THE LIVING BARRIER

THE ARCHITECTURAL ADAPTATION OF EXISTING FLOOD BARRIERS ON ZEELAND'S NEW BIODIVERSITY SYNERGY.

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ABSTRACT

The acceleration of the sea level rise will have an immediate global impact, especially on the Delta works. This projection increases the challenge for flood protection strategies and the existing flood barriers that currently lack adaptation for the higher water level. As an opportunity from the negative outcome of climate change and the most extensive maintenance period of the Delta works. This design research initiates by considering the further innovative stage of the flood defense system in Zeeland. Either way of strengthening the hydraulic systems, removing the flood barriers for environmental respect, or adapting both directions with the surrounding and biodiversity concerns.

This paper studies three crucial phasing investigations about the Delta works: the principle and life cycle, the alteration of the biodiversity, and multi-functionality. The research indicated two sides of the outcomes, leading to the methodology of the integration between the typology and methods of dam, locks, and storm surge barriers to create diversity in the specific context of Oosterscheldekering. Together with the multi-functionality of the new architecture, that could be a solution for the future adaptation of existing flood barriers.

KEYWORDS: *Sea level rise, The Delta works, massive infrastructure, The existing flood Barriers, Future adaptation, Second life, Biodiversity, Living symbiosis, Multifunctionality.*

I. INTRODUCTION

1.1 COASTAL REGION AND THE SEA LEVEL RISE

Due to the geographical location of the Netherlands, about one-third of the ground is below sea level in Dutch history. Consequently, the Netherlands inevitably has to cope with the tidal current and water level uncertainties. For more than 600 years since the 14th century (History | Dutch Dikes, n.d.), natural barriers such as dikes have been operated to protect the country from the water. These circumstances drove the Dutch to have flood control and land reclamation expertise. Nevertheless, that is before climate change. At the beginning of climate change, formed in the early 19th century (IPCC, 1988), an uncontrollable greatest catastrophe struck and devastated part of the Netherlands in 1953 from the North Sea. The extreme floods in the Netherlands' Southwestern delta, especially in the Zeeland region, are the turning point of the outstanding Dutch achievement in flood protection. "**The Delta works**" (Figure 1) The massive project includes three locks, six dams, and four storm surge barriers to cope with the future extreme disaster (Ministerie van Infrastructuur en Waterstaat, 2021). From 1960 to 1987, 13 flood barriers were built, safeguarding the Dutch coast from the sea for more than 60 years. Eventually, flood protection in the Netherlands was never complete due to the dynamic change of the future. If one day all these flood barriers reach their capacity and expire due to the material and structure life span. The next innovation step must be considered.

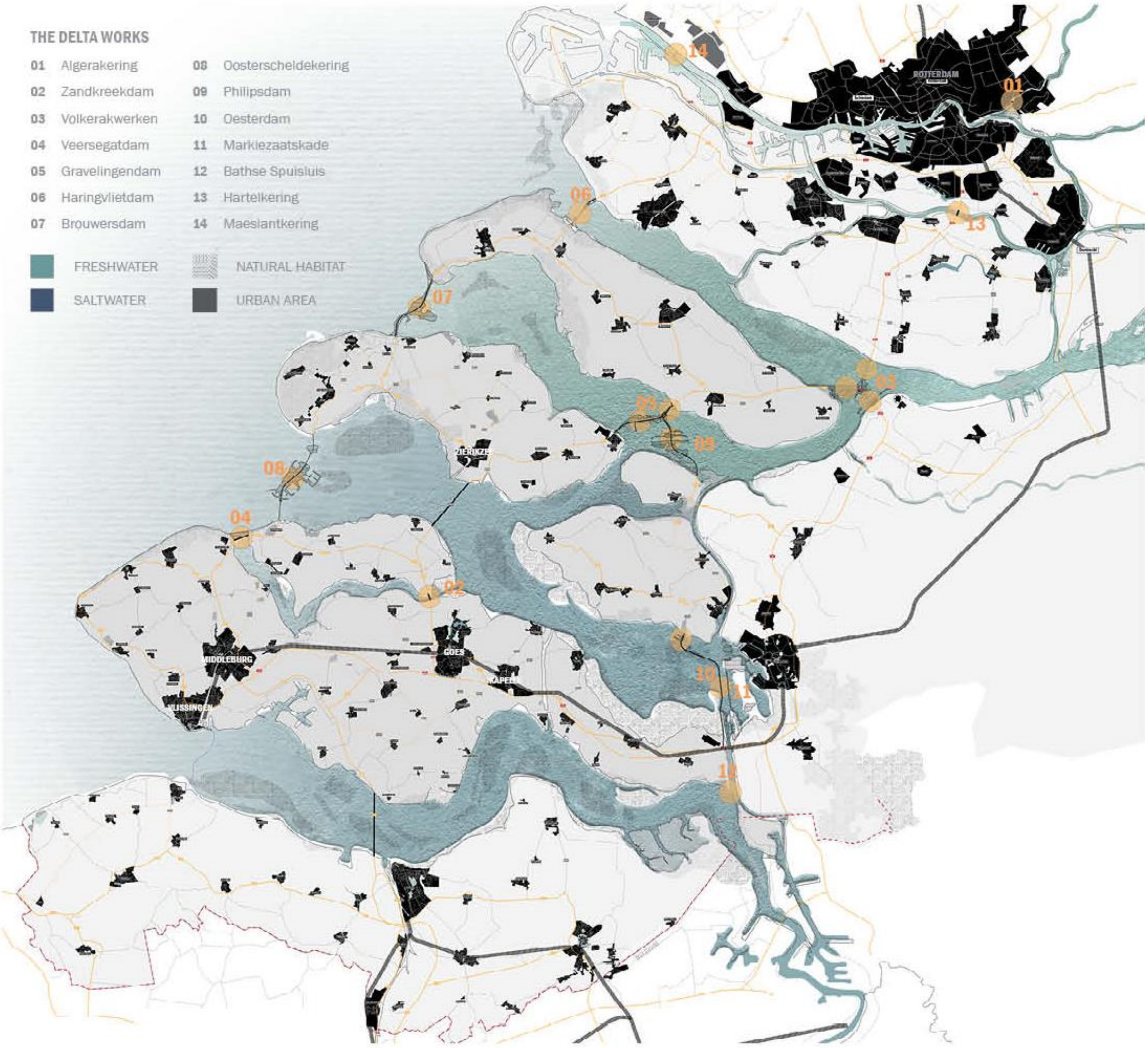

Figure 1. Map of Delta work in Zeeland — illustrator: the author / Source: The Storm Surge Barrier in the Eastern Scheldt: For Safety and Environment, (n.d.)

1.2 THE REPERCUSSION OF THE DELTA WORKS

The completion of The Delta works has been an immense triumph from a global perspective after achieving its objective of protecting the Netherlands from the rising sea. Nevertheless, from the calculation of the Delta Committee, The Delta works mainly serve one principal purpose, relying on future uncertainties or the extreme flooding that could happen once every four hundred years (The Delta Plan, n.d.). This calculation raises the question of how this structure can withstand the water level for more than a hundred years because its structure, parts, and material have a certain lifespan. Accordingly, after 70 years of this mega project, a critical concern about the maintenance process has begun. However, the selected solution for maintaining all these flood barriers is to add the capacity of hydraulic structures or the most affordable and manageable direction. This solution is the same method and technical as 70 years ago, while the dynamic of the water level will be different from what was in the past.

As a massive construction, the considered aspects should include more than just the flood barriers technology and climate change but also the impact on the Coastal area where its construction is located, where the sea and sweet water meet. The delta area of Zeeland has plentiful nutrients, sediment, and productive ecosystems that have attracted people for fisheries, aquaculture, and agriculture due to the rich and diversified resources. The natural control of the Delta works, and unpredictable water levels have considerably influenced this area. According to environmental research, many future directions for this structure follow the global environmental matter trend. (Record-breaking Year for Dam Removal Shows Growing Interest in River Restoration, 2022) Presenting another solution for the following maintenance stage of Delta works could lead to removing the flood barriers for better environmental matters.

However, since all the solutions come with a substantial investment, they corresponded with a considerable amount of money, knowledge, energy, labor, and time investment since the project began. Hence, this maintenance period presents a new challenge and opportunity for the flood protection life cycles on which direction could be the most circular pathway for both global and local aspects.

1.3 PROBLEM STATEMENT / RESEARCH QUESTIONS

In the era of rapid environmental transformation and the impact of Sea level rise, it is undeniable that designs and construction on both new and current projects demand greater adaptability and flexibility. Especially the flood defense systems' design in Zeeland coastal areas still requires more adaptability concerning the increasing seawater. According to the IPCC announcement in August 2021, the acceleration of the sea level rise will be faster than the Delta Scenarios (Climate Change 2022: Impacts, Adaptation, and Vulnerability, n.d.) Another meaning is that when the water level rises year after year, the lifespan of the flood barriers diminishes. For instance, the height of the static barriers could not withstand the dynamic of the water level. Also, storm surge barriers that once facilitated water passage must permanently close the estuaries. This action causes multiple environmental issues, such as obstructing the fish migratory path and decreasing the transition water zone where the seagrass meadow flourishes—resulting in the irreversible loss of one of the Netherlands' most diversified ecological locations. The massive construction of the Delta works came after a significant adjustment with positive and negative consequences, predominantly on local people, nature, and the environment. The positive example aspects are the successful flood protection for the whole country over seven centuries and the reservoir of fresh water for agriculture. Conversely, it came with much adjustment for the local people. The mono-function of tourism replaced Zeeland's historical culture of fisheries communities, aquaculture, and agriculture. All these cultures are beginning to vanish, along with the water rising. The domestic economy was left behind, and less population growth in the area because of future uncertainties.

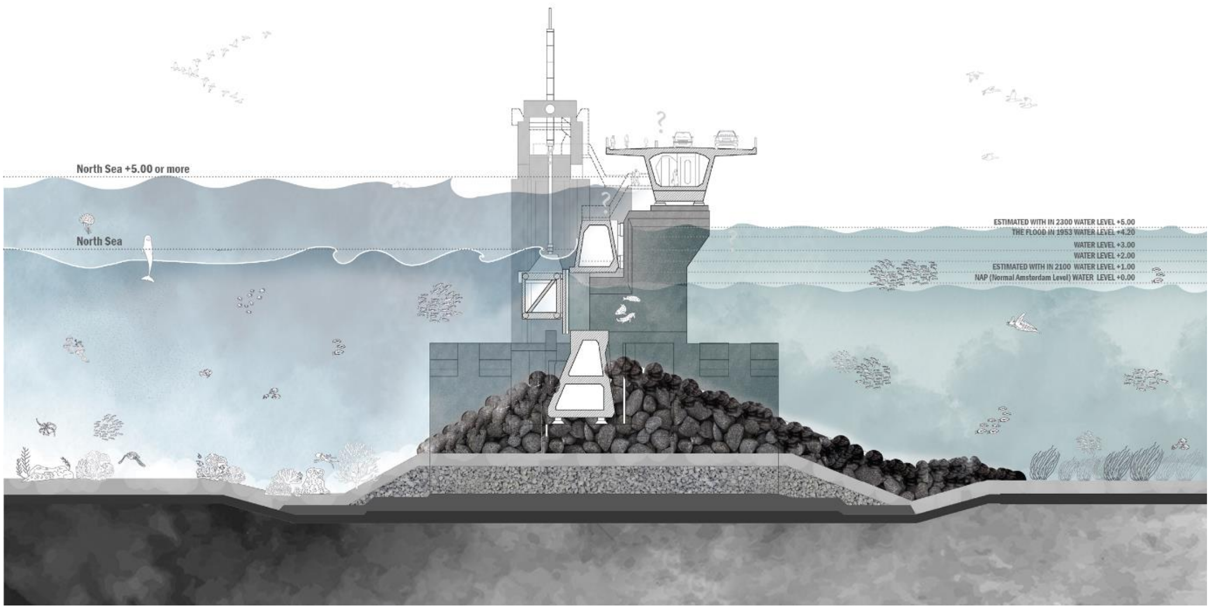

Figure 2. Future flood prone level in relation to Oosterscheldekering and the possibility of volume allowance. — illustrator by the author / Source: https://watersnoodmuseum.nl/kennisbank/oosterscheldekering/ and Pilarczyk, K.W. (2012). Impact of the Delta Works on the Recent Developments in Coastal Engineering.

This new challenge necessitates developing new approaches, planning, and strategies for the Delta works in the long term. As an opportunity from the negative outcome of climate change and the most extensive maintenance period of the Delta works. This design research initiates by considering the further innovative stage of the flood defense system in Zeeland. Either direction of strengthening the hydraulic systems, removing the flood barriers for environmental respect, or adapting both directions with the surrounding concern. In order to identify the best approach to extend the life expectancy of these existing flood barriers. Nonetheless, not only are the Delta works and sea-level rise of significance but so are local people and ecology in Zeeland.

The research paper examines the possibilities for extending the flood barrier's lifespan, cooperating with the solution from the consequence on local people and ecology after the construction of the Delta works. Then, investigate the potential of multifunctionality in the existing structure through architectural techniques to cope with extreme sea-level rise in the future. The study's main research question is: **'What flood barriers typology offers the greatest biodiversity potential for future biodiversity adaptation?'**. To further explore the topic, the sub-questions are:
01. What are Zeeland's flood barriers' principles and life cycle?
02. What are the significant spatial alterations on land and water after the completion of the Delta works?
03. What architectural techniques can increase the multifunctional capacity of the existing flood barriers?

II. METHODOLOGY

The research methodology is qualitative and derived from mixed research techniques because the topic impacts multiple scales, mainly through Literature research, typological research, and research analysis. In the specific location of Zeeland, the research investigates the process of three crucial phasing investigations.

2.1 PHASE 1: THE PRINCIPLE OF THE DELTA WORKS

One of the crucial aspects before taking the further innovation step is understanding the principles of the past. Thus, the first investigation is mainly about the life cycle of the thirteen Zeeland flood barriers by accumulating and translating information about the Design, construction, and typology. This research process overviews the history and principles of the flood-barriers, which could project the possible extend the life cycle. In order to prove why the adapting decision would be the solution for these barriers in the future.

The data was acquired through published literature, photos, drawing, infographics, and online data collecting, via three primary sources, The literature of De Deltawerken (Steenhuis, 2016), the official websites of the Rijkswaterstaat or Ministry of Infrastructure and Water Management (Ministerie van Infrastructuur en Waterstaat, 2022), Watersnoodmuseum (The Delta Plan, n.d.) of the flood museum. These references allow the researcher to explore each barrier's detail from different points of view, such as location, Size, function, characteristics, components, technique, nature relation, and operation. To differentiate the corresponding data from different sources and compile it into a catalog of all the thirteen flood barriers.

After reviewing and analyzing all the factors, the following research procedure is to apply the data to the timeline.

1. Compare the life cycles of each flood barrier through history and time from the beginning until the present, which could project the possibility of the future in the next 50 years. There are three divisions of the period in the timeline: construction, implementation, and maintenance. The most crucial information during the extensive maintenance period of Zeeland flood barriers from the 1950s, 60s, 70s, and 80s is from the annual update of an overview of all current water from Rijkswaterstaat.

2. All flood barriers can also be categorized by function and technical, design and material, and finally by the proportion of the barriers.

3. According to the comparison between time and categorization, the research results examine the crucial advantages and disadvantages of which type and method of flood barriers are the most effective for future adaptation.

2.2 PHASE 2: THE ALTERATION OF USER BEHAVIOR

(BIODIVERSITY: HUMANS, ANIMALS, PLANTS)

The extended period from three to twenty years of construction of the Delta works from 1954 to 1997 significantly impacted the local people, animals, and flora in one way or another. These could result in positive and negative consequences. On a global and national scale, this initiative has resulted in flood protection for over 70 years. Nonetheless, the initiative may have an unanticipated influence on a minority number of residents. This issue resulted in the investigation of phase 2. The second part of the study is mainly about the relationship between the flood barriers and the local Zeeland community through ethnographic research, research analysis, and historical mapping.

This phase's methodology begins with a study of Zeeland's historical and interactive maps of 1910 and 2022 from the national archives and the Rijkswaterstaat website to comprehend the repercussions before and after construction. Outlining and translating the original map into the infographic allows the researcher to differentiate the network's hidden layer within the original map. As a result of the tracing part of both years, there are two primary contexts of land and water relationships.

First, the land context can differentiate the parameters into the base map or the shape of the land, the public transportation, Cities and urban areas, and accessibility. The water context parameters are water level, Maritime pattern, fish migration, and plant location. The process of differentiation uses more than just the historical map. It is also essential to apply the additional research analysis—particularly the layer of fish migration, water level, and vegetation. There is reliable research on a particular topic that provides helpful information, such as the research in the Haringvliet river about fish migration (Reeze et al., n.d.). The research indicated the timeline of the migration route through years for each generation of 16 fish species. It contains a critical aspect that most species have some specific time of stay in the transition area or the brackish water. It proves the necessity of the transition area where is the location of the Delta works.

The mapping series, the last exploration in this phase, compares the 1910 and 2022 maps and combines each parameter's alterations into the conclusion of the alteration map. The expected result could be the guideline of the significant alteration to the new possibility functions for the future related to Zeeland's new biodiversity.

