	Aanbrengen barriers / wegbebakening	4200	m1	€	45,00	€	189.000,00
2.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
3.01	Ontgraven bouwput in den droge / nat (GW/HW)	972800	m3	€	1,50	€	1.459.200,00
3.01	Afvoer vrijgekomen grond (schoon)	972800	m3	€	4,50	€	4.377.600,00
3.02	Aanbrengen/verwijderen openbemaling	700	m1	€	350,00	€	245.000,00
3.02	Instandhouden/verbruikskosten openbemaling	78	wkn	€	12.900,00	€	1.006.200,00
3.02	Aanbrengen/verwijderen spanningsbemaling	700	m1	€	500,00	€	350.000,00
3.02	Instandhouden/verbruikskosten spanningsbemaling	63	wkn	€	54.700,00	€	3.446.100,00
4.01	Vervaardigen bodembescherming tbv constructie	140200	ton	€	27,50	€	3.855.500,00
4.01	Leveren en aanbrengen doek/matconstructie	34600	m2	€	12,50	€	432.500,00
4.01	Leveren en aanbrengen afstorting beton o.d.	19650	m3	€	150,00	€	2.947.500,00
5.01	Vervaardigen prefab schillen van de turbinetunnels	33110	m3	€	650,00	€	21.521.500,00
5.01	Vloer tbv plaatsen bulbtunnels	13500	m3	€	350,00	€	4.725.000,00
5.01	Aanvoer en plaatsen bulbtunnels op locatie	258	st	€	20.150,00	€	5.198.700,00
5.01	Voorzieningen tbv plaatsen prefab bulbtunnels	86	set	€	5.000,00	€	430.000,00
5.01	Materialen tbv koppelen / Incl het afspannen etc.	86	set	€	19.020,00	€	1.635.720,00
5.02	Bulbtunnels lijmen met beton naar doosvorm	70780	m3	€	375,00	€	26.542.500,00
5.03	Vervaardigen ruimtes erboven voor schuiven en N57	15290	m3	€	425,00	€	6.498.250,00
5.04	Leveren en aanbrengen schuiven in de wanden	172	st	€	202.500,00	€	34.830.000,00
6.01	Overstek vullen met grond	50625	m3	€	2,50	€	126.562,50
6.02	Aanleg N57 op turbineruimtes (tussen schuiven)	8100	m2	€	40,00	€	324.000,00
6.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€	55,00	€	396.000,00
6.02	Aanleg nieuwe parallelbaan op overstek	10400	m2	€	50,00	€	520.000,00
6.02	Geleiderail/babakening etc	2800	m1	€	75,00	€	210.000,00
6.03	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
6.04	Opbreken omgelegde N57	15600	m2	€	7,50	€	117.000,00
7.01	Slopen caissons in den droge / deels nat	163200	m3	€	40,00	€	6.528.000,00
7.02	Baggeren rest dijk incl bekleding en bestorting etc.	1410000	m3	€	2,00	€	2.820.000,00
7.02	Toeslag bekleding en bestorting	282000	m3	€	7,50	€	2.115.000,00
8.01	Leveren en aanbrengen bodembescherming all-in	135000	m2	€	50,00	€	6.750.000,00
8.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
8.03	Complete bouwterrein afwerken / opschonen / herstel	140000	m2	€	2,50	€	350.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	1	%	€	143.808.082,50	€	1.438.080,83
	Subtotaal Directe Kosten					*€*	*145.246.163,33*
	Nader te detailleren	10	%	€	145.246.163,33	€	14.524.616,33
DK	**Totaal Directe Kosten**					**€**	**159.770.779,66**
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	159.770.779,66	€	6.390.831,19
	Algemene Kosten	7	%	€	166.161.610,84	€	11.631.312,76
	Winst & Risico	3	%	€	166.161.610,84	€	4.984.848,33
IDK	**Totaal Indirecte Kosten**					**€**	**23.006.992,27**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**182.777.771,93**
	Onvoorzien Bouwkosten	10	%	€	182.777.771,93	€	18.277.777,19
	Totaal Budget Stichtingskosten					***€***	***201.056.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	3	%	€	201.056.000,00	€	6.031.680,00
	Adviesskosten OG voor aanbesteding	2	%	€	201.056.000,00	€	4.021.120,00
	Apparaatkosten OG	6	%	€	201.056.000,00	€	12.063.360,00
	Engineeringskosten ON na aanbesteding	0,5	%	€	201.056.000,00	€	1.005.280,00
	Onderzoekskosten OG voor aanbesteding	0,5	%	€	201.056.000,00	€	1.005.280,00
	Heffingen / leges / verzekering	0,4	%	€	201.056.000,00	€	804.224,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	201.056.000,00	€	2.010.560,00
	Groencompensatie / natuurtoeslag	0,5	%	€	201.056.000,00	€	1.005.280,00
	Nader te detailleren OBK	10	%	€	27.946.784,00	€	2.794.678,40
	Subtotaal OBK					*€*	*30.741.462,40*
	Eenmalige Kosten, ABK & Uitvoeringskosten	3	%	€	30.741.462,40	€	922.243,87
	Algemene Kosten	7	%	€	30.741.462,40	€	2.151.902,37
	Winst & Risico	3	%	€	30.741.462,40	€	922.243,87
	Totaal Voorziene OBK					**€**	**34.737.852,51**
	Onvoorzien OBK	10	%	€	34.737.852,51	€	3.473.785,25
	Totaal Overige Bijkomende Kosten					***€***	***38.212.000,00***
	Overkoepelend Project Onvoorzien	12,5	%	€	239.268.000,00	€	29.908.500,00
	INVESTERINGSKOSTEN VARIANT 1a					**€**	**269.180.000,00**

Onderbouwing investeringskosten

Project : INPA140433
Kunstwerk : Getijdecentrale (incluus nivelleringsstuw)
Locatie : Brouwersdam
Soort : Bulb turbine
Variant 1b : In den natte gebouwd (grotendeels prefab / insitu bovenbouw)

Post	Omschrijving	Hoeh.heid	eenh.	PPE	Totaal
1.01	Huurkosten prefablocatie elementen - Bouwdok	58050	m2	€ 50,00	€ 2.902.500,00
1.02	Aanlegkosten water / electra etc.	1	pst	€ 500.000,00	€ 500.000,00
1.02	Verbruikskosten tijdens bouw segmenten	60	wkn	€ 10.000,00	€ 600.000,00
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€ 500.000,00	€ 500.000,00
1.04	Dichten droogdok / volzetten met water	10	dgn	€ 12.500,00	€ 125.000,00
2.01	Vervaardigen van de turbinetunnels in een sectie	124614	m3	€ 450,00	€ 56.076.300,00
2.02	Afdichting tussen elementen	85	set	€ 21.000,00	€ 1.785.000,00
2.03	Aanbrengen voorzieningen tbv drijven secties	86	set	€ 10.000,00	€ 860.000,00
3.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	32500	m2	€ 8,00	€ 260.000,00
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	45500	m2	€ 5,00	€ 227.500,00
3.03	Bekleding aanbrengen / herstellen talud	16250	m2	€ 55,00	€ 893.750,00
4.01	Aanleg tijdelijke N57 over omgelegde dijk	15600	m2	€ 50,00	€ 780.000,00
4.02	Aanbrengen barriers / wegbebakening	4200	m1	€ 45,00	€ 189.000,00
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 250.000,00	€ 500.000,00
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	1248800	m3	€ 2,00	€ 2.497.600,00
5.01	Toeslag bekleding en bestorting	249760	m3	€ 7,50	€ 1.873.200,00
6.01	Vervaardigen bodembescherming tbv constructie	56100	ton	€ 27,50	€ 1.542.750,00
6.01	Leveren en aanbrengen doek/matconstructie	34600	m2	€ 25,00	€ 865.000,00
7.01	Aanvoer en plaatsen bulbtunnels op locatie afzinken	6	set	€ 38.700,00	€ 232.200,00
7.01	Voorzieningen tbv plaatsen prefab bulbtunnels	6	set	€ 15.000,00	€ 90.000,00
7.01	Afdichting tussen elementen	6	set	€ 21.000,00	€ 126.000,00
7.01	Secties ondergrouting tbv fixatie en fundatie	23275	m3	€ 225,00	€ 5.236.875,00
8.01	Vervaardigen ruimtes erboven voor schuiven en N57	15290	m3	€ 450,00	€ 6.880.500,00
8.02	Leveren en aanbrengen schuiven in de wanden	172	st	€ 202.500,00	€ 34.830.000,00
9.01	Overstek vullen met grond	50625	m3	€ 2,50	€ 126.562,50
9.02	Aanleg N57 op turbineruimtes (tussen schuiven)	8100	m2	€ 40,00	€ 324.000,00
9.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€ 55,00	€ 396.000,00
9.02	Aanleg nieuwe parallelbaan op overstek	10400	m2	€ 50,00	€ 520.000,00
9.02	Geleiderail/babakening etc	2800	m1	€ 75,00	€ 210.000,00
9.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 350.000,00	€ 700.000,00
9.04	Opbreken omgelegde N57	15600	m2	€ 7,50	€ 117.000,00
10.01	Slopen caissons in den droge / in den natte	163200	m3	€ 40,00	€ 6.528.000,00
10.02	Baggeren rest dijk incl bekleding en bestorting etc.	1134000	m3	€ 2,00	€ 2.268.000,00
10.02	Toeslag bekleding en bestorting	226800	m3	€ 7,50	€ 1.701.000,00
11.01	Leveren en aanbrengen bodembescherming all-in	135000	m2	€ 50,00	€ 6.750.000,00
11.02	Uiteinden ontgraving afwerken	4	st	€ 125.000,00	€ 500.000,00
11.03	Complete bouwterrein afwerken / opschonen / herstel	140000	m2	€ 2,50	€ 350.000,00
					€ -
					€ -
					€ -
					€ -
	Faseringskosten / Voorzieningen omgeving	1,5	%	€ 140.863.737,50	€ 2.112.956,06
	Subtotaal Directe Kosten				*€ 142.976.693,56*
	Nader te detailleren	10	%	€ 142.976.693,56	€ 14.297.669,36
DK	**Totaal Directe Kosten**				**€ 157.274.362,92**
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€ 157.274.362,92	€ 6.290.974,52
	Algemene Kosten	7	%	€ 163.565.337,44	€ 11.449.573,62
	Winst & Risico	3	%	€ 163.565.337,44	€ 4.906.960,12
IDK	**Totaal Indirecte Kosten**				**€ 22.647.508,26**
	Totaal Voorziene Kosten (DK + IDK)				**€ 179.921.871,18**
	Onvoorzien Bouwkosten	10	%	€ 179.921.871,18	€ 17.992.187,12
	Totaal Budget Stichtingskosten				***€ 197.915.000,00***
	Overige Bijkomende Kosten				
	Engineeringskosten OG voor aanbesteding	3	%	€ 197.915.000,00	€ 5.937.450,00
	Adviesskosten OG voor aanbesteding	2	%	€ 197.915.000,00	€ 3.958.300,00
	Apparaatkosten OG	6	%	€ 197.915.000,00	€ 11.874.900,00
	Engineeringskosten ON na aanbesteding	0,5	%	€ 197.915.000,00	€ 989.575,00
	Onderzoekskosten OG voor aanbesteding	0,5	%	€ 197.915.000,00	€ 989.575,00
	Heffingen / leges / verzekering	0,4	%	€ 197.915.000,00	€ 791.660,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€ 197.915.000,00	€ 1.979.150,00
	Groencompensatie / natuurtoeslag	0,5	%	€ 197.915.000,00	€ 989.575,00
	Nader te detailleren OBK	10	%	€ 27.510.185,00	€ 2.751.018,50
	Subtotaal OBK				*€ 30.261.203,50*
	Eenmalige Kosten, ABK & Uitvoeringskosten	3	%	€ 30.261.203,50	€ 907.836,11
	Algemene Kosten	7	%	€ 30.261.203,50	€ 2.118.284,25
	Winst & Risico	3	%	€ 30.261.203,50	€ 907.836,11
	Totaal Voorziene OBK				**€ 34.195.159,96**
	Onvoorzien OBK	10	%	€ 34.195.159,96	€ 3.419.516,00
	Totaal Overige Bijkomende Kosten				***€ 37.615.000,00***
	Overkoepelend Project Onvoorzien	12,5	%	€ 235.530.000,00	€ 29.441.250,00
	INVESTERINGSKOSTEN VARIANT 1b				**€ 264.980.000,00**

Onderbouwing investeringskosten

Project : INPA140433
Kunstwerk : Getijdecentrale (incluus nivelleringsstuw)
Locatie : Brouwersdam
Soort : Bulb turbine
Variant 1c : In den droge gebouwd op dijk (deels prefab / deels in situ) pneumatisch inzakken

Post	Omschrijving	Hoeh.heid	eenh.	PPE	Totaal
1.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	32500	m2	€ 8,00	€ 260.000,00
1.02	Afvlakken dijklichaam tbv ruimte omlegging N57	45500	m2	€ 5,00	€ 227.500,00
1.03	Bekleding aanbrengen / herstellen talud	16250	m2	€ 55,00	€ 893.750,00
2.01	Aanleg tijdelijke N57 over omgelegde dijk	15600	m2	€ 50,00	€ 780.000,00
2.02	Aanbrengen barriers / wegbebakening	4200	m1	€ 45,00	€ 189.000,00
2.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 250.000,00	€ 500.000,00
2.04	Bouwrijp maken dam tbv secties op dam bouwen	29250	m2	€ 40,00	€ 1.170.000,00
3.01	Vervaardigen prefab schillen van de turbinetunnels	33110	m3	€ 650,00	€ 21.521.500,00
3.01	Vloer tbv plaatsen bulbtunnels (let op in secties)	13500	m3	€ 350,00	€ 4.725.000,00
3.01	Aanvoer en plaatsen bulbtunnels op locatie	258	st	€ 19.350,00	€ 4.992.300,00
3.01	Voorzieningen tbv plaatsen prefab bulbtunnels	86	set	€ 5.000,00	€ 430.000,00
3.01	Materialen tbv koppelen / Incl het afspannen etc.	86	set	€ 19.020,00	€ 1.635.720,00
3.02	Bulbtunnels lijmen met beton naar doosvorm	70780	m3	€ 375,00	€ 26.542.500,00
3.02	Afdichting tussen elementen	85	set	€ 21.000,00	€ 1.785.000,00
3.02	Voorzieningen tbv ingraven en toegang constructie	85	set	€ 25.000,00	€ 2.125.000,00
3.03	Vervaardigen ruimtes erboven voor schuiven en N57	18655	m3	€ 425,00	€ 7.928.375,00
3.04	Leveren en aanbrengen schuiven in de wanden	172	st	€ 237.500,00	€ 40.850.000,00
4.01	Inrichten gronddepot tbv vrijkomend materiaal	1	pst	€ 250.000,00	€ 250.000,00
4.02	Voorzieningen tbv grondtransporten	197600	m3	€ 2,00	€ 395.200,00
5.01	Laten zakken van de segmenten door spoelen/zuigen	17	st	€ 254.880,00	€ 4.332.960,00
5.02	Continu meten/monitoren	17	st	€ 17.280,00	€ 293.760,00
5.03	Afvoer/handling/bewerking/stort vrijkomend materiaal	197600	m3	€ 15,00	€ 2.964.000,00
5.04	Secties koppelen en afdichten (zover als kan)	17	keer	€ 8.200,00	€ 139.400,00
6.01	Overstek vullen met grond	50625	m3	€ 2,50	€ 126.562,50
6.02	Aanleg N57 op turbineruimtes (tussen schuiven)	8100	m2	€ 40,00	€ 324.000,00
6.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€ 55,00	€ 396.000,00
6.02	Aanleg nieuwe parallelbaan op overstek	10400	m2	€ 50,00	€ 520.000,00
6.02	Geleiderail/babakening etc	2800	m1	€ 75,00	€ 210.000,00
6.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 350.000,00	€ 700.000,00
6.04	Opbreken omgelegde N57	15600	m2	€ 7,50	€ 117.000,00
7.01	Slopen caissons in den droge / in den natte	163200	m3	€ 40,00	€ 6.528.000,00
7.02	Baggeren rest dijk incl bekleding en bestorting etc.	2185200	m3	€ 2,00	€ 4.370.400,00
7.02	Toeslag bekleding en bestorting	437040	m3	€ 7,50	€ 3.277.800,00
8.01	Leveren en aanbrengen bodembescherming all-in	135000	m2	€ 50,00	€ 6.750.000,00
8.02	Uiteinden ontgraving afwerken	4	st	€ 125.000,00	€ 500.000,00
8.03	Complete bouwterrein afwerken / opschonen / herstel	140000	m2	€ 2,50	€ 350.000,00
					€ -
					€ -
					€ -
					€ -
	Faseringskosten / Voorzieningen omgeving	1	%	€ 149.100.727,50	€ 1.491.007,28
	Subtotaal Directe Kosten				*€ 150.591.734,78*
	Nader te detailleren	10	%	€ 150.591.734,78	€ 15.059.173,48
DK	**Totaal Directe Kosten**				**€ 165.650.908,25**
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€ 165.650.908,25	€ 6.626.036,33
	Algemene Kosten	7	%	€ 172.276.944,58	€ 12.059.386,12
	Winst & Risico	3	%	€ 172.276.944,58	€ 5.168.308,34
IDK	**Totaal Indirecte Kosten**				**€ 23.853.730,79**
	Totaal Voorziene Kosten (DK + IDK)				**€ 189.504.639,04**
	Onvoorzien Bouwkosten	20	%	€ 189.504.639,04	€ 37.900.927,81
	Totaal Budget Stichtingskosten				***€ 227.406.000,00***
	Overige Bijkomende Kosten				
	Engineeringskosten OG voor aanbesteding	3	%	€ 227.406.000,00	€ 6.822.180,00
	Adviesskosten OG voor aanbesteding	2	%	€ 227.406.000,00	€ 4.548.120,00
	Apparaatkosten OG	6	%	€ 227.406.000,00	€ 13.644.360,00
	Engineeringskosten ON na aanbesteding	0,5	%	€ 227.406.000,00	€ 1.137.030,00
	Onderzoekskosten OG voor aanbesteding	0,5	%	€ 227.406.000,00	€ 1.137.030,00
	Heffingen / leges / verzekering	0,4	%	€ 227.406.000,00	€ 909.624,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€ 227.406.000,00	€ 2.274.060,00
	Groencompensatie / natuurtoeslag	0,5	%	€ 227.406.000,00	€ 1.137.030,00
	Nader te detailleren OBK	10	%	€ 31.609.434,00	€ 3.160.943,40
	Subtotaal OBK				*€ 34.770.377,40*
	Eenmalige Kosten, ABK & Uitvoeringskosten	3	%	€ 34.770.377,40	€ 1.043.111,32
	Algemene Kosten	7	%	€ 34.770.377,40	€ 2.433.926,42
	Winst & Risico	3	%	€ 34.770.377,40	€ 1.043.111,32
	Totaal Voorziene OBK				**€ 39.290.526,46**
	Onvoorzien OBK	10	%	€ 39.290.526,46	€ 3.929.052,65
	Totaal Overige Bijkomende Kosten				***€ 43.220.000,00***
	Overkoepelend Project Onvoorzien	15	%	€ 270.626.000,00	€ 40.593.900,00
	INVESTERINGSKOSTEN VARIANT 1c				**€ 311.220.000,00**

Project	: INPA140433
Kunstwerk	: Getijdecentrale (incluus nivelleringsstuw)
Locatie	: Brouwersdam
Soort	: Free Flow
Variant 2a	: In den droge gebouwd (pijlers insitu / dekken prefab)

