The Water Institute

Graduation Report - Jiayi Huang - 4357671
Delta Interventions Studio
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Context

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Graduation Report
Delta Interventions Studio
Masters of Architecture
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Delta coast areas are dynamic areas where land mingles with water and where the solid meets the fluid. Their uniqueness provides abundant resources to make it preferable to inhabit. However, the potential of flooding also threaten inhabitants' lives and possession. Nowadays, sea level rise, increasing peak discharges of the rivers and intensification of rainstorms due to climate change drive us to water safety management and related issues. For architecture students, the theme of "Delta Interventions Studio" is to design an architecture in response to such water related issue.
1.1 Context
1.1.2 Dutch Delta

For centuries, the Netherlands has been “fighting against water” by reshaping its landscape to make it safer and more livable. The Dutch created canals and artificial watercourses; manipulated and drained water in lands; and built structures like dikes and dams to prevent the nation from being flooded and increase habitable land area. However, the increase of flood frequency and severity and the limited land for urban expansion lead to the reconsideration of current flood defense strategy. From my perspective as an architect, hard defense structures like dams and dikes creates a disconnection between the relation water and land, decreasing the water accessibly for inhabitants living in the protected areas. In order to improve the current defense system and respond to the urgent situation due to population growth, climate change and relative sea level rise, the former “building against water” strategy need to be replaced by “building with water” strategy.

"Room for the Rivers" Projects in the Netherlands is studied to research the switching notion mentioned above. Different from traditional “flood resistance” strategy which focus on constructing and improving artificial defense infrastructures to prevent the Netherlands from being flooded, the project intends to prevent flooding by creating more rooms for water to flow through.

"Room for the river Waal Nijmegen" is the biggest and most awe-inspiring of the national program. The project intends to provide additional room for the river Waal by relocate the Lentse dike 350 meters inwards. A canal with a depth of 10 meter and a width of 200 meter is created in the new flood plain (Fig. 1). During high discharges this canal flows together with the Waal. A part of the old dike is redesigned as an island opposite the historical center of Nijmegen. This creates a unique riverside park in between the ancillary channel and river Waal, where people could experience the dynamics of the river. The islands offers unprecedented opportunities for living, working, sports and nature (Royal HaskoningDHV, 2015).

Figure 1 Illustrations of the river's course before and after the project. [Source: Room for the river Waal
1.1 Context
1.1.2 Dutch Delta

My primary concern is, along with population growth, the demand for livable space expand and will begin to expand towards water by building water-adaptive architectures. In such cases, water defense infrastructures should not be the disconnection between water and city. It should be reconsidered and redesigned to be a transition zone between the two. I purpose a possible solution in Figure 2. The level or the ground surrounding the dike could be raised and function as public areas like coastal park to increase inhabitants’ accessibly to water while it could be functioned evacuation areas when flooded. The slope towards the protected side could be much slower and integrated with urban planning. Base on the urban planning where the relation between water and city is reconnect by redesigning the dike to a transition zone, architects could continue to examine and explore water-related architecture to allow urban expansion towards the sea.

To conclude, hard defense structures like dams and dikes creates a disconnection between water and land, decreasing the water accessibly for inhabitants living in the protected areas. Therefore, I set up the main theme of my graduation design which is to design an architecture to reactivate the relationship between water and land.

Figure 2 Purposed Future with “Building with Water” Strategy
[By Author]

HOW TO REACTIVATE THE RELATIONSHIP BETWEEN WATER & LAND?
1.2 Site  
1.2.1 Choice of Site

In order to achieve the theme, the chosen location is in a juncture between water and land. The site locates in the east point of Zeeburgereiland, a triangular poler constructed in 1912, in a juncture between Amsterdam city and IJsselmeer area. The polder is to the east of Noorder IJdijk, a lock that separated Markermeer and North Sea Canal. As a result, the polder is protected by series of locks in the North Sea Canal. Moreover, the chosen location is also protected by Afsluitdijk which dammed off IJsselmeer in 1932. The site is to the east of Zeeburgertunnel, a road tunnel connects the Zeeburgereiland (East Amsterdam) and Amsterdam-Noord with each other built in 1990. The site is currently empty and not used.
1.2 Site
1.2.2 3x3x3 Analysis

To further elaborate the “guiding theme” which is to design an architecture to reactivate the relationship between water and land, the “3x3x3 Analysis” of the chosen location was carried out. It is an analysis of comparing maps of the location in 3 different scale (Ijsselmeer Region; Amsterdam City; Zeeburgereiland), 3 different time (1630; 1940; 2016) and 3 different layers (Occupation; Infrastructure; Landscape). By comparing these 27 maps, the changing relationship between Amsterdam and Ijsselmeer area is discovered.