2.3 PHASE 3: MULTIFUNCTIONALITY

Multifunctionality is a central topic of this phase, uncovering the potential for future adaptation of the existing flood barriers. The beginning of the study is to identify a case study of infrastructure that provides more than simply transportation. The preferred case study is the Ponte di Rialto in Italy, the Kraanspoor in the Netherlands, and Refurbishment Viaduct Arches in Switzerland. Three of these case studies exemplify multifunctionality by applying and reusing the massive infrastructure. The methodology from these case studies inspires the topic of this phase. Such is multi-function, the second life of the existing structure, and densification. All these methods could be a solution for the new adaptation.

The third stage of the study is the transition between research and design, in which the research finding intentionally overlaps both parts. Following the conclusion of the principle of the Delta works in phase one and the relationship to the surrounding in phase two, the last step investigates the possibilities of integrating the current structure with the new multifunctionality. This phase's data is derived from the two preceding phases and experimental design with the existing structure. Regarding site selection, the subsequent step thoroughly analyzes the specified flood-barrier dimensions, components, and materials and evaluates the potential uses for the location. According to the research about biodiversity relationship in phase two, the inquiry of the function includes human, animal, and plant users. The desired outcome is a list of functions associated with the site and surroundings, such as the principal function in the city, Zeeland's local function, and animal and plant function. Ultimately, the experimental of spatial and operation is the research by design. First, initiate the spatial experiment by defining the space above, below, in between, and around from barriers proportion. Then, after understanding all the information about the current structure, new possible functions, and space. All these data will experiment with the three operations of the flood barriers, which are to strengthen the components, remove some of the barriers for the water flow, or adapt to the new multi-functions.

III. RESULT

3.1 PHASE 1: THE PRINCIPLE OF THE DELTA WORKS

3.1.1 The principle and categorization of the Delta works.

The investigation of the fourteen flood barriers of the Delta works from Literature research and the two official online websites reveal and explain correlative information. For example, the length of the Philipsdam on both Rijkswaterstaat website, the leading organization of the Delta works, and Watersnoodmuseum presents 7 kilometers, but on De Deltawerken appears only 6.1 kilometers. After researching the three sources, the understanding of the data is not only about the location, construction period, function, and size but also technical aspect, maintenance, operation, and relation to the environment. It required additional findings from the literature, related documents and achieved drawing to prove the data's correction. After exploring all the factors from different sources, it presents the general classification of the authority and engineer in charge of the project based on its function and technology application. In order to understand the different points of view. The material and design category and the proportion also apply to the research. The result demonstrated that the first category of function and technical and the second of Material and design are identical; the exception is the Haringvliet dam. The Dam's functionality translated into landscape design or as same as the dikes. While the storm surge barriers that the hydraulic systems are part of the function are more likely to have a monumental design. Also, Lock's function for shipping is more mixed between natural blend and monumental characteristics.

3.1.2 Life cycle of Delta works

The three stages of Delta work's life cycle started with the construction period, which began one year after the flood of 1953 and continued until 1997. Approximately 43 years of construction. The investigation of life cycles followed by the first implementation stage due to the surrounding issues from 1958 to 2020. Then the last stage of the most considerable maintenance period of the Delta works occurs in 2020 and is expected to be completed around 2028.

During construction, there were various lengths of time between flood barriers (Figure 3). Meanwhile, after comparing the construction time with three categorizations, the chart illustrates the dam function and landfill material utilized the shortest construction time, around 6.5 years. The least construction time could also present minor energy consumption. Contrary to the Locks and mixed design typology, which took twice the time, roundly 12 years. Lastly, the S scale has the fastest construction period, with flood defenses ranging from 200 to 830 meters. The construction period study aims to determine the typology that consumed the least amount of energy in the shortest time. Nevertheless, during the implementation period (Figure 4), the least amount of time could mean that that typology required implementation because there is a problem with the surroundings and usage—for instance, the increasing traffic and the environmental concerns. For example, after approximately 17 years, the Locks and Storm surge barriers typology needs the first implementation, as shown in the chart. Then, followed by mixed design, the L scale implies roundly 6 and 14.3 years, respectively. On the other hand, the Dam typology, monumental design, and S scale do not need implementation after 22, 24.6, and 29 years after construction.

This research's maintenance period (Figure 5) is crucial because it represents future maintenance. If the solution of strengthening the flood barriers with the same design and methodology. We need considerable maintenance of the flood barriers every 42.5 years. The three-category chart displays the period that each barrier required major maintenance after its completion. It demonstrates the similarity of the time before adequate supervision from 29 to 51 years or an average of around 42.5 years. There are two different outcomes in this period. First, there are five flood barriers with no record of consequential maintenance after the construction is complete: Zandkreekdam, Veersegatdam, Markiezaatskade, Hartelkering, and Maeslantkering. The S scale of the barriers might be possible for the Zandkreekdam and Veersegatdam. Hartelkering and Maeslantkering, on the other hand, are the most recent flood barriers, having been constructed 25 years ago. The second inspection is the Oosterscheldekering. After 29 years of construction, The Oosterscheldekering is one of the barricades needing replacement parts in the shortest time. Moreover, according to the report from Rijkswaterstaat, during the maintenance time, this flood barrier will have the most extended maintenance season for six years, from 2022 to 2027. At the same time, the Haringvlietdam will be the flood barrier with the most prolonged research program from 2014 to 2028, or 14 years.

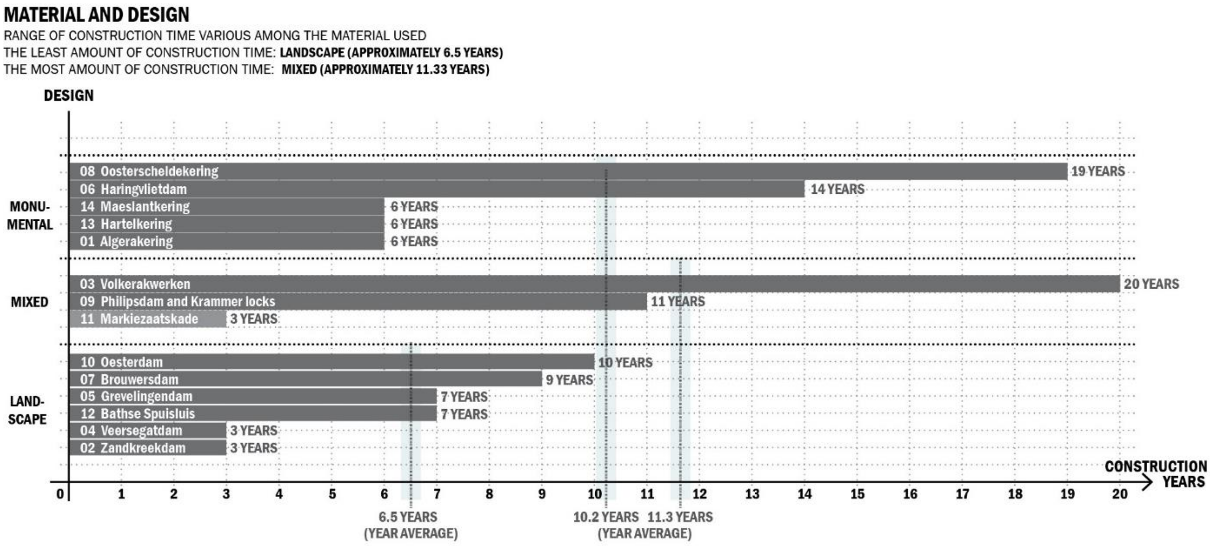

Figure 3. The selected bar chart in Material and design category during construction.

— illustrator by the author.

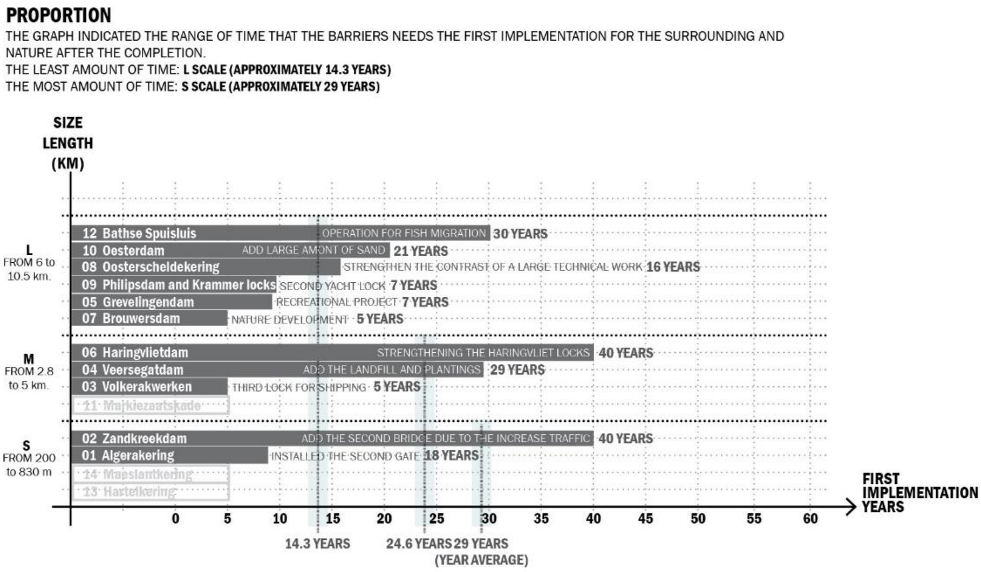

Figure 4. The selected bar chart in Proportion category during first implementation.

— illustrator by the author

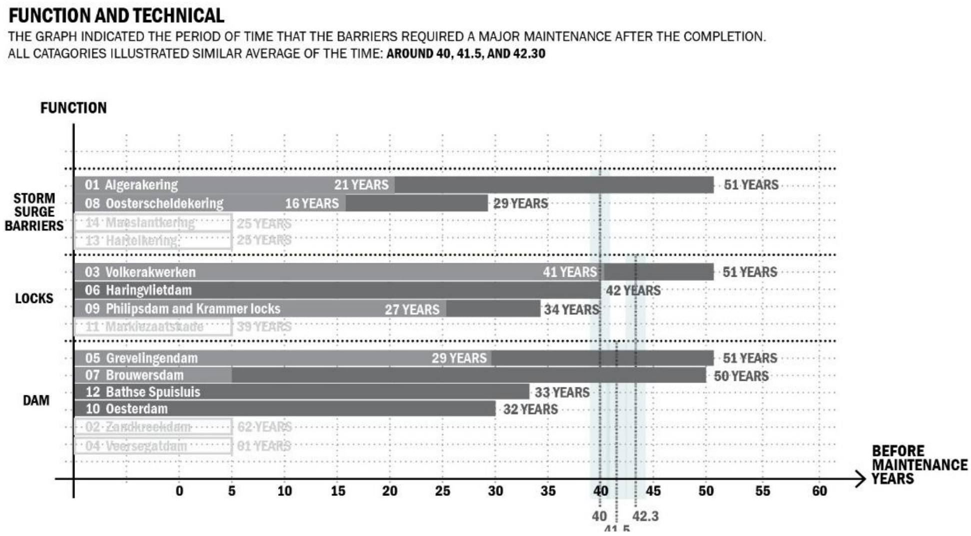

Figure 5. The selected bar chart in Function and technical category before maintenance.
— illustrator by the author

3.2 PHASE 2: THE ALTERATION OF USER BEHAVIOR

(BIODIVERSITY: HUMANS, ANIMALS, PLANTS)

3.2.1 The land connectivity of the Delta works (Land connection and cities development)

All the comparison maps in the land context demonstrated a significant difference between the two timeframes, with both positive and negative effects from the Delta work. The first comparison map's outcome portrayed the minor boundary change of the mainland and Island area. At the same time, there is a significant reduction of the land sediment or the Natural habitat for the animal and plants, especially between the islands.Generally, the Delta area is dynamic because the water influence from both directions brings sediment along the water flow and simultaneously erodes some parts of the land during storm and flood events. However, research from Vossestein about the Delta area (2011) raises another assumption about sediment reduction: the water level would be one of the factors. As a result of the development of the Delta works and the water level, the Delta works helped stabilize the current terrain while reducing immense amounts of sediment that created a home for terrestrial and aquatic species.

The flood barriers' function extends beyond that of a simple barrier to include a means of interconnecting the Zeeland Islands. As a result, the second transportation map includes that the accessibility and connection between the island and the mainland have greatly improved. These outcomes are revealed through the investigation of the function of each flood-barrier during phase one. This proves that every flood barrier serves more than one purpose and that the bridge and road were integrated into the barriers. In comparison, the transportation maps visualize how each Dam position and connection is based on the existing network or regional road.

Accessibility is a primary requirement of city development. When the road connected the land, it came with the city's expansion. According to the research, about 10% of the world's population lives in coastal communities due to the flourishing ecosystems (Global Commission on Adaptation, 2019). In contrast to the Zeeland province, the cities map displays that cities in 2022 are substantially the same as in 1910. Rarely find a new city, especially on the island. Based on the information of the top ten urban areas in Zeeland (*Zealand (Netherlands): Province & Urban Centers - Population Statistics, Charts and Map*, n.d.), The urban areas that have notable growth are mainly in the southern part of Zeeland or the area that connect directly to the mainland such as Middleburg, Vlissingen, and Goes. The only big city on the Island is Zierikzee.

3.2.2 Controlling the estuary area. (Water context)

From the primary assumption, Controlling and blocking the water from flood barriers negatively affects aquatic ecosystems and maritime routes. Corresponding to the result of the study, the comparison maps in a water environment highlight how each barrier functions while still having a passageway for water, fish migration, and boats. Even though there were more limitations to the water route than in 1910, the ecology can still survive despite the routes' restrictions. Additional evidence from phase one regarding the construction of the Delta works is that the flood barriers were designed with the environment as a consideration. For example, the hydraulic systems of the Oosterscheldekering allow the water to pass through almost the entire year. The hydraulic gates will close if the water level exceeds NAP 3 meters. Another example is Bathse spuisluis. There is a particular operation, especially for fish migration; the door will open twice daily. The limitation of the water routes might have a small impact on ecology at present, but substantial problems are upon us. Due to the result of the IPCC, the water level will be higher and accelerated than predicted in 2050. Thus, this announcement indicated that the gates of Oosterscheldekeing and Haringvlietdam will be permanently closed. The Oosterscheldekeing is one of the storm surge barriers in the estuary area and has the widest openness compared to the other flood barriers. This action will significantly impact the transition area of the Delta, which is home to 250 species. It could end the aquatic life cycles and entire ecosystems in the Zeeland. The second consequence of the route limitation is the considerable alteration of the domestic economy. In the past, local people relied more on fisheries, trading, agriculture, and aquaculture. During this time, the replacement of the mono-function of tourism, recreational activities, and private holiday houses has driven the economy in Zeeland, which is mainly located in the coastal area. Because of the limitation of the maritime routes, the flood of 1953, the central city nearby, such as Rotterdam and Antwerp, and other factors, the Zeeland area appears to be abandoned.

3.3 PHASE 3: MULTIFUNCTIONALITY

The exploration of the three case studies resulted in the potential of the spatial position, the volume of the architecture, and the material utilized in the new architecture. Starting with architectural orientation, according to the case study, architecture with functionality is frequently located on the top and under the infrastructure. Accordingly, the inclination is to maximize the available space from the structure's placement and morphology, such as the distance between columns. The architecture's location depends on the current infrastructure's operation, such as Kraanspoor by OTH Architecten. The shipyard's concrete crane path had been completely abandoned for the preceding two decades. As an opportunity of repurposing this abandoned structure, the new architecture utilizes and maximizes all the available space that the structure can provide.

The volume of the new function is defined by the existing structure's capacity and form. For instance, the height of the beamed ceiling limits the architecture underneath the railway in the Refurbishment Viaduct Arches case study. Regardless, the material selection does not depend on the existing structure. In comparison, the new design at Kraanspoor depended on the weight limit that the crane way could support, approximately 3 Floors. The weight limitation has also defined the selection of lightweight materials such as steel.

IV. CONCLUSIONS

The Delta works' seven centuries of operation, together with the rising sea level, brought the Netherlands substantial positive and negative alterations from a global to a local scale. From safeguarding the nation against storm surges and flooding, connecting the land, and causing a natural habitat loss in the future. Due to the massive scale of its structure as a flood defense, the Delta works inevitably involves multiple impacts affected by its construction. Every step of adjustment came with seen and unseen consequences. However, action must be taken as soon as possible when the nation's safety is in jeopardy. Prioritizing the best solutions for society at that time is the wisest course of action. After the tremendous achievement of the Delta works, one of the indispensable steps is to reconsider the cause of action and pave the way for a more promising future for all. Significantly, there is a continuation of the rising sea level waiting for us in the future.

