RESEARCH PLAN : Engaging with Water

An approach on how a 'sponge' building and surrounded area can reduce water shortage and water overflow, while using water as a medium to connect nature, humans and buildings to enhance our well-being and simultaneously use it as an example on how to become more sustainable for communities and other stakeholders.

Architectural Engineering Studio | AR3AE100
Gili Hofland | student nr. 4876091
11/12/2023

Content Research Plan

Personal Information
Gili Hofland
4876091
Julianalaan 134
2628 BL
Delft, Netherlands

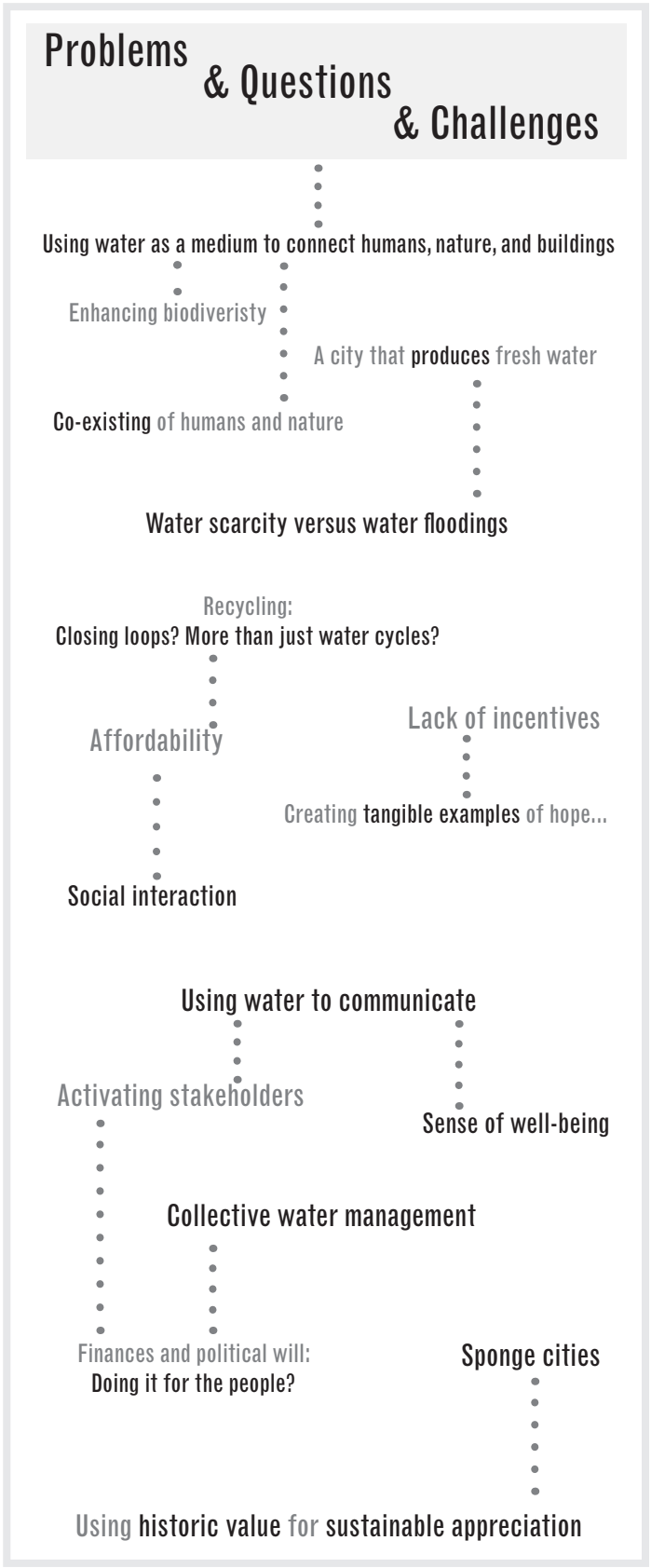
Studio
Architectural Engineering Graduation Studio
Design tutor: Stephan Verkuijlen
Research tutor: Nico Tillie

Interest in Architectural Engineering

Water has been an element that has always intrigued me. In times of stress I seek to go out to nature to find a place to relax. Mostly I can find myself along the coast to lose myself in staring away infinitely. During my travels, I have always visites coastal cities and love to see how people are enjoying the close connection to the waterside. In the nothern cities of Europe, like Denmark, Sweden and the Netherlands this connection to water is even more sensible.

Water can both be seen as a technical and psychological design element, means of why it interests me so much. In the field of Architectural Engineering you get the chance to discover your own fascination and combine it with a technical approach. During my studies, the focus had been on designing and the technical aspects were subject to the design process. Often technical solutions were integrated in the end, without fuly understanding the functionality or logic.

When relating water to the Architectural Engineering Studio, it creates the possibility to research how water can be implemented in architectural designs and how we as humans can engage more with water. Moreover, as climate change effects are increasing, we get to deal with more water problems like riverine floodings and heavy rainfall, but also water scarcity. Can water be the visible triggering element that stimulates people to think of creative sustainable solutions, that lead to collective water management and the formation of communities?



Keywords: High-water stress; floodings and water scarcity; water as communication medium; symbolism and effects of water on human health; biophilic design; biomimicry; sustainable awareness; social responsibility

Introduction to water

The contradiction of water... as our friend & enemy

In our current world we are experiencing accelerating climate changes. The effects of the changes are slowly, but surely becoming reality. On a large scale, we are dealing with high-risk flood areas, due to the rising sea level and heavy rainfalls, causing unpredictable floods (Hunt & Watkiss, 2010). Only in the summer of 2023 catastrophic floodings have happened and hit cities and towns in northwestern Turkey, southern of Brazil, China and the Netherlands, central Greece, Hong Kong, and southwestern parts in the Unites States (Chow, 2023). Heavy rainfall causes mud streams, provoking bursting riverbanks that wash away buildings, risking the safety of communities. Hundreds of people have died because of floodings, lose their homes, and have to build-up their home all over again. These flooded areas in cities mostly contain a lot of grey infrastructure like concrete tiles. This results in even more excess water that cannot be absorbed by the plants and ground, often referred to as green and blue infrastructure (Armour et al., 2014; Cooper, 2019). Also, floods and erosion are caused, because the infiltration capacity is exceeded due to the large volumes of rainfall. The soil becomes impermeable which leads to water scarcity, droughts, and lower river levels. (Raes & Savolainen, 2021).