In the 16th century, Amsterdam began to grow from dam square. At that time, shipping was the main transport, especially for trading. As ships needed go by Ijsselmeer before reaching North Sea, the relation between Amsterdam and Ijsselmeer was close (Fig.4).

However, the construction of North Sea Canal in 1860s enables ships to reach North Sea directly through the canal. It signified the declined relation between Amsterdam and Ijsselmeer. Moreover, the main transportation switched from shipping to train. In 1889, the construction of Amsterdam Centraal blocked the connection between dam square and IJ (Fig.5).

The triangular polder - Zeeburgereiland - was built after IJdijk which was built for discharge of sewage from Amsterdam to Ijsselmeer. Then, the polder was built to fill with dredged sediment coming from the IJ and the Eastern Docklands. Therefore, it was buit for storaging urban waste.
1.2 Site
1.2.2 3x3x3 Analysis

Along with the urban expansion of Amsterdam, the position of the triangular polder also changed.

After the construction of Road Zuiderzeeweg built in 1961 and Zeeburgetunnel built in 1988, the polder became a connection between north and south of Amsterdam. Besides, it is also the connection between Zeeburgereiland (East Amsterdam) and Amsterdam-Noord (Fig.6).

As a result, the theme of the project is further developed from merely reactivate the relationship between water and land to reactivate the relationship between Markermeer and Amsterdam(Fig.7) and the relationship between water and architecture users.
1.3 Research Question

In conclusion, the research question is inspired by the "guilding theme" of the studio which is to design an architecture related to water when facing sea level rise, increasing peak discharges of the rivers and intensification of rainstorms due to climate change. After series of researches, the main research question is to design an architecture to reactiviate the relationship between water and land. The research question is further elaborated to reactivate the relationship between Amsterdam and Markmermeer and the relationship between water and architecture users based on the research of the chosen site especially the 3X3X3 analysis.
1.4 Design Assignment

The design assignment is to design a water institute to use Amsterdam, an international port where talented scholars could gather, to deal with water related issues, especially ones happen in Ijsselmeer. The Water Institute is an educational facility which focus on the sustainable use and management of water resources to support health and prosperous communities. In the same time, public events would be held in the institute to raise the attention of citizens in Amsterdam to the issues mentioned above. With the increasing attention to the Ijsselmeer region, the connection between Amsterdam and Ijsselmeer is hoping to be reactive. In the perspective of architecture, water-related architecture will be explored to strengthen the relation between water and architecture users.
Part 2. Design
2.1 Urban Design
2.1.1 Site Analysis

The research of chosen site such as noise analysis, terrain analysis, surrounding water level and vehicle accessibility helped to design a site plan that could handle the situations happen at site.

1. Terrain
Currently, the site is surrounded by a dike ring of 4-5 meters high. However, the polder itself is already 2.2 meters above NAP. Besides, it is protected by locks in North Sea Cannel and Afsluitdijk. So the main reason for the change of water level is rainfall and wind setup. The waves are normally 40 cm high. To breeze they grow to an average of 60 cm and when it storms, they can reach a height of 1.5 meters. As a result, the use of this dynamic change of water level is one of the main issues in the urban design.
2.1. Urban Design

2.1.1 Site Analysis

2. Noise
The chosen site is strongly influenced by the noise from the adjacent highway. Almost the whole polder is covered by 55-60 dB and the problem is more severe in the west. As a result, suitable sound barrier is necessary to place at site to solve such problem.