Time has been an influential factor since the beginning of construction. More time spent might lead to higher expenses and energy consumption, particularly for a mega project like the Delta works. Thus, considering cost and time investment are essential factors for future adaptation. The discrepancies in each flood barrier's function, design, material, and size significantly revealed that the dam and landfill material design takes less construction time and requires minor maintenance than the locks and storm surge barriers. The possible reason is the complexity of both typologies' systems and construction methods. From an ecological perspective, the locks and storm surge barriers enable the water to pass through and preserve the aquatic ecology in the delta area; meanwhile, the dam type permanently blocks the water passage. In this result, All three categories are idiosyncratic, which could be why each location's fourteen flood barriers in the Delta works project are dissimilar. The difference between each barrier is intended to balance in-between protecting the country, investment, and ecological systems. Regardless, as the water level rises within 2050, the purpose of the flood barriers will alter. For example, the Oosterscheldekering, formerly allowing the water to pass, would be completely closed, functioning as a dam. This circumstance will impact the biodiversity in this area.

According to the study, most flood-barrier typologies require extensive maintenance every 42.5 years if we strengthen and maintain the same method—especially the Oosterscheldekering, which will spend the most effort replacing and preserving the hydraulic systems for six years or more. From the Delta Committee calculation, if an event such as the flood in 1953 happens every 4000 years, we must repeatedly maintain these barriers for 40 generations to achieve its purpose. This hypothesis might be impossible for future dynamics if the barriers remain the same.

More than dams and flood barriers. Even though the Delta works are being built to serve only one purpose flood protection; the result of the study indicated that all fourteen flood barriers were built for multifunction.The combination of flood barriers and transportation provided land accessibility to the Island part of the Zeeland. It serves not only as a road and a bridge, but some solid dams are also intended for nature reserves, creating new natural habitats in the area. The capability of a solid dam can be able to create land for wildlife while the locks and storm surge barriers sustain aquatic inhabitants. Combining three categories would be the best solution for land and water biodiversity.

Although the Delta works have numerous advantages, the impact after the construction is upon the local people. In the past, Zeeland people mainly rely on fisheries, aquaculture, and agriculture. Nonetheless, because of both the uncertainties of the sea level rise and the limitation of accessibility through water, people are more reliant on tourism and recreational activities. These monofunctional are temporary and only occur during the high season, leading to domestic economic stagnation. Along with the city's development through the map, there is a minor expansion of the city, specifically the island area. Zeeland might not be the option for people to settle down because of the impact of the sea level rise in the future.

Possibility for the future, the research directed to the site selection that significantly influences the future, such as permanently closing the gate of Oosterscheldekering. The result also guides the possibility of integration between the typology to create diversity. This combination also raises curiosity if we do not choose only to strengthen the dam or remove the dam but apply all the methods in the specific location suitable for the context. The integration experiment might lead to a new design for the future adaptability of flood barriers that also can be customized in another flood barrier for future study. The project about climate change is not only to find the solution but also to raise awareness in society. We have lived with the term climate change for more than a century; it has been normalized, and people may begin to believe that nothing has happened or that there is nothing we can do about it. It is time that we have to turn adverse outcomes into opportunities.

Nothing is permanent; even the most impressive enormous project requires adaptability in this dynamic world.

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Phase 3: The potential solutions. (Multifunctionality/Hybridity)

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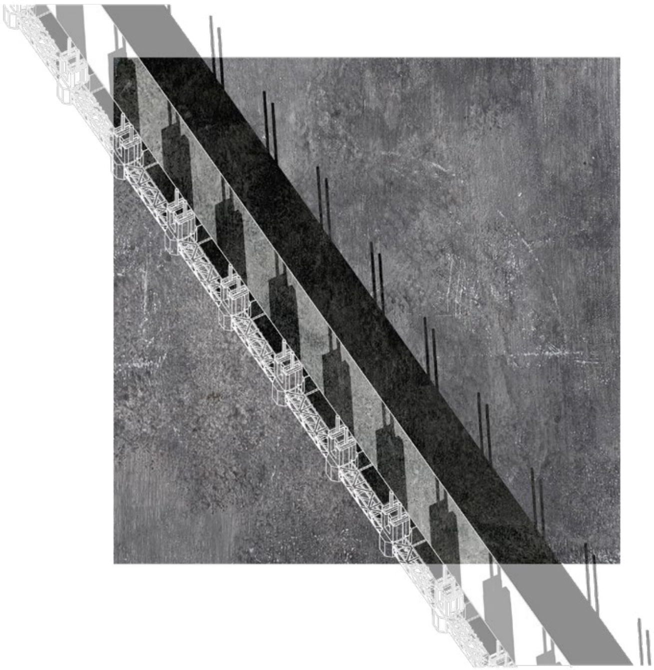
THE LIVING BARRIER

The architectural adaptation of existing flood barriers on Zeeland's new biodiversity synergy.



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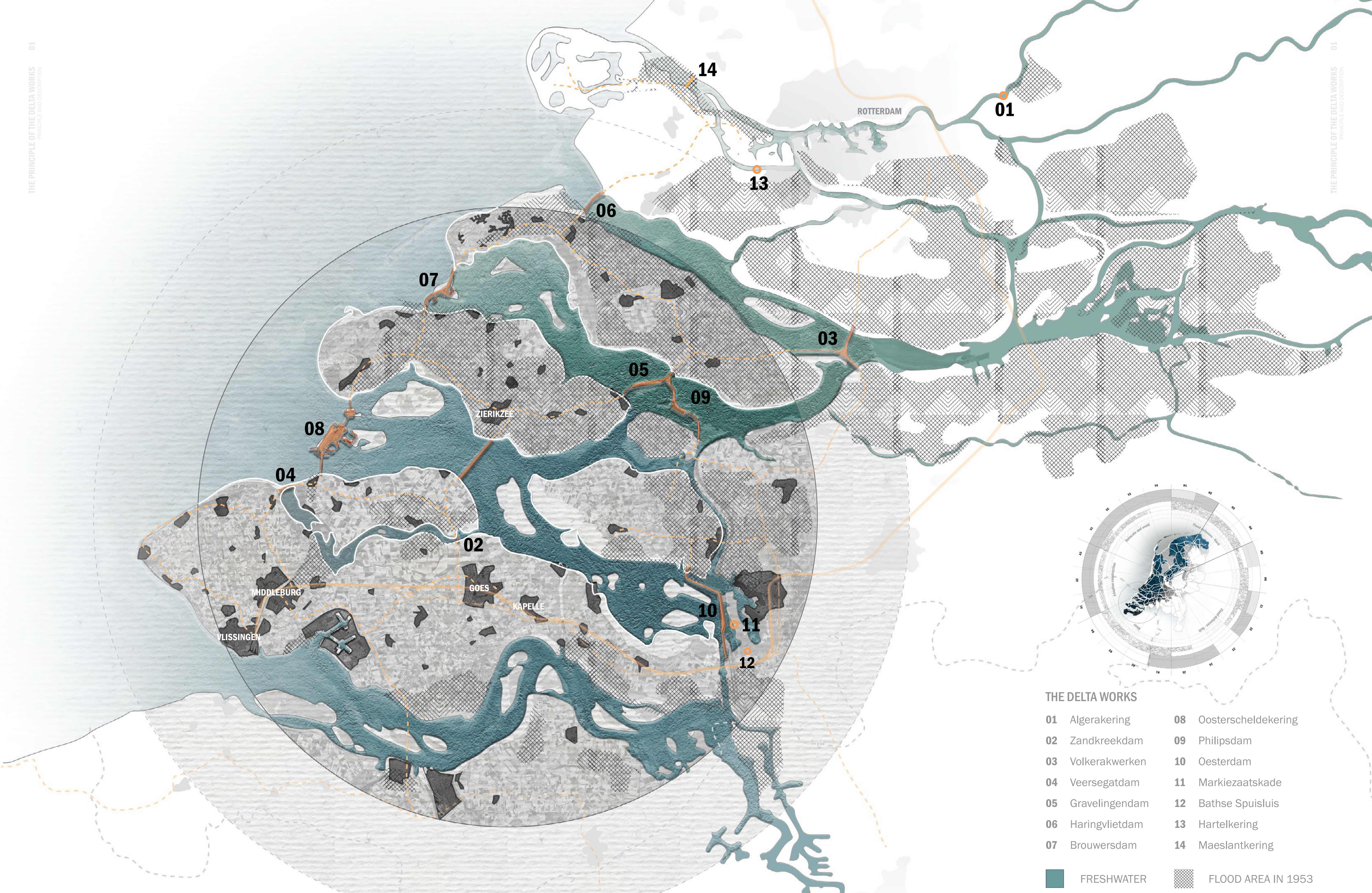
Research Plan | aE Graduation Studio | 2022-2023
Master of Science degree in Architecture, Urbanism and Building Sciences (Architecture track)

TABLE OF CONTENT

PHASE 1:
THE PRINCIPLE OF THE DELTA WORKS

THE DELTA WORKS
1954 - 1997

The Delta Works: Timeline of 14 Barriers



Map of Delta work in Zeeland and The 200,000 hectares of land flooded in the 1953 storms
— illustrator: the author / Source: The Storm Surge Barrier in the Eastern Scheldt: For Safety and Environment, (n.d.)

01 THE PRINCIPLE OF THE DELTA WORKS PRINCIPLE AND DESCRIPTION

01

ALGERA**KERING**

NAME	Algerakering or the Hollandse IJssel
LOCATION	South Holland, The Netherlands
CONSTRUCTION PERIOD	1954 - 1958
FUNCTION	Storm surge barrier Road (N210) with Bridge The combination of a storm surge barrier, lock and a road link between the Krimpenerwaard and the mainland of South Holland.
SIZE	Length: 200 Meters Height : 12 Meters (NAP) Towers 45 Meters Lock 24 Meters Width : 82 Meters The space between 2 gate is 250 Meters. The Algera ring closes on average 3 to 4 times a year
TECHNIQUE	Hydrulic system. First bascule bridge in the Netherlands with a shell construction. First Lattice girder bridge in the Netherlands with a steel driving deck
MAINTENANCE	1976 The second gate was installed. 1988 The bridge was widened because of the traffic intensity increased enormously in 1958. 2009 The entire complex was renovated 2020 Strengthening all steel sheet piles and carrying out concrete repairs.
OPERATION	The gates close at a water level of 2.25 meters above NAP The Algera ring protects the lowest part of the Netherlands, 6.76 meters. under NAP.

02

ZANDKREEK**DAM**

NAME	Zandkreekdam
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1957 - 1960
FUNCTION	Closure dam Road (N256) Bascule bridge (Bypass) Lock (For shipping) Sluice (2002)
SIZE	Length: 830 Meters Height : 7.45 Meters (NAP) Caisson Length: 11 Meters Height : 6 Meters (NAP) Width : 7.5 Meters
TECHNIQUE	Application of unit caissons on a large scale.
MAINTENANCE	1960 to 2000 Regular maintenance. 2000 Bypass was constructed with the second bridge on the Veerse Meer side. 2004 Constructed Katse Heule to improve the water quality.
OPERATION	The dam there is a lock for shipping between the Veerse Meer and the Oosterschelde
NATURE AND RECREATION	The Veerse Meer is an artificial lake, but it has the appearance of a nature reserve.

03

VOLKERAK**DAM**

The Volkerakdam has Europe's largest and busiest inland navigation lock complex.

NAME	Volkerakwerken
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1957 - 1977
FUNCTION	Closure dam Road (A29 / N59) Lock (For shipping)
SIZE	<u>Volkerekdam</u> Length: 4.5 Kilometers <u>Lock complex</u> Length: 4 Kilometers <u>Haringvliet bridge</u> Length: 1.2 Kilometers
TECHNIQUE	Complex integration of numerous functions in a single item conceived as a tripod
MAINTENANCE	1977 Complex expansion, an extra lock for inland shipping. 2020 Maintenance on the electronic part and mechanical.
OPERATION	The Volkerak locks are in operation day and night Almost 150,000 cargo ships pass through here every year.

04

VEERSEGAT**DAM**

The testing ground of the Delta Works

NAME	Veersegatdam
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1958 - 1961
FUNCTION	Closure dam Road (N57) Lock chambers
SIZE	Length: 2.8 Kilometers Height : 6 Meters (NAP) Width : 24 Meters <u>Lock chambers</u> Length: 320 Meters
TECHNIQUE	Engineering first implemented primary flood barrier in the Delta Plan First application of passage caissons of large dimensions
MAINTENANCE	1961 The Veerse Gat was closed. 1990s The dam was filled with sand. Planted with marram grass to imitate a dune as much as feasible.
OPERATION	Lower the water level to 30 cm below NAP in winter.
NATURE AND RECREATION	Landscaping cautious attempts to incorporate landscape embedding of the dam; closing of the estuary Veerse Gat, resulting in the development of an artificial lake (Veerse Meer) with recreational shores the initiative will test additional recreational services such as a beach and a cycling route on the dam's top.

05

GREVELINGEN**DAM**

The Grevelingendam was not designed primarily to defend against flooding.

NAME	Grevelingendam
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1958 - 1965
FUNCTION	Dam and sluice Road (N59) Lock (For shipping)
SIZE	Length: 6 Kilometers
TECHNIQUE	First closure with a cable car; experiment with landfill materials/ A special cable car is being built to dump large concrete blocks into the sea.
MAINTENANCE	2016 The renovation and functional improvement of the Flakkeese Spuisluis. 2022 Cylinder change 2023 Change at a different lock gate every 5 weeks
OPERATION	The sluice is open from 1. October to February end and closed from 1 March to September end.
NATURE AND RECREATION	First implemented recreation plan of size; high quality. The dam as an integral part of a recreational and natural area of national stature (the Grevelingen basin)

06

HARINGVLIET**DAM**

The Haringvliet locks are also known as the crane of Europe.

NAME	Haringvlietdam
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1958 - 1961
FUNCTION	Storm surge barrier Road (N57) A separate lock for shipping: the Goereese lock
SIZE	Length: 5 Kilometers <u>Sluices</u> Length: 1 Kilometers 17 Scuppers, each 56.5 Meters wide. 34 Slides
TECHNIQUE	Hydrulic system. Reuse of cableway Grevelingendam; no complete closure.
MAINTENANCE	2012 The management and maintenance of the Haringvliet locks2018 The Haringvliet sluices also function as a storm surge barrier. 2020 Maintenance work on the drive systems of 34 scrapers.
OPERATION	Rijkswaterstaat operates the 34 scuppers 24 hours a day.
NATURE AND RECREATION	landscape all technology under the roadway. The open gate for the fish migration between the North Sea and the Rhine river.

THE PRINCIPLE OF THE DELTA WORKS 01
PRINCIPLE AND DESCRIPTION

07

BROUWERS**DAM**

After the Oosterscheldekering, the Brouwersdam is the largest Delta project.

NAME	Brouwersdam
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1963 - 1972
FUNCTION	Dam (Flood defence) Road (N57) Lock
SIZE	Length: 6.5 Kilometers Height : 12 Meters
TECHNIQUE	Simultaneous closure of the two closure holes Both caissons and a cable car are used for the construction of the Brouwersdam
MAINTENANCE	Rijkswaterstaat inspects the dam on a regular basis and repairs or replaces old or damaged elements. There is a lot of sand on the N57. Rijkswaterstaat spray more sand along the coast to prevent waves from damaging the dam.
NATURE AND RECREATION	Landscape designed as a landscape at sea that blends naturally blends into the landscape. The dam as part of a recreational and natural area of national stature.

08

OOSTERSCHELDE**KERING**

The Oosterscheldekering is one of the most impressive hydraulic engineering objects in the Netherlands. Cost 2.5 billion Euro.

NAME	Oosterscheldekering
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1967 - 1986
FUNCTION	Storm surge barrier Road (N57)
SIZE	Length: 9 Kilometers <u>Colossal Pillars (65 pieces)</u> with 62 Steel slides in between. Height: 30 - 40 Meters <u>The gate</u> Length: 42 Meters Height : 6 - 12 Meters
TECHNIQUE	Hydrulic system. The first time large-scale use of computers operation. All the construction components are unprecedented scale
MAINTENANCE	2015 - 2020 Preserving the 124 cylinders. 2015 - 2014 Preserve 32 Steel Slides (4 Slide per season) 2021 - 2023 Replacing and intergrating various security systems. 2021 - 2024 Renovating 124 movement mechanisms of the barrier.
OPERATION	At a water level of three meters NAP, the barrier closes. The barrier closes once a year on average, but owing to increasing sea levels, this may become more frequent in the future. Closing the barrier takes 75 minutes
NATURE AND RECREATION	Program large influence of nature aspects combined with safety requirements The movable gate for environmental matter between the North Sea and the Oosterschlde.

09

PHILIPS**DAM**

An innovative fresh-salt separation system with buffer basins

NAME	Philipdam and Krammer locks
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1976 - 1987
FUNCTION	Dam and sluice as salt lock Lock complex
SIZE	Length: 6.1 Kilometers <u>Lock complex</u> <u>Commercial shipping locks</u> 280 by 24 Meters wide <u>Recreational shipping locks</u> 78 by 9 Meters
TECHNIQUE	Fresh-salt separation system
MAINTENANCE	2022 Tender for the renovation of the Krammer locks 2023 Replacing electric motors in push locks
OPERATION	open 13,000 times a year
NATURE AND RECREATION	Landscape creation of a special project group for the aesthetic aspect; functionality of the dam translated into the landscape design; contrast between the fresh and salt water landscape

10

OESTER**DAM**

The Oesterdam is the longest dam of the Delta Works.