Some cities are even experiencing a somewhat contradictory situation. Take for example London in England and Chennai in India, where they must combat a shortage of potable water, while enough water is falling from the sky (Bloomberg News, 2021; Leahy, 2021). Other examples are harbor cities dealing with the rising sea level meanwhile facing a potable water shortage (Bin, Tain, Wang, Xu & Zhuang, 2023). Now, water gets a more negative character and is seen as an obstruction, rather than seeing it as an opportunity to collect and re-use the surplus water. The collected water could then for example be used during times of drought to water greenery (AghaKouchak et al., 2018). Thereby, expectations of our water consumption are to be increased by 40% by 2030 and therefore exceeds the available water supply. This all, because of our growing population and food consumption, the increased urbanization and climate change (Raes & Savolainen, 2021). Overall, it results in a growing need for water protection systems and closed water cycles.

Figure 1: Removal of sediments from the Yellow River in Xiaolangdhi, China.

Photo by Wang Song, Xinhua Press, CORBIS. Retrieved from https://www.nationalgeographic.nl/fotografie/2018/03/indiase-goeroe-strijdt-tegen-vervuiling-van-rivieren, accessed on 9 September, 2023.

Figure 2: Vulnerable flooding zones in Dhaka. Photo by Sumaiya Ahmed – http://www.flickr.com/photos/snippets/. Used under Creative Commons.Retrieved from https://www.nationalgeographic.nl/fotografie/2018/03/indiase-goeroe-strijdt-tegen-vervuiling-van-rivieren, accessed on 9 September, 2023.

But nowadays we are not using water to its full potential anymore. Whilst we are very aware of what is happening around us regarding the high-water risk, not enough action is taken to combat the current and future water problems. Most of the drainage systems are unprepared to withdraw the large volumes of extra rainwater. The sewer systems have been built over a hundred years ago and within ten to twenty years some of the sewage pipes might collapse as they are deteriorating. Unfortunately, the repair and maintenance of the sewage system is challenging and expensive (Raes & Savolainen, 2021).

Figure 3: Garden design of Palace of Versailles: Water basins are placed to create infinite sightlines.

This disconnection between humans and water is remarkable since we are very water dependent and have always been surrounded by water. Water has been the main heart of origin of all civilizations. In the earlier times, a whole village was dependent on the tides of the river regarding the irrigation systems of the land, like in ancient Egypt on the coast of the Nile. Rivers were seen as a symbol of time and life. This makes water a historical and cultural symbol. Besides, water is also used as a way of communication in art and design. For example, the design of the Versailles gardens in France (figure 3), where infinite sightlines are created by using large longitudinal water basins. Also, in Italy water was being integrated into the urban structure and buildings during the Renaissance. They used it as an element to enrich their living environment. Fountains, to name an example, would become a place for meeting people. These were architectural-artistic solutions just like canals, arcades, and paving. Water had become the symbol of the flow of life and contemplation that promotes prosperity, progress, and technical power (Mikhailova, 2018).

If we now look our current existing city structures and the integration of water in designs, the disconnection of humans and water becomes even more clear. Many studies have analyzed what cities are likely going to have to deal with flood risks in the near future, see figure 4. It shows what the cities are facing a flood-risk increase when no action would be taken regarding the water protection systems. Therefore, cities need to enhance their natural infrastructure to become a so-called sponge city that absorbs and releases water when needed. In addition, they already have a natural sponge quality that only needs to be improved through interventions (CWRA Steering Group, 2019). Architects are then challenged to contribute to these new system developments, since buildings are also part of the urban planning designs.

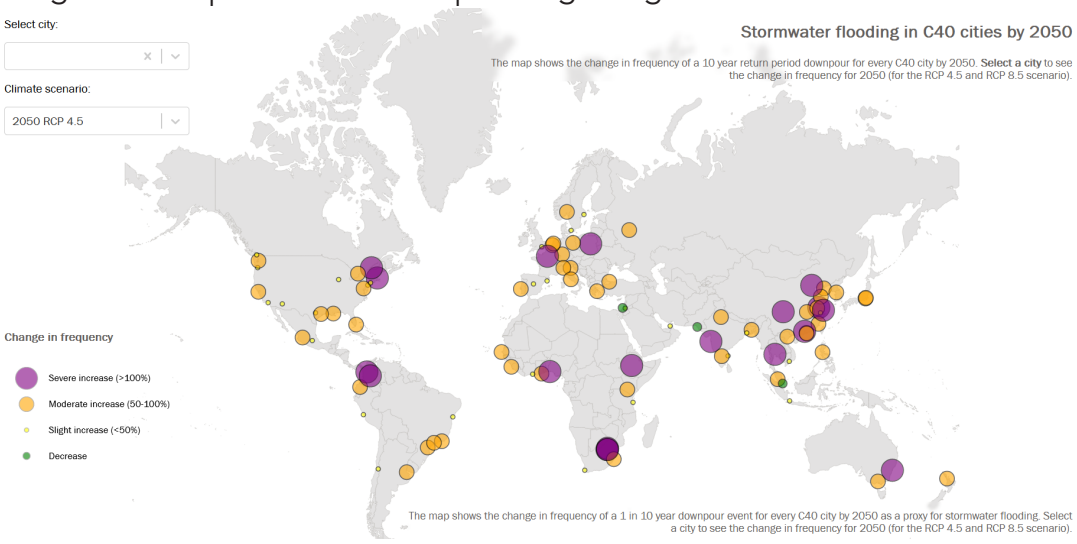


Figure 4:Water risks worldwide inventory by C40 Cities (2022).