3. Vehicle Accessibility
The current traffic condition of the site is not pleasing. It has three entrances now, one in the north and one from the highway. And an undeveloped footway from the south. And they need to be developed in the following design.
In the final proposal of urban district design, the institute is placed in the east point of the polder. It is linked with the rest district by a staircase shape landscape with the function of water purification. The ferry station is placed in the north to communicate Amsterdam and stops in Markermeer. A pier for the residents is placed in the south.
2.1 Urban Design
2.1.2 Site Plan
2.1 Urban Design
2.1.3 Development

In P2 proposal, a harbor and central park was first designed to link the urban district and the institute to reactivate the relationship between Amsterdam and Lake Markermeer (Fig.9). However, the research of surrounding water level, wind setup, the current route of shipping at site hold back the former proposal and a reconsideration of the design is needed. With the hope of maintaining the initial idea which is to reactivate the relationship between Amsterdam and Lake Markermeer and also create an outdoor areas for architecture users to have a closer relationship with water, the former idea of designing a harbor was developed to function as a “water purification landscape” (Fig.10). Then, the research of relevant projects create a landscape to increase the relation between the architecture and the context.
Besides, the relationship between architecture and water is strengthened in a sustainable way. The collected rainwater and gray water from the institute will be purified by stairs planting reeds and the purified water will be reused back to the building.
2.2 Architecture Design
2.2.1 Architecture Form

In terms of the architecture form, it is designed to introduce the view of the open water on the north and also the view of the bridge and Ijburg from the south. The east part of the building is stretched out pointing to the IJdijk in order to introduce the view of the dike and also the open view of Markermeer.
2.2 Architecture Design

2.2.2 Architecture Function

**Library**
- Lobby 100
- Electronic Browsing
- Cafe 100
- General Reading 240
- Reading Lounge 360
- Storage 40
- Binding 40
- Catalogue 60
- Purchase 20
- Office 20x4
- Meeting 40
- Security 20

**Public Event**
- Auditorium 384
- Exhibition 350
- Studio 80x4
- Program Room 90x2
- Lecture Room 80x3

**Teaching**
- Lecture Room 80x3
- Program Room 90x2
- Studio 80x4

**Research**
- General Purpose Area for Water or Maritime Models 700
- Office 20x6
- Workshop 40x8
- Hydraulics Basic Lab 240
- The Water Physical & Chemical Testing Lab
- Sediment Testing Lab
- Environmental Hydraulics Lab
- Wave Tank 360

**Private**
- Private

**Public**
- Public
2.2 Architecture Design
2.2.3 Function Division

**Teaching**
- Study
- Lecture Room
- Studios
- Program Room

**Public Event**
- Auditorium
- Exhibition

**Library**
- Reading Lounge
- Storage
- Administration

**Research**
- General Purpose Area
- Office
- Workshop
- Wave Tank
2.2 Architecture Design  
2.2.3 Function Division

Functions are arranged to provide better views for more public activities. Library function which is more “public” is placed in the north facing the view of water while research function which is more private is placed in the south. They are linked and separated by the function of public events.
In terms of approaches, architecture users can choose to access the public building by walking, bike or car. Bike parking is designed underneath the top level of the “Water Purification Landscape”. Car parking is placed in ground floor separating library and research function. The 3 entrances for pedestrians is on the first floor.
Since the entrances are placed on the first floor level, observers can have an open view of different views towards different directions.
2.2 Architecture Design
2.2.4 Framing the View
The reading lounge placed on the north is designed with a combination of staircase and bookshelves. Continuing the idea of using different levels in the design as in the landscape. It invites the open view of the water to these two stores. Provide a place for architecture users to sit on, to read and also to store books.
2.2 Architecture Design

2.2.6 Ground Floor Plan
2.2 Architecture Design
2.2.7 Floor Plans

First Floor Plan

Second Floor Plan
2.3 Structure

Architecture structures are constructed on a pile foundation where piles transit loads to the load bearing layer (dense sand or rock). Above ground, the structure mainly follows a column grid of 8 to 10 meters.
2.4 Detail Design
2.4.1 Section 1-1
The facade designed to have regular rectangular panels but create changes in section. In such case, although the facade is guided by a certain order, it has horizontal curve lines when it is observed from the side. Besides, as the grass panels have different angles towards sunlight, the light guided into the interior can be referred to the sparkling reflected light on water.
2.4 Detail Design
2.4.2 Detail A
2.4 Detail Design
2.4.2 Detail A