NAME	Oesterdam
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1979 - 1989
FUNCTION	Dam Road (N659) Bergse Diepsluis
SIZE	Length: 10.5 Kilometers
TECHNIQUE	Sand closure of large channels.
MAINTENANCE	2010 Strengthen the dam Build with nature, Wave reduction and also created a (small) beach, which increased the recreational opportunities.
NATURE AND RECREATION	Make use of the techniques and possibilities that nature offers.

11

MARKIEZAAT**SKADE**

The Markiezaatskade was built to make the construction of the Oesterdam simpler and cheaper.

NAME	Markiezaatskade
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	1980 - 1983
FUNCTION	Dam
SIZE	Length: 4 Kilometers
TECHNIQUE	Sand spraying.
MAINTENANCE	1982 the only part of the Delta Works that collapsed.
OPERATION	Divides the waters of Zeeland and South Holland into compartments for the purpose of freshwater management and shipping
NATURE AND RECREATION	Linking water management interests nature and recreational interests and the formation of an attractive residential environment

12

BATHSE SPUI**SLUIS**

The Bathse Spuisluis is the only Delta work that was not built for defense against the water

NAME	Bathse Spuisluis en Spuikanaal
LOCATION	Zeeland, The Netherlands
CONSTRUCTION PERIOD	Bathse Spuisluis 1980 - 1987 Bathse Spuikanaal 1982 - 1986
FUNCTION	Lock/canal (without shipping) Road (N659)
SIZE	Length: 8.4 Kilometers
TECHNIQUE	Discharge of fresh and/or polluted water into the Western Scheldt Consists of 6 concrete tubes
MAINTENANCE	2020 Renovation
OPERATION	Can drain 8.5 billion liters of water per day 2 times a day watch door and slide open for fish
NATURE AND RECREATION	Discharge of fresh and/or polluted water into the Western Scheldt

13

HARTEL**KERING**

The Hartelkering consists of a large and small gate that can be lowered into the water to close off the Hartel Canal.

NAME	Philipdam and Krammer locks
LOCATION	South Holland, The Netherlands
CONSTRUCTION PERIOD	1991 - 1997
FUNCTION	Storm surge barrier The Hartel bridge Road (N218)
SIZE	Length: 200 Kilometers <u>Two Passages</u> Width: 49 and 98 Meters
TECHNIQUE	Two elliptical gates with a span lengths of 49.3 and 98 meters, which are suspended between oval towers. Vertically movable barriers.
OPERATION	The automatic Decision and Support System (BOS). The Maeslantkering and Hartelkering will close if a water level of more than 3 m above NAP is predicted near Rotterdam and more than 2.9 m above NAP near Dordrecht. has only been closed 2 times (2007 and 2018) According to calculations, the Hartelkering will have to close once or twice every 10 years
NATURE AND RECREATION	landscape visual impact study of various locations; built next to and over existing bridge and lock

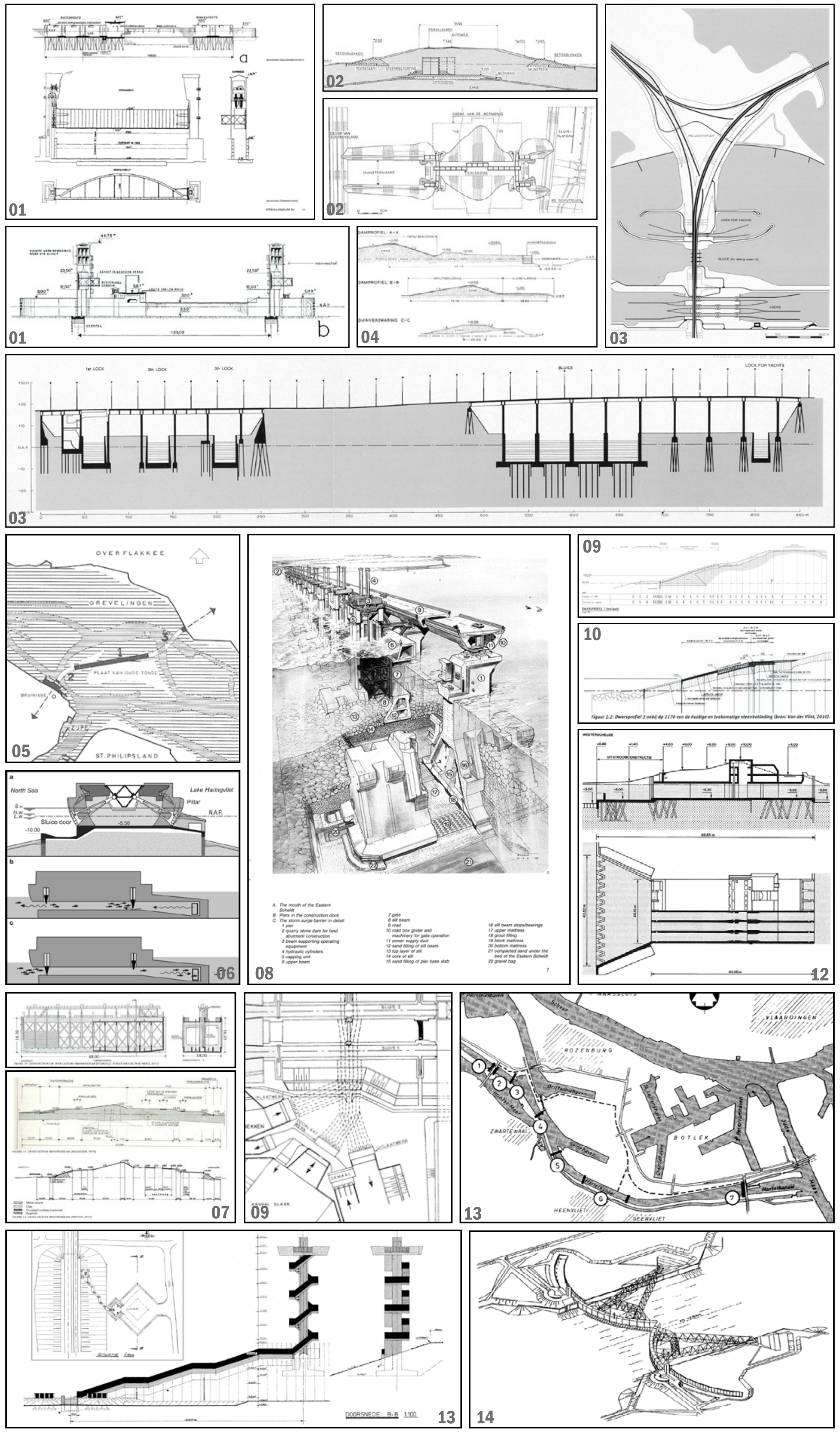
14

MAESLANT**KERING**

largest ball joints in the world

NAME	Maeslantkering
LOCATION	South Holland, The Netherlands
CONSTRUCTION PERIOD	1991 - 1997
FUNCTION	Storm surge barrier
SIZE	<u>The two curved doors</u> Length: 380 Meters (210 Meters each) Height: 22 Meters Width : 15 Meters
TECHNIQUE	Technique probabilistic risk analysis as a measure of value for the design and management process Automatic closure without human intervention
OPERATION	Test during september 1 time and storm season 1 times (1 October to Apirl)
NATURE AND RECREATION	landscape color and shape as contrast to surroundings

The Delta Works: 14 Barriers



Drawing and Dimensions

		NAME	LOCATION	CONSTRUCTION PERIOD	FUNCTION	SIZE
01		ALGERA**KERING**	South Holland, The Netherlands	1954 - 1958	Storm surge barrier Road (N210) with Bridge	Length : 200 Meters Height : 12 Meters Width : 82 Meters
02		ZANDKREEK**DAM**	Zeeland, The Netherlands	1957 - 1960	Closure dam Road (N256) Bascule bridge (Bypass) Lock (For shipping) Sluice (2002)	Length: 830 Meters Height : 7.45 Meters
03		VOLKERAK**WERKEN**	Zeeland, The Netherlands	1957 - 1977	Closure dam Road (A29 / N59) Lock (For shipping)	Volkerekdam Length: 4.5 Kilometers Lock complex Length: 4 Kilometers
04		VEERSEGAT**DAM**	Zeeland, The Netherlands	1958 - 1961	Closure dam Road (N57) Lock chambers	Length: 2.8 Kilometers Height : 6 Meters Width : 24 Meters
05		GREVELINGEN**DAM**	Zeeland, The Netherlands	1958 - 1965	Dam and sluice Road (N59) Lock (For shipping)	Length: 6 Kilometers
06		HARINGVLIET**DAM**	Zeeland, The Netherlands	1958 - 1961	Storm surge barrier Road (N57) Lock (For shipping)	Length: 5 Kilometers Lock complex Length: 1 Kilometers
07		BROUWERS**DAM**	Zeeland, The Netherlands	1963 - 1972	Dam (Flood defence) Road (N57) Lock	Length: 6.5 Kilometers Height : 12 Meters
08		OOSTERSCHELDE**KERING**	Zeeland, The Netherlands	1967 - 1986	Storm surge barrier Road (N57)	Length: 9 Kilometers Colossal Pillars (65 pieces) Height: 30 - 40 Meters
09		PHILIPS**DAM**	Zeeland, The Netherlands	1976 - 1987	Dam and sluice as salt lock Lock complex	Length: 6.1 Kilometers
10		OESTER**DAM**	Zeeland, The Netherlands	1979 - 1989	Dam Road (N659) Bergse Diepsluis	Length: 10.5 Kilometers
11		MARKIEZAATS**KADE**	Zeeland, The Netherlands	1980 - 1983	Dam	Length: 4 Kilometers
12		BATHSE SPUI**SLUIS**	Zeeland, The Netherlands	1980 - 1987	Lock/canal (without shipping) Road (N659)	Length: 8.4 Kilometers
13		HARTEL**KERING**	South Holland, The Netherlands	1991 - 1997	Storm surge barrier Road (N218) The Hartel bridge	Length: 200 Kilometers Two Passages Width: 49 and 98 Meters
14		MAESLANT**KERING**	South Holland, The Netherlands	1991 - 1997	Storm surge barrier	Length: 380 Meters Height: 22 Meters Width : 15 Meters

	TECHNIQUE	MAINTENANCE	OPERATION	NATURE AND RECREATION
01	Hydrulic system. First bascule bridge in the Netherlands with a shell construction.	1976 The second gate was installed. 1988 The bridge was widened because of the traffic intensity increased enormously in 1958.	The gates close at a water level of 2.25 meters above NAP The Algera ring protects the lowest part of the Netherlands, 6.76 meters. under NAP.	
02	Application of unit caissons on a large scale.	1960 Regular maintenance. 2000 Bypass was constructed with the second bridge on the Veerse Meer side. 2004 Constructed Katse Heule	The dam there is a lock for shipping between the Veerse Meer and the Oosterschelde	The Veerse Meer is an artificial lake, but it has the appearance of a nature reserve.
03	Complex integration of numerous functions in a single item conceived as a tripod	1977 Complex expansion, an extra lock for inland shipping. 2020 Maintenance on the electronic part and mechanical.	The Volkerak locks are in operation day and night Almost 150,000 cargo ships pass through here every year.	
04	First application of passage caissons of large dimensions	1961 The Veerse Gat was closed. 1990s The dam was filled with sand. Planted with marram grass to imitate a dune.	Lower the water level to 30 cm below NAP in winter.	The development of an artificial lake (Veerse Meer) with recreational shores such as a beach and a cycling route on the dam's top.
05	First closure with a cable car; experiment with landfill material A special cable car is being built to dump large concrete blocks into the sea.	2016 The renovation and functional improvement of the Flakkeese Spuisluis. 2022 Cylinder change 2023 Change at a different lock.	The sluice is open from 1. October to February end and closed from 1 March to September end.	First implemented recreation plan of size; high quality. The dam as an integral part of a recreational and natural area of the Grevelingen basin
06	Hydrulic system. Reuse of cableway Grevelingendam; no complete closure.	2018 The Haringvliet sluices also function as a storm surge barrier. 2020 Maintenance work on the drive systems of 34 scrapers.	Rijkswaterstaat operates the 34 scuppers 24 hours a day.	landscape all technology under the roadway. The open gate for the fish migration between the North Sea and the Rhine river.
07	Simultaneous closure of the two closure holes. Both caissons and a cable car are used for the construction of the Brouwersdam	Rijkswaterstaat inspects the dam on a regular basis and repairs or replaces old or damaged elements. Spray more sand along the coast to prevent waves.		Landscape designed as a landscape at sea that blends naturally blends into the landscape.
08	Hydrulic system. The first time large-scale use of computers operation. All the construction components are unprecedented scale.	2015 - 2020 Preserving the 124 cylinders. 2021 - 2024 Renovating 124 movement mechanisms of the barrier.	At a water level of three meters NAP, the barrier closes. The barrier closes once a year on average.	The movable gate for environmental matter between the North Sea and the Oosterschlde.
09	Fresh-salt separation system	2022 Tender for the renovation of the Krammer locks 2023 Replacing electric motors in push locks	open 13,000 times a year	Functionality of the dam translated into the landscape design; contrast between the fresh and salt water landscape
10	Sand closure of large channels.	2010 Strengthen the dam Build with nature, Wave reduction and also created a (small) beach, which increased the recreational opportunities.	about 80,000 ships pass each year.	Make use of the techniques and possibilities that nature offers.
11	Sand spraying.	1982 the only part of the Delta Works that collapsed.	Divides the waters of Zeeland and South Holland into compartments for the purpose of freshwater management and shipping	Linking water management interests nature and recreational interests and the formation of an attractive residential environment
12	Discharge of fresh and/or polluted water into the Western Scheldt Consists of 6 concrete tubes	2020 Renovation	Can drain 8.5 billion liters of water per day. 2 times a day watch door and slide open for fish	Discharge of fresh and/or polluted water into the Western Scheldt
13	Two elliptical gates with a span lengths of 49.3 and 98 meters, which are suspended between oval towers. Vertically movable barriers.		The automatic Decision and Support System (BOS). Close if a water level of more than 3 m above NAP.	landscape visual impact study of various locations; built next to and over existing bridge and lock
14	Technique probabilistic risk analysis as a measure of value for the design and management process. Automatic closure without human intervention		Test during september 1 time and storm season 1 times (1 October to Apirl)	landscape color and shape as contrast to surroundings

THE CATAGORIZATION
OF THE DELTA WORKS

BY

FUNCTION AND TECHNICAL (BY ENGINEER)
MATERIAL AND DESIGN
SIZE (LENGTH AND HEIGHT)

FUNCTION AND TECHNICAL
BY ENGINEER

three locks, six dams, and four storm surge barriers

STATIC → FLEXIBLE

	CLOSURE DAM	LOCKS (SHIPPING)	STORM SURGE BARRIERS
01			ALGERAKERING
02	ZANDKREEKDAM		
03		VOLKERAK WERKEN	
04	VEERSEGATDAM		
05	GREVELINGEN DAM		
06		HARINGVLIET DAM	
07	BROUWERSDAM		
08			OOSTERSCHELDE KERING
09		PHILIPSDAM	
10	OESTERDAM		
11		MARKIEZAATS KADE	
12	BATHSE SPUISLUIS		
13			HARTELKERING
14			MAESLANT KERING

MATERIAL AND DESIGN

LANDSCAPE → MONUMENTAL

	LANDSCAPE LANDFILL MATERIAL SAND / PLANTS	MIXED	MONUMENTAL CONCRETE - STEEL
01			ALGERAKERING
02	ZANDKREEKDAM		
03		VOLKERAK WERKEN	
04	VEERSEGATDAM		
05	GREVELINGEN DAM		
06			HARINGVLIET DAM
07	BROUWERSDAM		
08			OOSTERSCHELDE KERING
09		PHILIPSDAM	
10	OESTERDAM		
11		MARKIEZAATS KADE	
12	BATHSE SPUISLUIS		
13			HARTELKERING
14			MAESLANT KERING