General Problem Statement

A disconnetion between humans, nature and the built environment

"As climate change will have its effect on the frequency and intensity of rainfalls and the rising sea level, more interventions need to be taken to protect our cities from floods and droughts. Therefore, adjusting and transforming our current existing city structure to an inclusive water-retaining system city structure with a healthy living environment has to become a priority when shaping our future-proof city".

Missing link of implementing natural water cycles in cities

Now, water gets two faces, since we need to protect our living environment from it, but we are also very dependent on it regarding our basic needs. Collecting the water surplus could be a key to solve this problem to reduce floods, to use as cooling source in public spaces for instance or to filter to potable water. Only, in the existing largely paved city structures not enough space is available to retain large amounts of natural water and therefore ask for transformation (Raes & Savolainen, 2023).

The disconnection of humans and water is also sensible on a psychological level. In our current living environment, we have become used to living indoors, while this often leads to stress and depressions. Integrating water in designs can help solve the negative influence of living indoors as it has a positive effect on our health and can enhance our well-being on both a smaller indoor and larger urban scale. Studies have shown that the sound of water has a relaxing effect on people and can help to relieve stress and better our performance (Calabrese & Kellert, 2015). On a larger scale, water can be linked to our urban health (Angelakis, Koutsoyiannis, Tchobanoglous & Zarkadoulas, 2008; Arsénio et al., 2016). Nowadays, designers are trying to prioritize the connection between humans and nature in building designs again, which is also called biophilic designing; *'an approach to architecture that seeks to connect building occupants more closely to nature'* (Calabrese & Kellert, 2015; Sageglass, 2016). It is remarkable that we are not aware of the full potential and qualities water has to offer regarding our mental and physical health.

Lack of sustainable awareness and social responsibility

The lack of awareness regarding the effects of water on our health is a challenge for architects and designers as they must convince people of the positive effects of implementing water in designs. Worldwide actions are taken by the government, engineers, and designers to make cities adaptable to climate change. Only, among people there still is a lack of public knowledge and awareness of the necessity to become more sustainable regarding the water risks and health effects. Because if they are not directly threatened by floodings and water scarcity, why should they pay attention to it? Thereby, the consequences will mostly be carried by the elderly and low-income groups, or moreover the most vulnerable groups (IPCC, 2007). Activating other parties like investors and municipalities to participate in sustainable solutions is therefore of essential importance, as they have the money capacity to invest. The challenge is to stimulate the political will of stakeholders like investors and city planners to finance the sustainable solutions. The institutional capacity is there and studies already developed design strategies to solve water and health problems, but they still need to be put into practice (Dickinson, 2022, 28:04). The adaptation of climate change therefore brings social, economic, and governmental challenges to raise social responsibility (Douglas et al., 2011).

Lack of knowledge forms a barrier when it comes to the engagement of the public with climate change. Letting people engage can create understanding of the climate policies and interventions taken by the government but can also help to bond society. Besides, if a more sustainable and healthy living environment is the demand, then the potential solutions should be communicated in an easy-to-understand explanation for everyone (Buurman, Hoekstra, Van Ginkel, 2018). It can lead to a quicker adaptation to the changing climate (Dedekorkut-Howes, Howes, Khatibi & Torabi, 2021; Raes & Savolainen, 2021).

Overall Design Objective

Contextual approach

Lots of cities are going to have to deal with the contradictory situation of not having enough storage for excess water and a water shortage. Water sensitive designs can contribute to solving this problem. Hence, the chosen location for creating a water sensitive example building could be placed anywhere in an existing city structure experiencing these water problems. Multiple studies about what water problems cities will be facing in the future have been brought together in different maps. C40 (2022) even categorized how much additional costs per capita would have to be paid if no action would be taken regarding water protection systems. The appendix figure (B) shows a comparison of a few large cities that are categorized by multiple problem factors. One of the most problematic cities is London, capital city of the United Kingdom, with almost 10 million citizens (Macrotrends, 2023). The water resources are under great pressure as the population is still growing. Also, the rainfall intensity is increasing and the sewage pipes are ageing, leading to bursts and leaks. Thence, the water supply needs for 20 million people are lost every day (Environment Agency, 2018). And over time, green spaces had to make place for impermeable ground, which leads to more water needed to be drained via the sewage pipes (Cooper, 2019). All in all, enough challenges regarding the regulation of water that ask for a drastic change in the existing city structure and a need for water inclusive designs.

Using water as a medium to connect humans, nature and the built environment

Already, many studies about integrating water systems into our city structure have been conducted, but still need to be brought into practice. On a bigger urban and landscape scale, the floods and droughts need to be tackled by restoring the natural water cycles. Water sensitive urban designs will lead to fewer risks in the currently designated flood areas. This might be doable, as the city already has a natural sponge function and only small interventions will be needed to put into motion. On a smaller social scale, the necessity of raising sustainable awareness needs to be addressed to motivate multiple stakeholders like the municipality, inhabitants, and investors, to contribute to the collective water management system (ARUP, n.d.). Showing them the positive outcomes of implementing water in our city structure leading to a healthier living environment is part of the design approach that will be researched, whereby water engagement is used as a means of communication to bind these aspects. By showing people the outcomes, it activates them to want to participate in realizing sustainable solutions, resulting in communities that exchange ideas and knowledge. The design focus is then related to both indoor and outdoor and tries to create a connection between the two spheres, by means of a multifunctional building that connects private and public spaces. Water will be the guiding theme that connects humans, nature, and buildings since water can help to enhance our health and enrich our environment in a positive, interactive, and mainly visual way. The mutual connections are shown in the explanatory diagram (figure 5) ‘Interconnected Systems’. In the end, the building should become an example for future projects regarding the design of water sensitive buildings and cities.