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	20000	m2	€	8,00	€	160.000,00
1.02	Afvlakken dijklichaam tbv ruimte omlegging N57	28000	m2	€	5,00	€	140.000,00
1.03	Bekleding aanbrengen / herstellen talud	10000	m2	€	55,00	€	550.000,00
2.01	Aanleg tijdelijke N57 over omgelegde dijk	9600	m2	€	50,00	€	480.000,00
2.02	Aanbrengen barriers / wegbebakening	2700	m1	€	45,00	€	121.500,00
2.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
3.01	Ontgraven bouwput in den droge / nat (GW/HW)	274300	m3	€	1,50	€	411.450,00
3.01	Afvoer vrijgekomen grond (schoon)	274300	m3	€	4,50	€	1.234.350,00
3.02	Aanbrengen/verwijderen openbemaling	200	m1	€	400,00	€	80.000,00
3.02	Instandhouden/verbruikskosten openbemaling	55	wkn	€	6.400,00	€	352.000,00
3.02	Aanbrengen/verwijderen spanningsbemaling	200	m1	€	550,00	€	110.000,00
3.02	Instandhouden/verbruikskosten spanningsbemaling	44	wkn	€	33.500,00	€	1.474.000,00
4.01	Vervaardigen bodembescherming tbv constructie	35250	ton	€	27,50	€	969.375,00
4.01	Leveren en aanbrengen doek/matconstructie	8700	m2	€	25,00	€	217.500,00
4.01	Leveren en aanbrengen afstorting beton o.d.	4900	m3	€	150,00	€	735.000,00
5.01	Vervaardigen in situ "footplates"	11000	m3	€	425,00	€	4.675.000,00
5.01	Vervaardigen in situ pijlers	16756,25	m3	€	600,00	€	10.053.750,00
5.01	Vervaardigen van schuifdrempel op "footplates"	1800	m3	€	450,00	€	810.000,00
5.02	Vervaardigen sil-beam en top-beam (VG)	7000	m3	€	1.100,00	€	7.700.000,00
5.02	Transport en montage op locatie	8	st	€	18.550,00	€	148.400,00
5.02	Leveren en aanbrengen VG-liggers rijdek N57 &PW	3960	m2	€	650,00	€	2.574.000,00
5.02	Afwerking dekconstructie (schamkant e.d.)	3960	m2	€	200,00	€	792.000,00
5.02	Ondersteuning (extra betonwerk) tbv Par.weg	640	m3	€	750,00	€	480.000,00
5.03	Vervaardigen "casings" op pijlers (inhoud)	2500	m3	€	250,00	€	625.000,00
5.04	Leveren en aanbrengen schuiven in de wanden	4	st	€	3.749.500,00	€	14.998.000,00
6.01	Aanleg N57 & PW op prefab dek	3960	m2	€	40,00	€	158.400,00
6.01	Aanleg nieuwe N57 op aarde baan in lijn	8400	m2	€	55,00	€	462.000,00
6.01	Aanleg nieuwe PW op aarde baan in lijn	5600	m2	€	50,00	€	280.000,00
6.01	Geleiderail/babakening etc	1600	m1	€	75,00	€	120.000,00
6.02	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
6.03	Opbreken omgelegde N57	9600	m2	€	7,50	€	72.000,00
7.01	Slopen caissons in den droge / in den natte	43200	m3	€	40,00	€	1.728.000,00
7.02	Baggeren rest dijk incl bekleding en bestorting etc.	403000	m3	€	2,00	€	806.000,00
7.02	Toeslag bekleding en bestorting	80600	m3	€	7,50	€	604.500,00
8.01	Leveren en aanbrengen bodembescherming all-in	36000	m2	€	50,00	€	1.800.000,00
8.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
8.03	Complete bouwterrein afwerken / opschonen / herstel	50000	m2	€	2,50	€	125.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	2	%	€	57.747.225,00	€	1.154.944,50
	Subtotaal Directe Kosten					*€*	*58.902.169,50*
	Nader te detailleren	10	%	€	58.902.169,50	€	5.890.216,95
DK	**Totaal Directe Kosten**					**€**	**64.792.386,45**
	Eenmalige Kosten, ABK & Uitvoeringskosten	5	%	€	64.792.386,45	€	3.239.619,32
	Algemene Kosten	8	%	€	68.032.005,77	€	5.442.560,46
	Winst & Risico	3	%	€	68.032.005,77	€	2.040.960,17
IDK	**Totaal Indirecte Kosten**					**€**	**10.723.139,96**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**75.515.526,41**
	Onvoorzien Bouwkosten	12,5	%	€	75.515.526,41	€	9.439.440,80
	Totaal Budget Stichtingskosten					***€***	***84.955.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	4	%	€	84.955.000,00	€	3.398.200,00
	Adviesskosten OG voor aanbesteding	2	%	€	84.955.000,00	€	1.699.100,00
	Apparaatkosten OG	6	%	€	84.955.000,00	€	5.097.300,00
	Engineeringskosten ON na aanbesteding	1	%	€	84.955.000,00	€	849.550,00
	Onderzoekskosten OG voor aanbesteding	1,5	%	€	84.955.000,00	€	1.274.325,00
	Heffingen / leges / verzekering	1	%	€	84.955.000,00	€	849.550,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	84.955.000,00	€	849.550,00
	Groencompensatie / natuurtoeslag	1	%	€	84.955.000,00	€	849.550,00
	Nader te detailleren OBK	10	%	€	14.867.125,00	€	1.486.712,50
	Subtotaal OBK					*€*	*16.353.837,50*
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	16.353.837,50	€	654.153,50
	Algemene Kosten	8	%	€	16.353.837,50	€	1.308.307,00
	Winst & Risico	3	%	€	16.353.837,50	€	490.615,13
	Totaal Voorziene OBK					**€**	**18.806.913,13**
	Onvoorzien OBK	10	%	€	18.806.913,13	€	1.880.691,31
	Totaal Overige Bijkomende Kosten					***€***	***20.688.000,00***
	Overkoepelend Project Onvoorzien	15	%	€	105.643.000,00	€	15.846.450,00
	INVESTERINGSKOSTEN VARIANT 2a					**€**	**121.490.000,00**

Project : INPA140433
Kunstwerk : Getijdecentrale (incluus nivelleringsstuw)
Locatie : Brouwersdam
Soort : Free Flow
Variant 2c1 : In den droge gebouwd (in situ - blokkendoos opbouw)

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	19500	m2	€	8,00	€	156.000,00
1.02	Afvlakken dijklichaam tbv ruimte omlegging N57	27300	m2	€	5,00	€	136.500,00
1.03	Bekleding aanbrengen / herstellen talud	9750	m2	€	55,00	€	536.250,00
2.01	Aanleg tijdelijke N57 over omgelegde dijk	9600	m2	€	50,00	€	480.000,00
2.02	Aanbrengen barriers / wegbebakening	2700	m1	€	45,00	€	121.500,00
2.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
3.01	Ontgraven bouwput in den droge / nat (GW/HW)	246900	m3	€	1,50	€	370.350,00
3.01	Afvoer vrijgekomen grond (schoon)	246900	m3	€	4,50	€	1.111.050,00
3.02	Aanbrengen/verwijderen openbemaling	180	m1	€	400,00	€	72.000,00
3.02	Instandhouden/verbruikskosten openbemaling	65	wkn	€	6.000,00	€	390.000,00
3.02	Aanbrengen/verwijderen spanningsbemaling	180	m1	€	600,00	€	108.000,00
3.02	Instandhouden/verbruikskosten spanningsbemaling	52	wkn	€	33.500,00	€	1.742.000,00
4.01	Vervaardigen bodembescherming tbv constructie	33300	ton	€	27,50	€	915.750,00
4.01	Leveren en aanbrengen doek/matconstructie	8200	m2	€	25,00	€	205.000,00
4.01	Leveren en aanbrengen afstorting beton o.d.	4650	m3	€	150,00	€	697.500,00
5.01	Vervaardigen in situ vloer van de Doos	11760	m3	€	425,00	€	4.998.000,00
5.01	Vervaardigen wanden van de doosconstructie	3584	m3	€	550,00	€	1.971.200,00
5.01	Vervaardigen dak op doosconstructie	3920	m3	€	475,00	€	1.862.000,00
5.02	Wanden op dak van doosconstructies	4995	m3	€	500,00	€	2.497.500,00
5.02	Afbouw beton insitu van constructies op dak	2160	m3	€	450,00	€	972.000,00
6.01	Leveren en aanbrengen schuiven in de wanden	15	st	€	345.500,00	€	5.182.500,00
7.01	Dakconstructie vullen met grond	12960	m3	€	2,50	€	32.400,00
7.01	Aanleg N57 op grond op doosconstrucite	1680	m2	€	55,00	€	92.400,00
7.01	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€	55,00	€	396.000,00
7.01	Aanleg nieuwe parallelbaan op beton	1440	m2	€	50,00	€	72.000,00
7.01	Geleiderail/babakening etc	800	m1	€	75,00	€	60.000,00
7.02	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
7.03	Opbreken omgelegde N57	9600	m2	€	7,50	€	72.000,00
8.01	Slopen caissons in den droge / in den natte	36000	m3	€	40,00	€	1.440.000,00
8.02	Baggeren rest dijk incl bekleding en bestorting etc.	303000	m3	€	2,00	€	606.000,00
8.02	Toeslag bekleding en bestorting	60600	m3	€	7,50	€	454.500,00
9.01	Leveren en aanbrengen bodembescherming all-in	30000	m2	€	50,00	€	1.500.000,00
9.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
9.03	Complete bouwterrein afwerken / opschonen / herstel	44000	m2	€	2,50	€	110.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	2	%	€	31.060.400,00	€	621.208,00
	Subtotaal Directe Kosten					*€*	*31.681.608,00*
	Nader te detailleren	10	%	€	31.681.608,00	€	3.168.160,80
DK	**Totaal Directe Kosten**					**€**	**34.849.768,80**
	Eenmalige Kosten, ABK & Uitvoeringskosten	5	%	€	34.849.768,80	€	1.742.488,44
	Algemene Kosten	8	%	€	36.592.257,24	€	2.927.380,58
	Winst & Risico	3	%	€	36.592.257,24	€	1.097.767,72
IDK	**Totaal Indirecte Kosten**					**€**	**5.767.636,74**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**40.617.405,54**
	Onvoorzien Bouwkosten	12,5	%	€	40.617.405,54	€	5.077.175,69
	Totaal Budget Stichtingskosten					***€***	***45.695.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	4	%	€	45.695.000,00	€	1.827.800,00
	Adviesskosten OG voor aanbesteding	2	%	€	45.695.000,00	€	913.900,00
	Apparaatkosten OG	6	%	€	45.695.000,00	€	2.741.700,00
	Engineeringskosten ON na aanbesteding	1	%	€	45.695.000,00	€	456.950,00
	Onderzoekskosten OG voor aanbesteding	1,5	%	€	45.695.000,00	€	685.425,00
	Heffingen / leges / verzekering	1	%	€	45.695.000,00	€	456.950,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	45.695.000,00	€	456.950,00
	Groencompensatie / natuurtoeslag	1	%	€	45.695.000,00	€	456.950,00
	Nader te detailleren OBK	10	%	€	7.996.625,00	€	799.662,50
	Subtotaal OBK					*€*	*8.796.287,50*
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	8.796.287,50	€	351.851,50
	Algemene Kosten	8	%	€	8.796.287,50	€	703.703,00
	Winst & Risico	3	%	€	8.796.287,50	€	263.888,63
	Totaal Voorziene OBK					**€**	**10.115.730,63**
	Onvoorzien OBK	12,5	%	€	10.115.730,63	€	1.264.466,33
	Totaal Overige Bijkomende Kosten					***€***	***11.381.000,00***
	Overkoepelend Project Onvoorzien	12,5	%	€	57.076.000,00	€	7.134.500,00
	INVESTERINGSKOSTEN VARIANT 2c1					**€**	**64.220.000,00**

Project : INPA140433
Kunstwerk : Getijdecentrale (incluus nivelleringsstuw)
Locatie : Brouwersdam
Soort : Free Flow
Variant 2c2 : In den natte gebouwd (grotendeels prefab / insitu bovenbouw)

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Huurkosten prefablocatie elementen - Bouwdok	11520	m2	€	60,00	€	691.200,00
1.02	Aanlegkosten water / electra etc.	1	pst	€	200.000,00	€	200.000,00
1.02	Verbruikskosten tijdens bouw segmenten	50	wkn	€	5.000,00	€	250.000,00
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€	150.000,00	€	150.000,00
1.04	Dichten droogdok / volzetten met water	5	dgn	€	12.500,00	€	62.500,00
2.01	Vervaardigen in situ vloer van de Doos	11760	m3	€	425,00	€	4.998.000,00
2.01	Vervaardigen wanden van de doosconstructie	3584	m3	€	550,00	€	1.971.200,00
2.01	Vervaardigen dak op doosconstructie	3920	m3	€	475,00	€	1.862.000,00
2.02	Afdichting tussen elementen	2	set	€	16.800,00	€	33.600,00
2.03	Aanbrengen voorzieningen tbv drijven secties	3	set	€	25.000,00	€	75.000,00
3.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	19500	m2	€	8,00	€	156.000,00
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	27300	m2	€	5,00	€	136.500,00
3.03	Bekleding aanbrengen / herstellen talud	9750	m2	€	55,00	€	536.250,00
4.01	Aanleg tijdelijke N57 over omgelegde dijk	9360	m2	€	50,00	€	468.000,00
4.02	Aanbrengen barriers / wegbebakening	2340	m1	€	45,00	€	105.300,00
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	336500	m3	€	2,00	€	673.000,00
5.01	Toeslag bekleding en bestorting	67300	m3	€	7,50	€	504.750,00
6.01	Vervaardigen bodembescherming tbv constructie	11250	ton	€	27,50	€	309.375,00
6.01	Leveren en aanbrengen doek/matconstructie	8300	m2	€	25,00	€	207.500,00
7.01	Aanvoer en plaatsen doosconstr. op locatie afzinken	2	set	€	21.300,00	€	42.600,00
7.01	Voorzieningen tbv plaatsen prefab doosconstr.	2	set	€	20.000,00	€	40.000,00
7.01	Secties ondergrouting tbv fixatie en fundatie	4200	m3	€	250,00	€	1.050.000,00
8.01	Wanden op dak van doosconstructies	4995	m3	€	500,00	€	2.497.500,00
8.01	Afbouw beton insitu van constructies op dak	2160	m3	€	450,00	€	972.000,00
8.02	Leveren en aanbrengen schuiven in de wanden	15	st	€	345.500,00	€	5.182.500,00
9.01	Dakconstructie vullen met grond	12960	m3	€	2,50	€	32.400,00
9.02	Aanleg N57 op grond op doosconstrucite	1680	m2	€	55,00	€	92.400,00
9.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€	55,00	€	396.000,00
9.02	Aanleg nieuwe parallelbaan op beton	1440	m2	€	50,00	€	72.000,00
9.02	Geleiderail/babakening etc	800	m1	€	75,00	€	60.000,00
9.03	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
9.04	Opbreken omgelegde N57	0	m2	€	7,50	€	-
10.01	Slopen caissons in den droge / in den natte	36000	m3	€	40,00	€	1.440.000,00
10.02	Baggeren rest dijk incl bekleding en bestorting etc.	303000	m3	€	2,00	€	606.000,00
10.02	Toeslag bekleding en bestorting	60600	m3	€	7,50	€	454.500,00
11.01	Leveren en aanbrengen bodembescherming all-in	30000	m2	€	50,00	€	1.500.000,00
11.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
11.03	Complete bouwterrein afwerken / opschonen / herstel	44000	m2	€	2,50	€	110.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	2,5	%	€	29.638.075,00	€	740.951,88
	Subtotaal Directe Kosten					€	*30.379.026,88*
	Nader te detailleren	10	%	€	30.379.026,88	€	3.037.902,69
DK	**Totaal Directe Kosten**					**€**	**33.416.929,56**
	Eenmalige Kosten, ABK & Uitvoeringskosten	5	%	€	33.416.929,56	€	1.670.846,48
	Algemene Kosten	8	%	€	35.087.776,04	€	2.807.022,08
	Winst & Risico	3	%	€	35.087.776,04	€	1.052.633,28
IDK	**Totaal Indirecte Kosten**					**€**	**5.530.501,84**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**38.947.431,41**
	Onvoorzien Bouwkosten	12,5	%	€	38.947.431,41	€	4.868.428,93
	Totaal Budget Stichtingskosten					***€***	***43.816.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	4	%	€	43.816.000,00	€	1.752.640,00
	Adviesskosten OG voor aanbesteding	2	%	€	43.816.000,00	€	876.320,00
	Apparaatkosten OG	6	%	€	43.816.000,00	€	2.628.960,00
	Engineeringskosten ON na aanbesteding	1	%	€	43.816.000,00	€	438.160,00
	Onderzoekskosten OG voor aanbesteding	1,5	%	€	43.816.000,00	€	657.240,00
	Heffingen / leges / verzekering	1	%	€	43.816.000,00	€	438.160,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	43.816.000,00	€	438.160,00
	Groencompensatie / natuurtoeslag	1	%	€	43.816.000,00	€	438.160,00
	Nader te detailleren OBK	10	%	€	7.667.800,00	€	766.780,00
	Subtotaal OBK					€	*8.434.580,00*
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	8.434.580,00	€	337.383,20
	Algemene Kosten	8	%	€	8.434.580,00	€	674.766,40
	Winst & Risico	3	%	€	8.434.580,00	€	253.037,40
	Totaal Voorziene OBK					**€**	**9.699.767,00**
	Onvoorzien OBK	12,5	%	€	9.699.767,00	€	1.212.470,88
	Totaal Overige Bijkomende Kosten					***€***	***10.913.000,00***
	Overkoepelend Project Onvoorzien	12,5	%	€	54.729.000,00	€	6.841.125,00
	INVESTERINGSKOSTEN VARIANT 2c2					**€**	**61.580.000,00**

Project : INPA140433
Kunstwerk : Getijdecentrale (incluus nivelleringsstuw)
Locatie : Brouwersdam
Soort : Free Flow
Variant 2d : In den natte gebouwd (grotendeels prefab / insitu bovenbouw)
Drijvende pijlerbak op buispalen

Post	Omschrijving	Hoeh.heid	eenh.	PPE	Totaal
1.01	Huurkosten prefablocatie elementen - Bouwdok	6000	m2	€ 60,00	€ 360.000,00
1.02	Aanlegkosten water / electra etc.	1	pst	€ 150.000,00	€ 150.000,00
1.02	Verbruikskosten tijdens bouw segmenten	40	wkn	€ 5.000,00	€ 200.000,00
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€ 150.000,00	€ 150.000,00
1.04	Dichten droogdok / volzetten met water	5	dgn	€ 15.000,00	€ 75.000,00
2.01	Vervaardigen in situ vloer van de pijlerdoos	3000	m3	€ 425,00	€ 1.275.000,00
2.01	Vervaardigen wanden van de pijlerdoos	8340	m3	€ 550,00	€ 4.587.000,00
2.03	Aanbrengen voorzieningen tbv drijven secties	5	set	€ 15.000,00	€ 75.000,00
3.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	20000	m2	€ 8,00	€ 160.000,00
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	28000	m2	€ 5,00	€ 140.000,00
3.03	Bekleding aanbrengen / herstellen talud	10000	m2	€ 55,00	€ 550.000,00
4.01	Aanleg tijdelijke N57 over omgelegde dijk	9600	m2	€ 50,00	€ 480.000,00
4.02	Aanbrengen barriers / wegbebakening	2400	m1	€ 45,00	€ 108.000,00
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 250.000,00	€ 500.000,00
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	351200	m3	€ 2,00	€ 702.400,00
5.01	Toeslag bekleding en bestorting	70240	m3	€ 7,50	€ 526.800,00
6.01	leveren stalen buispalen 5x 12 st L=30m 2020x25mm	2240	ton	€ 1.650,00	€ 3.696.000,00
6.01	Handling/aanvoer stalen buispalen nat	2240	ton	€ 15,00	€ 33.600,00
6.01	Aanbrengen stalen buispalen met drijvende stellingen	30	dgn	€ 13.040,00	€ 391.200,00
8.01	Vervaardigen bodembescherming tbv constructie	11250	ton	€ 27,50	€ 309.375,00
8.01	Leveren en aanbrengen doek/matconstructie	8300	m2	€ 25,00	€ 207.500,00
7.01	Legen buispalen incl afvoer/stort grond	1200	m3	€ 25,00	€ 30.000,00
7.02	Leveren en aanbrengen beton in buispalen	1200	m3	€ 225,00	€ 270.000,00
7.02	Leveren en aanbrengen wapeningskorven	90000	kg	€ 1,50	€ 135.000,00
7.02	Kraanhulp tbv korven aanbrengen	90	ton	€ 55,00	€ 4.950,00
7.02	Duikerhulp bij de werkzaamheden	5	wkn	€ 12.500,00	€ 62.500,00
9.01	Aanvoer en plaatsen doosconstr. op locatie afzinken	5	st	€ 14.450,00	€ 72.250,00
9.01	Voorzieningen tbv plaatsen prefab pijlerdoos	5	set	€ 7.500,00	€ 37.500,00
9.02	Secties ondergrouting tbv fixatie / dichten gaten palen	1800	m3	€ 250,00	€ 450.000,00
10.01	Pijlerbakken volstorten met beton (natte stort)	9660	m3	€ 175,00	€ 1.690.500,00
10.01	Afwerken bovenzijde ivm werk op pijlers	1500	m2	€ 25,00	€ 37.500,00
11.01	Vervaardigen van schuifdrempel op "footplates"	1800	m3	€ 450,00	€ 810.000,00
11.01	Vervaardigen sil-beam en top-beam (VG)	7000	m3	€ 1.100,00	€ 7.700.000,00
11.01	Transport en montage op locatie	8	st	€ 18.550,00	€ 148.400,00
12.01	Leveren en aanbrengen VG-liggers rijdek N57 &PW	3960	m2	€ 650,00	€ 2.574.000,00
12.01	Afwerking dekconstructie (schamkant e.d.)	3960	m2	€ 200,00	€ 792.000,00
12.02	Ondersteuning (extra betonwerk) tbv Par.weg	800	m3	€ 750,00	€ 600.000,00
12.03	Vervaardigen "casings" op pijlers (inhoud)	2500	m3	€ 250,00	€ 625.000,00
12.04	Leveren en aanbrengen schuiven in de wanden	4	st	€ 3.749.500,00	€ 14.998.000,00
12.01	Aanleg N57 & PW op prefab dek	3960	m2	€ 40,00	€ 158.400,00
12.01	Aanleg nieuwe N57 op aarde baan in lijn	8400	m2	€ 55,00	€ 462.000,00
12.01	Aanleg nieuwe PW op aarde baan in lijn	5600	m2	€ 50,00	€ 280.000,00
12.01	Geleiderail/babakening etc	2400	m1	€ 75,00	€ 180.000,00
12.02	Aanpassen / vervaardigen kruispunten	2	keer	€ 350.000,00	€ 700.000,00
12.03	Opbreken omgelegde N57	11250	m2	€ 7,50	€ 84.375,00
14.01	Slopen caissons in den natte	43200	m3	€ 60,00	€ 2.592.000,00
14.02	Baggeren rest dijk incl bekleding en bestorting etc.	403000	m3	€ 2,00	€ 806.000,00
14.03	Toeslag bekleding en bestorting	80600	m3	€ 7,50	€ 604.500,00
15.01	Leveren en aanbrengen bodembescherming all-in	50000	m2	€ 50,00	€ 2.500.000,00
15.02	Uiteinden ontgraving afwerken	4	st	€ 125.000,00	€ 500.000,00
15.03	Complete bouwterrein afwerken / opschonen / herstel	44000	m2	€ 2,50	€ 110.000,00
					€ -
					€ -
					€ -
					€ -
	Faseringskosten / Voorzieningen omgeving	2	%	€ 54.691.750,00	€ 1.093.835,00
	Subtotaal Directe Kosten				*€ 55.785.585,00*
	Nader te detailleren	10	%	€ 55.785.585,00	€ 5.578.558,50
DK	**Totaal Directe Kosten**				**€ 61.364.143,50**
	Eenmalige Kosten, ABK & Uitvoeringskosten	5	%	€ 61.364.143,50	€ 3.068.207,18
	Algemene Kosten	8	%	€ 64.432.350,68	€ 5.154.588,05
	Winst & Risico	3	%	€ 64.432.350,68	€ 1.932.970,52
IDK	**Totaal Indirecte Kosten**				**€ 10.155.765,75**
	Totaal Voorziene Kosten (DK + IDK)				**€ 71.519.909,25**
	Onvoorzien Bouwkosten	15	%	€ 71.519.909,25	€ 10.727.986,39
	Totaal Budget Stichtingskosten				***€ 82.248.000,00***
	Overige Bijkomende Kosten				
	Engineeringskosten OG voor aanbesteding	4	%	€ 82.248.000,00	€ 3.289.920,00
	Adviesskosten OG voor aanbesteding	2	%	€ 82.248.000,00	€ 1.644.960,00
	Apparaatkosten OG	6	%	€ 82.248.000,00	€ 4.934.880,00
	Engineeringskosten ON na aanbesteding	1	%	€ 82.248.000,00	€ 822.480,00
	Onderzoekskosten OG voor aanbesteding	1,5	%	€ 82.248.000,00	€ 1.233.720,00
	Heffingen / leges / verzekering	1	%	€ 82.248.000,00	€ 822.480,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€ 82.248.000,00	€ 822.480,00
	Groencompensatie / natuurtoeslag	1	%	€ 82.248.000,00	€ 822.480,00
	Nader te detailleren OBK	10	%	€ 14.393.400,00	€ 1.439.340,00
	Subtotaal OBK				*€ 15.832.740,00*
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€ 15.832.740,00	€ 633.309,60
	Algemene Kosten	8	%	€ 15.832.740,00	€ 1.266.619,20
	Winst & Risico	3	%	€ 15.832.740,00	€ 474.982,20
	Totaal Voorziene OBK				**€ 18.207.651,00**
	Onvoorzien OBK	10	%	€ 18.207.651,00	€ 1.820.765,10
	Totaal Overige Bijkomende Kosten				***€ 20.029.000,00***
	Overkoepelend Project Onvoorzien	15	%	€ 102.277.000,00	€ 15.341.550,00
	INVESTERINGSKOSTEN VARIANT 2d				**€ 117.620.000,00**