Sheet-Metal Parapet Cap Sloped To Drain Roof Side
- Sheet-Metal Protection
- Paver with Shim
- Loose-Laid Retention Tee
- Engineered Soil
- Carex Nigra (Grasses)

Filter Fabric
- Reservoir Layer
- Retention Layer
- Aeration Layer
- Thermal Insulation

Drainage Layer
- Root Barrier
- Protection Course
- Thermoplastic Waterproofing Membrane

Aluminium Panel
- Aluminium Facade Rail
- Double Glazing

White Drywall Ceiling
2.4 Detail Design
2.4.2 Detail A

Double Glazing
Toughened Safety Glass
Insulated Aluminium Section, with Thermal Break
Insulated Facade Panel
Ventilation Element: Electronically Operated Aluminium Louvres
Aluminium Facade Rail

Detail A-2
2.4 Detail Design
2.4.3 Detail B

LED Light
White Drywall Ceiling

Detail B-2 1:10
2.4 Detail Design
2.4.4 Section 5-5

Section 5-5  1:200

Parking
Auditorium
Exhibition
Reading
Study
Detail C
2.4 Detail Design
2.4.5 Detail C

Roof Drain

Welded Stainless Steel Tab To Support Chain

Polished Stainless Steel Chain

Spring

Concrete Drain
2.4 Detail Design
2.4.6 Section 4-4
2.4 Detail Design
2.4.7 Detail D

Detail D-1

Aluminium Panel
Concrete
Anchor
Insulation

Section 4-4
2.5 Climate Design
2.5.1 Solar Energy

According to the solar altitude, solar panels are designed to place on the highest part of glass curtain walls so as to provide solar energy to the public building.
2.5 Climate Design
2.5.2 Sustainability

Apart from using solar energy, it has a sustainable water system. Rain water is collected on the green roof, guided towards the landscape along with other grey water and it will be purified and be reused back to the building.
2.6 Perspectives
2.6 Perspectives
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P4 Reflection

Graduation Studio: Delta Interventions
Title of Graduation Project: The Water Institute
Mentors: Prof. Frits Palmboom / Jan van de Voort

The process of the graduation design is an experiment of the interaction between research and design; a practice of setting up the designer’s own theme base on the studio’s theme and personal research; and an exercise of trying different possible research and design methods to search for the most suitable one.

Different from the architecture design whose design assignment is given, participants in the graduation studio have to set up our own theme including the location and architecture type within a border theme of the design studio. The “Guiding Theme” of Delta Interventions Studio is to design an architecture related to water when facing sea level rise, increasing peak discharges of the rivers and intensification of rainstorms due to climate change. Location can be chosen within both the Southwest delta near Rotterdam, and the Ijsselmeer area near Amsterdam, however, other locations between cities and their water-landscapes are also acceptable. Under this frame, the research and design began by a serious of self-questioning: What kind of architecture is the best to study the relationship between water and architecture? Where is the best location to perform the design?

The theme of the graduation studio is wide enough to give flexibility for students to explore different possibilities, but the flexibility also gives difficulties on choosing architecture type, the location and related design issues. As a result, research is necessary not only for building up personal design theme, but also for supporting the following design.

The research began with the history of human interventions towards water and how Dutch citizens protect their land and properties from being flooded. One of the most valuable discovery during this procedure is people’s changing notion from “Building against Water” to “Building with Water”. The Dutch created canals and artificial watercourses; manipulated and drained water in lands; and built structures like dikes and dams to prevent the country from being flooded and increase habitable land area. However, the increase of flood frequency and severity and the limited land for urban expansion lead to the reconsideration of current flood defense strategy. Facing such situation, new strategies like “Room for the River” project in the Netherlands (Fig.1), a project to manage increasing water level by increasing river conveyance by opening up more room for the water to flow through, is designed to increase flood resilience ability by a more natural way.