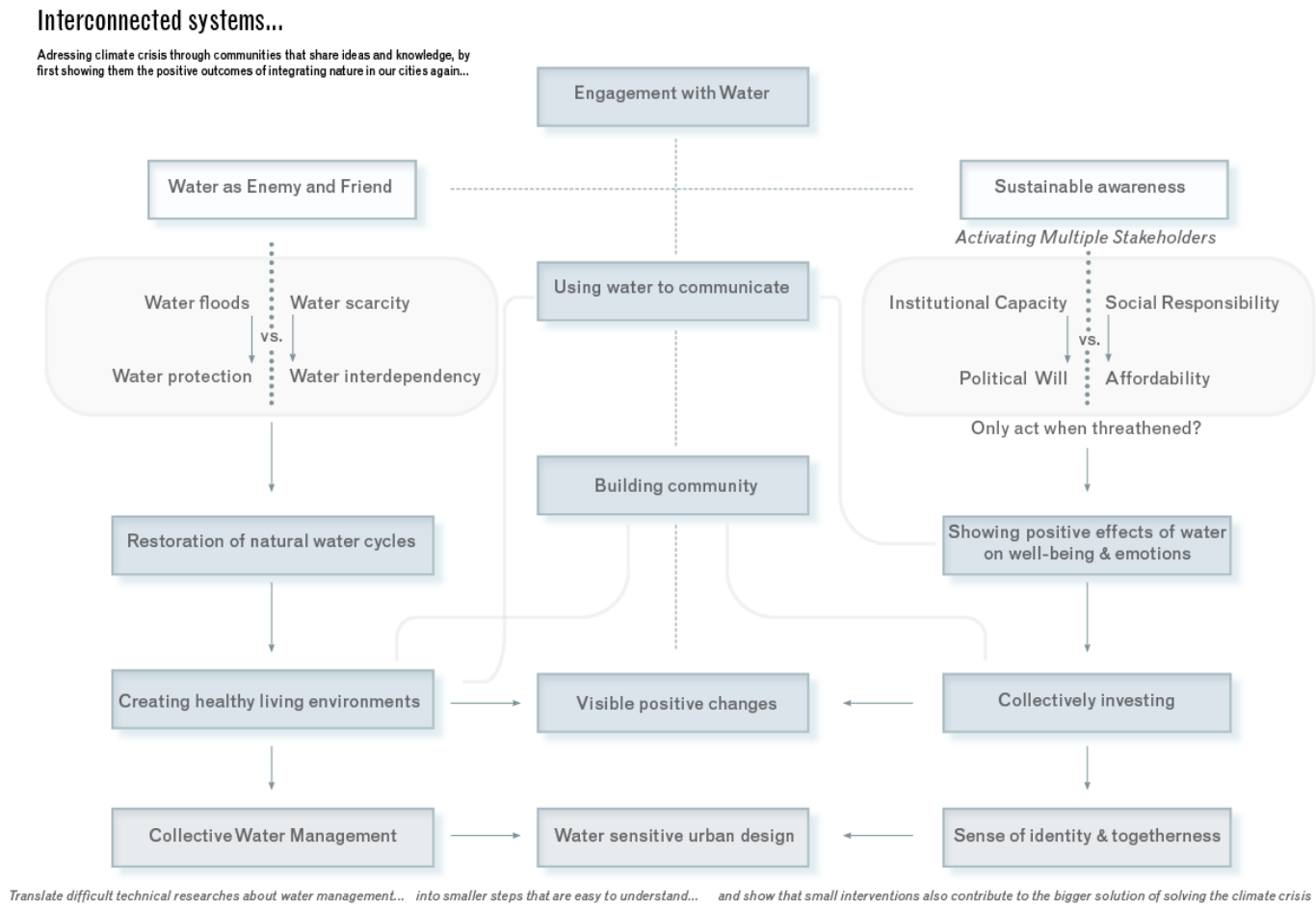


Figure 5: Interconnected systems explainatory diagram (by author)

Combining these aspects leads to the following overall design question that stands central during the research:

"What water cycle interventions can be integrated into a site-specific building design approach with its surrounding area to let it function as a sponge (regarding water absorption / release) to help regulate and prevent water scarcity and floods in the existing city structures of London, while simultaneously creating a healthy, pleasant living environment?"

The overall design question focusses on water cycle interventions because it seeks to connect multiple layers like combatting flood-risk areas, the positive health effects of water, and raising awareness to develop creative sustainable outcomes for collective water management. The collective water management will support social engagement among inhabitants that leads to social responsibility and sustainable awareness. Also, the involvement of external parties to combine institutional capacity, political will and affordability are part of the translation of technical water management solutions into tangible, understandable solutions (ARUP, n.d.). They will form guiding themes during the research. As an architect, it is our chance to try to balance these aspects and translate it into sustainable and healthy building designs that stimulate the connection with nature, raise awareness for sustainability and teach communities how to contribute to sustainable water management systems.

Overall Research Objective

The prescence of water in architecture

Water can be the connecting bridge between the three subjects of working with high-water stress, the lack of sustainability awareness and the positive impact water has on our well-being (figure 6). The close relation between water and humans can be related to biomimicry and biophilic design, which is becoming more relevant when designing buildings. Nowadays, there is a disconnection between nature and humans and biophilic design implements natural aspects into the design process to rebuild this connection again. Biomimicry on the other hand simulates natural systems that promotes sustainability (Calabrese & Kellert, 2015; Arpitha, 2023; Verma, 2023). As designer might understand the effects of sustainability on our health and environment improvement, it might be difficult to understand for others. Biomimicry and biophilia are both visible, pleasant translations of creative sustainable knowledge and solutions that can be used as mediums to communicate the importance of implementing collective water systems in our everyday life. These two aspects will form leading themes in the thematic research, as well as water sensitive design examples that explain different design strategies on how to implement water in designs. The thematic research question is a more deepened question on how to research the implementation of water in designing on different scales:

"How can the qualities and potentials of natural water cycles be embedded in our current city structure to connect water, nature, and buildings on different scales by translating research about biomimicry, biophilic and water sensitive design interventions examples into a design approach for an existing area?"