PROPORTION
LENGTH / HEIGHT

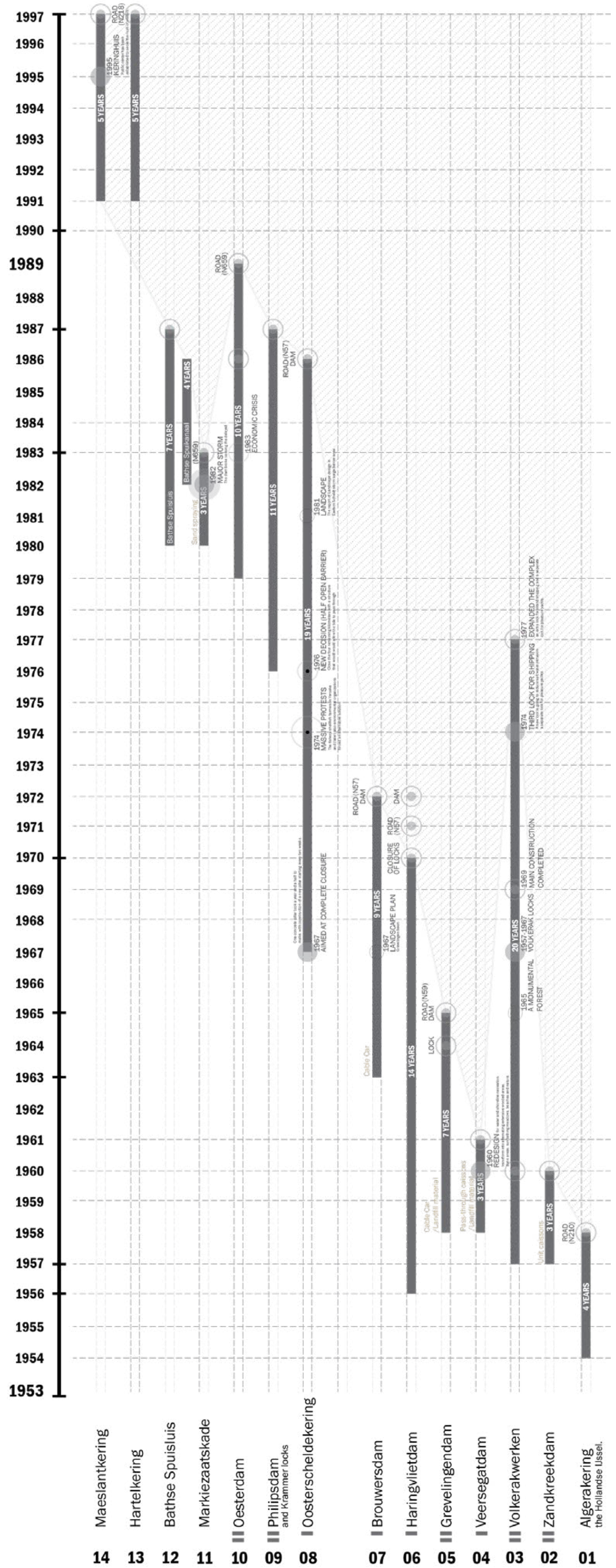
	S FROM 200 to 830 m	M FROM 2.8 to 5 km.	L FROM 6 to 10.5 km.
01	ALGERAKERING		
02	ZANDKREEKDAM		
03		VOLKERAK WERKEN	
04		VEERSEGATDAM	
05			GREVELINGEN DAM
06		HARINGVLIET DAM	
07			BROUWERSDAM
08			OOSTERSCHELDE KERING
09			PHILIPSDAM
10			OESTERDAM
11		MARKIEZAATS KADE	
12			BATHSE SPUISLUIS
13	HARTELKERING		
14	MAESLANT KERING		

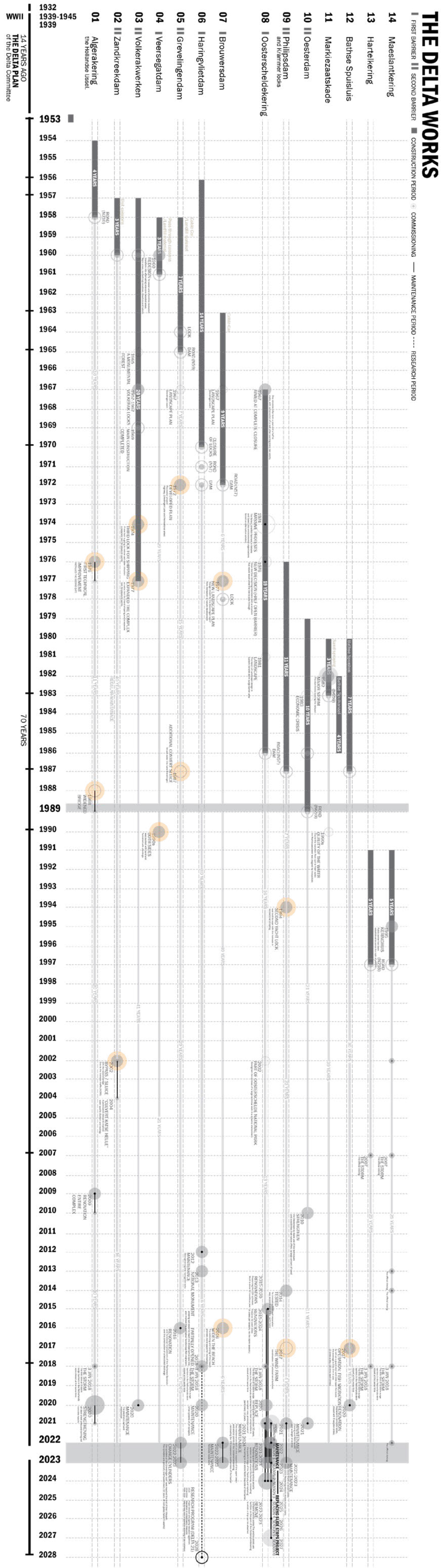
LIFE CYCLE
OF THE DELTA WORKS

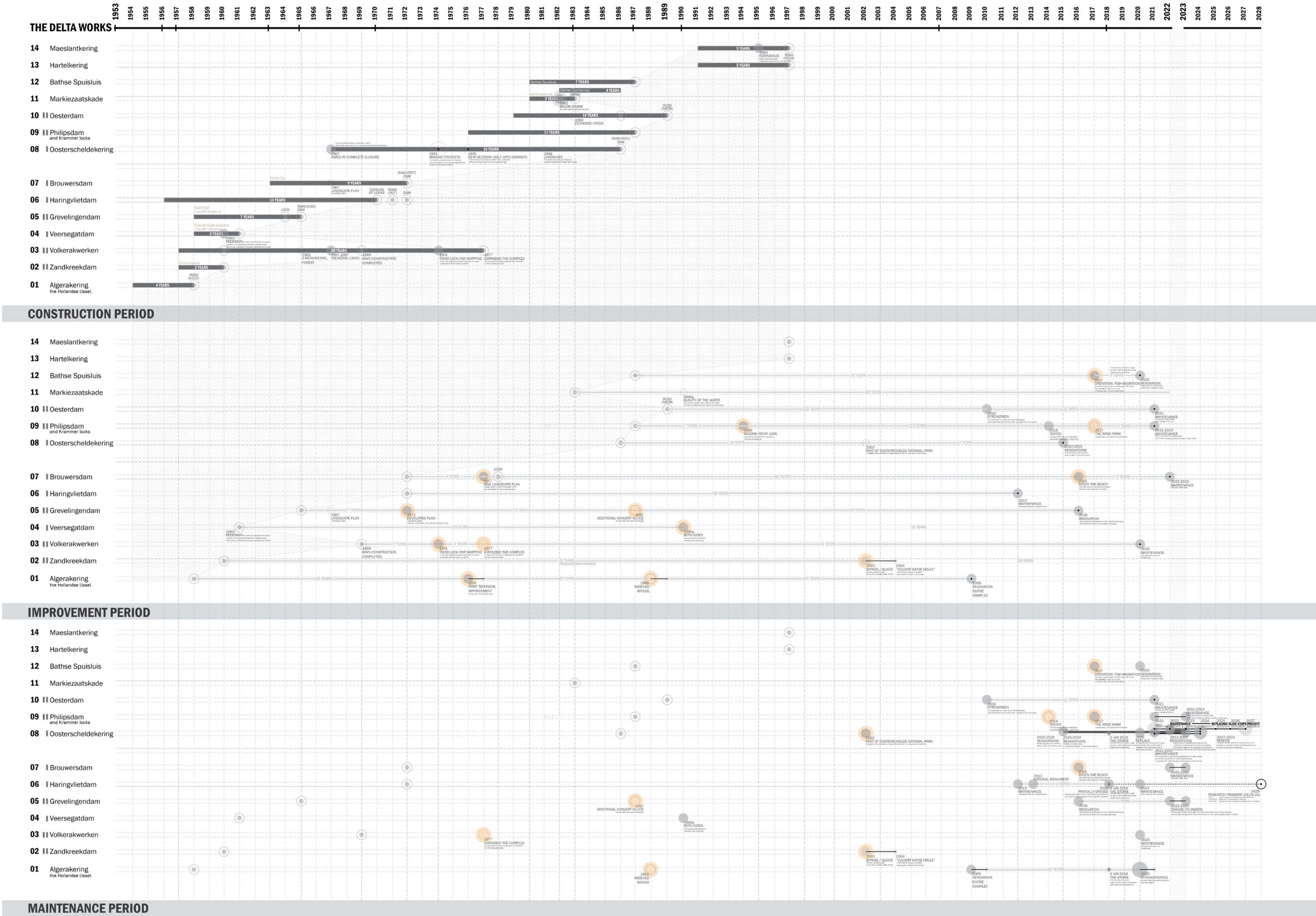
THE PERIOD OF

CONSTRUCTION
IMPROVEMENT
MAINTENANCE

CONSTRUCTION PERIOD
FROM 1954 to 1997




THE DELTA WORKS
FIRST BARRIER
SECOND BARRIER
CONSTRUCTION PERIOD
COMMISSIONING
MAINTENANCE PERIOD
RESEARCH PERIOD
01 Algerakering
the Hollandse IJssel
02 Zandkreekdam
03 Volkerakwerken
04 Veersegatdam
05 Grevelingendam
06 Haringvlietdam
07 Brouwersdam
08 Oosterscheldekering
09 Philipsdam
and Krammer locks
10 Oesterdam
11 Markiezaatskade
12 Bathse Spuisluis
13 Hartelkering
14 Maeslantkering
1932
1939-1945
1939
WWII
14 YEARS AGO
THE DELTA PLAN
of the Delta Committee
70 YEARS



THE PRINCIPLE OF THE DELTA WORKS 01
CATAGORIZATION

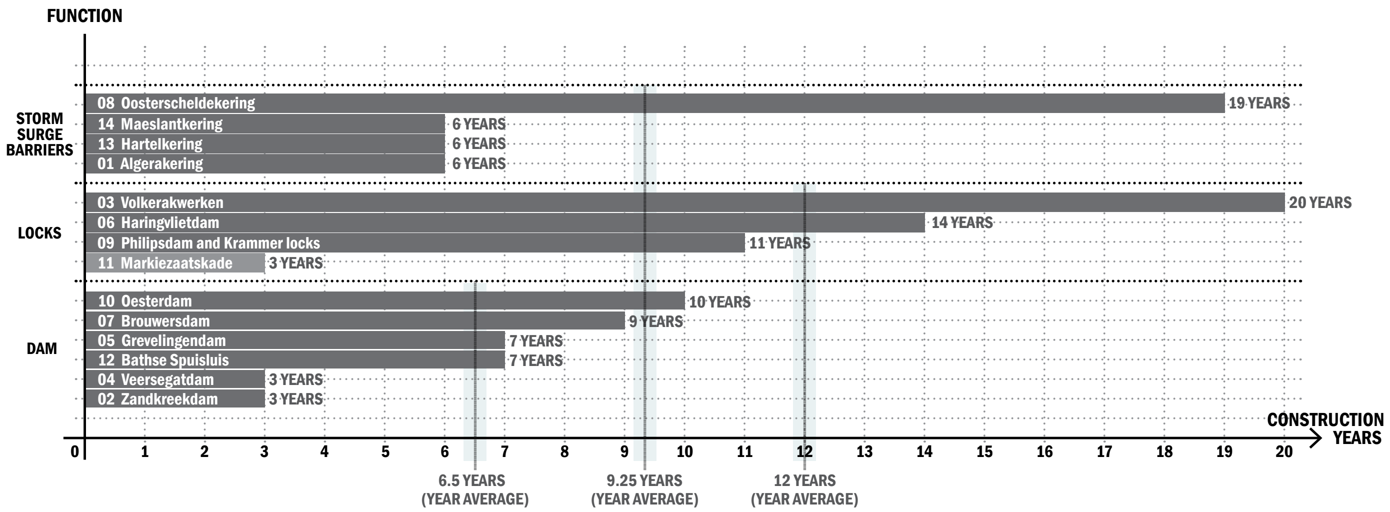
CONSTRUCTION PERIOD

FROM 1954 to 1997

43 YEARS OF CONSTRUCTION

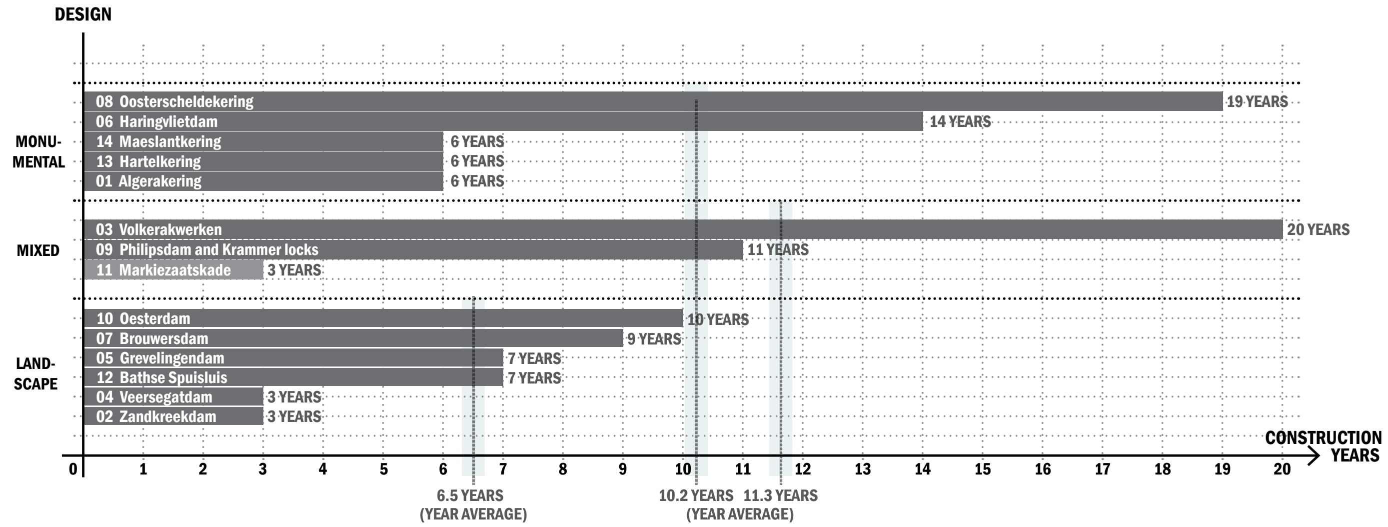
FUNCTION AND TECHNICAL

RANGE OF CONSTRUCTION TIME VARIOUS AMONG THE FUNCTION OF THE BARRIERS
THE LEAST AMOUNT OF CONSTRUCTION TIME: **DAM (APPROXIMATELY 6.5 YEARS)**
THE MOST AMOUNT OF CONSTRUCTION TIME: **LOCKS (APPROXIMATELY 12 YEARS)**



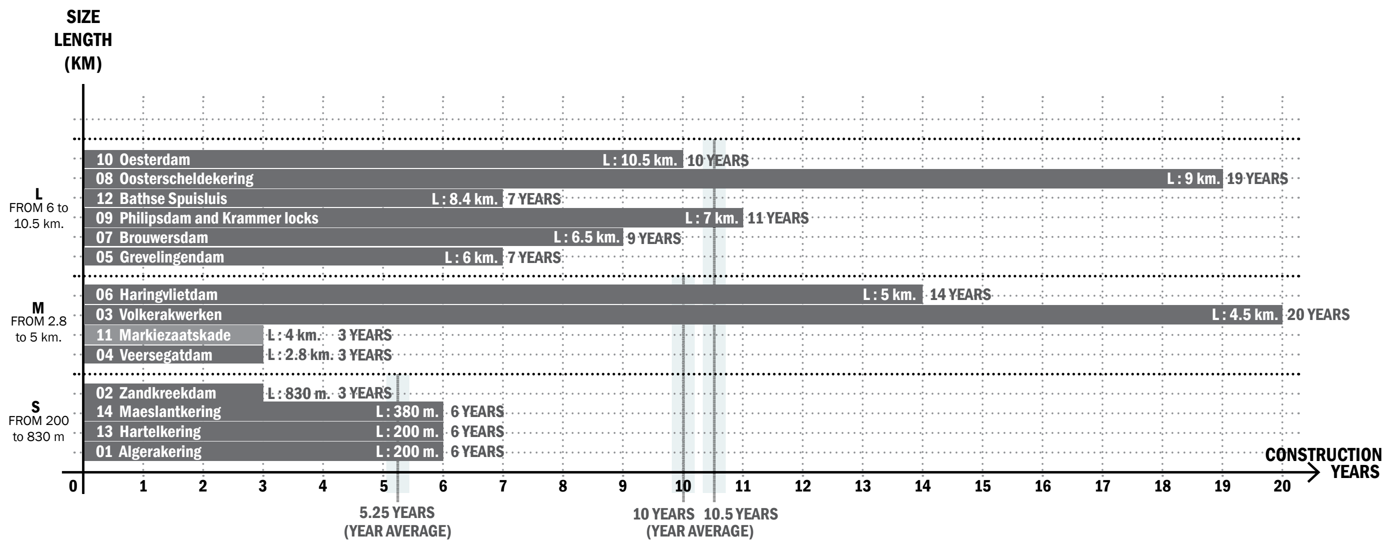
MATERIAL AND DESIGN

RANGE OF CONSTRUCTION TIME VARIOUS AMONG THE MATERIAL USED
THE LEAST AMOUNT OF CONSTRUCTION TIME: **LANDSCAPE (APPROXIMATELY 6.5 YEARS)**
THE MOST AMOUNT OF CONSTRUCTION TIME: **MIXED (APPROXIMATELY 11.33 YEARS)**