Project : INPA140433
Kunstwerk : Getijdecentrale
Locatie : Brouwersdam
Soort : Siphon
Variant 3a : In den droge gebouwd (in bouwkuip damwand)

Post	Omschrijving	Hoeh.heid	eenh.	PPE	Totaal
1.01	Omleggen fietspad naar parallelweg zeezijde	5400	m2	€ 45,00	€ 243.000,00
1.01	Voorzieningen tbv oversteek / aansluitingen	2	keer	€ 50.000,00	€ 100.000,00
1.02	Opbreken bestaand fietspad	3200	m2	€ 12,50	€ 40.000,00
2.01/3.01	Leveren damwand (zwaar type)	15890	ton	€ 925,00	€ 14.698.250,00
2.01/3.01	Aanbrengen damwand (zwaar type)	56800	m2	€ 12,50	€ 710.000,00
2.01/3.01	Aanbr/verw/huur gording	1968	m1	€ 797,50	€ 1.569.480,00
2.01/3.01	Leveren en aanbrengen verankering	692	st	€ 5.500,00	€ 3.806.000,00
2.01/3.01	Verwijderen ankers als weer aangevuld is	692	st	€ 500,00	€ 346.000,00
4.01	Ontgraven bouwput in den droge / nat (GW/HW)	810000	m3	€ 1,50	€ 1.215.000,00
4.01	Afvoer vrijgekomen grond (schoon)	810000	m3	€ 4,50	€ 3.645.000,00
4.02	Leegpompen complete kuip / gefaseerd	20	dgn	€ 3.140,00	€ 62.800,00
4.03	Aanbrengen/verwijderen openbemaling	800	m1	€ 350,00	€ 280.000,00
4.03	Instandhouden/verbruikskosten openbemaling	80	wkn	€ 14.700,00	€ 1.176.000,00
4.03	Aanbrengen/verwijderen spanningsbemaling	800	m1	€ 500,00	€ 400.000,00
4.03	Instandhouden/verbruikskosten spanningsbemaling	64	wkn	€ 54.700,00	€ 3.500.800,00
5.01	Slopen caissons in den droge	115200	m3	€ 25,00	€ 2.880.000,00
5.02	Dak storten op caissons ivm stabiliteit en oplegging	14400	m3	€ 450,00	€ 6.480.000,00
5.03	Leveren prefab turbine huizen	50700	m3	€ 200,00	€ 10.140.000,00
5.03	Leveren buisconstructies siphons staal d=25mm	96	st	€ 816.750,00	€ 78.408.000,00
5.03	Transport en overslag	15840	ton	€ 50,00	€ 792.000,00
5.03	Installeren siphons in bouwkuip incl turbinehuis	96	st	€ 22.380,00	€ 2.148.480,00
5.03	Materiaalkosten tbv fixatie buizen onderling & caisson	96	st	€ 25.000,00	€ 2.400.000,00
6.01	Kuip vullen met grond uit depot	404800	m3	€ 2,00	€ 809.600,00
6.02	Leveren en aanbrengen verankering damwanden	346	st	€ 17.100,00	€ 5.916.600,00
6.03	Aanleg nieuwe N57 op aarde baan	26400	m2	€ 55,00	€ 1.452.000,00
6.03	Aanleg nieuwe PW op aarde baan	11200	m2	€ 50,00	€ 560.000,00
6.03	Geleiderail/babakening etc	4200	m1	€ 75,00	€ 315.000,00
6.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 350.000,00	€ 700.000,00
6.03	Opbreken bestaande N57 + par.weg	28000	m2	€ 7,50	€ 210.000,00
7 is in 6 verwerkt					
8.01	Baggeren dijk incl bekleding en bestorting etc.	1296000	m3	€ 2,00	€ 2.592.000,00
8.01	Toeslag bekleding en bestorting	259200	m3	€ 7,50	€ 1.944.000,00
8.01	Werkzaamheden tbv doorstroomopeningen damwand	96	st	€ 3.180,00	€ 305.280,00
8.02	Leveren en aanbrengen bodembescherming all-in	80000	m2	€ 50,00	€ 4.000.000,00
8.02	Uiteinden ontgraving afwerken	2	st	€ 125.000,00	€ 250.000,00
8.03	Complete bouwterrein afwerken / opschonen / herstel	85000	m2	€ 2,50	€ 212.500,00
					€ -
9.01	Baggeren dijk incl bekleding en bestorting etc.	1037000	m3	€ 2,00	€ 2.074.000,00
9.01	Toeslag bekleding en bestorting	207400	m3	€ 7,50	€ 1.555.500,00
9.01	Werkzaamheden tbv doorstroomopeningen damwand	96	st	€ 3.180,00	€ 305.280,00
9.02	Leveren en aanbrengen bodembescherming all-in	80000	m2	€ 50,00	€ 4.000.000,00
9.02	Uiteinden ontgraving afwerken	2	st	€ 125.000,00	€ 250.000,00
9.03	Complete bouwterrein afwerken / opschonen / herstel	85000	m2	€ 2,50	€ 212.500,00
					€ -
					€ -
					€ -
					€ -
	Faseringskosten / Voorzieningen omgeving	1	%	€ 162.705.070,00	€ 1.627.050,70
	Subtotaal Directe Kosten				*€ 164.332.120,70*
	Nader te detailleren	15	%	€ 164.332.120,70	€ 24.649.818,11
DK	**Totaal Directe Kosten**				**€ 188.981.938,81**
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€ 188.981.938,81	€ 7.559.277,55
	Algemene Kosten	7	%	€ 196.541.216,36	€ 13.757.885,15
	Winst & Risico	3	%	€ 196.541.216,36	€ 5.896.236,49
IDK	**Totaal Indirecte Kosten**				**€ 27.213.399,19**
	Totaal Voorziene Kosten (DK + IDK)				**€ 216.195.337,99**
	Onvoorzien Bouwkosten	20	%	€ 216.195.337,99	€ 43.239.067,60
	Totaal Budget Stichtingskosten				***€ 259.435.000,00***
	Overige Bijkomende Kosten				
	Engineeringskosten OG voor aanbesteding	3	%	€ 259.435.000,00	€ 7.783.050,00
	Adviesskosten OG voor aanbesteding	2	%	€ 259.435.000,00	€ 5.188.700,00
	Apparaatkosten OG	6	%	€ 259.435.000,00	€ 15.566.100,00
	Engineeringskosten ON na aanbesteding	0,5	%	€ 259.435.000,00	€ 1.297.175,00
	Onderzoekskosten OG voor aanbesteding	0,5	%	€ 259.435.000,00	€ 1.297.175,00
	Heffingen / leges / verzekering	0,4	%	€ 259.435.000,00	€ 1.037.740,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€ 259.435.000,00	€ 2.594.350,00
	Groencompensatie / natuurtoeslag	0,5	%	€ 259.435.000,00	€ 1.297.175,00
	Nader te detailleren OBK	10	%	€ 36.061.465,00	€ 3.606.146,50
	Subtotaal OBK				*€ 39.667.611,50*
	Eenmalige Kosten, ABK & Uitvoeringskosten	3	%	€ 39.667.611,50	€ 1.190.028,35
	Algemene Kosten	7	%	€ 39.667.611,50	€ 2.776.732,81
	Winst & Risico	3	%	€ 39.667.611,50	€ 1.190.028,35
	Totaal Voorziene OBK				**€ 44.824.401,00**
	Onvoorzien OBK	10	%	€ 44.824.401,00	€ 4.482.440,10
	Totaal Overige Bijkomende Kosten				***€ 49.307.000,00***
	Overkoepelend Project Onvoorzien	20	%	€ 308.742.000,00	€ 61.748.400,00
	INVESTERINGSKOSTEN VARIANT 3a				**€ 370.500.000,00**

Project : INPA140433
Kunstwerk : Getijdecentrale
Locatie : Brouwersdam
Soort : Siphon
Variant 3b : In den natte gebouwd (deels prefabben en nat aanbrengen) in deels gebaggerde dijk

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Huurkosten prefablocatie elementen - Bouwdok	50400	m2	€	50,00	€	2.520.000,00
1.02	Aanlegkosten water / electra etc.	1	pst	€	450.000,00	€	450.000,00
1.02	Verbruikskosten tijdens bouw segmenten	60	wkn	€	10.000,00	€	600.000,00
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€	400.000,00	€	400.000,00
1.04	Dichten droogdok / volzetten met water	10	dgn	€	12.500,00	€	125.000,00
2.01	Prefabriceren betonnen caissons / ruimtes	96	st	€	756.000,00	€	72.576.000,00
2.01	Leveren stalen koker van de siphon	96	st	€	306.900,00	€	29.462.400,00
2.01	Plaatsen siphonkoker in prefab segment	96	st	€	14.700,00	€	1.411.200,00
						€	-
3.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	35000	m2	€	8,00	€	280.000,00
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	49000	m2	€	5,00	€	245.000,00
3.03	Bekleding aanbrengen / herstellen talud	17500	m2	€	55,00	€	962.500,00
4.01	Aanleg tijdelijke N57 over omgelegde dijk	16800	m2	€	50,00	€	840.000,00
4.02	Aanbrengen barriers / wegbebakening	4800	m1	€	45,00	€	216.000,00
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	1423900	m3	€	2,00	€	2.847.800,00
5.01	Toeslag bekleding en bestorting	284780	m3	€	7,50	€	2.135.850,00
6.01	Vervaardigen bodembescherming tbv constructie	75250	ton	€	27,50	€	2.069.375,00
6.01	Leveren en aanbrengen doek/matconstructie	46000	m2	€	25,00	€	1.150.000,00
7.01	Aanvoer en plaatsen prefabsecties op locatie afzinken	96	st	€	19.400,00	€	1.862.400,00
7.01	Voorzieningen tbv plaatsen prefab prefabsecties	96	set	€	7.500,00	€	720.000,00
7.01	Afdichting tussen elementen	95	set	€	10.800,00	€	1.026.000,00
7.02	Secties ondergrouting tbv fixatie en fundatie	40700	m3	€	225,00	€	9.157.500,00
8.01	Aanleg N57 op prefabsegmenten	9120	m2	€	40,00	€	364.800,00
8.01	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€	55,00	€	396.000,00
8.01	Aanleg nieuwe parallelbaan prefabsegmenten	6080	m2	€	40,00	€	243.200,00
8.01	Aanleg nieuwe Par.weg op aarde baan in lijn	4800	m2	€	55,00	€	264.000,00
8.02	Geleiderail/babakening etc	4800	m1	€	75,00	€	360.000,00
8.02	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
8.03	Opbreken omgelegde N57	16800	m2	€	7,50	€	126.000,00
9.01	Baggeren rest dijk incl bekleding en bestorting etc.	1296000	m3	€	2,00	€	2.592.000,00
9.01	Toeslag bekleding en bestorting	259200	m3	€	7,50	€	1.944.000,00
10.01	Slopen caissons in den droge / in den natte	115200	m3	€	40,00	€	4.608.000,00
10.01	Dak storten op caissons ivm stabiliteit en oplegging	14400	m3	€	450,00	€	6.480.000,00
11.01	Leveren buisconstructies siphons staal d=25mm	96	st	€	405.900,00	€	38.966.400,00
11.01	Transport en overslag	8832	ton	€	50,00	€	441.600,00
12.01	Installeren siphons in den natte en connectie aan huis	96	st	€	19.140,00	€	1.837.440,00
12.01	Materiaalkosten tbv fixatie buizen onderling & caisson	96	st	€	22.500,00	€	2.160.000,00
13.01	Leveren en aanbrengen bodembescherming all-in	160000	m2	€	50,00	€	8.000.000,00
13.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
13.03	Complete bouwterrein afwerken / opschonen / herstel	176000	m2	€	2,50	€	440.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	1	%	€	201.980.465,00	€	2.019.804,65
	Subtotaal Directe Kosten					€	*204.000.269,65*
	Nader te detailleren	10	%	€	204.000.269,65	€	20.400.026,97
DK	**Totaal Directe Kosten**					**€**	**224.400.296,62**
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	224.400.296,62	€	8.976.011,86
	Algemene Kosten	7	%	€	233.376.308,48	€	16.336.341,59
	Winst & Risico	3	%	€	233.376.308,48	€	7.001.289,25
IDK	**Totaal Indirecte Kosten**					**€**	**32.313.642,71**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**256.713.939,33**
	Onvoorzien Bouwkosten	15	%	€	256.713.939,33	€	38.507.090,90
	Totaal Budget Stichtingskosten					***€***	***295.222.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	3	%	€	295.222.000,00	€	8.856.660,00
	Adviesskosten OG voor aanbesteding	2	%	€	295.222.000,00	€	5.904.440,00
	Apparaatkosten OG	6	%	€	295.222.000,00	€	17.713.320,00
	Engineeringskosten ON na aanbesteding	0,5	%	€	295.222.000,00	€	1.476.110,00
	Onderzoekskosten OG voor aanbesteding	0,5	%	€	295.222.000,00	€	1.476.110,00
	Heffingen / leges / verzekering	0,4	%	€	295.222.000,00	€	1.180.888,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	295.222.000,00	€	2.952.220,00
	Groencompensatie / natuurtoeslag	0,5	%	€	295.222.000,00	€	1.476.110,00
	Nader te detailleren OBK	10	%	€	41.035.858,00	€	4.103.585,80
	Subtotaal OBK					€	*45.139.443,80*
	Eenmalige Kosten, ABK & Uitvoeringskosten	3	%	€	45.139.443,80	€	1.354.183,31
	Algemene Kosten	7	%	€	45.139.443,80	€	3.159.761,07
	Winst & Risico	3	%	€	45.139.443,80	€	1.354.183,31
	Totaal Voorziene OBK					**€**	**51.007.571,49**
	Onvoorzien OBK	10	%	€	51.007.571,49	€	5.100.757,15
	Totaal Overige Bijkomende Kosten					***€***	***56.109.000,00***
	Overkoepelend Project Onvoorzien	15	%	€	351.331.000,00	€	52.699.650,00
	INVESTERINGSKOSTEN VARIANT 3b					**€**	**404.040.000,00**

Project : INPA140433
Kunstwerk : Getijdecentrale
Locatie : Brouwersdam
Soort : Siphon
Variant 3c : In den droge gebouwd in open ontgraving

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Nieuwe grondkering aanbrengen (koop materialen)	46800	m3	€	25,00	€	1.170.000,00
1.01	Bekleding aanbrengen (waterbouwasfalt)	21600	m2	€	60,00	€	1.296.000,00
2.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	35000	m2	€	8,00	€	280.000,00
2.01	Afvlakken dijklichaam tbv ruimte omlegging N57	49000	m2	€	5,00	€	245.000,00
2.01	Bekleding aanbrengen / herstellen talud	17500	m2	€	55,00	€	962.500,00
2.02	Aanleg tijdelijke N57 over omgelegde dijk	16800	m2	€	50,00	€	840.000,00
2.02	Aanbrengen barriers / wegbebakening	4800	m1	€	45,00	€	216.000,00
2.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
3.01	Ontgraven bouwput in den droge / nat (GW/HW)	873940	m3	€	1,50	€	1.310.910,00
3.01	Afvoer vrijgekomen grond (schoon)	873940	m3	€	4,50	€	3.932.730,00
3.02	Aanbrengen/verwijderen openbemaling	800	m1	€	350,00	€	280.000,00
3.02	Instandhouden/verbruikskosten openbemaling	100	wkn	€	14.700,00	€	1.470.000,00
3.02	Aanbrengen/verwijderen spanningsbemaling	800	m1	€	500,00	€	400.000,00
3.02	Instandhouden/verbruikskosten spanningsbemaling	80	wkn	€	54.700,00	€	4.376.000,00
4.01	Slopen caissons in den droge / in den natte	115200	m3	€	40,00	€	4.608.000,00
4.02	Dak storten op caissons ivm stabiliteit en oplegging	14400	m3	€	450,00	€	6.480.000,00
5.01	Vervaardigen bodembescherming tbv constructie	70200	ton	€	27,50	€	1.930.500,00
5.01	Leveren en aanbrengen doek/matconstructie	17200	m2	€	12,50	€	215.000,00
5.01	Leveren en aanbrengen afstorting beton o.d.	9750	m3	€	150,00	€	1.462.500,00
6.01	Leveren buisconstructies siphons staal d=25mm	96	st	€	618.750,00	€	59.400.000,00
6.01	Transport en overslag	12000	ton	€	50,00	€	600.000,00
6.01	Installeren siphons in bouwkuip	96	st	€	19.880,00	€	1.908.480,00
6.01	Materiaalkosten tbv fixatie buizen onderling & beton	96	st	€	25.000,00	€	2.400.000,00
6.02	Vervaardigen betonwerk in situ in bouwkuip	75500	m3	€	550,00	€	41.525.000,00
7.01	Bak vullen met grond uit depot	164160	m3	€	2,00	€	328.320,00
7.01	Aanleg nieuwe N57 op aarde baan	25920	m2	€	55,00	€	1.425.600,00
7.01	Aanleg nieuwe PW op aarde baan	11040	m2	€	50,00	€	552.000,00
7.01	Geleiderail/babakening etc	4200	m1	€	75,00	€	315.000,00
7.01	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
7.01	Opbreken tijdelijke N57	16800	m2	€	7,50	€	126.000,00
8.01	Baggeren rest dijk incl bekleding en bestorting etc.	1658800	m3	€	2,00	€	3.317.600,00
8.01	Toeslag bekleding en bestorting	331760	m3	€	7,50	€	2.488.200,00
9.01	Leveren en aanbrengen bodembescherming all-in	160000	m2	€	50,00	€	8.000.000,00
9.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
9.03	Complete bouwterrein afwerken / opschonen / herstel	160000	m2	€	2,50	€	400.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	1	%	€	155.961.340,00	€	1.559.613,40
	Subtotaal Directe Kosten					*€*	*157.520.953,40*
	Nader te detailleren	10	%	€	157.520.953,40	€	15.752.095,34
DK	**Totaal Directe Kosten**					**€**	**173.273.048,74**
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	173.273.048,74	€	6.930.921,95
	Algemene Kosten	7	%	€	180.203.970,69	€	12.614.277,95
	Winst & Risico	3	%	€	180.203.970,69	€	5.406.119,12
IDK	**Totaal Indirecte Kosten**					**€**	**24.951.319,02**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**198.224.367,76**
	Onvoorzien Bouwkosten	15	%	€	198.224.367,76	€	29.733.655,16
	Totaal Budget Stichtingskosten					***€***	***227.959.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	3	%	€	227.959.000,00	€	6.838.770,00
	Adviesskosten OG voor aanbesteding	2	%	€	227.959.000,00	€	4.559.180,00
	Apparaatkosten OG	6	%	€	227.959.000,00	€	13.677.540,00
	Engineeringskosten ON na aanbesteding	0,5	%	€	227.959.000,00	€	1.139.795,00
	Onderzoekskosten OG voor aanbesteding	0,5	%	€	227.959.000,00	€	1.139.795,00
	Heffingen / leges / verzekering	0,4	%	€	227.959.000,00	€	911.836,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	227.959.000,00	€	2.279.590,00
	Groencompensatie / natuurtoeslag	0,5	%	€	227.959.000,00	€	1.139.795,00
	Nader te detailleren OBK	10	%	€	31.686.301,00	€	3.168.630,10
	Subtotaal OBK					*€*	*34.854.931,10*
	Eenmalige Kosten, ABK & Uitvoeringskosten	3	%	€	34.854.931,10	€	1.045.647,93
	Algemene Kosten	7	%	€	34.854.931,10	€	2.439.845,18
	Winst & Risico	3	%	€	34.854.931,10	€	1.045.647,93
	Totaal Voorziene OBK					**€**	**39.386.072,14**
	Onvoorzien OBK	10	%	€	39.386.072,14	€	3.938.607,21
	Totaal Overige Bijkomende Kosten					***€***	***43.325.000,00***
	Overkoepelend Project Onvoorzien	15	%	€	271.284.000,00	€	40.692.600,00
	INVESTERINGSKOSTEN VARIANT 3c					**€**	**311.980.000,00**

Onderbouwing investeringskosten

Project : INPA140433
Kunstwerk : Getijdecentrale (incluus nivelleringsstuw)
Locatie : Brouwersdam
Soort : Free Flow
Variant VE : In den droge gebouwd (in situ) conform rapportage 70 units