The thematic research question can be divided into different supporting themes that will be facing water problems; the symbolism and effects of water; social responsibility; and raising sustainable awareness. Each subject contains a few sub-questions that should help to translate the technical knowledge into a research and design approach, which will be divided under three different research scales that will be introduced in the following paragraph. The thematic research question helps to shape a research design tool that encourages designers to create water sensitive designs. The research design tool will then form a guideline for designers on how to implement water in designs on the multiple scales by creating an inventory and analysis of best-practice examples.

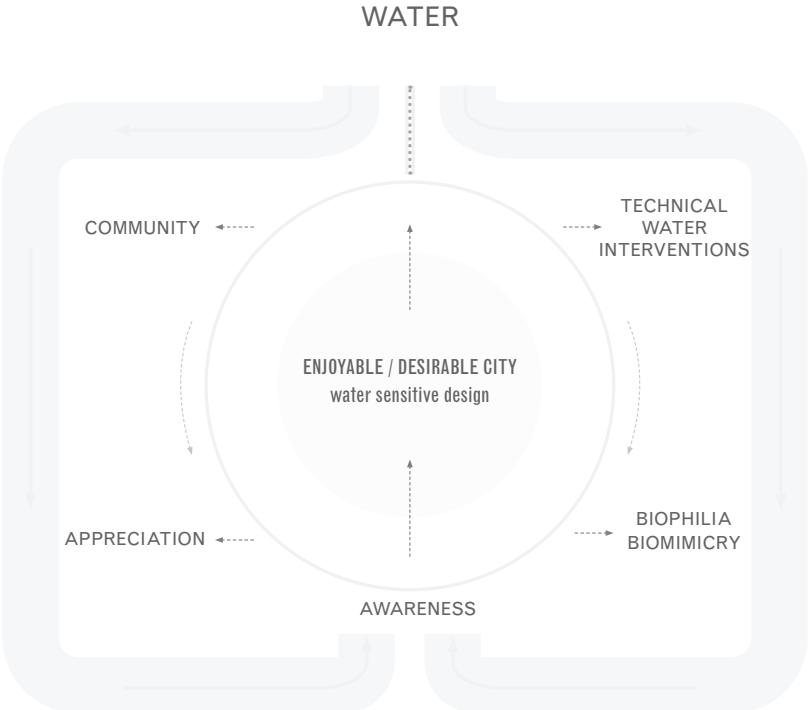


Figure 6: Explainatory diagram integrating water into design (by author)

Methodology

Theoretical framework

The aim of the theoretical framework (figure 7) is to create understanding of water cycles on different scales to be able to connect them to buildings and communities. Examples of developed strategies and diagrams can be seen in the Appendix (C, D, E). During this research there will be focus on the water problems in London. Simultaneously, the effects water can have on the well-being of humans is being explored. In the end, the intention is to collect already conducted studies about collective water management in buildings with surrounding areas and translate them into understandable, graspable solutions brought into practice for everyone.

Conceptual framework

A more detailed explanation of the required information needed for this research is explained in the conceptual framework diagram (figure 8). Different scales are distinguished to analyze the implementation of water, which can be seen in the conceptual framework. The scales will divide the understanding of natural water cycles on a landscape level, urban square level, and the social building level. The landscape scale is a more general data collection about the water problems the chosen city is dealing with on macro level, while the urban square scale looks more detailed into water sensitive design strategies (best-practice examples) and examples of studies. On a micro level, the social building scale focusses on the positive health effect of water on our well-being and how to create positive interaction with it to create understanding and awareness. The conceptual framework shows a more deepened diagram of the desired information needed and the type of method on how to gather the specific knowledge. Examples are collecting best-practice projects to reflect upon, analyzing design strategies to show the possibilities and interviews to gain insight in the specific chosen neighborhood and site. The connection of the three-scale division and sub-themes are displayed in the extensive theoretical framework (figure 9). Combining the knowledge needed to analyze each scale and the sub-themes together formed sub-questions that help answer the thematic research question. Thus, there are several ways to implement water into a building design that will be further investigated and inventoried (see an overview of the theoretical research approach in appendix A).

"The challenge is scale. It's relatively easy to find these wonderful examples in small places. But we need this to happen on every project globally. And not a few projects in well-developed areas". - Dickinson (2022, 28:04).

Theoretical Framework Overview: Water as our friend and enemy

Design approach for the sponginess of cities, while addressing the qualities of water and therefore of nature to shape our future-proof city....