PROPORTION

RANGE OF CONSTRUCTION TIME VARIOUS AMONG THE PROPORTION
THE LEAST AMOUNT OF CONSTRUCTION TIME: **S SCALE (5.25 YEARS)**
THE MOST AMOUNT OF CONSTRUCTION TIME: **BOTH M AND L SCALE (10 and 10.5 YEARS)**

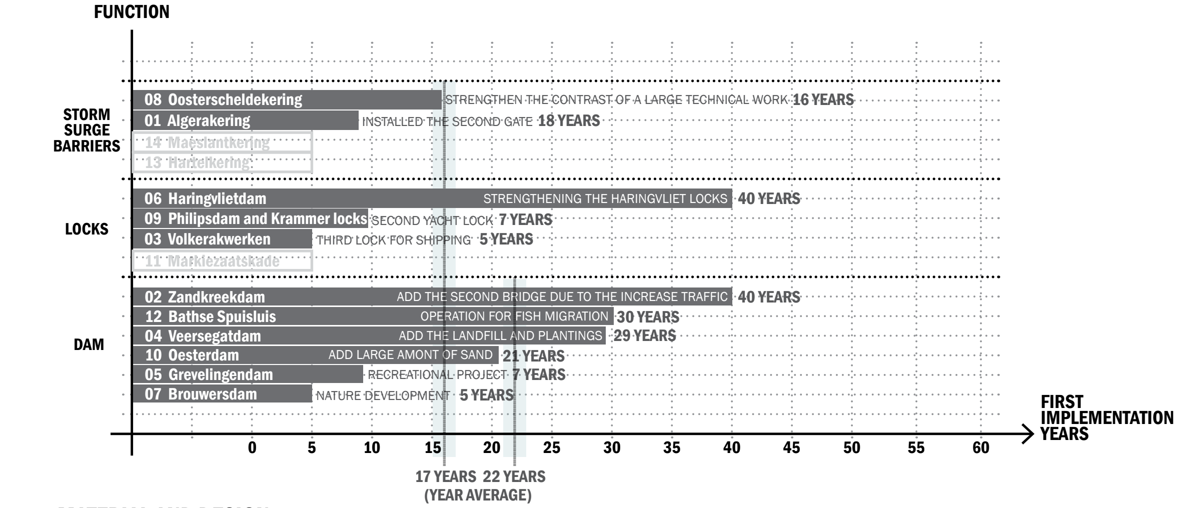


IMPLEMENTATION PERIOD

FROM 1958 to 2020

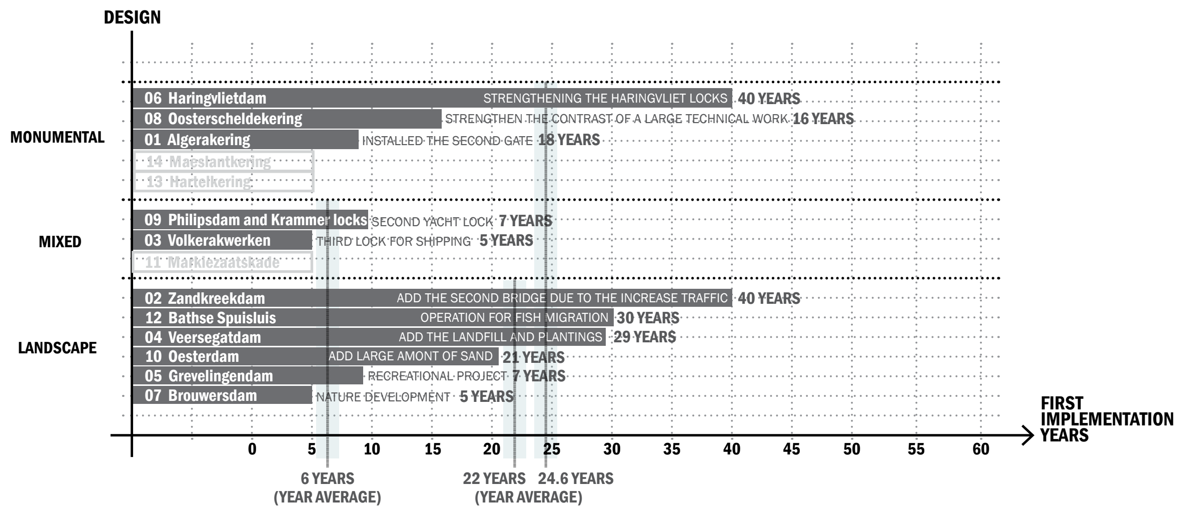
FUNCTION AND TECHNICAL

THE GRAPH INDICATED THE RANGE OF TIME THAT THE BARRIERS NEEDS THE FIRST IMPLEMENTATION FOR THE SURROUNDING AND NATURE AFTER THE COMPLETION.
THE LEAST AMOUNT OF TIME: **LOCKS AND STORM SURGE BARRIERS (APPROXIMATELY 17 YEARS)**
THE MOST AMOUNT OF TIME: **DAM (APPROXIMATELY 22 YEARS)**



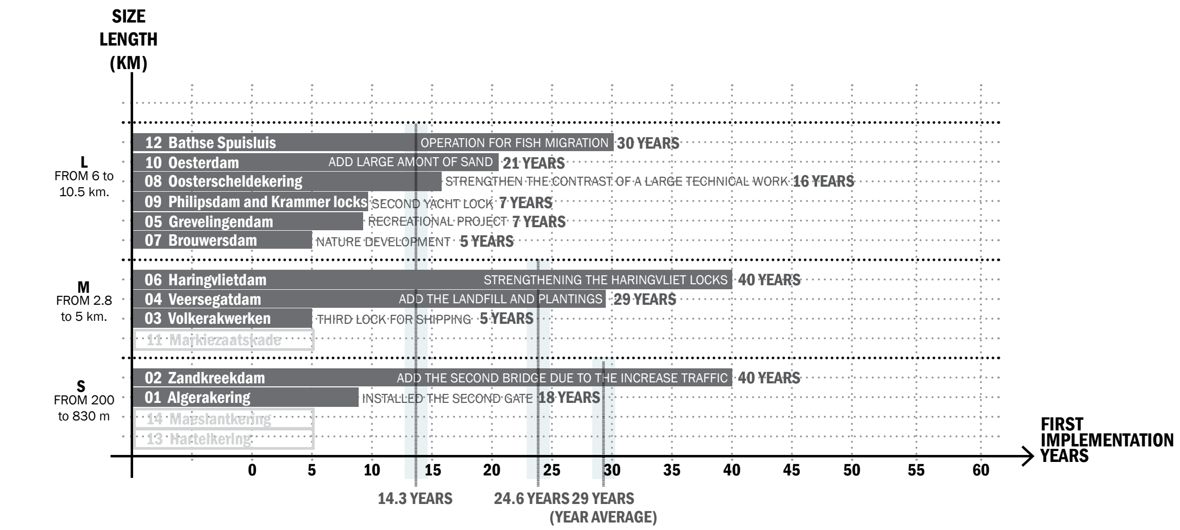
MATERIAL AND DESIGN

THE GRAPH INDICATED THE RANGE OF TIME THAT THE BARRIERS NEEDS THE FIRST IMPLEMENTATION FOR THE SURROUNDING AND NATURE AFTER THE COMPLETION.
THE LEAST AMOUNT OF TIME: **MIXED DESIGN (APPROXIMATELY 6 YEARS)**
THE MOST AMOUNT OF TIME: **MONUMETAL DESIGN (APPROXIMATELY 24.6 YEARS)**



PROPORTION

THE GRAPH INDICATED THE RANGE OF TIME THAT THE BARRIERS NEEDS THE FIRST IMPLEMENTATION FOR THE SURROUNDING AND NATURE AFTER THE COMPLETION.
THE LEAST AMOUNT OF TIME: **L SCALE (APPROXIMATELY 14.3 YEARS)**
THE MOST AMOUNT OF TIME: **S SCALE (APPROXIMATELY 29 YEARS)**

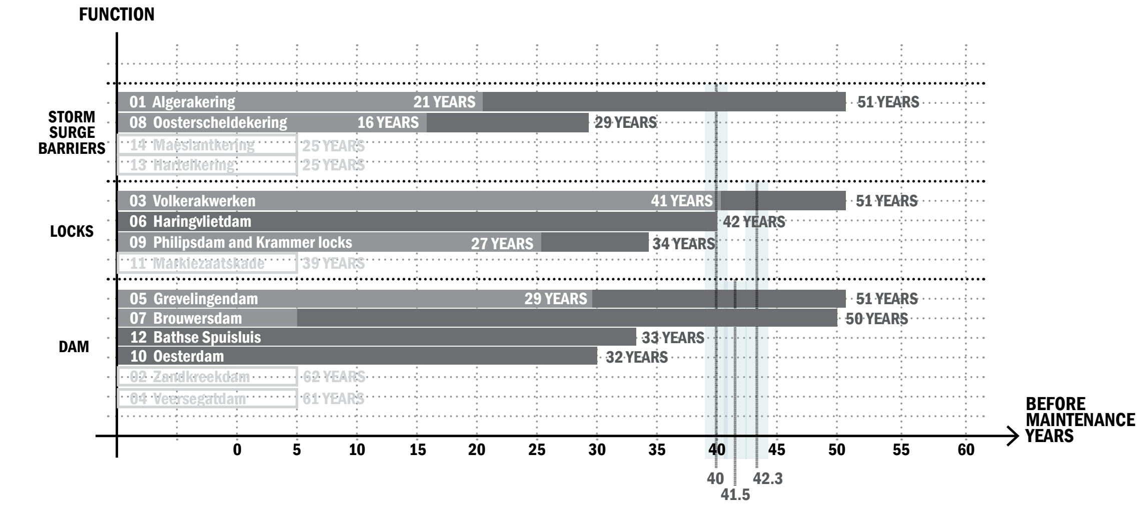


MAINTENANCE PERIOD

APPROXIMATELY **42.5 YEARS** *THAT THE FLOOD BARRIERS REQUIRED A CONSIDERABLE MAINTENANCE.*

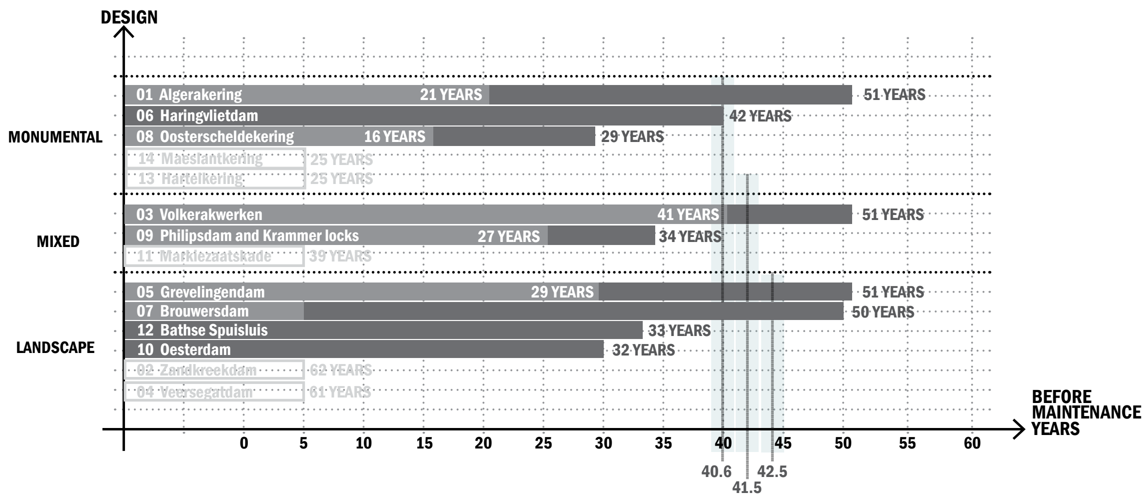
FUNCTION AND TECHNICAL

THE GRAPH INDICATED THE PERIOD OF TIME THAT THE BARRIERS REQUIRED A MAJOR MAINTENANCE AFTER THE COMPLETION.
ALL CATAGORIES ILLUSTRATED SIMILAR AVERAGE OF THE TIME: **AROUND 40, 41.5, AND 42.30**



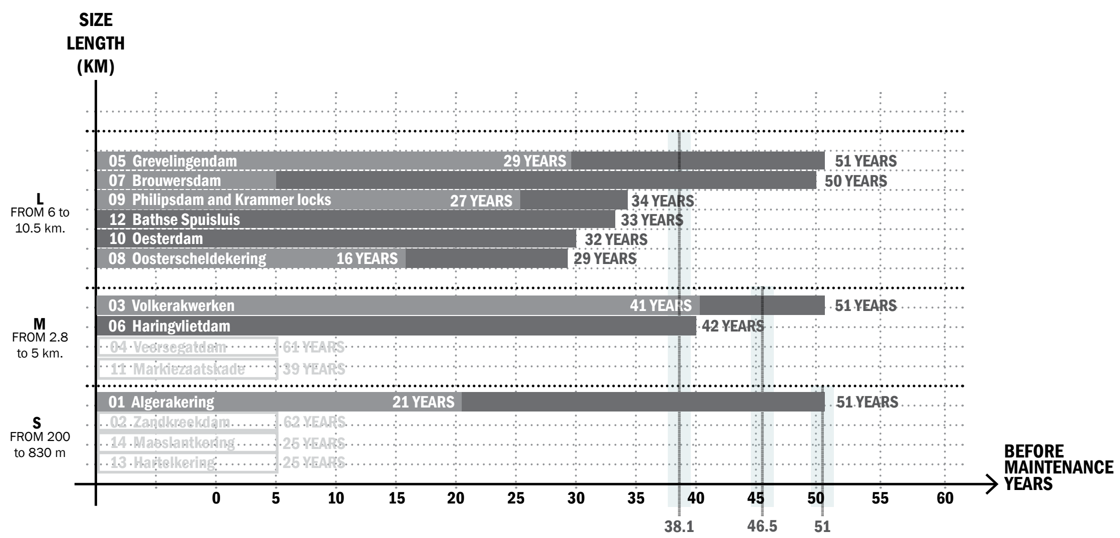
MATERIAL AND DESIGN

THE GRAPH INDICATED THE PERIOD OF TIME THAT THE BARRIERS REQUIRED A MAJOR MAINTENANCE AFTER THE COMPLETION.
ALL CATAGORIES ILLUSTRATED SIMILAR AVERAGE OF THE TIME: **AROUND 40.6, 40.6, AND 42.5**

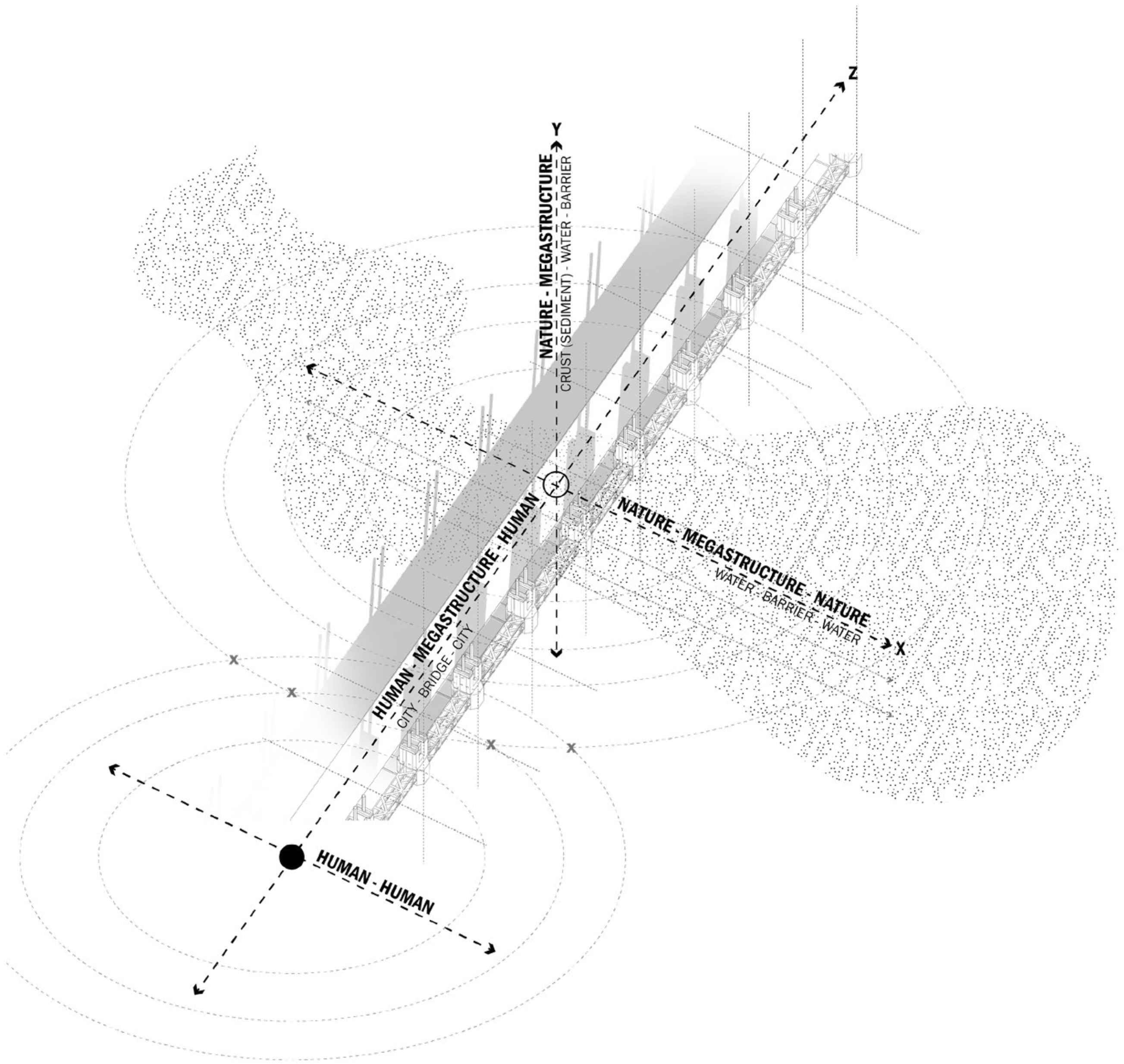


PROPORTION

THE GRAPH INDICATED THE PERIOD OF TIME THAT THE BARRIERS REQUIRED A MAJOR MAINTENANCE AFTER THE COMPLETION.
THE LEAST AMOUNT OF TIME: **L SCALE** (APPROXIMATELY 38.1 YEARS)
THE MOST AMOUNT OF TIME: **S SCALE** (APPROXIMATELY 51 YEARS)