Post	Omschrijving	Hoeh.heid	eenh.		PPE		Totaal
1.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	20000	m2	€	8,00	€	160.000,00
1.02	Afvlakken dijklichaam tbv ruimte omlegging N57	28000	m2	€	5,00	€	140.000,00
1.03	Bekleding aanbrengen / herstellen talud	10000	m2	€	55,00	€	550.000,00
2.01	Aanleg tijdelijke N57 over omgelegde dijk	9600	m2	€	50,00	€	480.000,00
2.02	Aanbrengen barriers / wegbebakening	2700	m1	€	45,00	€	121.500,00
2.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000,00
3.01	Ontgraven bouwput in den droge / nat (GW/HW)	315400	m3	€	1,50	€	473.100,00
3.01	Afvoer vrijgekomen grond (schoon)	315400	m3	€	4,50	€	1.419.300,00
3.02	Aanbrengen/verwijderen openbemaling	220	m1	€	400,00	€	88.000,00
3.02	Instandhouden/verbruikskosten openbemaling	65	wkn	€	6.700,00	€	435.500,00
3.02	Aanbrengen/verwijderen spanningsbemaling	220	m1	€	550,00	€	121.000,00
3.02	Instandhouden/verbruikskosten spanningsbemaling	52	wkn	€	33.500,00	€	1.742.000,00
4.01	Vervaardigen bodembescherming tbv constructie	38750	ton	€	27,50	€	1.065.625,00
4.01	Leveren en aanbrengen doek/matconstructie	10000	m2	€	25,00	€	250.000,00
4.01	Leveren en aanbrengen afstorting beton o.d.	5650	m3	€	150,00	€	847.500,00
5.01	Vervaardigen in situ vloer van de constructie	24600	m3	€	425,00	€	10.455.000,00
5.01	Vervaardigen wanden van de constructie	25720	m3	€	550,00	€	14.146.000,00
5.01	Vervaardigen dak op doosconstructie	8200	m3	€	475,00	€	3.895.000,00
5.02	Wanden op dak van doosconstructies	3600	m3	€	500,00	€	1.800.000,00
5.02	Afbouw beton insitu van constructies op dak	2000	m3	€	450,00	€	900.000,00
6.01	Leveren en aanbrengen schuiven in de wanden	140	st	€	117.000,00	€	16.380.000,00
7.01	Aanleg N57 op doosconstructie beton	2640	m2	€	50,00	€	132.000,00
7.01	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€	55,00	€	396.000,00
7.01	Aanleg nieuwe parallelbaan op beton	1440	m2	€	50,00	€	72.000,00
7.01	Geleiderail/bebakening etc	880	m1	€	75,00	€	66.000,00
7.02	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000,00
7.03	Opbreken omgelegde N57	9600	m2	€	7,50	€	72.000,00
8.01	Slopen caissons in den droge / in den natte	52800	m3	€	40,00	€	2.112.000,00
8.02	Baggeren rest dijk incl bekleding en bestorting etc.	610000	m3	€	2,00	€	1.220.000,00
8.02	Toeslag bekleding en bestorting	122000	m3	€	7,50	€	915.000,00
9.01	Leveren en aanbrengen bodembescherming all-in	44000	m2	€	50,00	€	2.200.000,00
9.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000,00
9.03	Complete bouwterrein afwerken / opschonen / herstel	500000	m2	€	2,50	€	1.250.000,00
						€	-
						€	-
						€	-
						€	-
	Faseringskosten / Voorzieningen omgeving	2	%	€	65.604.525,00	€	1.312.090,50
	Subtotaal Directe Kosten					€	*66.916.615,50*
	Nader te detailleren	10	%	€	66.916.615,50	€	6.691.661,55
DK	**Totaal Directe Kosten**					**€**	**73.608.277,05**
	Eenmalige Kosten, ABK & Uitvoeringskosten	5	%	€	73.608.277,05	€	3.680.413,85
	Algemene Kosten	8	%	€	77.288.690,90	€	6.183.095,27
	Winst & Risico	3	%	€	77.288.690,90	€	2.318.660,73
IDK	**Totaal Indirecte Kosten**					**€**	**12.182.169,85**
	Totaal Voorziene Kosten (DK + IDK)					**€**	**85.790.446,90**
	Onvoorzien Bouwkosten	12,5	%	€	85.790.446,90	€	10.723.805,86
	Totaal Budget Stichtingskosten					***€***	***96.515.000,00***
	Overige Bijkomende Kosten						
	Engineeringskosten OG voor aanbesteding	4	%	€	96.515.000,00	€	3.860.600,00
	Adviesskosten OG voor aanbesteding	2	%	€	96.515.000,00	€	1.930.300,00
	Apparaatkosten OG	6	%	€	96.515.000,00	€	5.790.900,00
	Engineeringskosten ON na aanbesteding	1	%	€	96.515.000,00	€	965.150,00
	Onderzoekskosten OG voor aanbesteding	1,5	%	€	96.515.000,00	€	1.447.725,00
	Heffingen / leges / verzekering	1	%	€	96.515.000,00	€	965.150,00
	Kabels en leidingen (niet turbine gebonden)	1	%	€	96.515.000,00	€	965.150,00
	Groencompensatie / natuurtoeslag	1	%	€	96.515.000,00	€	965.150,00
	Nader te detailleren OBK	10	%	€	16.890.125,00	€	1.689.012,50
	Subtotaal OBK					€	*18.579.137,50*
	Eenmalige Kosten, ABK & Uitvoeringskosten	4	%	€	18.579.137,50	€	743.165,50
	Algemene Kosten	8	%	€	18.579.137,50	€	1.486.331,00
	Winst & Risico	3	%	€	18.579.137,50	€	557.374,13
	Totaal Voorziene OBK					**€**	**21.366.008,13**
	Onvoorzien OBK	12,5	%	€	21.366.008,13	€	2.670.751,02
	Totaal Overige Bijkomende Kosten					***€***	***24.037.000,00***
	Overkoepelend Project Onvoorzien	12,5	%	€	120.552.000,00	€	15.069.000,00
	INVESTERINGSKOSTEN VARIANT 2c1					**€**	**135.630.000,00**

Colofon

SSK-Rekenmodel, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Project:

Project	**ProTide Project**
Deelproject	Optimalisatie civieltechnische constructie getijdencentrale Browuwersdam
Projectfase	Vooronderzoek
Opdrachtgever	Provincie Zeeland
Projectmanager	J. van Spengen
Projectleider	W. v.d. Wiel

Raming:

Type raming	variantenonderzoek
Datum opstelling raming	05-12-14
Opsteller raming	E. van der Blom
Mede opstellers raming	.
Versie raming	1
Status raming	Definitief
Prijspeil raming	01-11-14

Archivering:

Project-/dossier-/SAP-nummer	INPA140433 / 14013948
Documentnummer raming	var 1d ssk-001
Bestandsnaam raming	SSK raming var 1b 20141205 v1c.xls
Locatie opgeslagen raming	N:\INPA140433 PZ, Getijdencentrale Brouwersdam\05 Werkmap\Ed van der Blom\SSK raminger

Toetsing:

Raming intern getoetst door	.
Datum interne toetsing	.
Raming extern getoetst door	.
Datum externe toetsing	.

Parafering:

Paraaf opsteller raming	Paraaf
Paraaf interne toetser	Paraaf
Paraaf externe toetser	Paraaf
Paraaf projectleider	Paraaf
Paraaf projectmanager	Paraaf

BTW:

☑ Inclusief BTW? — Raming is inclusief BTW

Samenvatting raming

SSK-Rekenmodel, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Kostengroepen / Kostencategorieën	Directe kosten Benoemd	Directe kosten Nader te detailleren	Indirecte kosten	Voorziene kosten	Risicoreservering	Totaal
Investeringskosten (indeling naar categorie):						
Bouwkosten	€ 144.276.759	€ 14.427.676	€ 23.200.049	€ 181.904.484	€ 18.190.448	€ 200.094.932
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten	€ 21.828.538	€ 2.182.854	€ 3.245.452	€ 27.256.844	€ 2.725.684	€ 29.982.528
Overige bijkomende kosten	€ 3.456.185	€ 345.619	€ 513.863	€ 4.315.667	€ 431.567	€ 4.747.234
Subtotaal investeringskosten	**€ 169.561.482**	**€ 16.956.148**	**€ 26.959.364**	**€ 213.476.994**	**€ 21.347.699**	**€ 234.824.694**
Objectoverstijgende risico's				12,5%	€ 29.353.087	€ 29.353.087
Investeringskosten deterministisch	**€ 169.561.482**	**€ 16.956.148**	**€ 26.959.364**	**€ 213.476.994**	**€ 50.700.786**	**€ 264.177.781**
Scheefte					€ -	€ -
Investeringskosten exclusief BTW				**€ 213.476.994**	**€ 50.700.786**	**€ 264.177.781**
BTW				€ 44.162.376	€ 10.488.564	€ 54.650.940
Investeringskosten inclusief BTW				**€ 257.639.371**	**€ 61.189.350**	**€ 318.828.721**
Bandbreedte : met 70% zekerheid liggen de investeringskosten inclusief BTW tussen				€ -	en	€ -
Variatiecoëfficiënt					0%	

Projectkosten inclusief BTW	**€ 257.639.371**	**€ 61.189.350**	**€ 318.828.721**
	81%	19%	100%

Budgetvaststelling investeringskosten:			
Investeringskosten inclusief BTW	€ 257.639.371	€ 61.189.350	€ 318.828.721
Onzekerheidsreserve (in te vullen door financier)		€ -	€ -
Reservering scope wijzigingen (in te vullen door financier)		€ -	€ -
Aan te houden risicoreservering en totaal budget investeringskosten	**€ 257.639.371**	**€ 61.189.350**	**€ 318.828.721**

Deelraming variant 1b ..l, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
	Investeringskosten:					
	Vervaardigen in droogdok en in 3 grote secties afzinken					
1.01	Huurkosten prefablocatie elementen - Bouwdok	58100	m2	€ 50,00	€ 2.905.000	21,00%
1.02	Aanlegkosten water / electra etc.	1	pst	€ 494.000,00	€ 494.000	21,00%
1.02	Verbruikskosten tijdens bouw segmenten	60	wkn	€ 10.000,00	€ 600.000	21,00%
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€ 500.000,00	€ 500.000	21,00%
1.04	Dichten droogdok / volzetten met water	10	dgn	€ 12.500,00	€ 125.000	21,00%
2.01	Vervaardigen van de turbinetunnels in een sectie	124614	m3	€ 450,00	€ 56.076.300	21,00%
2.02	Afdichting tussen elementen	85	set	€ 21.000,00	€ 1.785.000	21,00%
2.03	Aanbrengen voorzieningen tbv drijven secties	86	set	€ 9.950,00	€ 855.700	21,00%
	De 86 bulbs worden in 3 secties van ca. 220m vervaardigd.					
3.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	32000	m2	€ 8,00	€ 256.000	21,00%
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	44800	m2	€ 5,00	€ 224.000	21,00%
3.03	Bekleding aanbrengen / herstellen talud	16250	m2	€ 55,00	€ 893.750	21,00%
4.01	Aanleg tijdelijke N57 over omgelegde dijk	15360	m2	€ 50,00	€ 768.000	21,00%
4.02	Aanbrengen barriers / wegbebakening	4200	m1	€ 45,00	€ 189.000	21,00%
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 250.000,00	€ 500.000	21,00%
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	1248800	m3	€ 1,00	€ 1.248.800	21,00%
5.01	Toeslag bekleding en bestorting	249760	m3	€ 4,25	€ 1.061.480	21,00%
5.01	Afvoer/stortkosten	1860768	ton	€ 1,25	€ 2.325.960	21,00%
6.01	Vervaardigen bodembescherming tbv constructie	44050	ton	€ 27,50	€ 1.211.375	21,00%
6.01	Leveren en aanbrengen doek/matconstructie	27200	m2	€ 25,00	€ 680.000	21,00%
7.01	Aanvoer en plaatsen bulbtunnels op locatie afzinken	6	set	€ 38.700,00	€ 232.200	21,00%
7.01	Voorzieningen tbv plaatsen prefab bulbtunnels	6	set	€ 15.000,00	€ 90.000	21,00%
7.01	Afdichting tussen elementen	5	set	€ 21.000,00	€ 105.000	21,00%
7.01	Secties ondergrouting tbv fixatie en fundatie	24605	m3	€ 225,00	€ 5.536.125	21,00%
8.01	Vervaardigen ruimtes erboven voor schuiven en N57	40570	m3	€ 450,00	€ 18.256.500	21,00%
8.02	Leveren en aanbrengen schuiven in de wanden	86	st	€ 215.500,00	€ 18.533.000	21,00%
8.02	leveren reserve deuren/aandrijving etc.	10	set	€ 215.500,00	€ 2.155.000	21,00%
9.01	Overstek vullen met grond (hergebruik van baggerwerk)	117040	m3	€ 2,50	€ 292.600	21,00%
9.02	Aanleg N57 op turbineruimtes (tussen schuiven)	7980	m2	€ 40,00	€ 319.200	21,00%
9.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€ 55,00	€ 396.000	21,00%
9.02	Aanleg nieuwe parallelbaan op overstek	5320	m2	€ 40,00	€ 212.800	21,00%
9.02	Aanleg nieuwe parallelbaan op aarde baan in lijn	4800	m2	€ 55,00	€ 264.000	21,00%
9.02	Geleiderail/bebakening etc	2800	m1	€ 75,00	€ 210.000	21,00%
9.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 350.000,00	€ 700.000	21,00%
9.03	Aanpassen 2e parallelweg	2	keer	€ 75.000,00	€ 150.000	21,00%
9.04	Opbreken omgelegde N57	15360	m2	€ 7,50	€ 115.200	21,00%

Deelraming variant 1b ...l, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
10.01	Slopen caissons in den droge / in den natte	162000	m3	€ 40,00	€ 6.480.000	21,00%
10.02	Baggeren rest dijk incl bekleding en bestorting etc.	1134000	m3	€ 1,00	€ 1.134.000	21,00%
10.02	Toeslag bekleding en bestorting	226800	m3	€ 4,25	€ 963.900	21,00%
10.02	Afvoer/stortkosten	1859760	ton	€ 1,25	€ 2.324.700	21,00%
11.01	Leveren en aanbrengen bodembescherming all-in	202500	m2	€ 50,00	€ 10.125.000	21,00%
11.02	Uiteinden ontgraving afwerken	4	st	€ 125.000,00	€ 500.000	21,00%
11.03	Complete bouwterrein afwerken / opschonen / herstel	140000	m2	€ 2,50	€ 350.000	21,00%
FK/VO	Faseringskosten / Voorzieningen omgeving	1,50	%	€ 142.144.590,00	€ 2.132.169	21,00%
Code	Post benoemde directe bouwkosten	-	ehd	€ -	€ -	21,00%
Code	Post benoemde directe bouwkosten	-	ehd	€ -	€ -	21,00%
	Benoemde directe bouwkosten				**€ 144.276.759**	21,00%
Code	Nader te detailleren bouwkosten	10,00%	%	€ 144.276.758,85	€ 14.427.676	21,00%
	Directe bouwkosten				**€ 158.704.435**	21,00%
Code	Eenmalige kosten	1,00%	%	€ 158.704.434,74	€ 1.587.044	21,00%
Code	Algemene bouwplaatskosten	1,00%	%	€ 158.704.434,74	€ 1.587.044	21,00%
Code	Uitvoeringskosten	2,00%	%	€ 158.704.434,74	€ 3.174.089	21,00%
Code	Algemene kosten	7,00%	%	€ 165.052.612,12	€ 11.553.683	21,00%
Code	Winst en/of risico	3,00%	%	€ 176.606.294,97	€ 5.298.189	21,00%
Code	Bijdrage RAW	0,00%	%	€ 181.904.483,82	€ -	0,00%
Code	Bijdrage FCO	0,00%	%	€ 181.904.483,82	€ -	0,00%
	Indirecte bouwkosten	*14,62%*			**€ 23.200.049**	21,00%
	Voorziene bouwkosten				**€ 181.904.484**	**21,00%**
Code	Niet benoemd objectrisico bouwkosten	10,00%	%	€ 181.904.483,82	€ 18.190.448	21,00%
	Risico's bouwkosten	*10,00%*			**€ 18.190.448**	**21,00%**
BK01	**Bouwkosten deelraming variant 1b**				**€ 200.094.932**	**21,00%**

Deelraming variant 1b — ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs		Totaal		BTW %
Code	Post benoemde directe vastgoedkosten	-	ehd	€	-	€	-	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€	-	€	-	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€	-	€	-	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€	-	€	-	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€	-	€	-	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€	-	€	-	0,00%
	Benoemde directe vastgoedkosten					**€**	**-**	0,00%
Code	Nader te detailleren vastgoedkosten	0,00%	%	€	-	€	-	0,00%
	Directe vastgoedkosten					**€**	**-**	0,00%
Code	Eenmalige vastgoedkosten	0,00%	%	€	-	€	-	0,00%
Code	Algemene kosten	0,00%	%	€	-	€	-	0,00%
Code	Winst en/of risico	0,00%	%	€	-	€	-	0,00%
	Indirecte vastgoedkosten	*0,00%*				**€**	**-**	0,00%
	Voorziene vastgoedkosten					**€**	**-**	**0,00%**
Code	Niet benoemd objectrisico vastgoedkosten	0,00%	%	€	-	€	-	0,00%
	Risico's vastgoedkosten	*0,00%*				**€**	**-**	**0,00%**
VK01	**Vastgoedkosten deelraming variant 1b**					**€**	**-**	**0,00%**

Deelraming variant 1b ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs		Totaal	BTW %
Code	Engineeringskosten OG voor aanbesteding	3,00%	%	€ 181.904.483,82	€	5.457.135	21,00%
Code	Adviesskosten OG voor aanbesteding	2,00%	%	€ 181.904.483,82	€	3.638.090	21,00%
Code	Apparaatkosten OG	6,00%	%	€ 181.904.483,82	€	10.914.269	21,00%
Code	Engineeringskosten ON na aanbesteding	0,50%	%	€ 181.904.483,82	€	909.522	21,00%
Code	Onderzoekskosten OG voor aanbesteding	0,50%	%	€ 181.904.483,82	€	909.522	21,00%
Code	Post benoemde directe engineeringskosten	-	ehd	€ -	€	-	21,00%
	Benoemde directe engineeringskosten				**€**	**21.828.538**	21,00%
Code	Nader te detailleren engineeringskosten	10,00%	%	€ 21.828.538,06	€	2.182.854	21,00%
	Directe engineeringskosten				**€**	**24.011.392**	21,00%
Code	Eenmalige engineeringskosten	3,00%	%	€ 24.011.391,86	€	720.342	21,00%
Code	Algemene kosten	7,00%	%	€ 24.731.733,62	€	1.731.221	21,00%
Code	Winst en/of risico	3,00%	%	€ 26.462.954,97	€	793.889	21,00%
	Indirecte engineeringskosten	13,52%			**€**	**3.245.452**	21,00%
	Voorziene engineeringskosten				**€**	**27.256.844**	**21,00%**
Code	Niet benoemd objectrisico engineeringskosten	10,00%	%	€ 27.256.843,62	€	2.725.684	21,00%
	Risico's engineeringskosten	10,00%			**€**	**2.725.684**	**21,00%**
EK01	**Engineeringskosten deelraming variant 1b**				**€**	**29.982.528**	**21,00%**

Deelraming variant 1b

ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
Code	Heffingen en leges vergunningen, verzekeringen % over de bouwkosten	0,40%	%	€ 181.904.483,82	€ 727.618	0,00%
Code	Kabels en leidingen (niet turbine gebonden)	1,00%	%	€ 181.904.483,82	€ 1.819.045	0,00%
Code	Groencompensatie / natuurteslag	0,50%	%	€ 181.904.483,82	€ 909.522	21,00%
Code	Post benoemde directe overige bijkomende kosten	-	ehd	€ -	€ -	21,00%
	Benoemde directe overige bijkomende kosten				**€ 3.456.185**	5,53%
Code	Nader te detailleren overige bijkomende kosten	10,00%	%	€ 3.456.185,19	€ 345.619	5,53%
	Directe overige bijkomende kosten				**€ 3.801.804**	5,53%
Code	Eenmalige overige bijkomende kosten	3,00%	%	€ 3.801.803,71	€ 114.054	5,53%
Code	Algemene kosten	7,00%	%	€ 3.915.857,82	€ 274.110	5,53%
Code	Winst en/of risico	3,00%	%	€ 4.189.967,87	€ 125.699	5,53%
	Indirecte overige bijkomende kosten	13,52%			**€ 513.863**	5,53%
	Voorziene overige bijkomende kosten				**€ 4.315.667**	**5,53%**
Code	Niet benoemd objectrisico overige bijkomende kosten	10,00%	%	€ 4.315.666,91	€ 431.567	5,53%
	Risico's overige bijkomende kosten	10,00%			**€ 431.567**	**5,53%**
OBK01	**Overige bijkomende kosten deelraming variant 1b**				**€ 4.747.234**	**5,53%**
INV01	**Investeringskosten deelraming variant 1b**				**€ 234.824.694**	**20,69%**

Colofon

SSK-Rekenmodel, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Project:

Project	**ProTide Project**
Deelproject	Optimalisatie civieltechnische constructie getijdencentrale Browuwersdam
Projectfase	Vooronderzoek
Opdrachtgever	Provincie Zeeland
Projectmanager	J. van Spengen
Projectleider	W. v.d. Wiel

Raming:

Type raming	variantenonderzoek
Datum opstelling raming	05-12-14
Opsteller raming	E. van der Blom
Mede opstellers raming	.
Versie raming	1
Status raming	Definitief
Prijspeil raming	01-11-14

Archivering:

Project-/dossier-/SAP-nummer	INPA140433 / 14013948
Documentnummer raming	var 2c2 ssk-002
Bestandsnaam raming	SSK raming var 2c2 20141205 v1c.xls
Locatie opgeslagen raming	N:\INPA140433 PZ, Getijdencentrale Brouwersdam\05 Werkmap\Ed van der Blom\SSK raminger

Toetsing:

Raming intern getoetst door	.
Datum interne toetsing	.
Raming extern getoetst door	.
Datum externe toetsing	.

