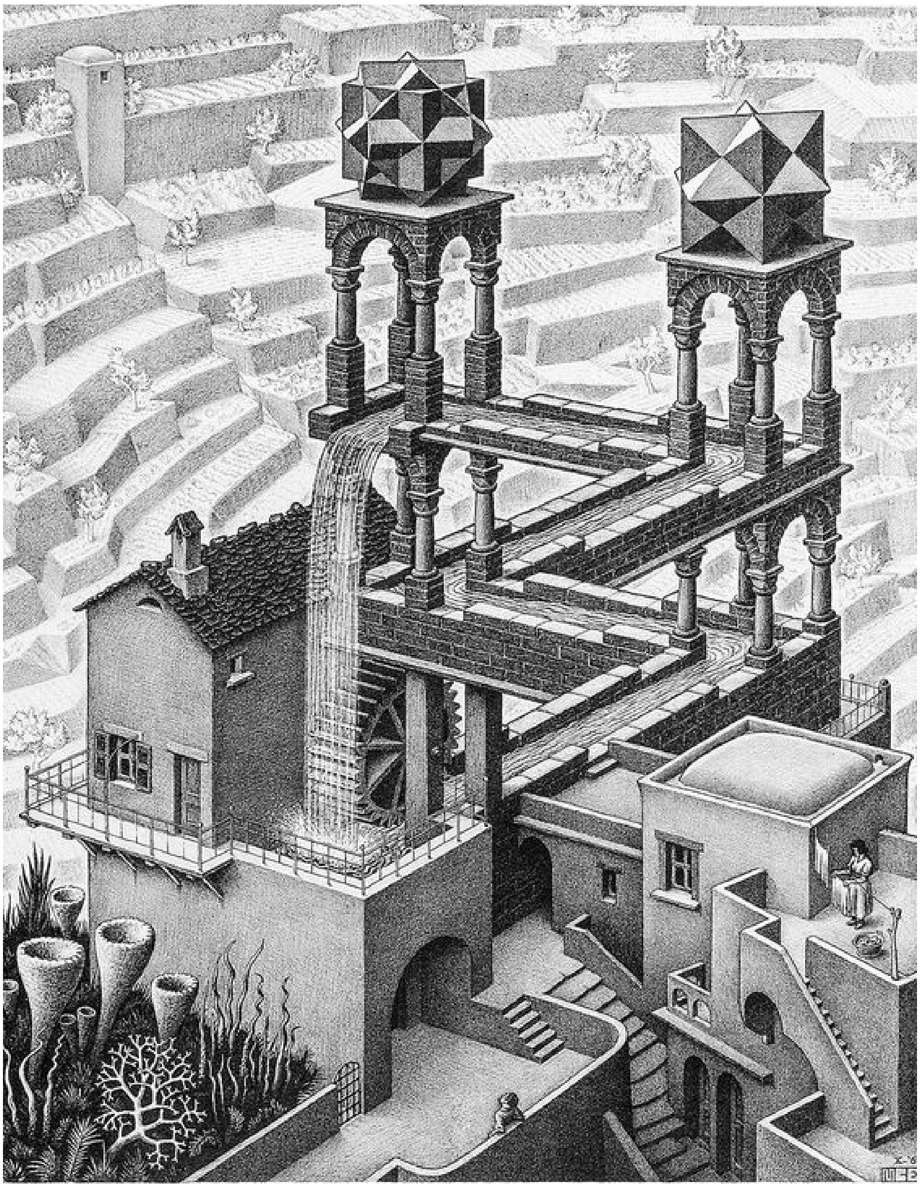
RESEARCH PLAN

Harvesting Water for Climate Design

Exploring how harvested rain- and floodwater can be integrated in the climate design of a building while mitigating the impact of pluvial floods



Architectural Engineering Graduation Studio

Nicole Hartmann
7 - 11 - '22

Personal Information

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Nicole Hartmann
4605853

Studio

Architectural Engineering
Tutors:
Thomas Offermans
Fransje Hooimeijer

Argumentations of choice of the studio

I decided to complete my master with the Architectural Engineering studio because I value a problem-solution oriented approach. The studio offers the opportunity to combine important challenges from different fields. I think it is very interesting to integrate architecture and engineering and I feel like this studio can support me to grow in both disciplines. The Architectural Engineering Studio motivates to think out-of-the-box, but also helps to stay grounded and find technically feasible solutions. Starting from my own fascination and finding my own problem and context motivates me to work on the project for the whole graduation year.