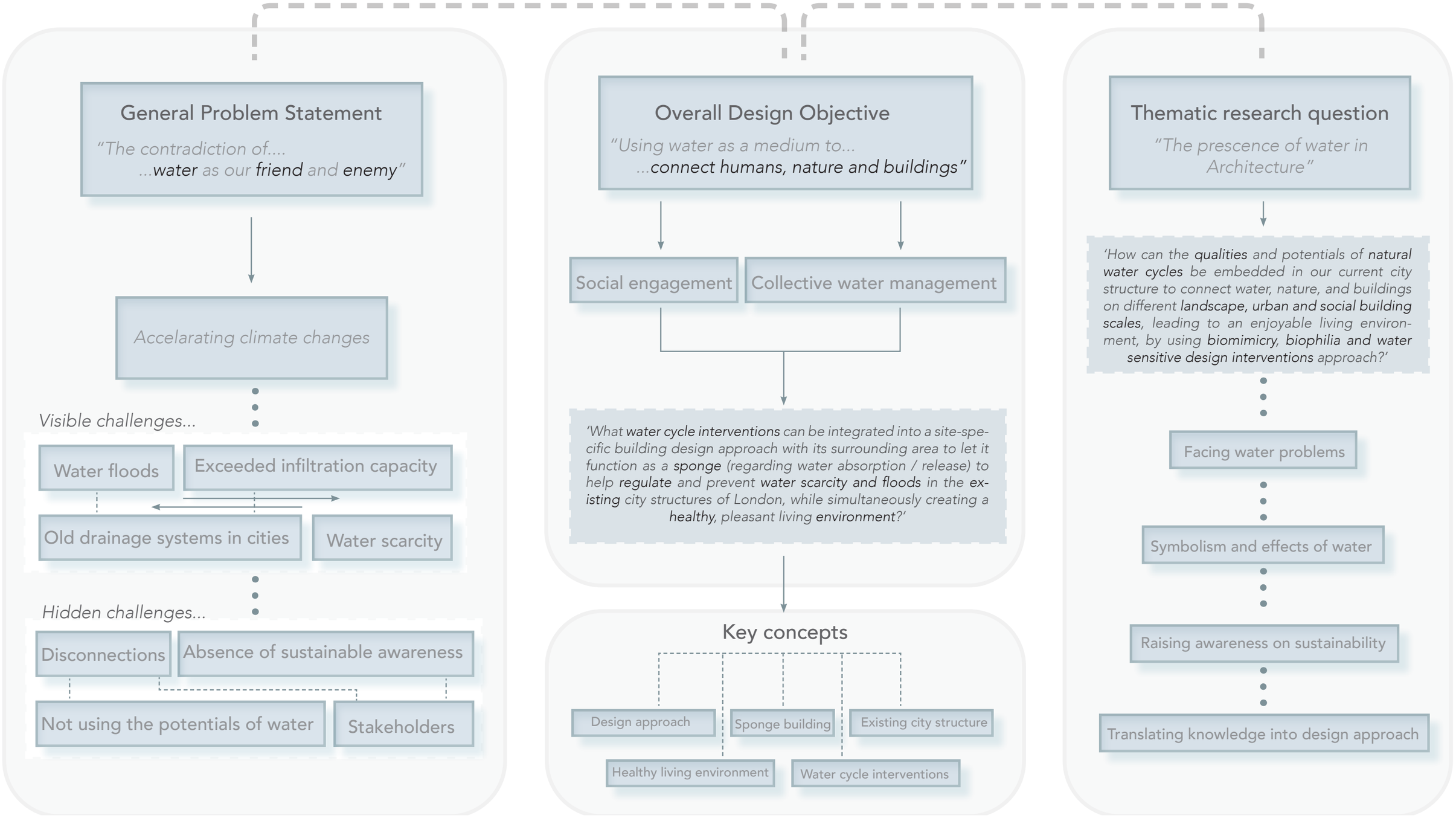


Figure 7: Theoretical framework diagram (by author)

Conceptual framework: Water as design element through three different scales...

Using the visual qualities of water to address the importance of becoming sustainable on multiple levels to activate people to participate in collective water management, while enhancing our living environment...