Figure 1: Illustrations of the river’s course before and after the project. [Source: Room for the river Waal Nijmegen]
From my perspective as an architect, hard defense structures like dams and dikes creates a disconnection between water and land, decreasing the water accessibly for inhabitants living in the protected areas. Therefore, I set up the main theme of my graduation design which is to design an architecture to reactivate the relationship between water and land.

In order to achieve the theme, the chosen location is in a juncture between water and land. The site locates in the east point of Zeeburgereiland, a triangular polder constructed in 1912, in a juncture between Amsterdam city and IJsselmeer area. The polder is to the east of Noorder IJdijk, a lock that separated Markermeer and North Sea Canal. As a result, the polder is protected by a series of locks in the North Sea Canal. Moreover, the chosen location is also protected by Afsluitdijk which dammed off IJsselmeer in 1932. The site is to the east of Zeeburgertunnel, a road tunnel connects the Zeeburgereiland (East Amsterdam) and Amsterdam-Noord with each other built in 1990. The site is separated by the Zeeburgertunnel from the main polder, leaving it isolated and a problem of traffic noise. The site is currently empty and not used.

To further elaborate the “guiding theme” which is to design an architecture to reactivate the relationship between water and land, the “3x3x3 Analysis” of the chosen location was carried out. It is an analysis of comparing maps of the location in 3 different scale (Ijsselmeer Region; Amsterdam City; Zeeburgereiland), 3 different time (1630; 1940; 2016) and 3 different layers (Occupation; Infrastructure; Landscape). By comparing these 27 maps, the changing relationship between Amsterdam and IJsselmeer area is discovered. The relationship reduced due to the construction of North Sea Canal and the change of main transportation from ship to train. However, along with the development of Amsterdam city, the position of the chosen site changed as well. Originally, it was a place of filling with dredged sediment coming from the IJ and the Eastern Docklands and a place to dispose sewerage from Amsterdam to IJsselmeer. It became the new connection between north and south of Amsterdam and the connection between Amsterdam and IJsselmeer area (Fig.5). As a result, the theme of the project is further developed from merely reactivate the relationship between water and land to reactivate the relationship between...
Markermeer and Amsterdam and the relationship between water and architecture users. The theme is inspired by the boarder theme of Delta Interventions Studio and is developed by a series of personal research.

With the theme to reactivate the relationships mentioned above, the design assignment was made. It is to design a water institute to use Amsterdam, an international port where talented scholars could gather, to deal with water related issues, especially ones happen in Ijsselmeer. The water Institute is an educational facility which focus on the sustainable use and management of water resources to support health and prosperous communities. In the same time, public events would be held in the institute to raise the attention of citizens in Amsterdam to the issues mentioned above. With the increasing attention to the Ijsselmeer region, the connection between Amsterdam and Ijsselmeer is hoping to be reactive. In the perspective of architecture, water-related architecture will be explored to strengthen the relation between water and architecture users.

The design assignment which is to design a water institute in the east point of Zeeburgereiland is finally set up after different researches of water related issues. However, as architecture design begin, research is still required for giving guidance. For example, the research of chosen site such as noise analysis, terrain analysis, surrounding water level and vehicle accessibility (Fig.6) helped to design a site plan that could handle the situations happen at site (Fig.7). And with the attention of introducing the outdoor views to indoor, the shape of architecture is guide by researching surrounding views. Furthermore, the research of existing architecture projects especially research institute, library and campus not only gives inspiration of the architecture design but also its programs. However, the arrangement of plans and ideas of interior atmosphere also influence the settlement of programs.
Although research give guidance to design, design also determine what kind of research is needed. For example, a harbor and central park was first designed to link the urban district and the institute to reactivate the relationship between Amsterdam and Lake Markermeer (Fig.7). However, the research of surrounding water level, wind setup, the current route of shipping at site hold back the former proposal and a reconsideration of the design is needed. With the hope of maintaining the initial idea which is to reactivate the relationship between Amsterdam and Lake Markermeer and also create an outdoor areas for architecture users to have a closer relationship with water, former idea of designing a harbor was reformed to function as a “water purification landscape” (Fig.8)(Fig.9). Then, the research of relevant projects create a landscape to increase the relation between the architecture and the context. Moreover, the relationship between architecture and water is strengthened in a sustainable way. The collected rain water and gray water from the institute will be purified by stairs planting reeds and the purified water will be reused back to the building.
During the design procedure, although some methods work during the design process, some approaches failed to achieve the expect outcome. One example is the design of harbor need to be reconsidered and redesigned to a “Water Purification Landscape” as mentioned before. Another similar example is the façade design. The proposal of façade design in P3 (Fig.10) is too geometrical and requires adding the character of water. In order to add character of water into the architecture, different approaches such as changing the initial shape to curve lines and adding curve panels to the façade were tried but failed to fit the original design. I also tried to use different triangular panels to form curve line to imitate the shape of water waves (Fig.11). But such strong character weaken the initial architectural concept and it requires a stronger geometrical order. After different trials, the final proposal is to have regular rectangular panels but create changes in section (Fig.12). In such case, although the façade is guided by a certain order, it has horizontal curve lines when it is observed from the side. Besides, as the grass panels have different angles towards sunlight, the light guided into the interior can be referred to the sparkling reflected light on water. From these experiences, I learned that although some design approaches may not work as expected, they are necessary and essential. The failed approaches could give guidance for the following research and design. Thanks to the unworked approaches, different design possibilities are tried and the design develops through such procedure.