Keywords

Water Architecture, Passive Climate Design, Water Harvesting, Water Storage, Flood Accommodation, Pluvial Flood, Water Nuisance, Urban Areas, Gouda

Glossary of Key Terms

Adaptation
‘Adaptation is defined as the process of adjusting to climate change by taking appropriate action to prevent or minimize the damage it may cause’ (Douka, 2020, p 1).

Climate design
‘Design and development of a comfortable and healthy (indoor) climate in and around buildings, the integration of sustainable climate concepts in the architectural design and urban planning’ (*Climate Design & Sustainability*, n.d.). ‘A practice in which systems to control indoor climates are designed and installed’ (*What is Climate Design?*, 2022*).*

Pluvial flooding
‘Abnormal amounts of water in the streets or on the land due to heavy rainfall’ (Terpstra et al. 2006).

Flood accommodation
‘Accommodate approaches are those adaptive strategies which are designed to allow continued use of flood-prone areas by improving the resilience of communities or valued facilities/ infrastructure to occasional flooding, or by limiting damage in these areas’ (Doberstein et al., 2018, p 2).

Flood resilient building
‘A flood resilient building is one that can recover from a flood quickly and at minimal cost and disruption. This means that the building is designed to withstand the structural and material damage of flood water’ important: ‘not designed to keep the water out’ (*Flood Resilient Construction*, n.d.).

Passive design
Passive climate design makes optimal use of ‘natural’ sources of heating, cooling and ventilation and lightning and uses form, layout and material to minimize the demand. This instead of depending on mechanical systems for thermal comfort (Altan et al., 2016).

Subsidence
The slow collapse (compaction) of soft peat and clay layers, lowering the general ground level (Hoogheemraadschap van Rijnland & Gemeente Gouda, 2020).

Water architecture
‘Architecture associated with the water element, either in the utilitarian, symbolic, therapeutic, leisure or visual context’ (Wylson, 1986).

Water harvesting
A term covering techniques whereby water is collected and stored instead of letting it run off. A distinction can be made between rainwater harvesting (RWH) and floodwater harvesting (FWH). The term water harvesting is used when water is collected and stored with the purpose of providing water for later use (Hillel, 2005).

Water storage
‘Water storage refers to holding water in a contained area for a period of time’ (*Water Storage* - Energy Education, n.d.). The retained water can be kept and later be used, in that case, water storage is a component of water harvesting (Beckers et al., 2013). Another option is that the water is retained and later gradually released back to the water system. This can be deployed to lower the pressure on the sewage system during heavy precipitation and release the water in times of lower flows.

Water system
‘The natural cycle of water moving through the built environment as rainwater, surface water or groundwater’ (Van Hoof, 2021, p 4).

Water chain
An ‘artificially constructed process […] the cycle which involves the extraction, treatment, usage and transport of water used for sustaining humans their lives’ (Van Hoof, 2021, p 4).

WHY

Context & Problem Statement

Gouda inner city - Water as a threat

All around the world, subsidence is a problem in coastal and delta areas. In the Netherlands, the land has been subsiding for over a thousand years, and large cities including Amsterdam, Rotterdam, Dordrecht, and Gouda are dealing with problems caused by fluctuating groundwater levels. The risk of flooding in these areas increase and differences in subsidence lead to damage of buildings and infrastructure (Deltares, 2021).

The historic city of Gouda is built on peat and clay and is sinking because of peat oxidation and compression by the weight of the city (Van Loenen, A., 2018 and Hoogheemraadschap van Rijnland & Gemeente Gouda, 2020). Because of this, the proportionate water level in the ground rises and there is less space for water storage in the ground. At the same time, the KNMI expects heavy precipitation to happen more frequently, due to climate change (Hoogheemraadschap van Rijnland, 2018). This combination leads to a growing risk of flooding and water nuisance in Gouda. In the inner city of Gouda, (ground)water nuisance is already a significant problem, the most urgent problems are moisture because of high groundwater levels and water in buildings and on the streets in case of heavy rainfall (Hoogheemraadschap van Rijnland and Gemeente Gouda, 2020). A response to these problems would be lowering the groundwater level, as has been done regularly. However, about 4% of the buildings in the inner city of Gouda are constructed with wooden foundations. These wooden poles need to remain under water, in order to avoid rotting and damaging of the foundation. Therefore, the groundwater levels cannot be lowered too much (Willemse, 2017).
Buildings are not built to be able to withstand groundwater levels or flooding, therefore these events lead to damage of buildings and displacement of people. This problem is expected to grow as subsidence keeps happening and extreme precipitation events are occuring more often.