Parafering:

Paraaf opsteller raming	Paraaf
Paraaf interne toetser	Paraaf
Paraaf externe toetser	Paraaf
Paraaf projectleider	Paraaf
Paraaf projectmanager	Paraaf

BTW:

☑ Inclusief BTW? Raming is inclusief BTW

Samenvatting raming

SSK-Rekenmodel, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Kostengroepen / *Kostencategorieën*	*Directe kosten Benoemd*	*Directe kosten Nader te detailleren*	*Indirecte kosten*	*Voorziene kosten*	*Risicoreservering*	*Totaal*
Investeringskosten (indeling naar categorie):						
Bouwkosten	€ 31.158.286	€ 3.115.829	€ 5.758.737	€ 40.032.852	€ 5.004.106	€ 45.036.958
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten	€ 5.804.763	€ 580.476	€ 1.001.819	€ 7.387.058	€ 923.382	€ 8.310.441
Overige bijkomende kosten	€ 1.200.986	€ 120.099	€ 207.273	€ 1.528.357	€ 191.045	€ 1.719.402
Subtotaal investeringskosten	**€ 38.164.035**	**€ 3.816.404**	**€ 6.967.828**	**€ 48.948.267**	**€ 6.118.533**	**€ 55.066.800**
Objectoverstijgende risico's				12,5%	€ 6.883.350	€ 6.883.350
Investeringskosten deterministisch	**€ 38.164.035**	**€ 3.816.404**	**€ 6.967.828**	**€ 48.948.267**	**€ 13.001.883**	**€ 61.950.150**
Scheefte					€ -	€ -
Investeringskosten exclusief BTW				**€ 48.948.267**	**€ 13.001.883**	**€ 61.950.150**
BTW				€ 10.065.166	€ 2.673.560	€ 12.738.726
Investeringskosten inclusief BTW				**€ 59.013.433**	**€ 15.675.443**	**€ 74.688.876**
Bandbreedte : met 70% zekerheid liggen de investeringskosten inclusief BTW tussen				€ -	*en*	€ -
Variatiecoëfficiënt					*0%*	

Projectkosten inclusief BTW	**€ 59.013.433**	**€ 15.675.443**	**€ 74.688.876**
	79%	*21%*	*100%*

Budgetvaststelling investeringskosten:			
Investeringskosten inclusief BTW	€ 59.013.433	€ 15.675.443	€ 74.688.876
Onzekerheidsreserve (in te vullen door financier)		€ -	€ -
Reservering scope wijzigingen (in te vullen door financier)		€ -	€ -
Aan te houden risicoreservering en totaal budget investeringskosten	**€ 59.013.433**	**€ 15.675.443**	**€ 74.688.876**

Deelraming Variant 2c2 ı, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs		Totaal		BTW %
	Investeringskosten:							
	Vervaardigen in droogdok en in 1 grote secties afzinken							
1.01	Huurkosten prefablocatie elementen - Bouwdok	15600	m2	€	60,00	€	936.000	21,00%
1.02	Aanlegkosten water / electra etc.	1	pst	€	195.000,00	€	195.000	21,00%
1.02	Verbruikskosten tijdens bouw segmenten	50	wkn	€	5.000,00	€	250.000	21,00%
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€	150.000,00	€	150.000	21,00%
1.04	Dichten droogdok / volzetten met water	5	dgn	€	12.500,00	€	62.500	21,00%
2.01	Vervaardigen in situ vloer van de Doos	8160	m3	€	425,00	€	3.468.000	21,00%
2.01	Vervaardigen wanden van de doosconstructie	3840	m3	€	550,00	€	2.112.000	21,00%
2.01	Vervaardigen dak op doosconstructie	6120	m3	€	475,00	€	2.907.000	21,00%
2.03	Aanbrengen voorzieningen tbv drijven secties	1	set	€	50.000,00	€	50.000	21,00%
3.01	Opbreken N57 + parweg tbv werkzaamheden	19000	m2	€	8,00	€	152.000	21,00%
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	26600	m2	€	5,00	€	133.000	21,00%
3.03	Bekleding aanbrengen / herstellen talud	9500	m2	€	55,00	€	522.500	21,00%
4.01	Aanleg tijdelijke N57 over omgelegde dijk	9120	m2	€	50,00	€	456.000	21,00%
4.02	Aanbrengen barriers / wegbebakening	2400	m1	€	45,00	€	108.000	21,00%
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€	250.000,00	€	500.000	21,00%
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	299900	m3	€	1,00	€	299.900	21,00%
5.01	Toeslag bekleding en bestorting	59980	m3	€	4,25	€	254.915	21,00%
5.01	Afvoer/stortkosten	464418,4	ton	€	1,25	€	580.523	21,00%
6.01	Vervaardigen bodembescherming tbv constructie	11000	ton	€	27,50	€	302.500	21,00%
6.01	Leveren en aanbrengen doek/matconstructie	6700	m2	€	25,00	€	167.500	21,00%
7.01	Aanvoer en plaatsen doosconstr. op locatie afzinken	1	set	€	31.950,00	€	31.950	21,00%
7.01	Voorzieningen tbv plaatsen prefab doosconstr.	1	set	€	20.000,00	€	20.000	21,00%
7.01	Secties ondergrouting tbv fixatie en fundatie	4200	m3	€	250,00	€	1.050.000	21,00%
8.01	Wanden op dak van doosconstructies	5505	m3	€	500,00	€	2.752.500	21,00%
8.01	Afbouw beton insitu van constructies op dak	1700	m3	€	450,00	€	765.000	21,00%
8.02	Leveren en aanbrengen schuiven in de wanden	15	st	€	345.500,00	€	5.182.500	21,00%
9.01	Dakconstructie vullen met grond	17136	m3	€	2,50	€	42.840	21,00%
9.02	Aanleg N57 op grond op doosconstrucite	1680	m2	€	55,00	€	92.400	21,00%
9.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€	55,00	€	396.000	21,00%
9.02	Aanleg nieuwe parallelbaan op aanvulling doos	1120	m2	€	55,00	€	61.600	21,00%
9.02	Aanleg nieuwe parallelbaan op aarde baan in lijn	4800	m2	€	55,00	€	264.000	21,00%
9.02	Geleiderail/babakening etc	800	m1	€	75,00	€	60.000	21,00%
9.03	Aanpassen / vervaardigen kruispunten	2	keer	€	350.000,00	€	700.000	21,00%
9.03	Aanpassen 2e parallelweg	2	keer	€	75.000,00	€	150.000	21,00%
9.04	Opbreken omgelegde N57	9120	m2	€	7,50	€	68.400	21,00%
10.01	Slopen caissons in den droge / in den natte	33600	m3	€	40,00	€	1.344.000	21,00%

Deelraming Variant 2c2 ›l, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
10.02	Baggeren rest dijk incl bekleding en bestorting etc.	282000	m3	€ 1,00	€ 282.000	21,00%
10.02	Toeslag bekleding en bestorting	56400	m3	€ 4,25	€ 239.700	21,00%
10.02	Afvoer/stortkosten	462480	ton	€ 1,25	€ 578.100	21,00%
11.01	Leveren en aanbrengen bodembescherming all-in	42000	m2	€ 50,00	€ 2.100.000	21,00%
11.02	Uiteinden ontgraving afwerken	4	st	€ 125.000,00	€ 500.000	21,00%
11.03	Complete bouwterrein afwerken / opschonen / herstel	44000	m2	€ 2,50	€ 110.000	21,00%
FK/VO	Faseringskosten / Voorzieningen omgeving	2,50	%	€ 30.398.328,00	€ 759.958	21,00%
Code	Post benoemde directe bouwkosten	-	ehd	€ -	€ -	21,00%
Code	Post benoemde directe bouwkosten	-	ehd	€ -	€ -	21,00%
	Benoemde directe bouwkosten				**€ 31.158.286**	21,00%
Code	Nader te detailleren bouwkosten	10,00%	%	€ 31.158.286,20	€ 3.115.829	21,00%
	Directe bouwkosten				**€ 34.274.115**	21,00%
Code	Eenmalige kosten	1,00%	%	€ 34.274.114,82	€ 342.741	21,00%
Code	Algemene bouwplaatskosten	2,00%	%	€ 34.274.114,82	€ 685.482	21,00%
Code	Uitvoeringskosten	2,00%	%	€ 34.274.114,82	€ 685.482	21,00%
Code	Algemene kosten	8,00%	%	€ 35.987.820,56	€ 2.879.026	21,00%
Code	Winst en/of risico	3,00%	%	€ 38.866.846,21	€ 1.166.005	21,00%
Code	Bijdrage RAW	0,00%	%	€ 40.032.851,59	€ -	0,00%
Code	Bijdrage FCO	0,00%	%	€ 40.032.851,59	€ -	0,00%
	Indirecte bouwkosten	16,80%			**€ 5.758.737**	21,00%
	Voorziene bouwkosten				**€ 40.032.852**	**21,00%**
Code	Niet benoemd objectrisico bouwkosten	12,50%	%	€ 40.032.851,59	€ 5.004.106	21,00%
	Risico's bouwkosten	12,50%			**€ 5.004.106**	**21,00%**
BK01	**Bouwkosten deelraming variant 2c2**				**€ 45.036.958**	**21,00%**

Deelraming Variant 2c2 ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
	Benoemde directe vastgoedkosten				**€ -**	0,00%
Code	Nader te detailleren vastgoedkosten	0,00%	%	€ -	€ -	0,00%
	Directe vastgoedkosten				**€ -**	0,00%
Code	Eenmalige vastgoedkosten	0,00%	%	€ -	€ -	0,00%
Code	Algemene kosten	0,00%	%	€ -	€ -	0,00%
Code	Winst en/of risico	0,00%	%	€ -	€ -	0,00%
	Indirecte vastgoedkosten	*0,00%*			**€ -**	0,00%
	Voorziene vastgoedkosten				**€ -**	**0,00%**
Code	Niet benoemd objectrisico vastgoedkosten	0,00%	%	€ -	€ -	0,00%
	Risico's vastgoedkosten	*0,00%*			**€ -**	**0,00%**
VK01	**Vastgoedkosten deelraming variant 2c2**				**€ -**	**0,00%**

Deelraming Variant 2c2 ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
Code	Engineeringskosten OG voor aanbesteding	4,00%	%	€ 40.032.851,59	€ 1.601.314	21,00%
Code	Adviesskosten OG voor aanbesteding	2,00%	%	€ 40.032.851,59	€ 800.657	21,00%
Code	Apparaatkosten OG	6,00%	%	€ 40.032.851,59	€ 2.401.971	21,00%
Code	Engineeringskosten ON na aanbesteding	1,00%	%	€ 40.032.851,59	€ 400.329	21,00%
Code	Onderzoekskosten OG voor aanbesteding	1,50%	%	€ 40.032.851,59	€ 600.493	21,00%
Code	Post benoemde directe engineeringskosten	-	ehd	€ -	€ -	21,00%
	Benoemde directe engineeringskosten				**€ 5.804.763**	21,00%
Code	Nader te detailleren engineeringskosten	10,00%	%	€ 5.804.763,48	€ 580.476	21,00%
	Directe engineeringskosten				**€ 6.385.240**	21,00%
Code	Eenmalige engineeringskosten	4,00%	%	€ 6.385.239,83	€ 255.410	21,00%
Code	Algemene kosten	8,00%	%	€ 6.640.649,42	€ 531.252	21,00%
Code	Winst en/of risico	3,00%	%	€ 7.171.901,38	€ 215.157	21,00%
	Indirecte engineeringskosten	*15,69%*			**€ 1.001.819**	21,00%
	Voorziene engineeringskosten				**€ 7.387.058**	**21,00%**
Code	Niet benoemd objectrisico engineeringskosten	12,50%	%	€ 7.387.058,42	€ 923.382	21,00%
	Risico's engineeringskosten	*12,50%*			**€ 923.382**	**21,00%**
EK01	**Engineeringskosten deelraming variant 2c2**				**€ 8.310.441**	**21,00%**

Deelraming Variant 2c2 ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
Code	Heffingen en leges vergunningen, verzekeringen % over de bouwkosten	1,00%	%	€ 40.032.851,59	€ 400.329	0,00%
Code	Kabels en leidingen (niet turbine gebonden)	1,00%	%	€ 40.032.851,59	€ 400.329	0,00%
Code	Groencompensatie / natuurteslag	1,00%	%	€ 40.032.851,59	€ 400.329	21,00%
Code	Post benoemde directe overige bijkomende kosten	-	ehd	€ -	€ -	21,00%
	Benoemde directe overige bijkomende kosten				**€ 1.200.986**	7,00%
Code	Nader te detailleren overige bijkomende kosten	10,00%	%	€ 1.200.985,55	€ 120.099	7,00%
	Directe overige bijkomende kosten				**€ 1.321.084**	7,00%
Code	Eenmalige overige bijkomende kosten	4,00%	%	€ 1.321.084,10	€ 52.843	7,00%
Code	Algemene kosten	8,00%	%	€ 1.373.927,47	€ 109.914	7,00%
Code	Winst en/of risico	3,00%	%	€ 1.483.841,66	€ 44.515	7,00%
	Indirecte overige bijkomende kosten	15,69%			**€ 207.273**	7,00%
	Voorziene overige bijkomende kosten				**€ 1.528.357**	**7,00%**
Code	Niet benoemd objectrisico overige bijkomende kosten	12,50%	%	€ 1.528.356,91	€ 191.045	7,00%
	Risico's overige bijkomende kosten	12,50%			**€ 191.045**	**7,00%**
OBK01	**Overige bijkomende kosten deelraming variant 2c2**				**€ 1.719.402**	**7,00%**
INV01	**Investeringskosten deelraming variant 2c2**				**€ 55.066.800**	**20,56%**

Colofon

SSK-Rekenmodel, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Project:

Project	**ProTide Project**
Deelproject	Optimalisatie civieltechnische constructie getijdencentrale Browuwersdam
Projectfase	Vooronderzoek
Opdrachtgever	Provincie Zeeland
Projectmanager	J. van Spengen
Projectleider	W. v.d. Wiel

Raming:

Type raming	variantenonderzoek
Datum opstelling raming	05-12-14
Opsteller raming	E. van der Blom
Mede opstellers raming	.
Versie raming	1
Status raming	Definitief
Prijspeil raming	01-11-14

Archivering:

Project-/dossier-/SAP-nummer	INPA140433 / 14013948
Documentnummer raming	var 3d ssk-003
Bestandsnaam raming	SSK raming var 3d 20141205 v1c.xls
Locatie opgeslagen raming	N:\INPA140433 PZ, Getijdencentrale Brouwersdam\05 Werkmap\Ed van der Blom\SSK raminger

Toetsing:

Raming intern getoetst door	.
Datum interne toetsing	.
Raming extern getoetst door	.
Datum externe toetsing	.

Parafering:

Paraaf opsteller raming	Paraaf
Paraaf interne toetser	Paraaf
Paraaf externe toetser	Paraaf
Paraaf projectleider	Paraaf
Paraaf projectmanager	Paraaf

BTW:

☑ Inclusief BTW? Raming is inclusief BTW

Project: ProTide Project - Projectnr: INPA140433 / 14013948 - Opdr.gever: Provincie Zeeland | Prijspeil raming: 01-11-14
Versie raming: 1 - Status: Definitief - Opgesteld door: E. van der Blom | Datum raming: 05-12-14

Samenvatting raming

SSK-Rekenmodel, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Kostengroepen / Kostencategorieën	Directe kosten Benoemd	Directe kosten Nader te detailleren	Indirecte kosten	Voorziene kosten	Risicoreservering	Totaal
Investeringskosten (indeling naar categorie):						
Bouwkosten	€ 58.230.190	€ 5.823.019	€ 10.762.220	€ 74.815.429	€ 9.351.929	€ 84.167.357
Vastgoedkosten	€ -	€ -	€ -	€ -	€ -	€ -
Engineeringskosten	€ 10.848.237	€ 1.084.824	€ 1.872.250	€ 13.805.310	€ 1.725.664	€ 15.530.974
Overige bijkomende kosten	€ 2.244.463	€ 224.446	€ 387.362	€ 2.856.271	€ 357.034	€ 3.213.305
Subtotaal investeringskosten	**€ 71.322.890**	**€ 7.132.289**	**€ 13.021.832**	**€ 91.477.010**	**€ 11.434.626**	**€ 102.911.637**
Objectoverstijgende risico's				12,5%	€ 12.863.955	€ 12.863.955
Investeringskosten deterministisch	**€ 71.322.890**	**€ 7.132.289**	**€ 13.021.832**	**€ 91.477.010**	**€ 24.298.581**	**€ 115.775.591**
Scheefte					€ -	€ -
Investeringskosten exclusief BTW				**€ 91.477.010**	**€ 24.298.581**	**€ 115.775.591**
BTW				€ 17.770.652	€ 4.720.329	€ 22.490.982
Investeringskosten inclusief BTW				**€ 109.247.663**	**€ 29.018.910**	**€ 138.266.573**
Bandbreedte : met 70% zekerheid liggen de investeringskosten inclusief BTW tussen				€ -	en	€ -
Variatiecoëfficiënt					0%	
Projectkosten inclusief BTW				**€ 109.247.663**	**€ 29.018.910**	**€ 138.266.573**
				79%	21%	100%
Budgetvaststelling investeringskosten:						
Investeringskosten inclusief BTW				€ 109.247.663	€ 29.018.910	€ 138.266.573
Onzekerheidsreserve (in te vullen door financier)					€ -	€ -
Reservering scope wijzigingen (in te vullen door financier)					€ -	€ -
Aan te houden risicoreservering en totaal budget investeringskosten				**€ 109.247.663**	**€ 29.018.910**	**€ 138.266.573**

Deelraming Variant 3d ›l, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
	Investeringskosten:					
	Vervaardigen 4 secties en dan afzinken					
1.01	Huurkosten prefablocatie elementen - Bouwdok	21600	m2	€ 60,00	€ 1.296.000	21,00%
1.02	Aanlegkosten water / electra etc.	1	pst	€ 270.000,00	€ 270.000	21,00%
1.02	Verbruikskosten tijdens bouw segmenten	50	wkn	€ 6.000,00	€ 300.000	21,00%
1.03	Inrichten terrein tbv droog/nat zetten etc	1	pst	€ 150.000,00	€ 150.000	21,00%
1.04	Dichten droogdok / volzetten met water	6	dgn	€ 12.500,00	€ 75.000	21,00%
2.01	Vervaardigen in situ vloer van de constructie	7200	m3	€ 425,00	€ 3.060.000	21,00%
2.01	Vervaardigen wanden van de constructie	19780	m3	€ 550,00	€ 10.879.000	21,00%
2.01	Vervaardigen dak op doosconstructie	7200	m3	€ 475,00	€ 3.420.000	21,00%
2.02	Betonwerk 8 turbinebakken onder doosconstructie	8112	m3	€ 475,00	€ 3.853.200	21,00%
3.01	Opbreken N57 + parweg tbv bouwkuip en toeritten	20000	m2	€ 8,00	€ 160.000	21,00%
3.02	Afvlakken dijklichaam tbv ruimte omlegging N57	28000	m2	€ 5,00	€ 140.000	21,00%
3.03	Bekleding aanbrengen / herstellen talud	10000	m2	€ 55,00	€ 550.000	21,00%
4.01	Aanleg tijdelijke N57 over omgelegde dijk	9600	m2	€ 50,00	€ 480.000	21,00%
4.02	Aanbrengen barriers / wegbebakening	2700	m1	€ 45,00	€ 121.500	21,00%
4.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 250.000,00	€ 500.000	21,00%
5.01	Baggeren dijk grevelingen zijde incl bekleding etc.	401800	m3	€ 1,00	€ 401.800	21,00%
5.01	Toeslag bekleding en bestorting	80360	m3	€ 4,25	€ 341.530	21,00%
5.01	Afvoer/stortkosten	588232	ton	€ 1,25	€ 735.290	21,00%
6.01	Vervaardigen bodembescherming tbv constructie	38750	ton	€ 27,50	€ 1.065.625	21,00%
6.01	Leveren en aanbrengen doek/matconstructie	10000	m2	€ 25,00	€ 250.000	21,00%
7.01	Aanvoer en plaatsen doosconstr. op locatie afzinken	4	set	€ 21.300,00	€ 85.200	21,00%
7.01	Voorzieningen tbv plaatsen prefab doosconstr.	4	set	€ 12.500,00	€ 50.000	21,00%
7.01	Secties ondergrouting tbv fixatie en fundatie	8000	m3	€ 250,00	€ 2.000.000	21,00%
8.01	Wanden op dak van doosconstructies	10800	m3	€ 500,00	€ 5.400.000	21,00%
8.01	Afbouw beton insitu van constructies op dak	2000	m3	€ 450,00	€ 900.000	21,00%
8.02	Leveren en aanbrengen schuiven in de wanden	80	st	€ 117.000,00	€ 9.360.000	21,00%
9.01	Dakconstructie vullen met grond	44200	m3	€ 2,50	€ 110.500	21,00%
9.02	Aanleg N57 op grond op doosconstrucite	2400	m2	€ 55,00	€ 132.000	21,00%
9.02	Aanleg nieuwe N57 op aarde baan in lijn	7200	m2	€ 55,00	€ 396.000	21,00%
9.02	Aanleg nieuwe parallelbaan op aanvulling doosconstructie	1600	m2	€ 55,00	€ 88.000	21,00%
9.02	Aanleg nieuwe parallelbaan op aarde baan in lijn	4800	m2	€ 55,00	€ 264.000	21,00%
9.02	Geleiderail/babakening etc	960	m1	€ 75,00	€ 72.000	21,00%
9.03	Aanpassen / vervaardigen kruispunten	2	keer	€ 350.000,00	€ 700.000	21,00%
9.03	Aanpassen 2e parallelweg	2	keer	€ 75.000,00	€ 150.000	21,00%
9.04	Opbreken omgelegde N57	9600	m2	€ 7,50	€ 72.000	21,00%
10.01	Slopen caissons in den droge / in den natte	52800	m3	€ 40,00	€ 2.112.000	21,00%

Deelraming Variant 3d

ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs		Totaal		BTW %
10.02	Baggeren rest dijk incl bekleding en bestorting etc.	610000	m3	€	1,00	€	610.000	21,00%
10.02	Toeslag bekleding en bestorting	122000	m3	€	4,25	€	518.500	21,00%
10.02	Afvoer/stortkosten	1000400	ton	€	1,25	€	1.250.500	21,00%
11.01	Leveren en aanbrengen bodembescherming all-in	66000	m2	€	50,00	€	3.300.000	21,00%
11.02	Uiteinden ontgraving afwerken	4	st	€	125.000,00	€	500.000	21,00%
11.03	Complete bouwterrein afwerken / opschonen / herstel	500000	m2	€	2,50	€	1.250.000	21,00%
FK/VO	Faseringskosten / Voorzieningen omgeving	2,00	%	€	57.369.645,00	€	860.545	21,00%
Code	Post benoemde directe bouwkosten	-	ehd	€	-	€	-	21,00%
Code	Post benoemde directe bouwkosten	-	ehd	€	-	€	-	21,00%
	Benoemde directe bouwkosten					**€**	**58.230.190**	19,61%
Code	Nader te detailleren bouwkosten	10,00%	%	€	58.230.189,68	€	5.823.019	19,61%
	Directe bouwkosten					**€**	**64.053.209**	19,61%
Code	Eenmalige kosten	1,00%	%	€	64.053.208,64	€	640.532	19,61%
Code	Algemene bouwplaatskosten	2,00%	%	€	64.053.208,64	€	1.281.064	19,61%
Code	Uitvoeringskosten	2,00%	%	€	64.053.208,64	€	1.281.064	19,61%
Code	Algemene kosten	8,00%	%	€	67.255.869,07	€	5.380.470	19,61%
Code	Winst en/of risico	3,00%	%	€	72.636.338,60	€	2.179.090	19,61%
Code	Bijdrage RAW	0,00%	%	€	74.815.428,76	€	-	0,00%
Code	Bijdrage FCO	0,00%	%	€	74.815.428,76	€	-	0,00%
	Indirecte bouwkosten	*16,80%*				**€**	**10.762.220**	19,61%
	Voorziene bouwkosten					**€**	**74.815.429**	**19,61%**
Code	Niet benoemd objectrisico bouwkosten	12,50%	%	€	74.815.428,76	€	9.351.929	19,61%
	Risico's bouwkosten	*12,50%*				**€**	**9.351.929**	**19,61%**
BK01	**Bouwkosten deelraming variant 3d**					**€**	**84.167.357**	**19,61%**