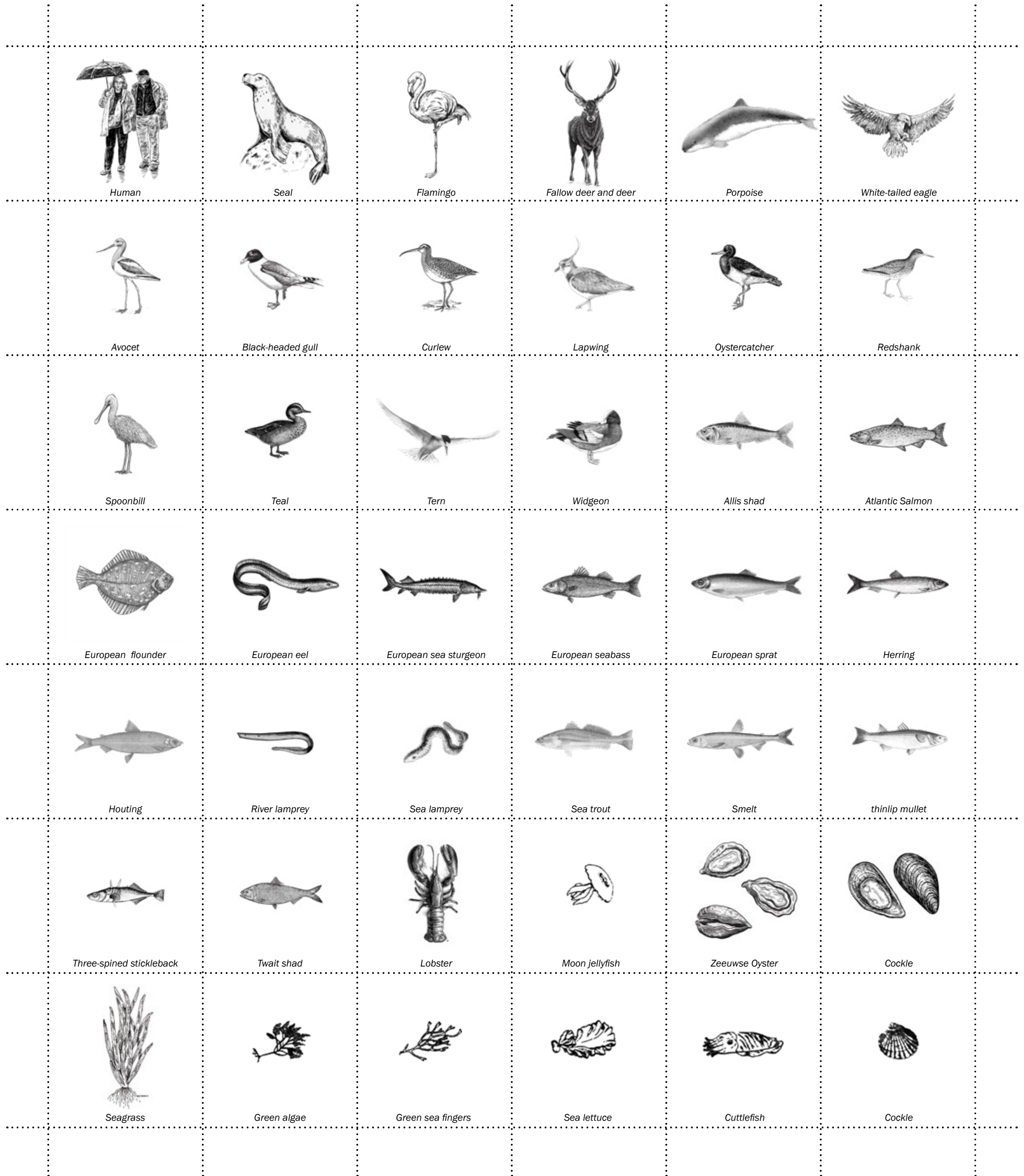


PHASE 2: THE ALTERATION OF USER BEHAVIOR (BIODIVERSITY: HUMANS, ANIMALS, PLANTS)



BIODIVERSITY IN ZEELAND

250 common and recognizable species from groups such as seaweeds, sponges, jellyfish, crabs, sea spiders, snails, starfish and sea squirts.