Subsidence because of peat oxidation and compression by the weight of the city, groundwater level relatively high

Heavier and more frequent precipitation, leading to flooding and water nuisance

Lowering of the groundwater level, wooden foundations get dry, leading to rotting poles

Figure 1. Problems in Gouda

Climate change - need to reduce energy

With limited energy sources, climate change and, recently, unstable energy prices, it is important to find ways to lower the energy demand for buildings. Climate systems used for heating, cooling and ventilating buildings use a lot of energy, which makes it interesting to look into alternative ways to create a comfortable indoor climate. Passive climate design makes optimal use of 'natural' sources of heating, cooling and ventilation and lightning and uses form, layout and material to minimize the demand. This instead of depending on mechanical systems for thermal comfort (Altan et al., 2016).
Since ancient times, water has been utilized to (passively) control the climate in buildings and urban areas and since then, many developments have been made to use water in a smarter and more sustainable way. With the current problems and need for a change in energy use, climate design using water should be looked into as a possible solution.

Project & Research Objective

When looking for solutions for flooding of cities and buildings, several strategies can be find in literature and government plans. The 'PARA' framework gives an overview of the four most important strategies and can be useful for flood risk reduction and flood resilience for coastal, fluvial and pluvial floods. The framework presents three main approaches to reduce flood risk and resilience: Protect, Accommodate, Retreat and Avoid. 'Accommodate approaches are those adaptive strategies which are designed to allow continued use of flood-prone areas by improving the resilience of communities or valued facilities/ infrastructure to occasional flooding, or by limiting damage in these areas' (Doberstein et al., 2018, p. 2). With this approach, we accept that areas are going to flood and try to design with this situation. In a report published by Deltares, a similar framework is used, describing the accommodate strategy as 'living with water' (Klijn et al., 2007, p. 3-2). This description points towards a more positive view on floods and how floods can be handled with a new form of living. This way of thinking about floods is the inspiration for this project.

Figure 2. The PARA framework and resilience (Doberstein et al., 2018)

The objective of the project is to see the abundance of water as an opportunity instead of a threat in areas that are at risk of flooding. Despite its power to damage and destroy cities and buildings, water plays an important role in human life and our surroundings. Water can be seen as a 'multidimensional object which appears in various fields', environmentally, socially, culturally, aesthetically and even financially (*Effect of Water Bodies in a Space* - Architecture Blog, 2020). These fields offer many opportunities to deploy its positive characteristics in the built environment. Wylson describes the concept of water architecture as 'architecture associated with the water element, either in the utilitarian, symbolic, therapeutic, leisure or visual context' (Wylson, 1986). Water has a wide range of possibilities as a building element (Albrecht et al., 2009), 'not only ornamental or enjoyable but effectively contributing to face the current issues of inhabiting our planet, thus benefiting from its multi-functional potentials' (Daglio, 2014, p. 105-2).

The project aims to investigate the opportunities of water in architecture in a wide variety of aspects, I would like to design a building that is not only safe to flooding, but also utilizes the water for thermal comfort in the building, aesthetics, acoustics, etc. In the end, these techniques will be used to create an integral design that is safe, sustainable, and comfortable. The project will focus specifically on the situation of regular pluvial floods in an urban area: the inner city of Gouda.

The research paper will focus more specifically on the role water can play in the field of climate design. The objective is to investigate and categorize the characteristics of water that can be used and the effects it can have in climate control. With the idea of ‘opportunity instead of a threat’ in mind, the aim is to explore whether the potential of water in climate control can be combined with flood control.

To combine water in climate systems and flood control, water harvesting is found as a possible connection. Water harvesting has been a method for climate adaptation all through history. In ancient cities, water harvesting methods were an important part of the water system to store water for use in dryer periods and more recently the role of water storage and harvesting during extreme precipitation has become more important. Rain- and floodwater harvesting can help reduce the impact of flooding when water is stored during rainfall or flood to reduce the pressure on the urban drainage system (Hofman et al., 2014).