In the wider social context, we are not only facing problems of sea level rise, increasing peak discharges of the rivers and intensification of rainstorms due to climate change but also facing sustainable problems such as environmental pollution and energy depletion. The architecture
design began with the intention to solve the problem of water related issues. The initial intention of the Water Institute is to raise people’s attention towards water related issues but also use architecture to weaken the disconnection between water and land. However, as the design developed, other sustainable issues are also considered. For example, the design of “Water Purification Landscape” and the recycle water system intentions to solve water pollution. The use of solar cells in façade design intentions to solve the problem of energy depletion. All in all, the architecture design intents to solve sustainable problems not only in water related issues but in a wider environmental range.

In conclusion, the graduation design is an experiment of the interaction between research and design. Research firstly helped to establish the design assignment. Within the design procedure, some issues and questions are to be answered. As a result, new research is needed and it could either reinforce the initial idea, hold-up the idea or give new ideas to the design. Research and design interact with each other and gradually contributes to the establishment of the final result. The most valuable lesson is to always keep the design flexible. Some methods and approaches during the design may not work as expected. But design is not about setting up the “correct approach” from the beginning but to try and compare different approaches in order to find the most suitable approach. During this procedure, more and more research and design are required and the product is developed.
From Flood Resistance to Flood Resilience
A Case Study of ‘Room for the River’ Project in the Netherlands

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Abstract
Facing rising sea levels, increasing peak discharges of the rivers and intensification of rainstorms due to climate change; the subsidence of land; development of urbanization; and the growth of population, flood risks continue to be the prime issue to the Netherlands. As the frequency and severity of floods increase, the reconsideration of current flood defense strategies is imperative. This paper reviews a new approach – “flood resilience” strategy – that was introduced to better deal with increasing flood risks. Different from the traditional “flood resistance” strategy which focuses on building flood defense constructions such as dikes to prevent the land from being flooded, “flood resilience” strategy aims at reducing the damage and increasing the capacity of recovering from the flood. The “Room for the River”, which is a series of Dutch projects to manage increasing water level by increasing river conveyance by opening up more room for the water to flow through, is introduced to arouse the notion of the importance of increasing flood resilient capacity. Finally, by analyzing the “Room for the River” projects in the Netherlands and comparing advantages and disadvantages of both strategies, the paper discusses the reason why the switching focus on “flood resistance” strategy in water management in the Netherlands.