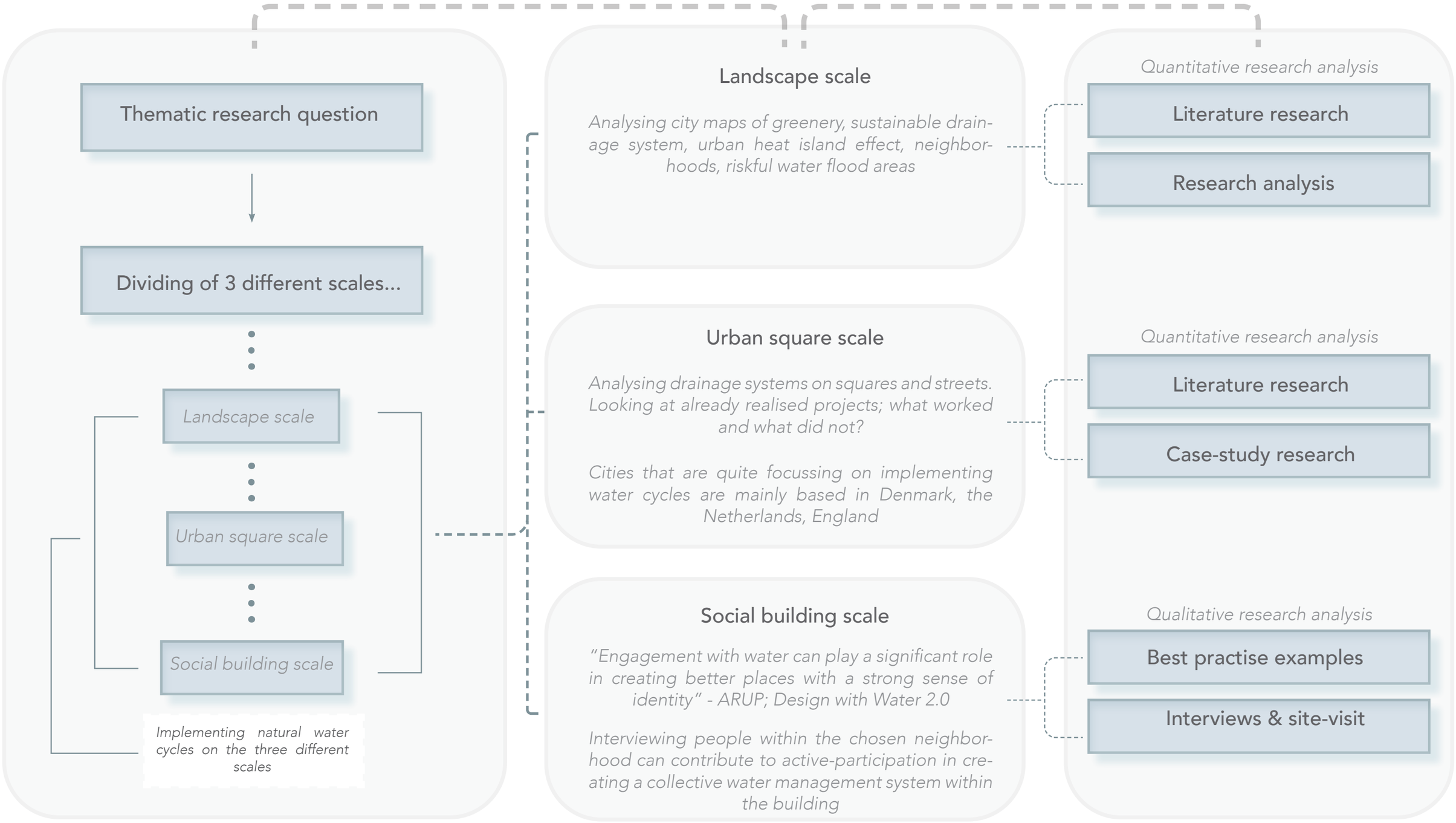


Figure 8: Theoretical framework diagram (by author)

Extensive research framework

Combining different scales....

Landscape scale ; analysing London's natural water cycles

What areas in London are currently dealing with high-risk floodings and water scarcity? General understanding of the Thames' flows; analysis of water problem areas. *(Using maps of urban heat island effect, flood risks, tree canopy, blue and green land cover, surface water flood risk and already developed researches about most high-risk areas to compare areas)*

How does the natural sponge function (regarding release and absorption) of London work? Analysis of intervention network references in London - what site could add to the network? *(Study of Urban Waters).*

What knowledge about water management on all three scales is already available? Reference inventory of water sensitive urban designs, studies, and design strategies; implementation of drainage systems in buildings and streets. *(Collection of studies: ARUP, SWECO, Greater authority London, C40 Cities)*

Urban square scale ; implementing water design strategies

What design interventions can be taken to restore grey infrastructure to a more connected natural environment to stimulate people to participate in water management design as a community? Combine best-practice examples and studies about health effects into design aspects.

What type of neighborhood needs attention, regarding affordability? Analysis of area developments; media and news *(Main problem of people not actively engaging in sustainable systems is the lack of incentives to do the right thing or having no money available to invest).*

What type of public building will enrich the chosen neighborhood? Conducting interviews; categorizing references - types of buildings that stimulate social interactions among inhabitants. Gather information about existing are and building that needs revitalization - transformation / renovation. *(The building has to contribute to the neighborhoods needs, thus combines private and public spaces (multifunctional)).*

Social building scale ; water interaction of nature and humans

What are the effects and experiences of water on our well-being reflecting on history? Research historic use of water in design; studies about stress-relief and relaxation.

How can the usage of biomimicry and biophilia in a building design enhance our living environment? Gathering reference projects and studies on how to incorporate natural forms into design.

How do you teach people about sustainable solutions? Categorizing sustainable activities: organising educational activities that connect people to the building. The building can teach the communities about collective water management. (*Implementing biophylia and biomimicry (psychological and design-related) as design approach to create this connection and awareness showcasing importance of our nature).*

Design approach questions

How to show that connecting water and green structures with humans enhances our sense of well-being among all stakeholders using a historic valuable site?

Gathering information to compare site-specific areas with historic value; opportunities and challenges.)*Transformation of vacant site contributes to realisation that sustainable solutions can also be beautiful).*

How to create a building that functions as an example for implementing collective water cycles in our everyday life?

Showcasing visible ways on the positive effect of water on our living environment and nature - finding ways on how to connect water to humans - sound, touch, reflections, shadows. Design translations will be healthy spaces: biomimicry and biophylia to enhance human emotions and experiences in buildings.

How to raise awareness to all stakeholders on the importance of natural water cycle management in politics, investing strategies and communities regarding partnership and collaborations?

Collect information about affordable housing and investment problems in London.

Figure 9: Extensive research framework (by author)

Reflection on the relevance

Considerate architecture for community and nature

The aim of the design is to optimize the existing city structure regarding water conservation and revitalize the current living environment to a healthier habitat that benefits inhabitants on multiple aspects. The design is used as a translation tool to address communities on how to become sustainable on indoor and outdoor level. Surface water used in designs for example, functions as a water reservoir and cooling element for people. By using different design criteria that can be applied to each location with a unique approach, the research becomes generic but is still location specific. And since the existing areas that are facing floods and droughts are being transformed into interconnecting spheres of water retainment, a deeper connection to nature is created (ARUP, n.d.). Of course, different interventions need to be taken on different locations. The chosen location in London will be an example that will apply and test the guideline tool. See the appendix F for an illustration of the design tool outcome). In general, the thematic research is a research design tool to help understand natural water cycles and how to implement them in our society on a sustainable and social level leading to healthier cities.

Whilst the media mostly informs us on the disastrous events happening around the world regarding the climate change with people dying from the inevitable devastation of settlements and nature, this will make it seem as if acting upon the climate change is of no importance anymore. Seemingly makes it even feel there is no possibility in saving the planet anymore. Focus on the small sustainable improvements to better our environment is therefore important as it brings a more positive glance of the future. It encourages people to think of creative outcomes mentions Harald Dunnink in an interview with Berting (2023).