Recently, especially in urban design, measures are being taken to cope with heavy precipitation in urban areas. Solutions include innovations in water storage and other ways to delay rainwater discharge. However, often the retained water is led to the nearest water body, instead of being used for another purpose (Mackenzie, 2010). Could this water be harvested instead of only stored and be used in the climate design for buildings?

The research paper aims to investigate the possibilities of water storage and water harvesting and how these could be integrated in the climate design of a building while at the same time play a role in flood adaptation.

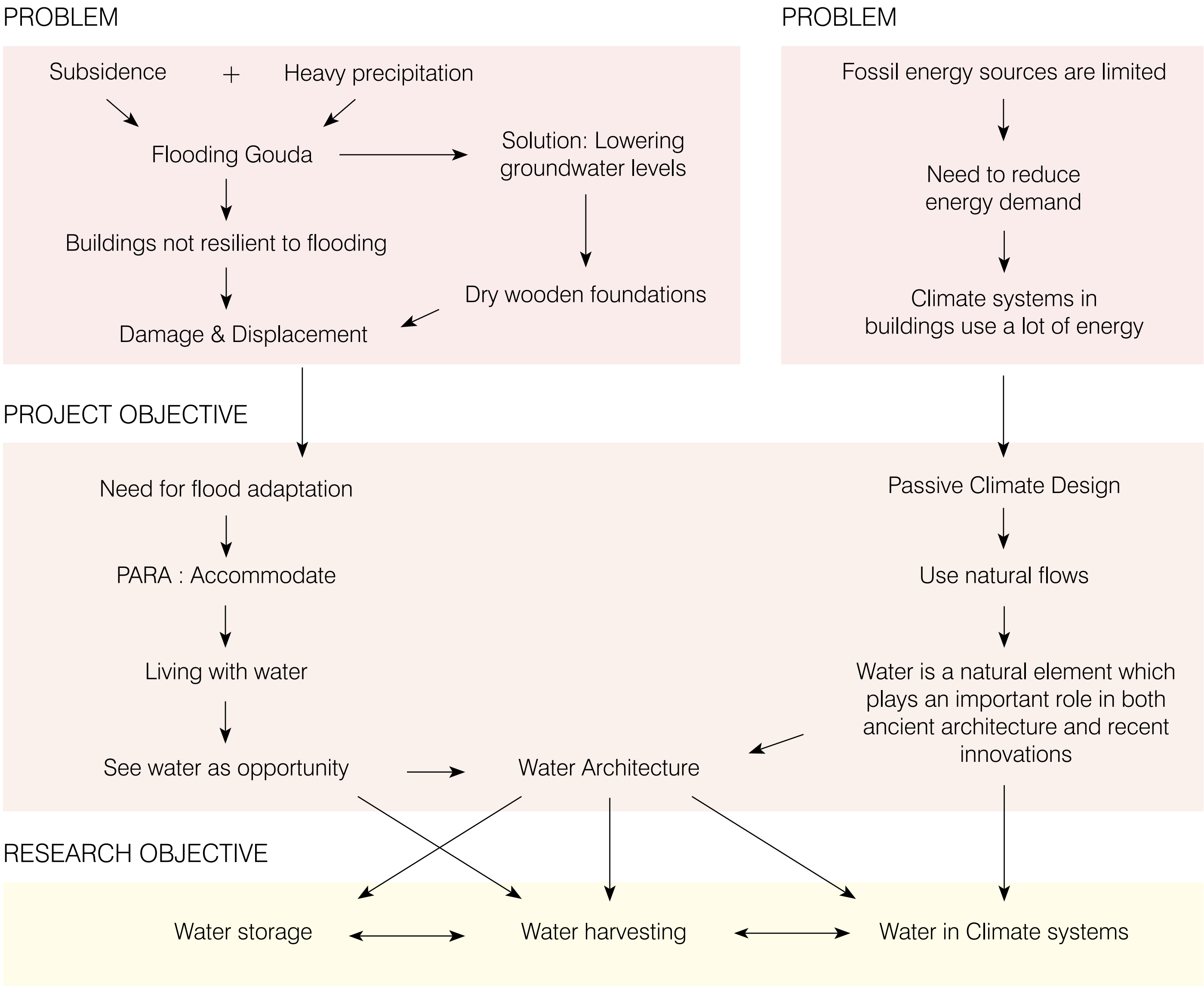

Figure 3. Problem and Objective

HOW
Research Questions

Overall Design Question

How to mitigate the impact of subsidence and pluvial flooding on buildings in Gouda by designing a building that is resilient to flooding and utilizes the abundance of water in various aspects of the design while creating a new way of living with water?