Key Words
Flood risks; Flood defense; The Netherlands; Resilience; Room for the River

1. Instruction
Situated at the northwest corner of the European continent, the Netherlands has always faced the threat of flooding from the North Sea, the Rhine and Meuse rivers. The coastline of the Netherlands is more than 400 kilometers long and about 60% of its land is flood-prone (Fig. 1). Throughout history, the Dutch people and society worked and developed approaches in response to water-related challenges. Since the 9th century, the Netherlands began to “fight against the water” by building artificial defenses and reshaping the natural coast. It has developed a flood defense system that can prevent its people and land from the risk of a flood disaster. The flood resistance strategies were applied successfully until recently.
However, the increase of flood frequency and severity lead to reconsideration of current flood defense strategies. The focus of flood defense program gradually switches from “fighting against the water” to “working with nature” (Han Meyer, 2010). Because of climate change, the Netherlands is facing a more crucial situation from flood risks. The potential
danger from rising sea levels, increasing peak discharges of the rivers and intensification of rainstorms due to climate change and the notion of increasing the quality of the natural environment lead to new strategies that could better cope with the issue. Traditionally, flood defense of the Netherlands concentrate on flood resistance. To be more precise, defensive structures like dykes and dams to prevent the country’s lowland from being flooded. However, flood risks involve not only the danger brought by the flood, but also the damage and destruction to the area after such an event. “Flood resistance”, the traditional strategy that still largely applied in Netherlands and the world, aims at flood prevention. On the other hand, “flood resilient” strategies focus more on living with floods instead of preventing them. Such strategies rely on a flexible response to floods and a rapid recovery from them (De Bruijn & Klijn, 2001; Vis et al., 2001).

This paper firstly explains and discusses the concept of resilience and resistance in a flood, risk management context. By analyzing the changing flood defense strategies in the Netherlands, the paper indicates the importance of increasing the capacity of flood resilience. Following this, a review of the research on ‘Room for the River’ project in the Netherlands, which is a series of Dutch projects to manage higher water levels by increasing river conveyance by opening up more room for the water to flow through (Royal HaskoningDHV, 2015). This new approach would be studied as an example as the flood resilience strategy. Finally, through comparing advantages and disadvantages of both strategies, the thesis discusses the reason why the switching focus on “flood resistance” strategy in water management in the Netherlands.

2. Flood Resistance and Flood Resilience
Flood risk can be defined as the product of probability and consequences of flooding (Hall et al. 2003). Flood defense strategies aims at reducing either one of or both of probability and consequences of floods. “Flood Resistance” strategy and “flood resilience” strategy are both intent to prevent flooding but focus on two different aspects. While “flood resistance” strategy focus on reducing the probability of flooding, “flood resilience” strategy aims at reducing the consequence of a flood and increasing the capacity of recovering from it. In order to further understand the concept of resilience and resistance in the context of flood risk management, the concept of resilience itself needs to be studied and clarified first. According to Oxford dictionary, resilience is the capacity to recover quickly from difficulties, toughness or the ability of a substance or object to spring back into shape and elasticity. Resilience allows potential obstacle to occur, but such obstacle could be controlled and solved. Essentially, resilience is the flexibility of an object to regain its original status.
The concept of resilience of water management root in ecological resilience, which was put forward by the Canadian ecologist C.S. Holling in 1973. Ecological resilience was defined as the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures (defined as alternative stable states). The concept was put forward to explain the capacity of the ecosystems to recover from disturbances. A system’s reaction to disturbance depends on its resistance and resilience (Fig. 2). The resistance of a system determines which disturbances a system can withstand without reacting; which its resilience determines the response to and recovery from more intense disturbances (Bruijn, 2004).

Figure 2: The relationship between reaction amplitude and disturbance severity for a resilient and a resistant system and a system that has both system characteristics [source: De Bruijn, 2004]

Resilience was applied to flood risk management to explore and study the reaction of lowland river systems to flood waves. As mentioned, resistance is defined as the ability of this system to prevent floods, while resilience is defined as the ability of this system to recover from floods (Bruijn K.d., 2005). In such cases, resilience strategies for flood risk management allows potential flooding, but aims at minimizing the impacts while maximizing the capacity to recover from a possible flood. The following paper will further explain such approach by analyzing ‘Room for the River’ Project in the Netherlands which is an ongoing project using flood resilience strategy.