Deelraming Variant 3d ɪl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs	Totaal	BTW %
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
Code	Post benoemde directe vastgoedkosten	-	ehd	€ -	€ -	0,00%
	Benoemde directe vastgoedkosten				**€ -**	0,00%
Code	Nader te detailleren vastgoedkosten	0,00%	%	€ -	€ -	0,00%
	Directe vastgoedkosten				**€ -**	0,00%
Code	Eenmalige vastgoedkosten	0,00%	%	€ -	€ -	0,00%
Code	Algemene kosten	0,00%	%	€ -	€ -	0,00%
Code	Winst en/of risico	0,00%	%	€ -	€ -	0,00%
	Indirecte vastgoedkosten	0,00%			**€ -**	0,00%
	Voorziene vastgoedkosten				**€ -**	**0,00%**
Code	Niet benoemd objectrisico vastgoedkosten	0,00%	%	€ -	€ -	0,00%
	Risico's vastgoedkosten	0,00%			**€ -**	**0,00%**
VK01	**Vastgoedkosten deelraming variant 3d**				**€ -**	**0,00%**

Deelraming Variant 3d

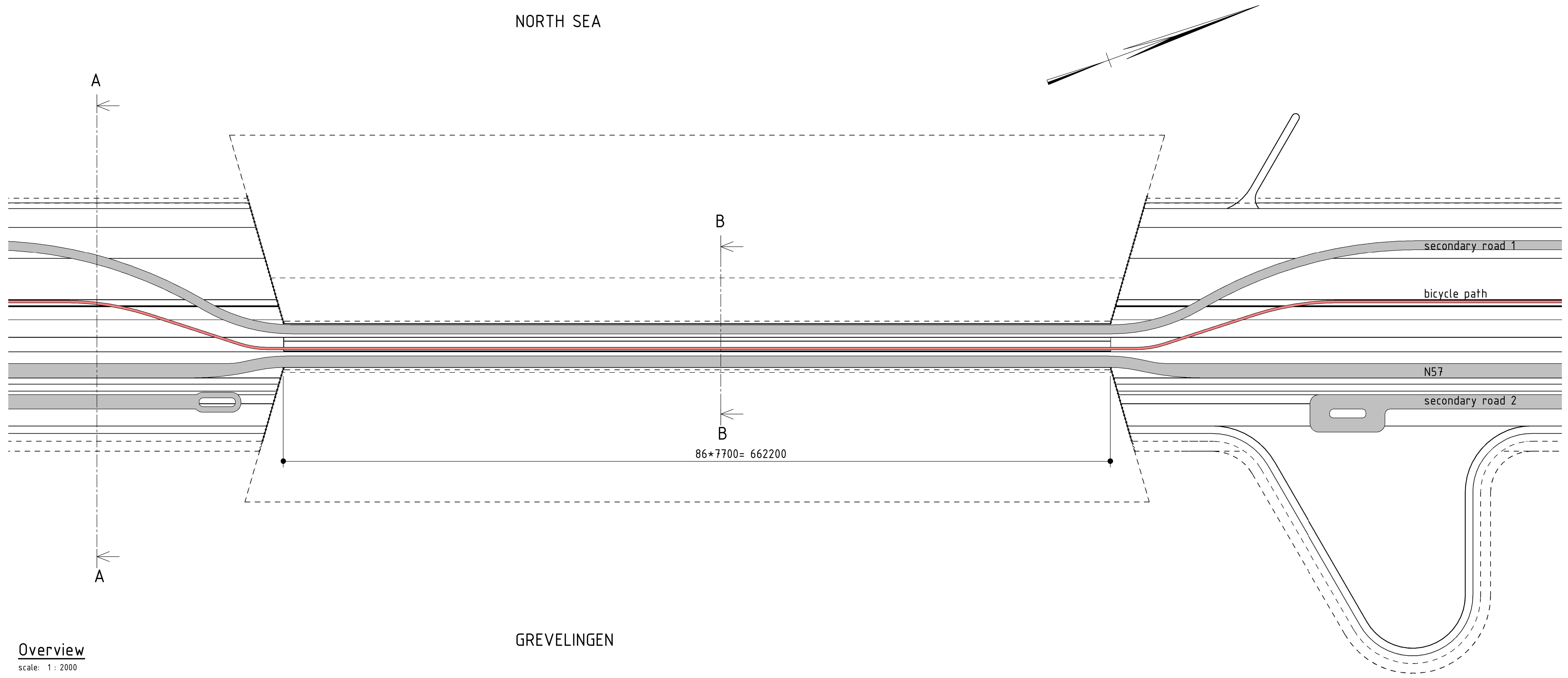
ıl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs		Totaal		BTW %
Code	Engineeringskosten OG voor aanbesteding	4,00%	%	€	74.815.428,76	€	2.992.617	21,00%
Code	Adviesskosten OG voor aanbesteding	2,00%	%	€	74.815.428,76	€	1.496.309	21,00%
Code	Apparaatkosten OG	6,00%	%	€	74.815.428,76	€	4.488.926	21,00%
Code	Engineeringskosten ON na aanbesteding	1,00%	%	€	74.815.428,76	€	748.154	21,00%
Code	Onderzoekskosten OG voor aanbesteding	1,50%	%	€	74.815.428,76	€	1.122.231	21,00%
Code	Post benoemde directe engineeringskosten	-	ehd	€	-	€	-	21,00%
	Benoemde directe engineeringskosten					**€**	**10.848.237**	21,00%
Code	Nader te detailleren engineeringskosten	10,00%	%	€	10.848.237,17	€	1.084.824	21,00%
	Directe engineeringskosten					**€**	**11.933.061**	21,00%
Code	Eenmalige engineeringskosten	4,00%	%	€	11.933.060,89	€	477.322	21,00%
Code	Algemene kosten	8,00%	%	€	12.410.383,32	€	992.831	21,00%
Code	Winst en/of risico	3,00%	%	€	13.403.213,99	€	402.096	21,00%
	Indirecte engineeringskosten	*15,69%*				**€**	**1.872.250**	21,00%
	Voorziene engineeringskosten					**€**	**13.805.310**	**21,00%**
Code	Niet benoemd objectrisico engineeringskosten	12,50%	%	€	13.805.310,41	€	1.725.664	21,00%
	Risico's engineeringskosten	*12,50%*				**€**	**1.725.664**	**21,00%**
EK01	**Engineeringskosten deelraming variant 3d**					**€**	**15.530.974**	**21,00%**

Deelraming Variant 3d ɪl, versie 2.1 (15-04-2012) 'vereenvoudigde versie, zonder levensduurkosten en spreidingen'

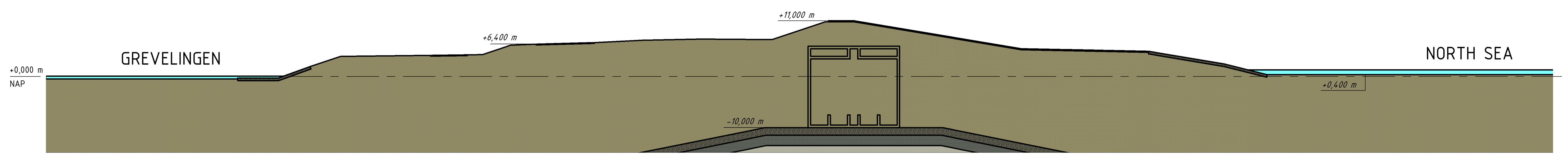
Code	Omschrijving post	Hoeveelheid	Eenheid	Prijs		Totaal		BTW %
Code	Heffingen en leges vergunningen, verzekeringen % over de bouwkosten	1,00%	%	€	74.815.428,76	€	748.154	0,00%
Code	Kabels en leidingen (niet turbine gebonden)	1,00%	%	€	74.815.428,76	€	748.154	0,00%
Code	Groencompensatie / natuurteslag	1,00%	%	€	74.815.428,76	€	748.154	21,00%
Code	Post benoemde directe overige bijkomende kosten	-	ehd	€	-	€	-	21,00%
	Benoemde directe overige bijkomende kosten					**€**	**2.244.463**	7,00%
Code	Nader te detailleren overige bijkomende kosten	10,00%	%	€	2.244.462,86	€	224.446	7,00%
	Directe overige bijkomende kosten					**€**	**2.468.909**	7,00%
Code	Eenmalige overige bijkomende kosten	4,00%	%	€	2.468.909,15	€	98.756	7,00%
Code	Algemene kosten	8,00%	%	€	2.567.665,51	€	205.413	7,00%
Code	Winst en/of risico	3,00%	%	€	2.773.078,76	€	83.192	7,00%
	Indirecte overige bijkomende kosten	15,69%				**€**	**387.362**	7,00%
	Voorziene overige bijkomende kosten					**€**	**2.856.271**	**7,00%**
Code	Niet benoemd objectrisico overige bijkomende kosten	12,50%	%	€	2.856.271,12	€	357.034	7,00%
	Risico's overige bijkomende kosten	12,50%				**€**	**357.034**	**7,00%**
OBK01	**Overige bijkomende kosten deelraming variant 3d**					**€**	**3.213.305**	**7,00%**
INV01	**Investeringskosten deelraming variant 3d**					**€**	**102.911.637**	**19,43%**

Appendix H: Drawings / 3D Visualizations



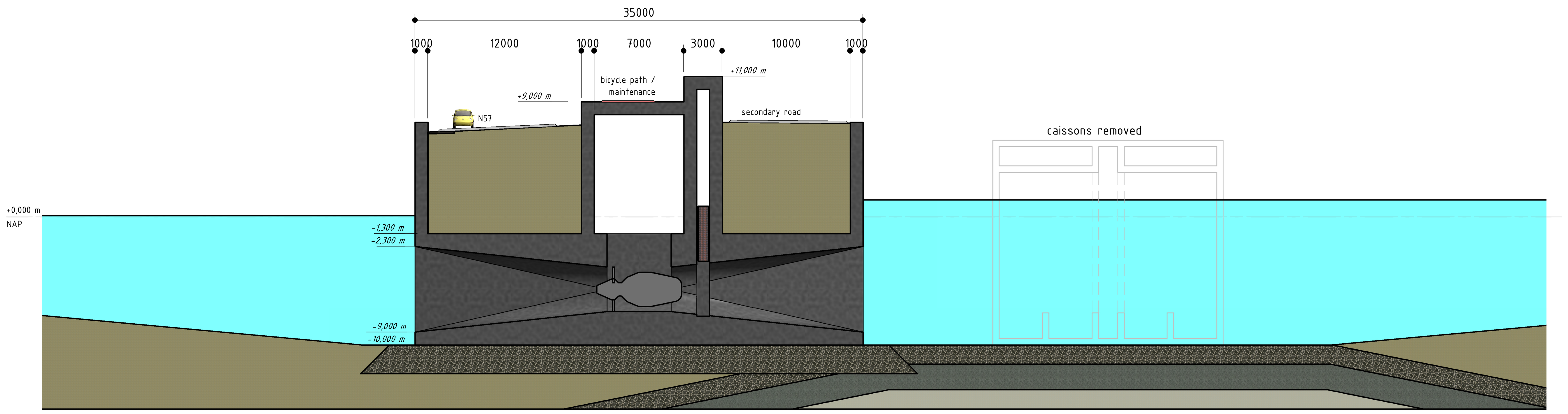
Overview

scale: 1 : 2000



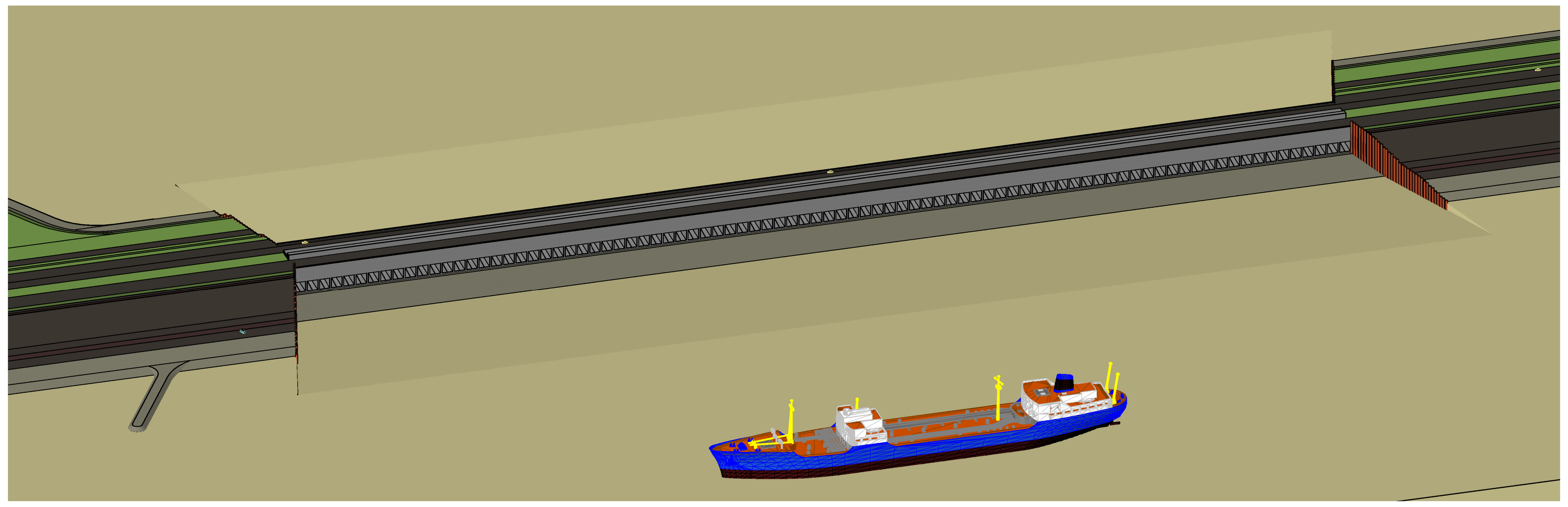
Section A-A

scale: 1 : 500

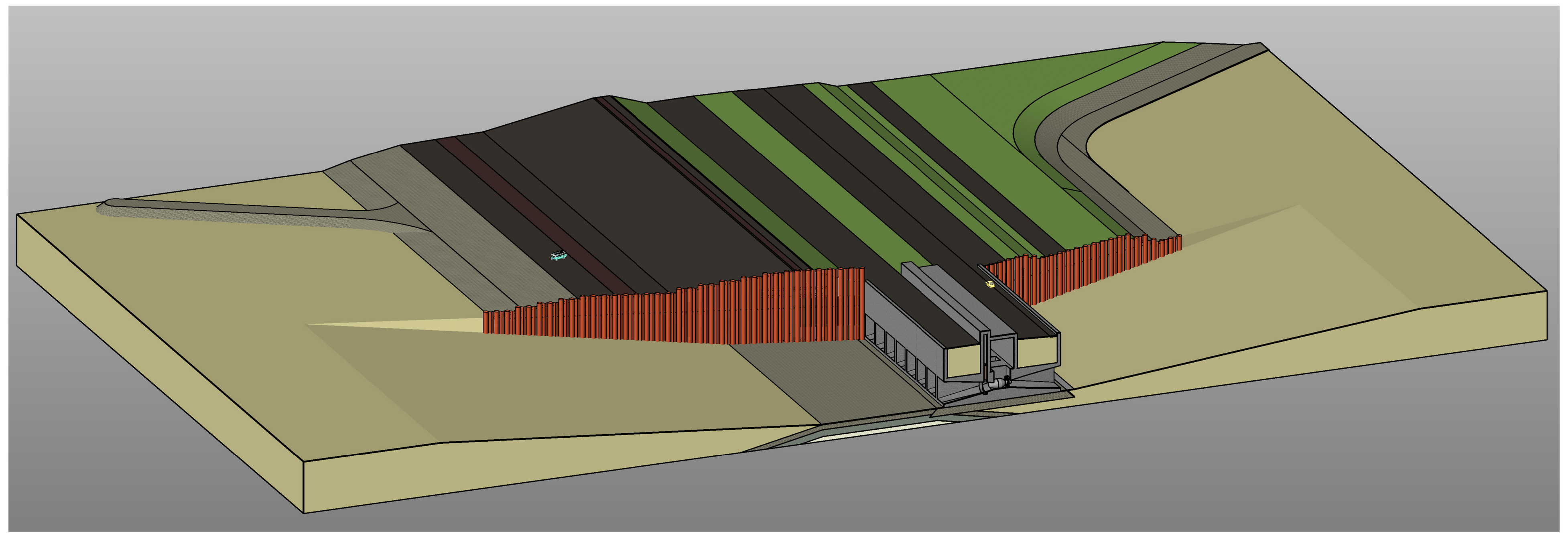


Section B-B

scale: 1 : 200



3D Overview



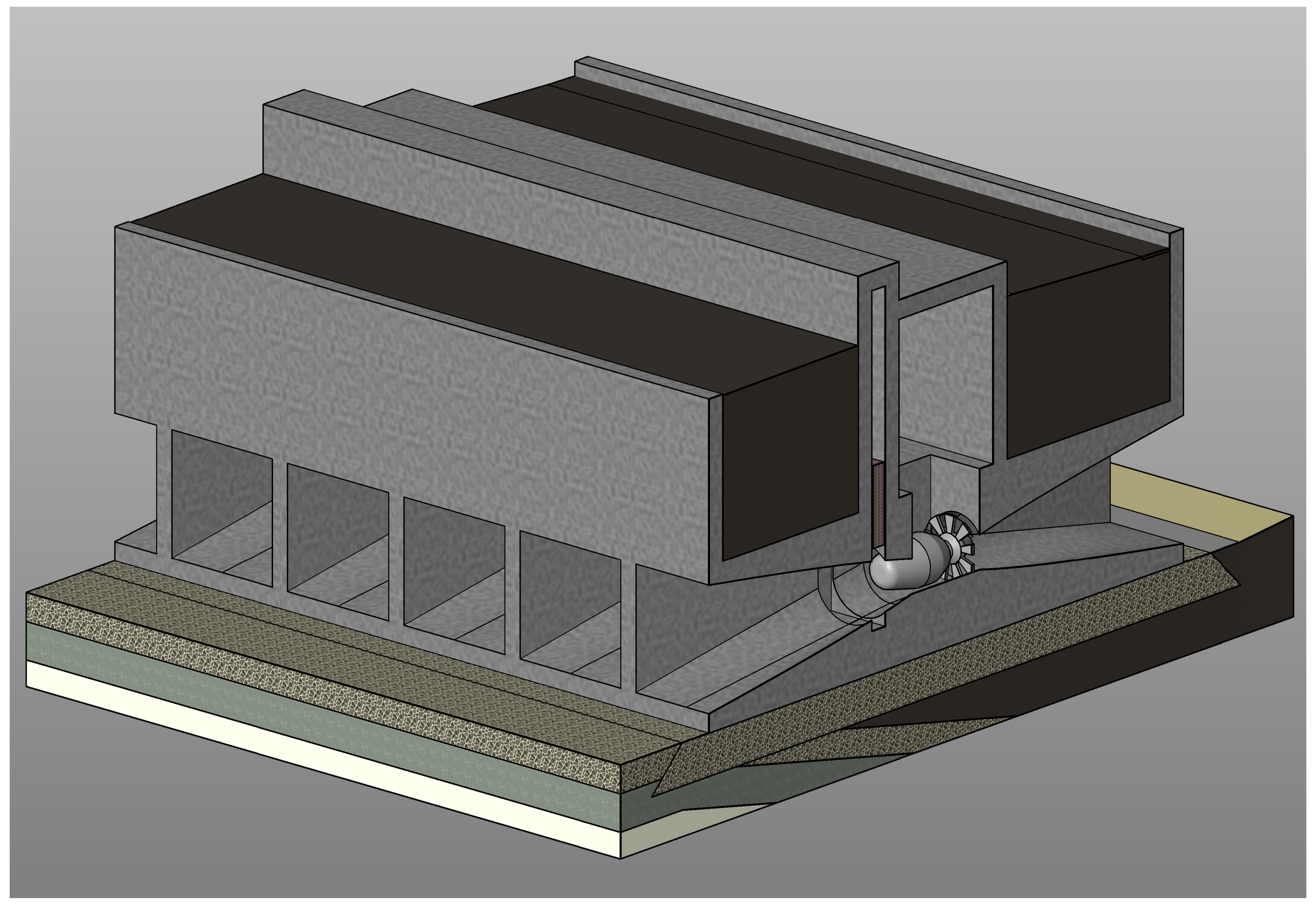
3D Transition

ASSOCIATED DRAWINGS:

- TEK-001 Design variant 1B Diffuser
- TEK-002 Design variant 2C2 Ducted
- TEK-003 Design variant 3D Venturi

REMARKS:

- Dimensions in millimeters, unless otherwise indicated
- Levels in meters relative to N.A.P., unless otherwise indicated



3D Detail

Situation

OPDR.GEVER	Pro-Tide-NL
PROJECT	Brouwersdam Tidal Energy Plant
ONDERDEEL	Design variant 1B Diffuser
OMSCHR./ VERSIE:	0
DATUM:	28-11-2014
GECONTROLEERD:	J.D. Reijneveld
GETEKEND:	R. Dankers
AKKOORD:	J. van Spengen
STATUS:	Concept
SCHAAL:	ALS AANGEGEVEN
FORMAAT:	A0
PROJECTNR.	INPA140433
TEKENINGNR.	TEK-001
BLADNR.	