Thematic Research Question

How can harvested rain- and floodwater be integrated in the climate design of a building while mitigating the impact of pluvial flood (& reduce the energy demand of the building)?

Sub questions

- How can water be used in (passive) climate design of a building?
    - What existing techniques for climate control use water, what are the developments from ancient techniques until recent innovations?
    - What are characteristics, effects, advantages and disadvantages of these techniques?
    - What sources of water are used for these techniques?
- How can rain- and floodwater be harvested in buildings or urban areas?
    - Can these techniques help mitigate the impact of urban pluvial floods?
- How can rain- and floodwater be stored in buildings or urban areas to mitigate flood risk?
    - How can this water be not only stored, but also used?

- How can the analyzed techniques for rain- and floodwater storage and harvesting be combined with the analyzed techniques for climate design?

Episteme (Design Research)

Morphology (shape, form)
How to shape a building to be resilient to urban pluvial floods?

Ecology (natural environment)
See water as an opportunity
Use water in climate design of a building

Phenomenology (human experience)
How to create a new way of living with water in urban areas?

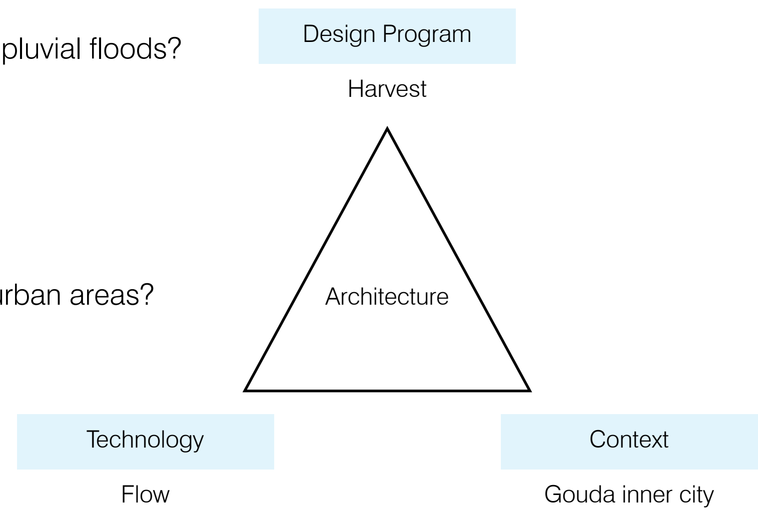

Figure 4. Graduation Frame: Triangle Approach

HOW
Methodology

Thematic Research Methodology

To answer the sub-questions and finally the research question, qualitative research will be executed using literature and case studies. Roughly, the research will be split up in three phases: investigation, categorization and integration.

INVESTIGATION
The research will start with a literature study on techniques using water to influence the climate of a building. Water in architecture has a long history but is also a large topic in recent innovations, therefore ancient techniques as well as new developments will be studied. Case study analysis will support the literature research to deeper understand specific techniques and their advantages and disadvantages.
A similar study using literature and case studies will be done on techniques for storage and harvesting rain- and floodwater in architecture and urban design. Case studies will be analyzed and visited if possible. Several kinds of water harvesting will be studied, but special attention will lie on techniques that are used for water storage during heavy rainfall or flood, or techniques that have the potential to contribute to this.

CATEGORIZATION
To deeper understand and compare the techniques, an overview and categorization will be made. The techniques will be categorized on aspects like used water characteristic, effect, co-benefits, etc. The exact way of categorizing will be developed during the research process. In the end, a 'catalog' will be developed to give a clear overview on all possibilities. This will be done for water in climate design and water storage and harvesting.

INTEGRATION
Finally, the investigations and catalogs will be compared to see if there is a potential to combine systems. Are there opportunities to use (on site) harvested rain- or floodwater in the climate system of the building?
This comparison will lead to conclusions which are the base of the design process.

Hypothesis - Antithesis

The result of the research will be an elaborate inventory of techniques to use water in climate design. The characteristics, effects, advantages and disadvantages will be mapped and compared. The same will be done for techniques for rainwater and floodwater storage and harvesting, and connections will be found between the topics. The expectation is that abundant rain- and floodwater can be utilized by integrating it in the climate system of a building. The expected conclusion is that water harvesting and climate design can be combined to mitigate the impact of pluvial floods.