3. ‘Room for the River’ Project in the Netherlands

3.1 Pressure of Reconsideration

Due to geographical reasons, the Netherlands has being dealing with water-related issues to protect the country from being flooded. However, its flood risk management strategy primarily relies on “flood resistance”. In order to protect the low-lying lands, multi-layers of defense system was constructed and developed. Along the main rivers and coastal areas, the “dike rings” were built as the primary defenses because these structures directly protect citizens and property from storm surges and river flooding. Currently, the low lands of Netherlands are divided by 53 of such dike rings. With the flood defenses, each dike-ring area could withstand a flood with a probability (‘return period’) of 1/10,000 years to 1/1,250 years and the probability is designed by the number of inhabitants and the economic value of the assets within a dike ring (Aerts, 2009). Even though the strong artificial defense system is constructed, little attention was paid to the consequences of floods until recently.

The increasingly elevating dikes and relative infrastructures wedge the rivers and giving them less space to throw through. While at the same time, land subsidence of the land behind dikes increase the potential dangers when a flood happens. What such questionable system is facing is the increasing flood risk due to climate change. According to the most recent scenarios of the Royal Netherlands Meteorological Institute, sea level on the Southern North Sea will be 25 to 80 cm higher in 2071-2100 (averaged year 2085) than in 1981-2010. For 2100, a projection for the
upper level of sea rise 100 cm. As a result, the traditional “food resistance” strategy has certain obstacles, and the continuing threat of rising sea levels, increasing peak discharges of the rivers and intensification of rainstorms due to climate change raise the pressure of reconsidering the system’s feasibility. In the other hand, spatial quality in delta areas is paid more and more attention. The traditional flood defense system was from an engineering point of view. Since flood protection is the primary concern, the spatial quality around defense infrastructures was not well design. But with the notion of increasing environmental quality began in 1970 and it continues to grow. Nowadays, the Netherlands has switched from “fighting with nature” to “working with nature” and the consideration of making flood defenses and surrounding environments more eco-friendly and with better spatial quality is still developing.

3.2 Direct Reasons

In 1993 and 1995, extreme discharges happened in the Netherlands. In 1993, heavy rainfall caused flooding in Limburg locates in southeast of the Netherlands. One fifth of Limburg was flooded because of the rainfall in France and Belgian. In 1995, widespread flooding in Europe caused by rainfall resulted in the evacuation of 250,000 people and a million animals (Fig. 3).

These two floods results in the reconsideration of former flood defense system. It is necessary to increase the discharge capacity of the major rivers and the former method of rising the height of dikes could not ensure long-term safety. As a result, the Dutch government began to discover possible approaches to mitigate flooding and “Room for the Rivers” project was put forward.

3.3 “Room for the Rivers” Project

In order to protect four million inhabitants of the river catchment areas from high water level and create a better spatial quality in these areas, the Central Government of the Netherlands approved the Room for the River Plan in 2007. Different from traditional “flood resistance” strategy which focus on constructing and improving artificial defense infrastructures to prevent the Netherlands from being flooded, the project intents to build a safer river area with an attractive living environment.

Room for the River is working on 34 projects along the Rhine tributaries, such as the IJssel, Waal, Lower Rhine and Lek (Fig. 4). And the goal of the project is to give more room to be able to manage higher water levels. The project intended to increase the maximum discharge capacity from 15,000 m³/sec in 2007 to 16,000 m³/sec in 2015. By the end of the project, water safety is expected to increase
while the overall environmental quality will also be improved. The project will restore marshy riverine landscape to serve once again as natural ‘water storage’ sponges and provide biodiversity and aesthetic and recreational values (Dutch Ministry of Infrastructure and the Environment).

3.4 Methods and Examples
There are nine methods consisted in the project:

Room for the Waal

4. Reason of the Switching Focus
The land behind the river embankments is becoming more heavily used and populated. More homes are being built and affluence is on the rise. So a flood would have disastrous results. High river discharges can be expected as a result of climate changes, which makes these areas even more vulnerable. While new dike reinforcements are an option and will reduce the risk of flooding, if a flood occurs anyway, the effects will be even greater. So to make the Netherlands a safe, comfortable and pleasant place to live, a trend has to be broken. The answer lies in the plan to make more ‘room for the river’.

5. Conclusion
In recent centuries, the rivers have increasingly less space. The rivers are wedged between ever higher dikes and embankments behind which live more and more people. At the same time subsidence land behind the dikes to be lower. Also, it rains more often and harder causing the rivers have to process more and more water.
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