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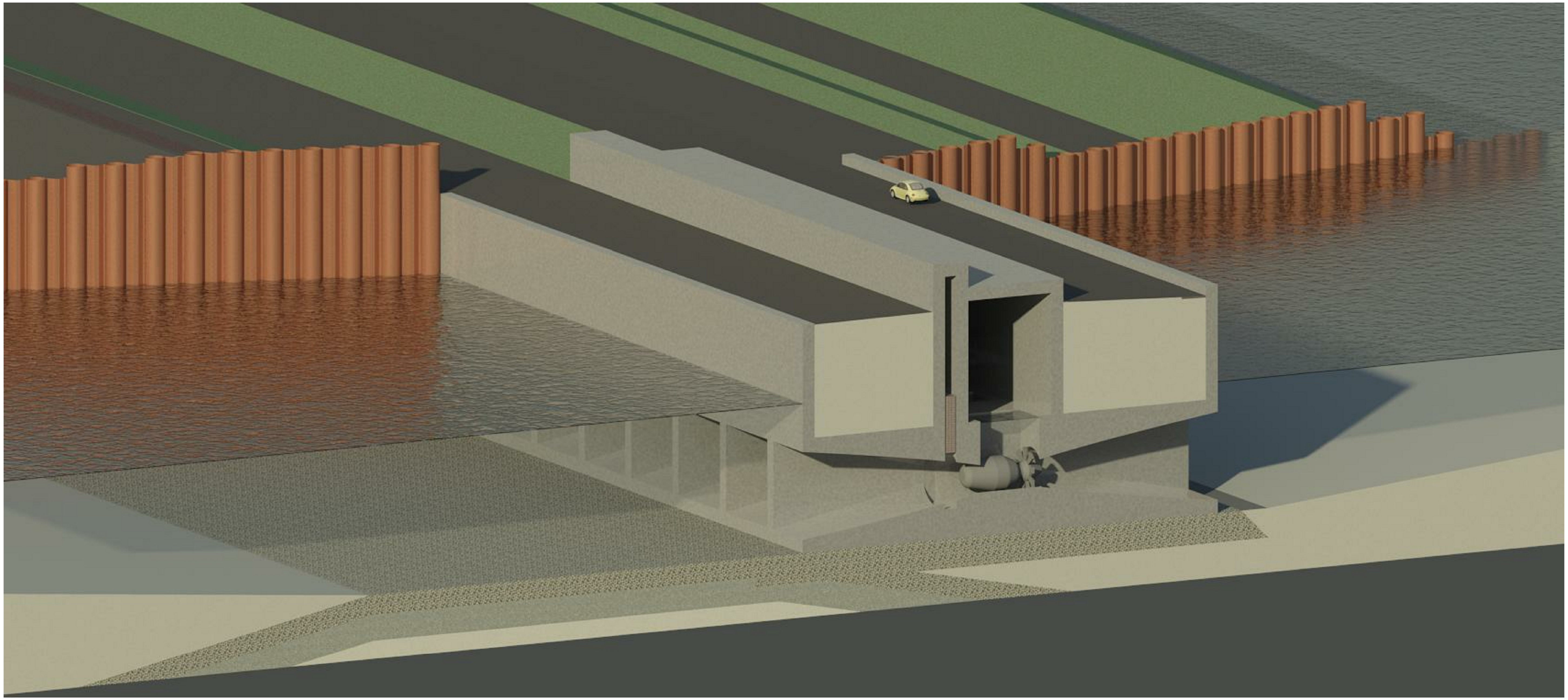
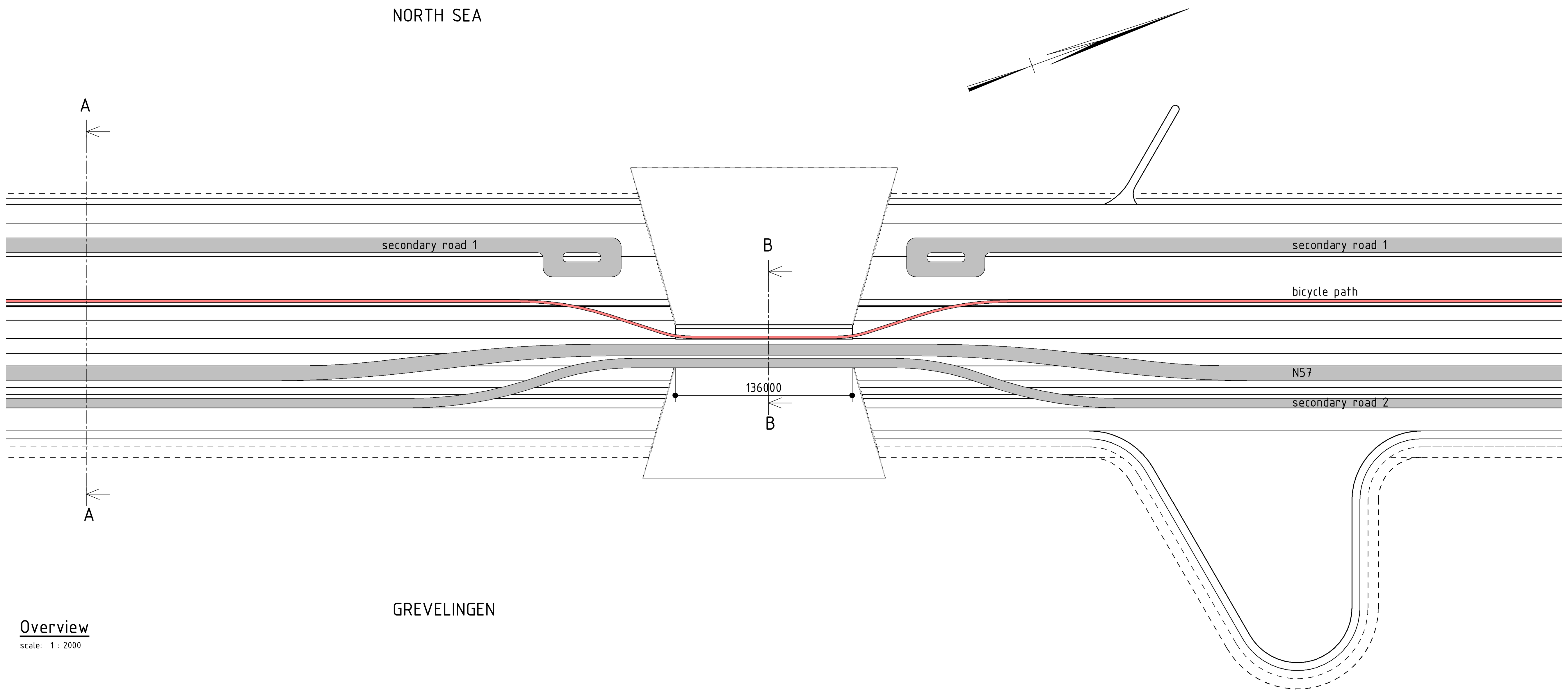
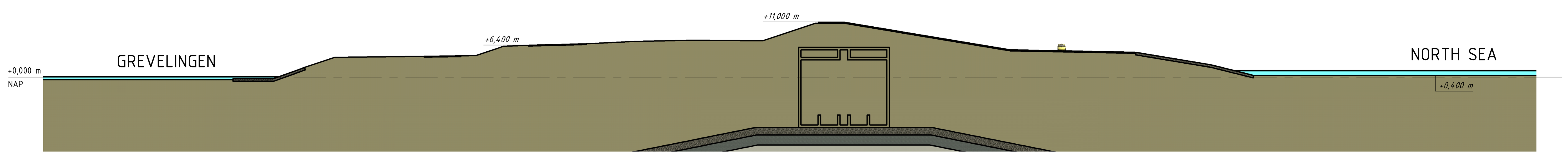
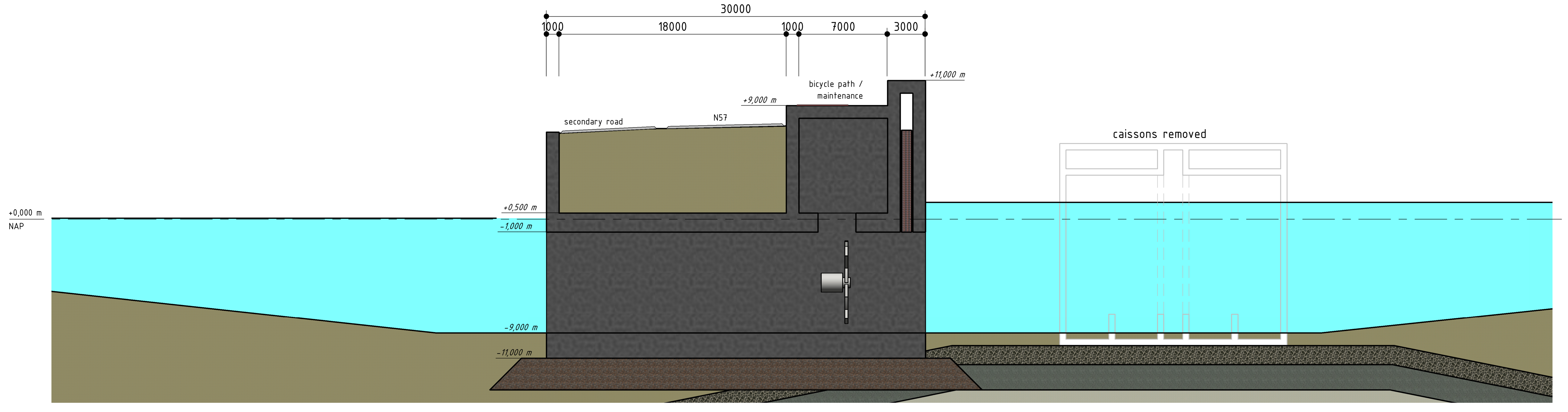




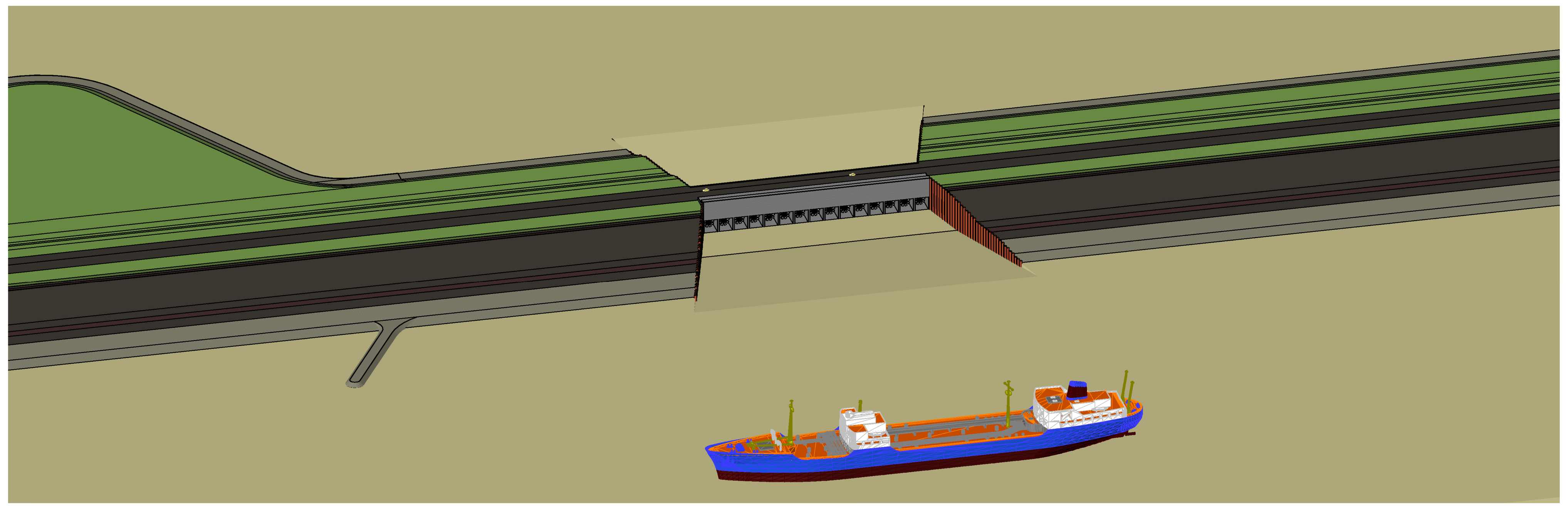
Overview
scale: 1 : 2000



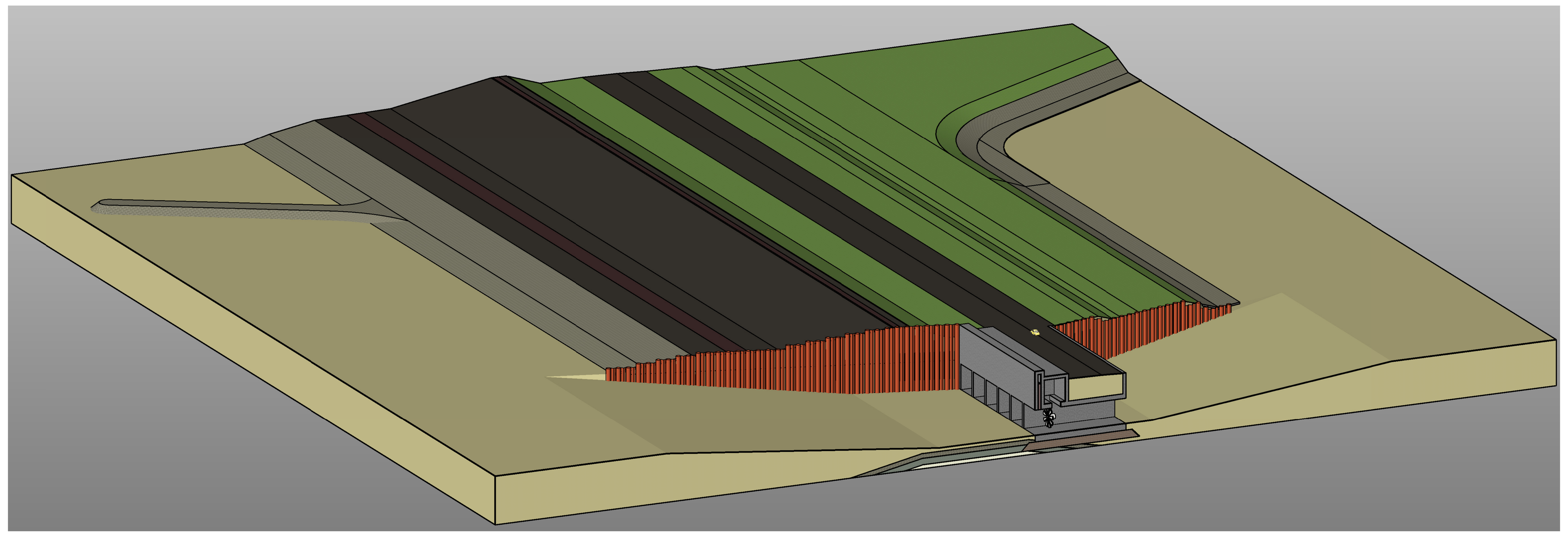
Section A-A
scale: 1 : 500



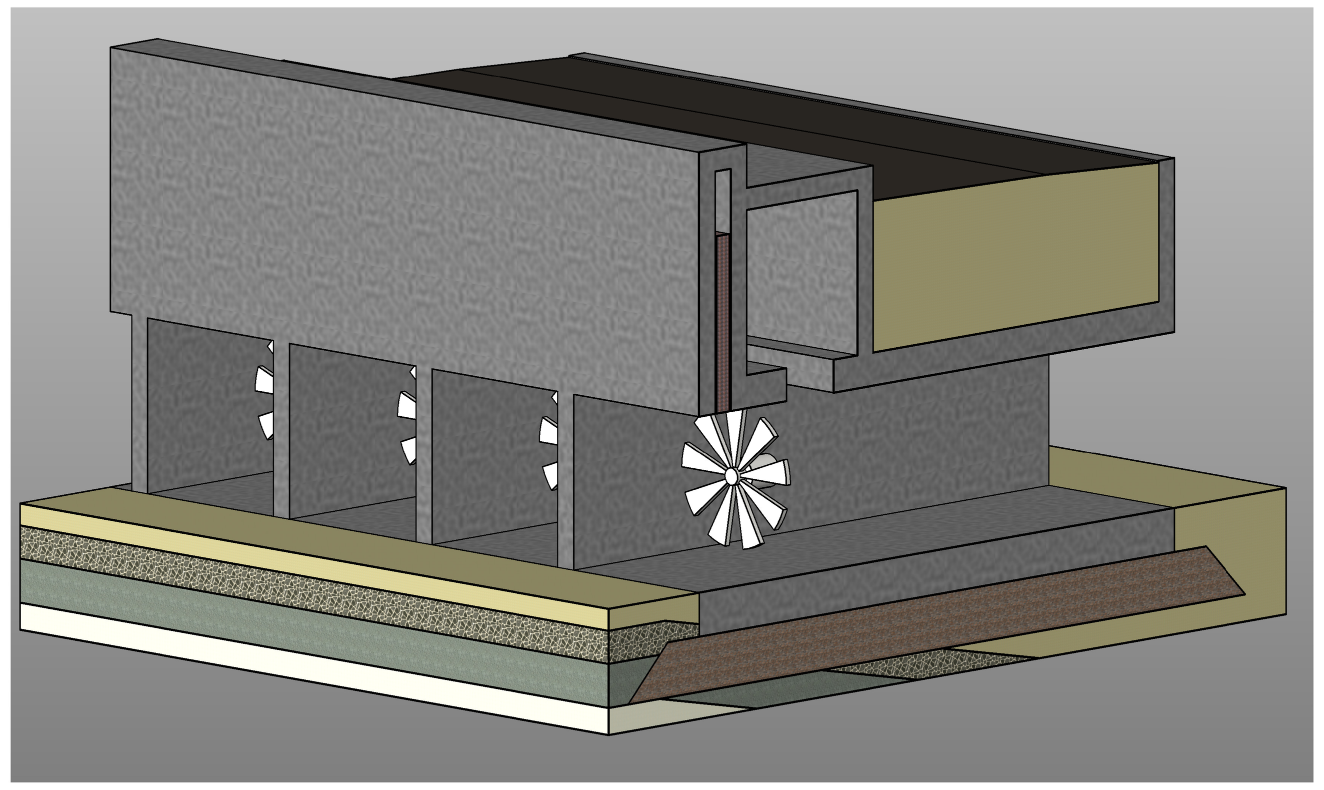
Section B-B
scale: 1 : 200



3D Overview



3D Transition



3D Detail

ASSOCIATED DRAWINGS:

- TEK-001 Design variant 1B Diffuser
- TEK-002 Design variant 2C2 Ducted
- TEK-003 Design variant 3D Venturi

REMARKS:

- Dimensions in millimeters, unless otherwise indicated
- Levels in meters relative to N.A.P., unless otherwise indicated

Situation

OPDR.GEVER	Pro-Tide-NL
PROJECT	Brouwersdam Tidal Energy Plant
ONDERDEEL	Design variant 2C2 Ducted
OMSCHR./ VERSIE:	0
DATUM:	28-11-2014
GECONTROLEERD:	J.D. Reijneveld
GETEKEND:	R. Dankers
AKKOORD:	J. van Spengen
STATUS:	Concept
SCHAAL:	ALS AANGEGEVEN
FORMAAT:	A0
PROJECTNR.	INPA140433
TEKENINGNR.	TEK-002
BLADNR.	