However, it is possible that the climate systems using water are complex and therefore hard to implement. Using harvested rain- and floodwater for these systems might be more complex and expensive in comparison to using water from the potable water supply, and therefore an unrealistic alternative. In general, centralized water and climate systems might be more economically feasible solutions.

Relevance

The problems as described are relevant all over the world and the Netherlands can be seen as an example for other areas. The research into climate systems, water storage and water harvesting can be seen as generic for urban areas, the research will not be further specified towards a specific location or situation. The final inventories and conclusions can be used as reference and inspiration for all kinds of projects. The complete design project will be done for the inner city of Gouda and can be seen as a specific example of how the research can be deployed in practice. The goal is to present an integral design that showcases a new way of living and of rethinking the role water can play in architecture.

HOW

Research Structure

DESIGN QUESTION

How to mitigate the impact of subsidence and pluvial flooding on buildings in Gouda by designing a building that is resilient to flooding and utilizes the abundance of water in various aspects of the design while creating a new way of living with water?

RESEARCH QUESTION

How can harvested rain- and floodwater be integrated in the climate design of a building while mitigating the impact of pluvial flood?

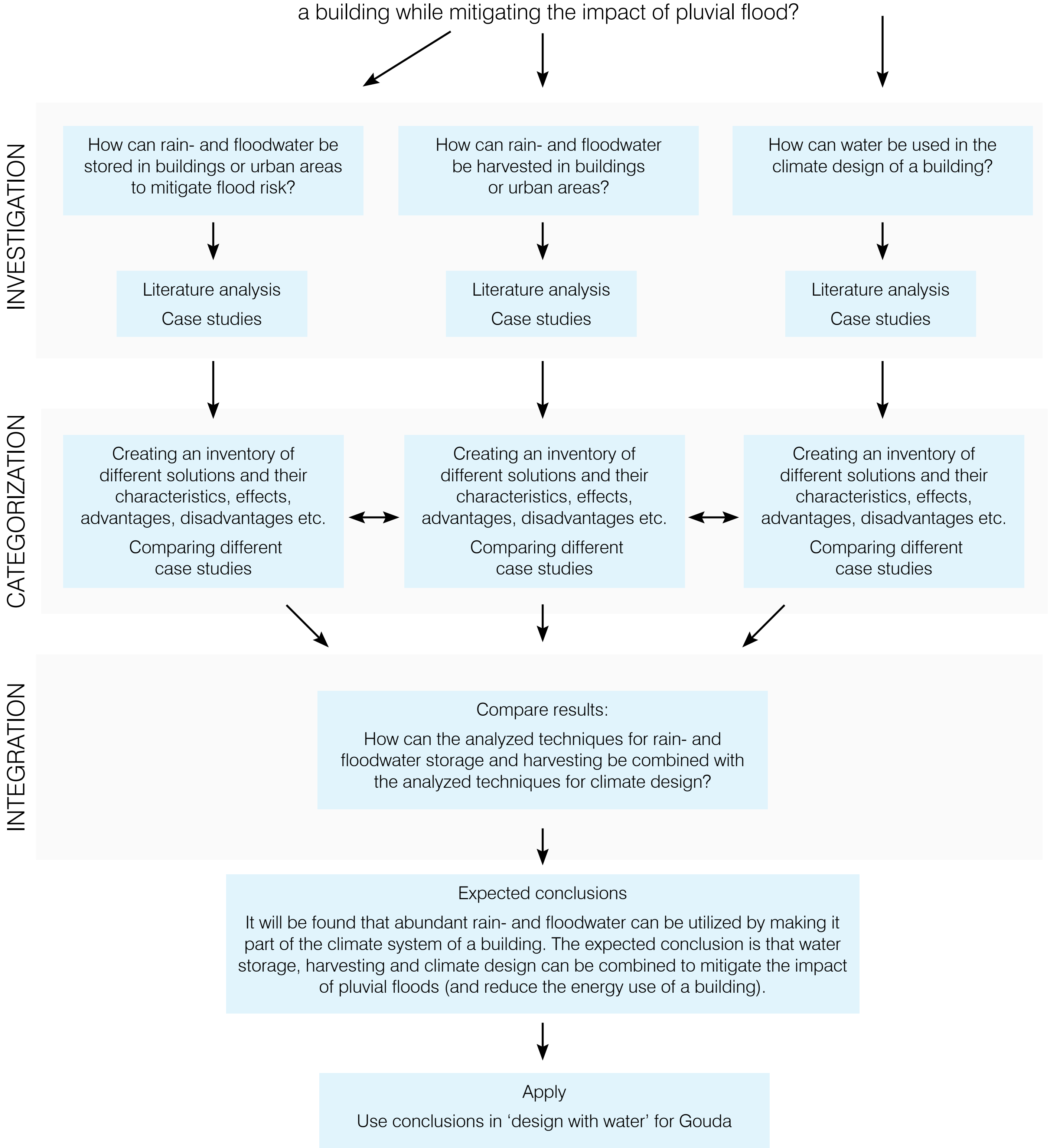

Figure 5. Research Structure

HOW Planning

Date		Week	Phase	Deliverable	Research tasks	Design tasks
September	5	1.1				
	12	1.2				
	19	1.3				
	26	1.4				
October	3	1.5				
	10	1.6				
	17	1.7				
	24	1.8		Draft research plan		
November	31	1.9			Research Plan	Program analysis
	7	1.10	P1	Research Plan	Presentation	Site analysis
	14	2.1			Water in climate design - investigation	
	21	2.2			Water in climate design - categorization	
	28	2.3			Water storage & harvesting - investigation	
December	5	2.4			Water storage & harvesting - categorization	
	12	2.5			Combine topics	
	19	2.6		Draft paper	Write paper	
	26	Christmas break				
January	2					