BEFORE AND AFTER THE DELTA WORKS

The Network of

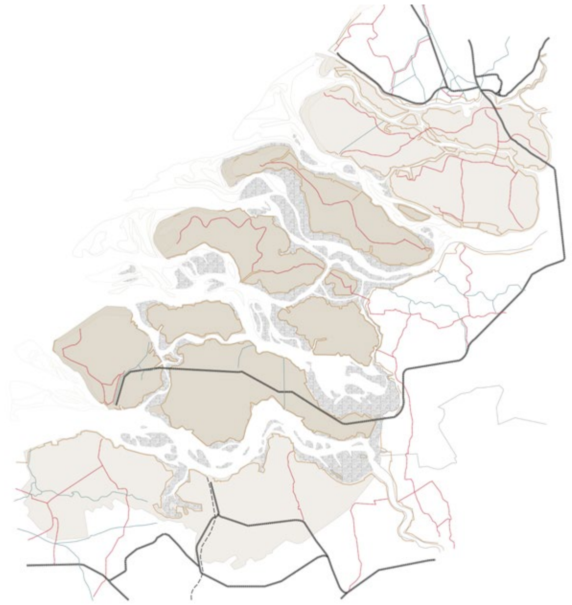
Land
Water

BEFORE
BASE MAP 1910

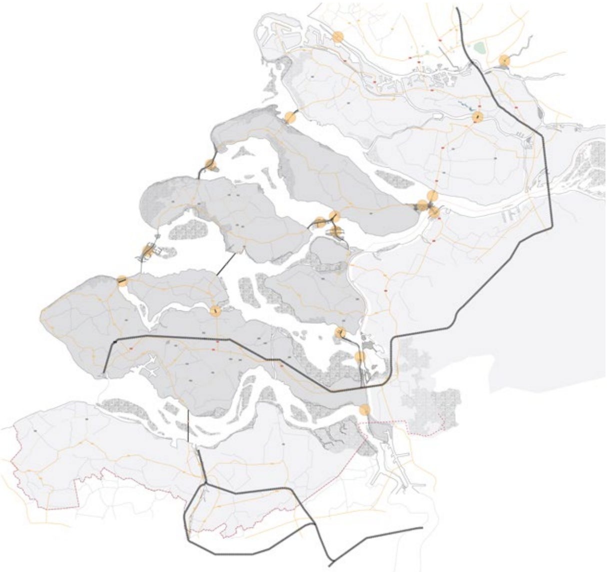
AFTER
BASE MAP 2022

The base map of the land and Natural habitat in 1910

The base map of the land and Natural habitat in 2022



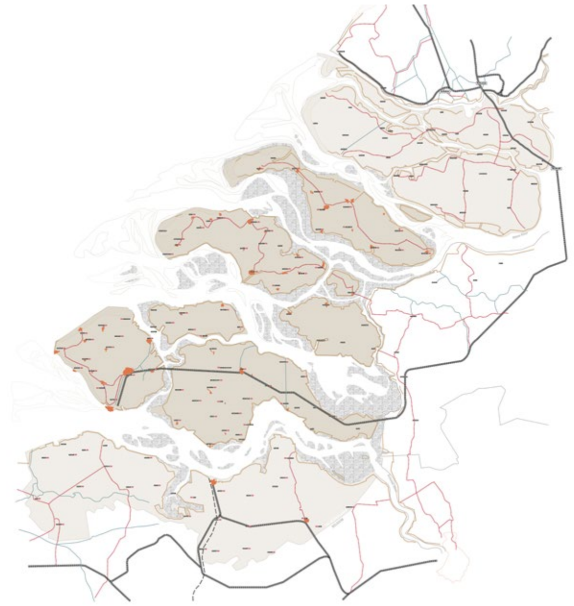
Public transportation in 1910



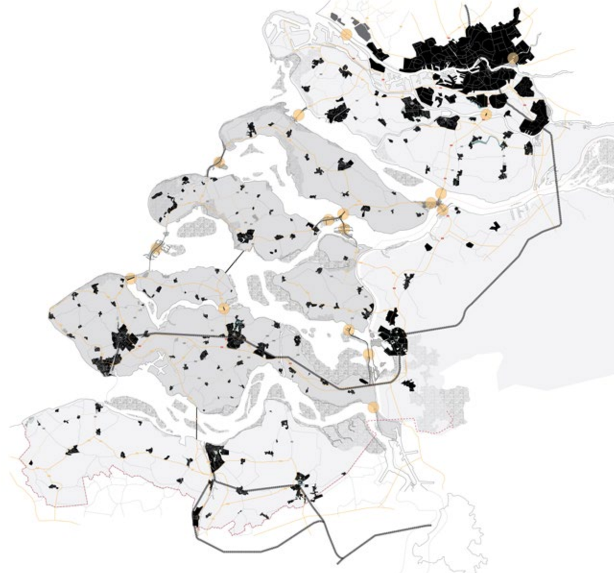
Public transportation in 2022

BEFORE
BASE MAP 1910

AFTER
BASE MAP 2022



Cities and Urban area in 1910

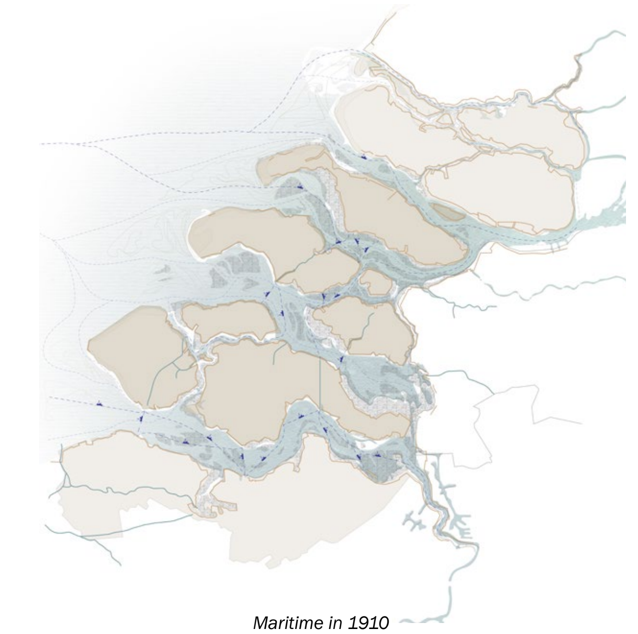


Cities and Urban area in 2022

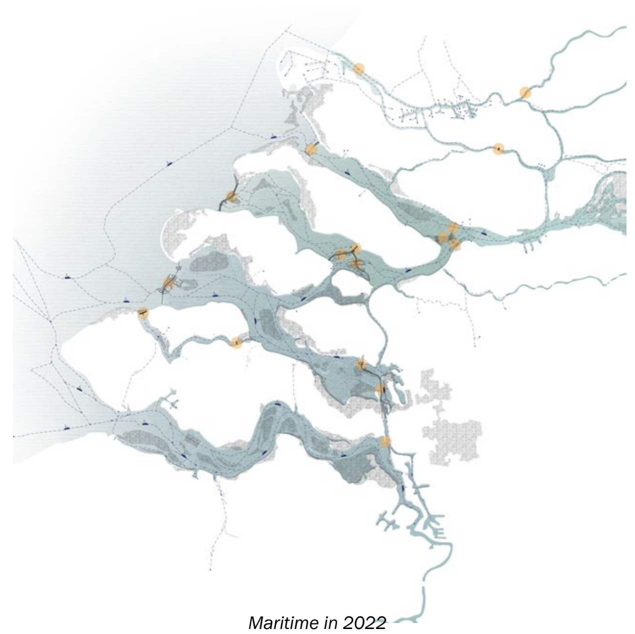
Accessibility by land in 1910

Accessibility by land in 2022

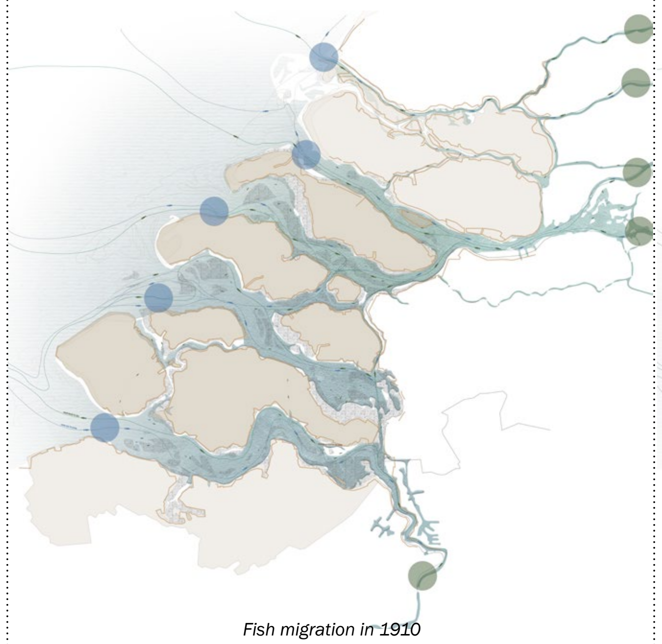
BEFORE BASE MAP 1910	**AFTER** BASE MAP 2022



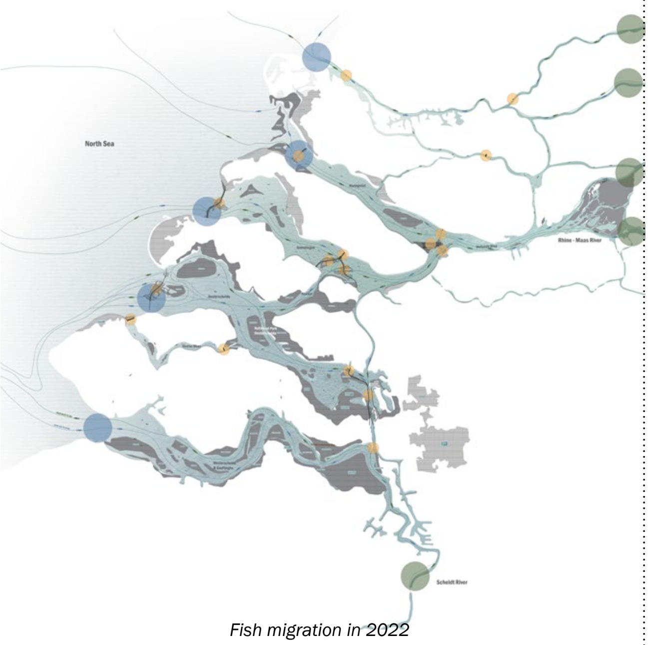
Maritime in 1910



Maritime in 2022



Fish migration in 1910



Fish migration in 2022

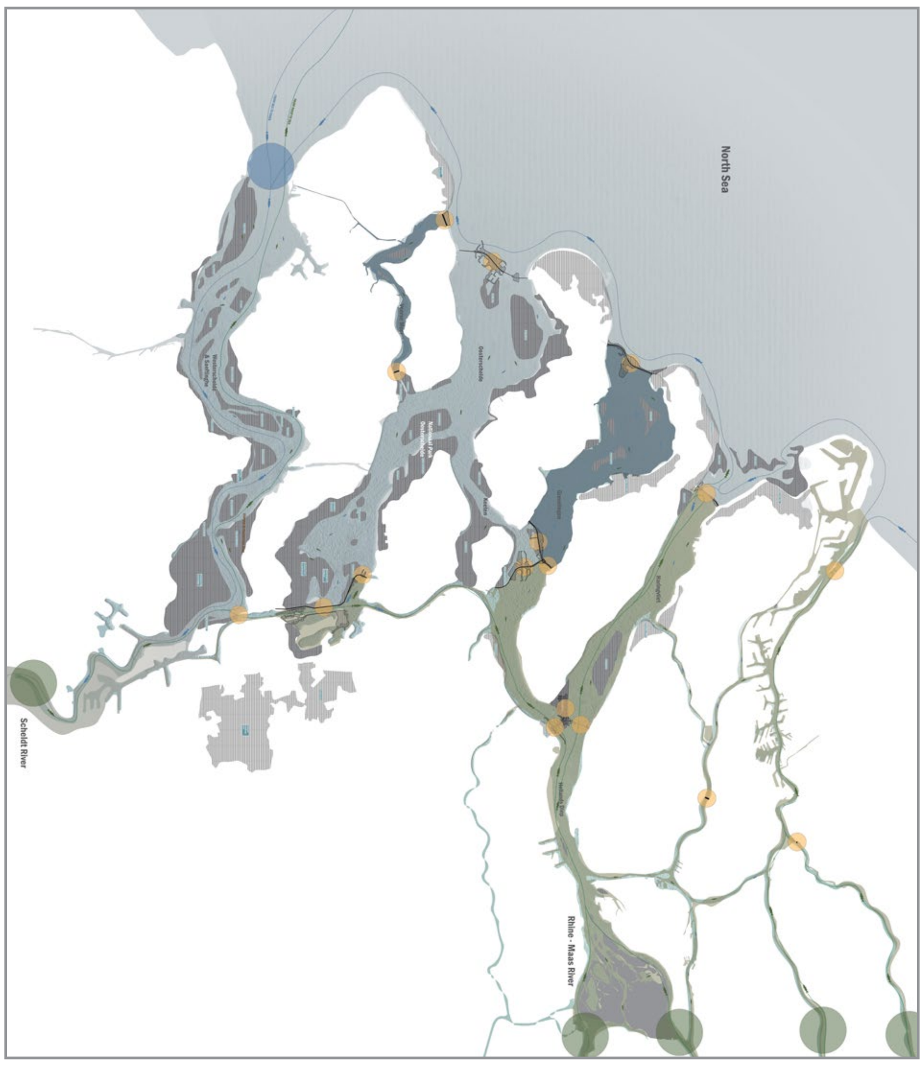
BEFORE BASE MAP 1910	**AFTER** BASE MAP 2022

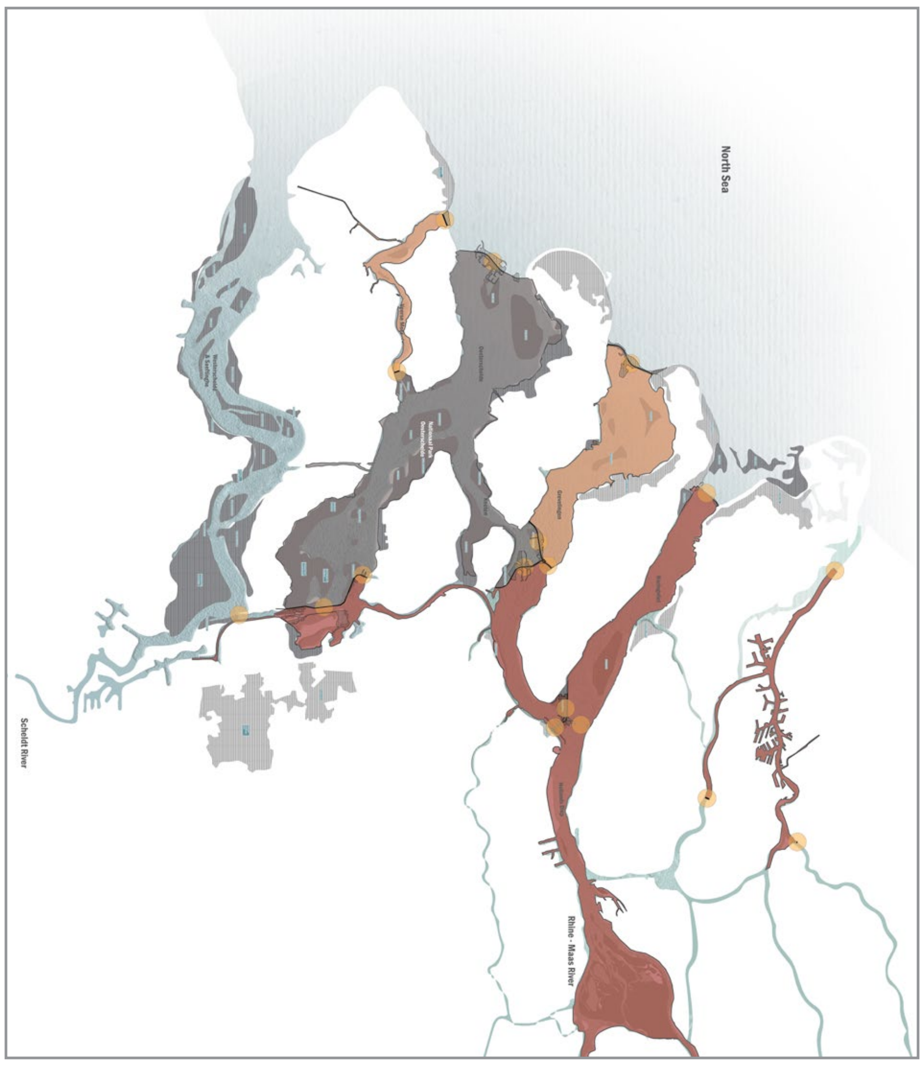
Water level in 1910

Water level in 2022

Vegetation in 1910

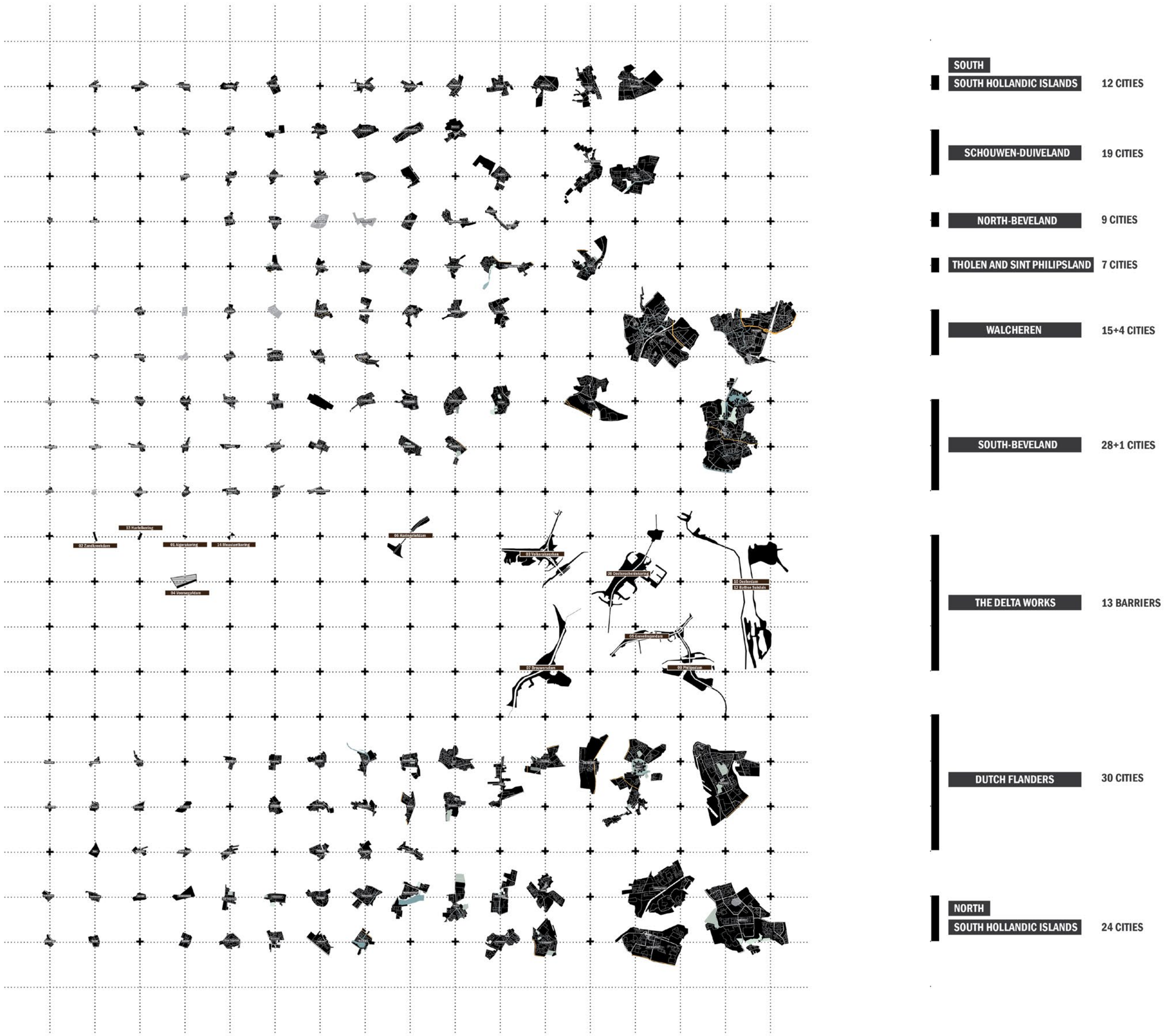
Vegetation in 2022


North Sea
Scheldt River
Rhine - Maas River


North Sea
Scheldt River
Rhine - Maas River

FINAL MAP

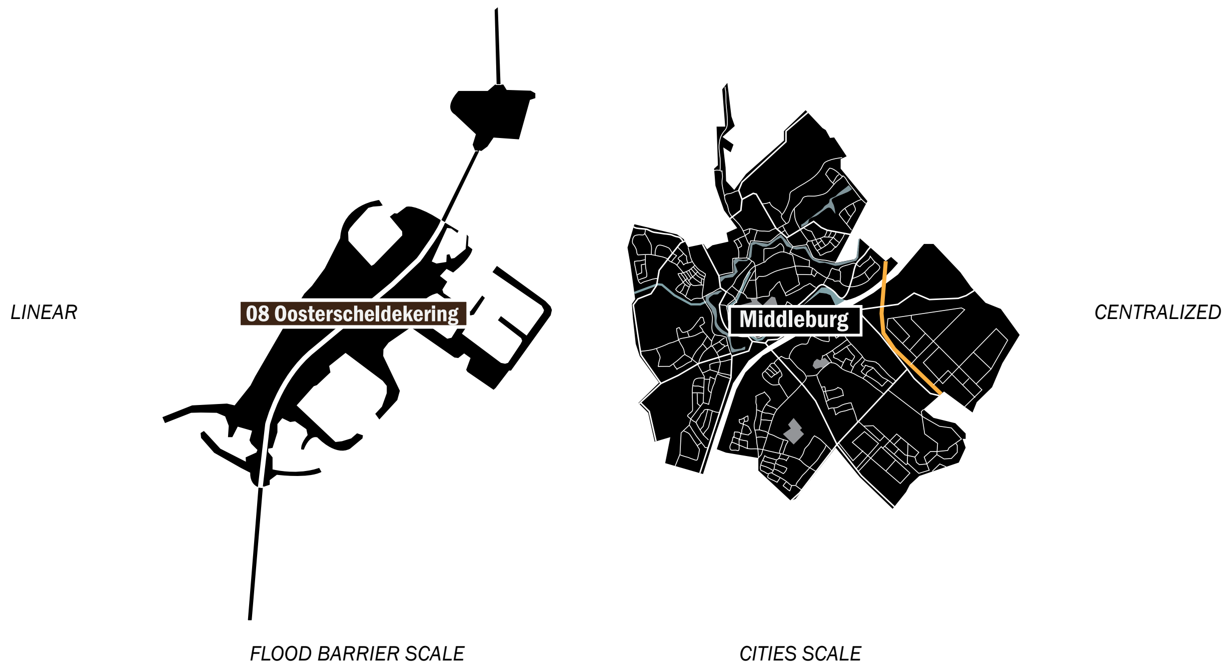
THE DELTA WORKS AND CITIES



The scale comparison of the cites in Zeeland and the Delta works

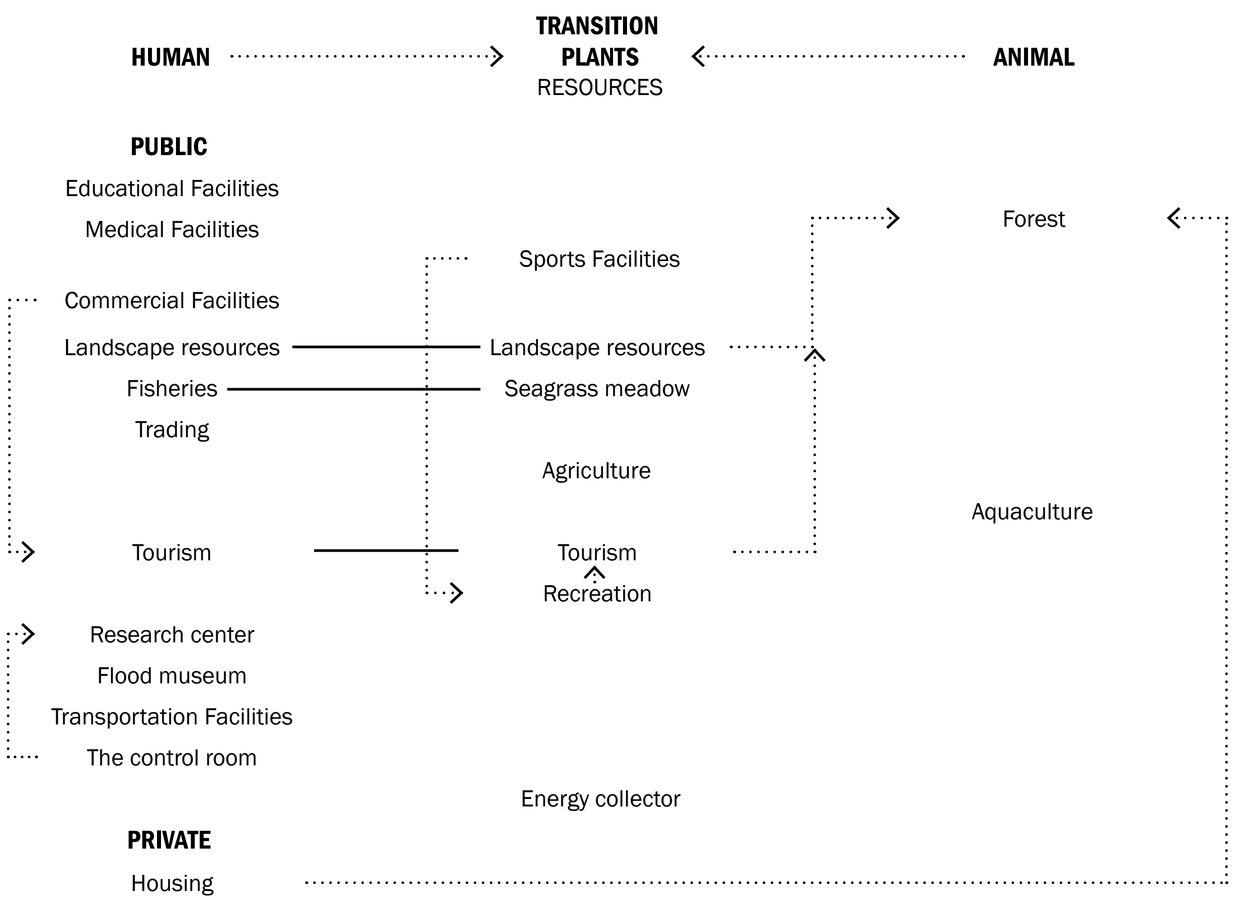
PHASE 3: MULTIFUNCTIONALITY

PROGRAM REQUIREMENT
FUNCTION RELATIONSHIP



BIODIVERSITY HABITATION

TERRESTRIAL HABITAT (LAND)
AQUATIC HABITAT (WATER)
ARBOREAL HABITAT (ON TREE)



	BASIC FUNCTION IN CITIES		
PUBLIC	Educational Facilities Medical Facilities Cultural Facilities Sports Facilities Commercial Facilities Transportation Facilities Landscape resources	School / University Hospital Museum / Library Recreational activities Supermarket Bus stop / Parking lot Park	
PRIVATE	Housing	Smallest size (Apartment Unit) 2 Rooms for Apartment Unit) Amsterdam average The national average Average House Size in Holland	17 Sqm 35-50 Sqm 49 Sqm 75 Sqm 117 Sqm
	FUNCTION RELATED TO ZEELAND COMMUNITIES		
PUBLIC Past	Fisheries Trading Agriculture Aquaculture		
PUBLIC Present	Tourism Recreation	Holiday house / camping Cycling / Watersport	
	FUNCTION RELATED TO FLOOD-BARRIERS		
PUBLIC	Research center Flood museum Transportation The control room Energy collector	Road Topshuis	
	FUNCTION RELATED TO VEGETATION		
	Landscape resources Seagrass meadow	Water / Soil / Air / Light Nursery area	
	FUNCTION RELATED TO ANIMAL		
	Landscape resources Seagrass meadow Forest	Water / Soil / Air / Light Nursery area	