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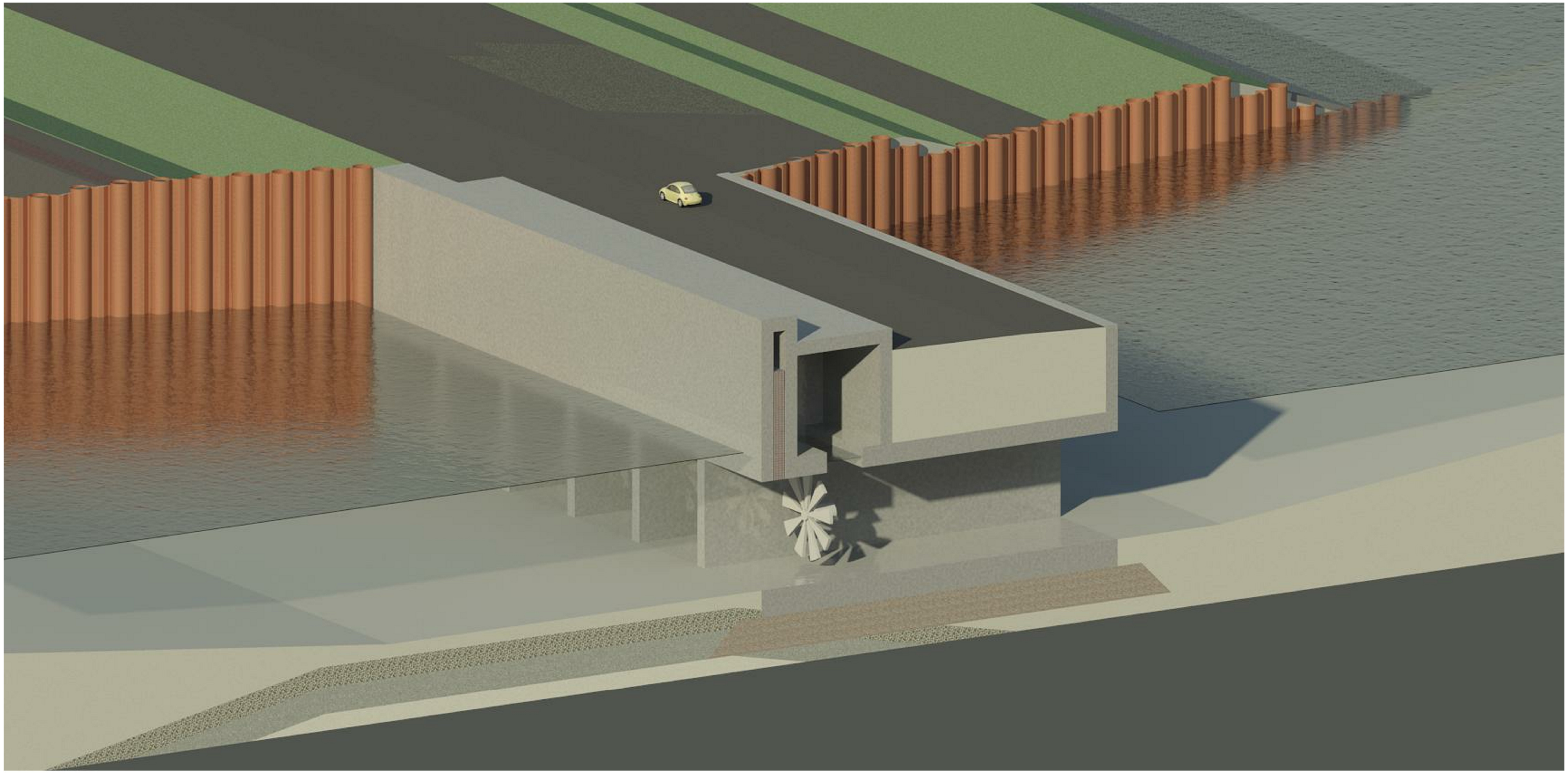
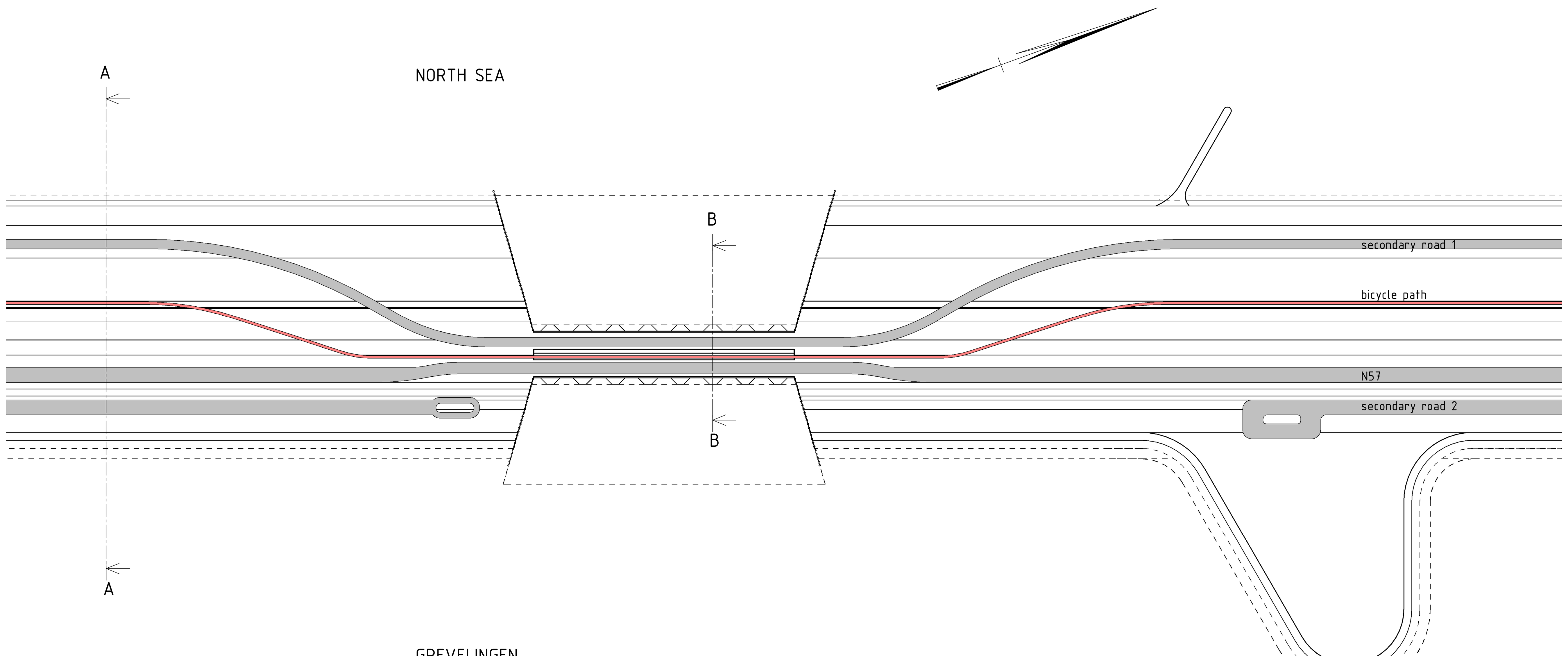
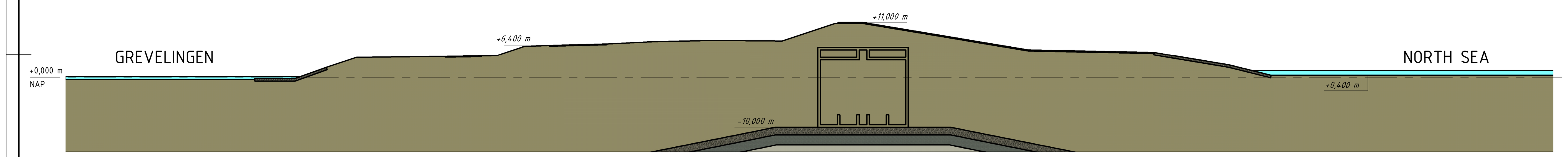
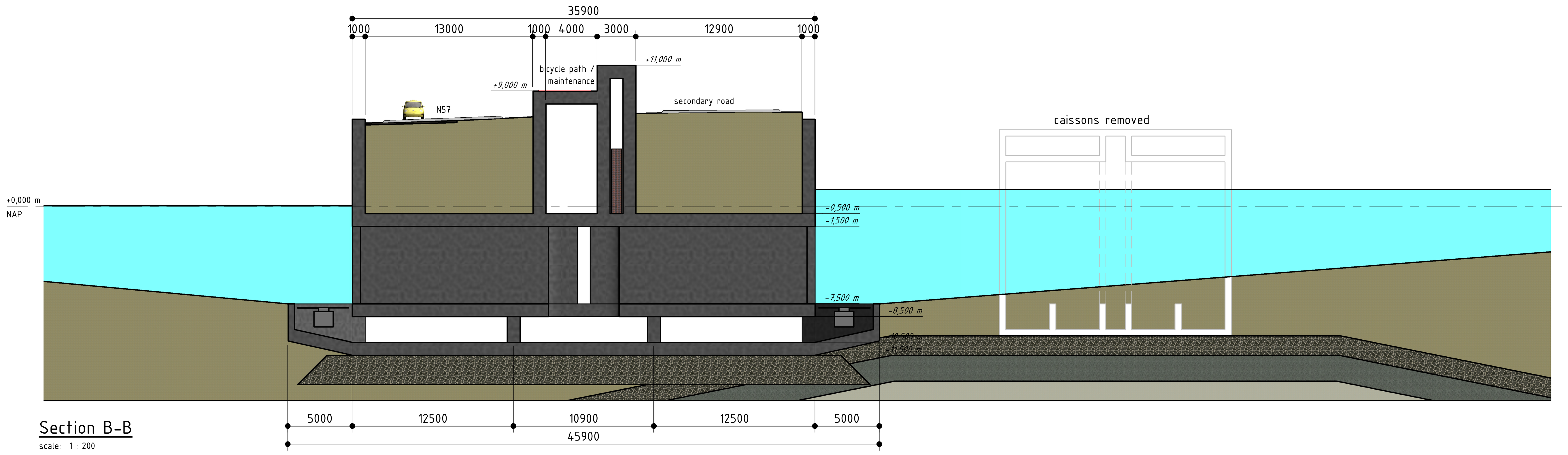




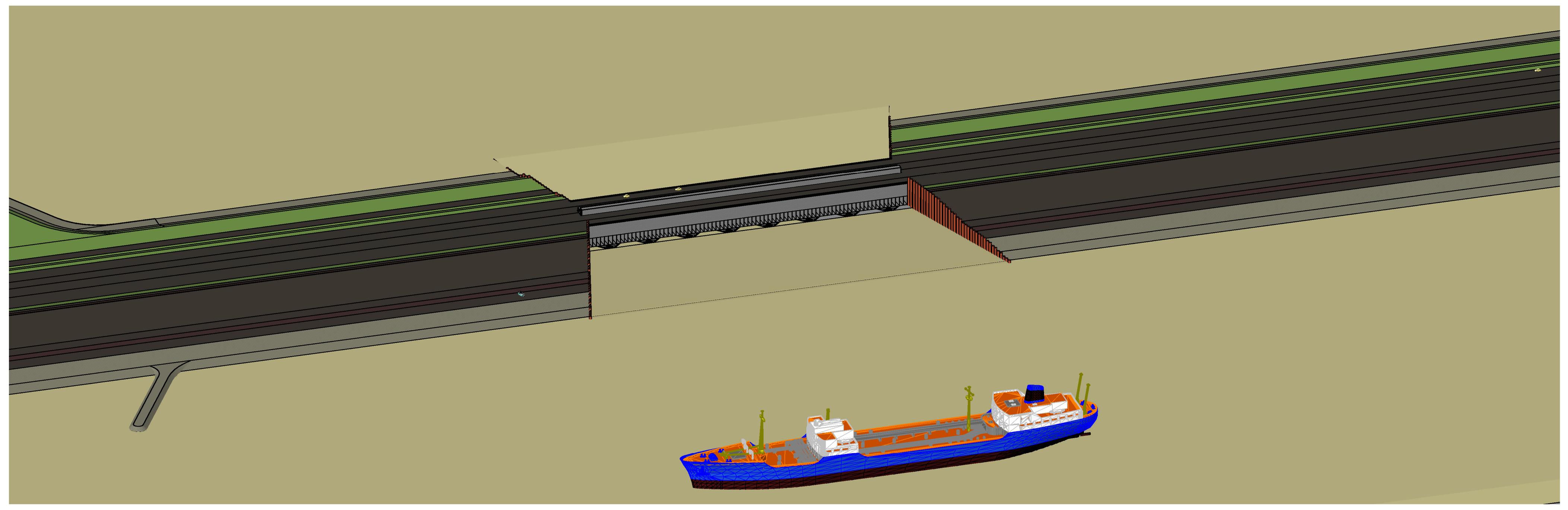
Overview
scale: 1 : 2000



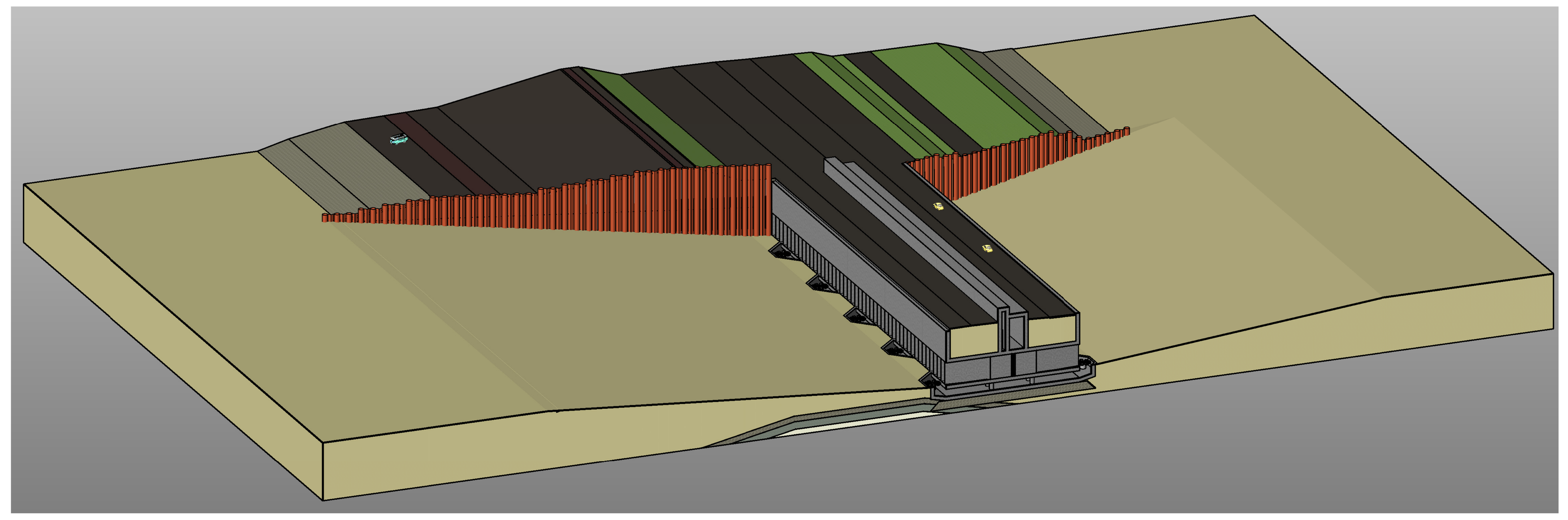
Section A-A
scale: 1 : 500



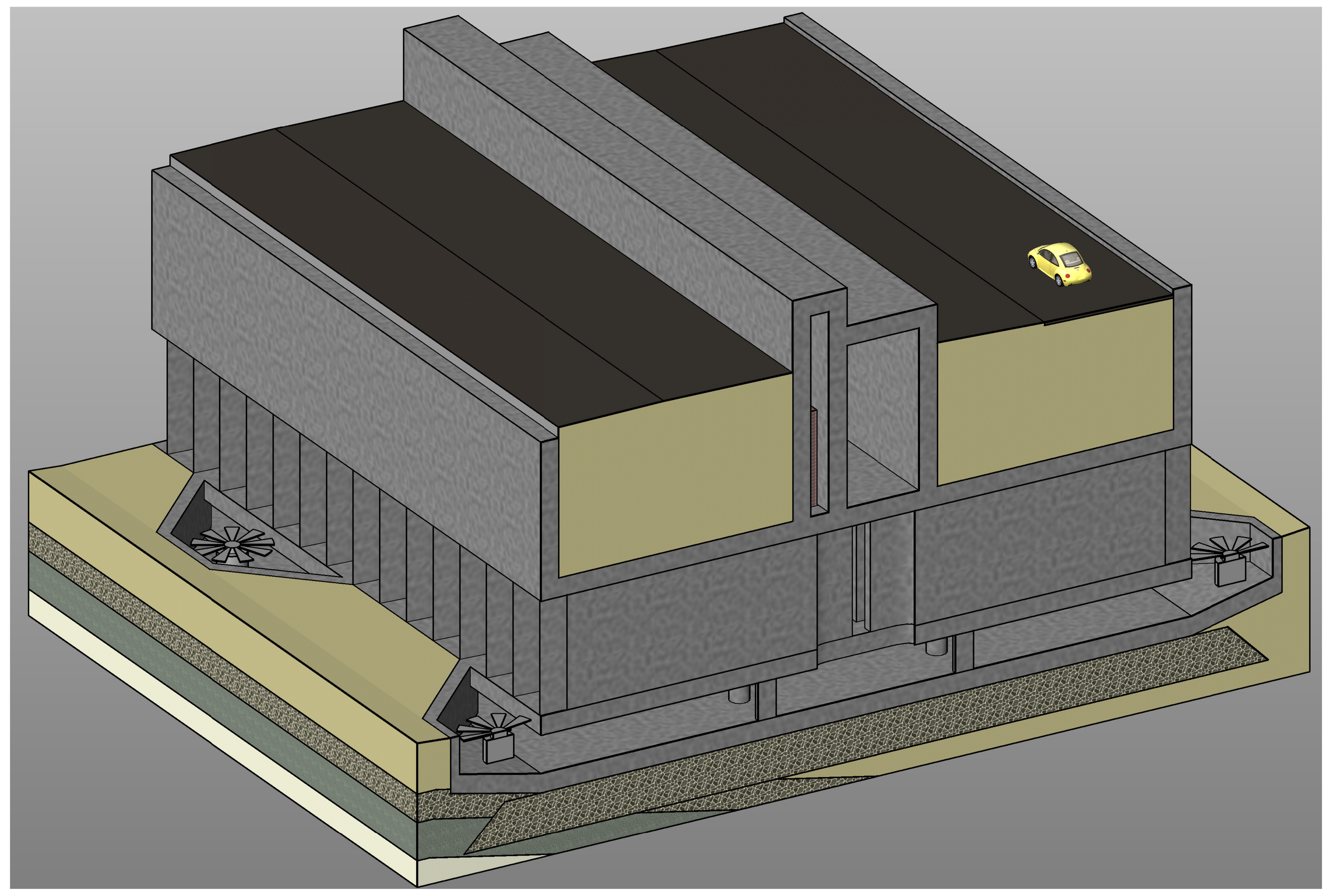
Section B-B
scale: 1 : 200



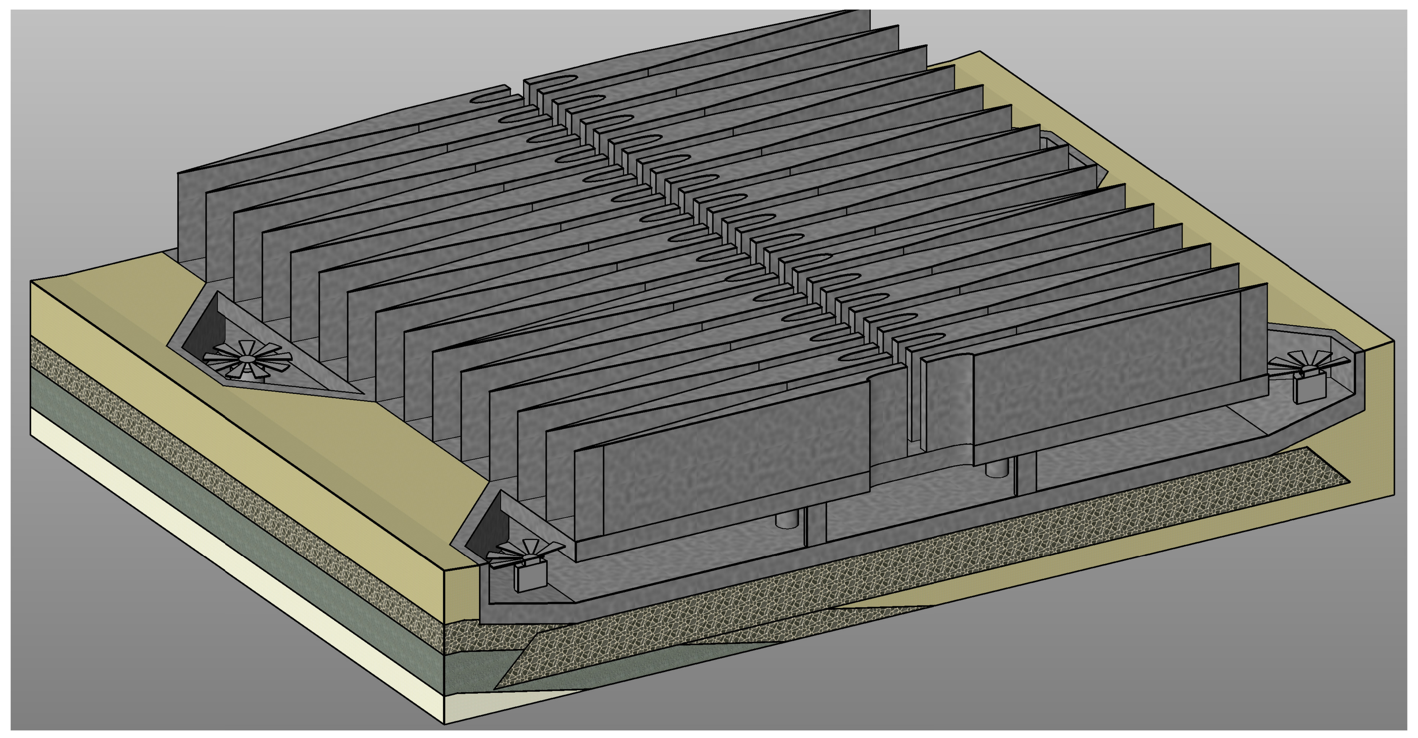
3D Overview



3D Transition



3D Detail 2



3D Detail 1

ASSOCIATED DRAWINGS:

- TEK-001 Design variant 1B Diffuser
- TEK-002 Design variant 2C2 Ducted
- TEK-003 Design variant 3D Venturi

REMARKS:

- Dimensions in millimeters, unless otherwise indicated
- Levels in meters relative to N.A.P., unless otherwise indicated

Situation

CLIENT	Pro-Tide-NL
PROJECT	Brouwersdam Tidal Energy Plant
PART	Design variant 3D Venturi
VERSION:	0
DATE:	28-11-2014
CHECKED:	J.D. Reijneveld
DRAWN BY:	R. Dankers
APPROVED:	J. van Spengen
STATUS:	Concept
SCALE:	AS INDICATED
SIZE:	A0
PROJECT NR.	INPA140433
DRAWING NR.	TEK-003
SHEET NR.	

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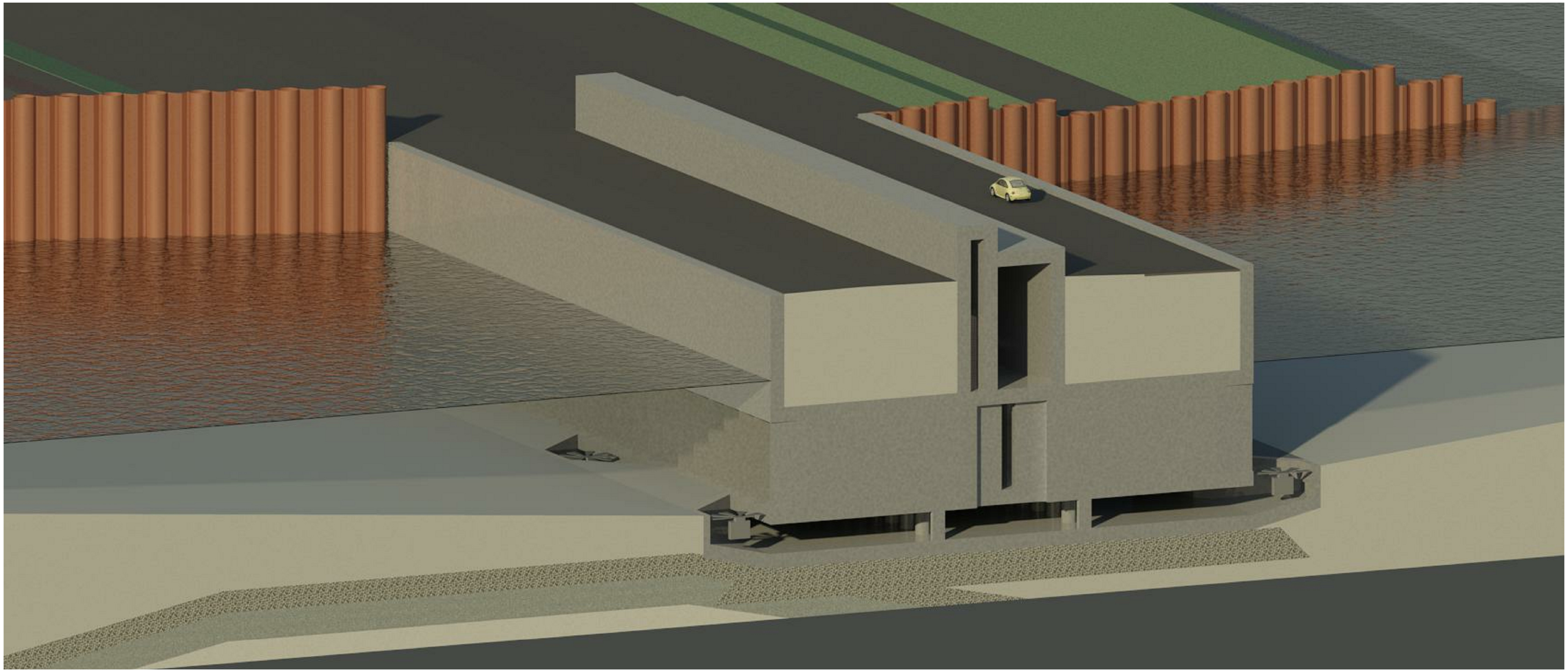

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