	9	2.7		Research paper	Finalize research paper	Gouda analysis
	16	2.8			Presentation	Architecture for Elderly
	23	2.9	P2	Presentation	Presentation	
	30	2.10	P2	Presentation	Presentation	
February	6	TU break				
	13	3.1			Site & Program analysis	Define design requirements & develop concept
	20	3.2			Water architecture	Shape & Floorplans
	27	3.3			Look back on research	Structure & Climate concepts
March	6	3.4				Materiality & Detailing
	13	3.5				Drawing set
	20	3.6			Reflection paper	Drawing set
	27	3.7	P3	Presentation	Presentation	Presentation
April	3	3.8	P3	Presentation	Presentation	Presentation
	10	3.9	P3	Draft reflection paper	Presentation	Presentation
	17	3.10				Situational drawings
	24	4.1				Plans & Facades
May	1	4.2				Details
	8	4.3				Final drawing set
	15	4.4	P4	Presentation	Presentation	Final drawing set
	22	4.5	P4	Presentation	Presentation	Presentation
	29	4.6				Final drawings
June	5	4.7				Final visualization
	12	4.8				Model making
	19	4.9	P5	Presentation	Presentation	Presentation prep
	26	4.10	P5	Presentation	Presentation	Presentation

WHAT
First references

Water in Climate Design

Figure 6-7

Water Harvesting

Figure 8-9

Water Storage

Figure 10-11

Literature references

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Figure references

Cover image	Escher, M.C. (1961) *Waterval* [Lithograph]
Figure 1.	Hartmann, N. (2022) *Problems in Gouda*
Figure 2.	Doberstein et al. (2018) *The PARA framework and resilience*
Figure 3.	Hartmann, N. (2022) *Problem and Objective*
Figure 4.	Hartmann, N. (2022) *Graduation Frame: Triangle Approach*
Figure 5.	Hartmann, N. (2022) *Research Structure*
Figure 6.	GRIMSHAW. (1992) *British Pavilion Expo 1992*, Seville, Spain
Figure 7.	*How to Store Excess Solar Energy at Home. (*2022) https://www.howtogosolar.org/water-tanks-passive-solar-heat-storage/
Figure 8.	Rua Arquitetos. (2016) *Rio 2016 Olympic Golf Course*, Rio de Janeiro, Brazil
Figure 9.	*Cisternerne: A Subterranean Water Reservoir Turned Into Art Gallery*, Copenhagen, Denmark photo credit: unknown/imgur via https://www.amusingplanet.com/2016/03/cisternerne-subterranean-water.html
Figure 10.	Oscar Niemeyer (1960) *The Planalto Palace*, Brasilia, Brazil
Figure 11.	Rik de Nooijer, gemeente Rotterdam (2012) *Waterplein Bellamyplein,* Rotterdam, Netherlands