Expected research and design outcome

A design tool for connecting multiple scales

Using the historical value to create appreciation

All these research inventories will be translated into a research design approach on an existing area with its own unique opportunities and challenges, but is mainly suffering from high-water stress and heavy rainfalls. It should be an area that asks for transformation. The location of the example sponge building should be carefully considered, as the focus is placed on raising social awareness among residents, the municipality, investors, and the government. For example, a historical valued building could be used to create appreciation, since they are widely appreciated by all citizens. It reflects the memories and events of the past. A vacant building that is now left in despair, could be redeveloped to its original state and an even more vibrant area, which shows a visible change. The citizens then might appreciate its restoration which is an extra stimulating factor on why to maintain the building with collective water management. The diagram of figure 13 shows the placement of the historical value of the building within the overall water sensitive design framework. Three locations on industrialized ground have been selected, that will be further investigated throughout the weeks: Three locations on industrialized ground have been selected, that will be further investigated throughout the weeks (see the expected research schedule (figure 14) for a comprehensive division of the research and the design booklet for more information about the chosen locations):

1. Lots Road Power Station
2. The Thames Ironworks and Shipyards
3. Rotherhithe Gas Works

Figure 10: Thames Ironworks & Shipyard

Figure 11 Lots Road Power Station

Figure 12: Rotherhide Gas Works

Social engagement in raising sustainability awareness

To address the cruciality on why to become sustainable, water could be the key element to help and stimulate this process. The implementation of the natural water cycles in a building, leads to collective water management and helps to bond people. It might even help to form communities. Since climate change is impacting us all, communities are crucial to form collective solutions, as it can be used as a method to connect everyone and create a mutual feeling of responsibility. Moreover, in a community ideas and knowledge are shared, which also gives them a bigger voice in exchanging ideas, resulting in a bigger influence on policies and form an inspiration to others. Finally, the individual efforts have an increasing collective impact on multiple levels (Berting, 2023).

Therefore, the buildings' main function will become a public function surrounded with more private spaces, such as different housing types. It will include educational activities to teach all stakeholders. The specific determination of the public function is part of the research tool and will be determined after a location analysis, to see what function the neighborhood is asking for.

Overall, the building can help to reduce the risks of flooding by contributing to the regulation process of excess of water that cannot be absorbed by our nature. When implementing water systems in a building design, it becomes part of its environment. In general, more attention needs to be paid to water systems in cities to both regulate excess water and to enrich our environment to create a healthier living environment. The building functions as a sponge by releasing and collecting water when needed and therefore stimulates a closed water cycle, while it simultaneously improves a human's well-being when engaging with water. The desired design outcome is a visible, pleasant, and impactful example building that might help to activate citizens to want to participate in communities and think of sustainable solutions that enhance a pleasant living environment.

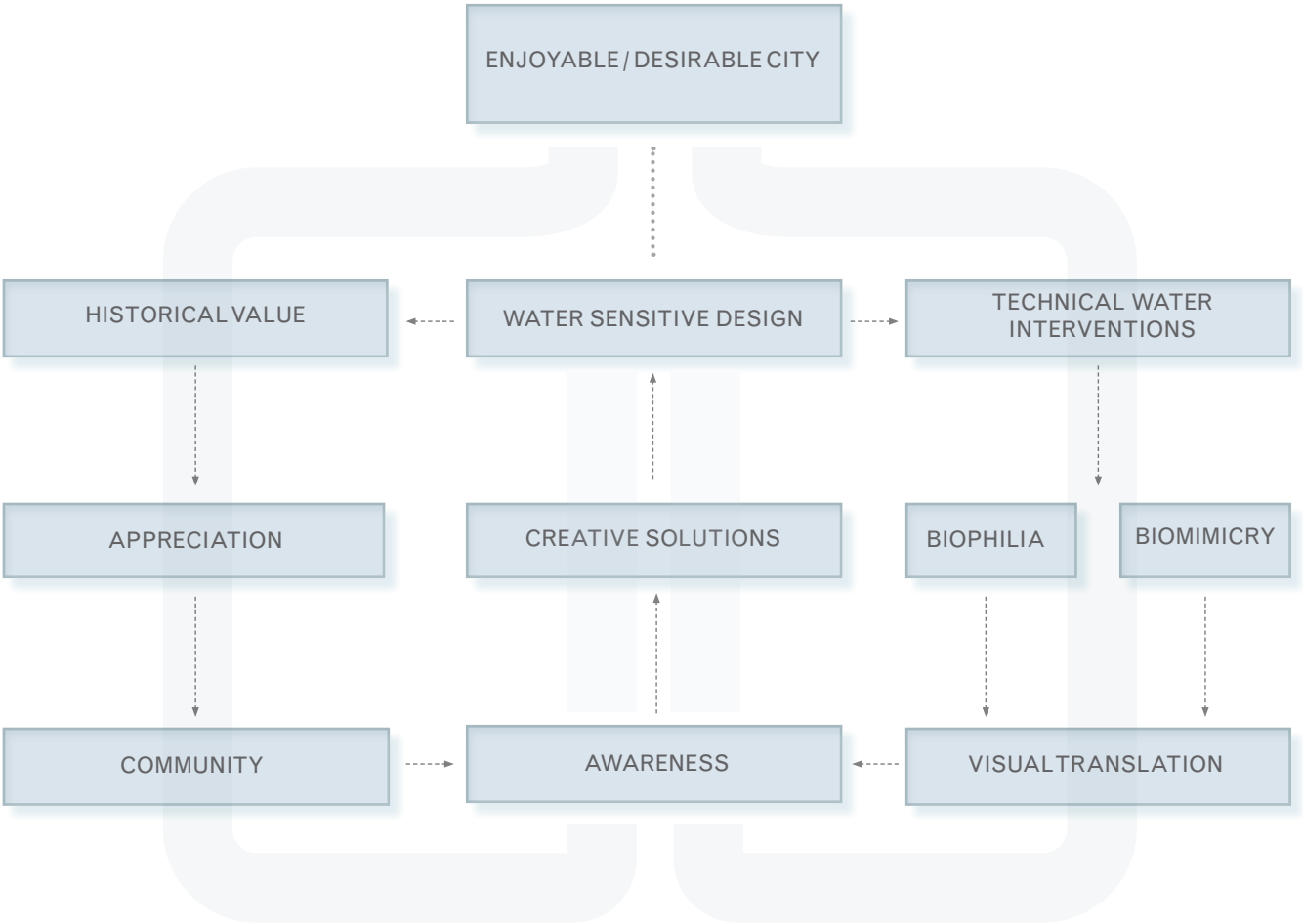


Figure 13: Thames Ironworks & Shipyard

Expected research schedule

An expected time line of the research on how and when to gather the needed knowledge to form the desired outcome

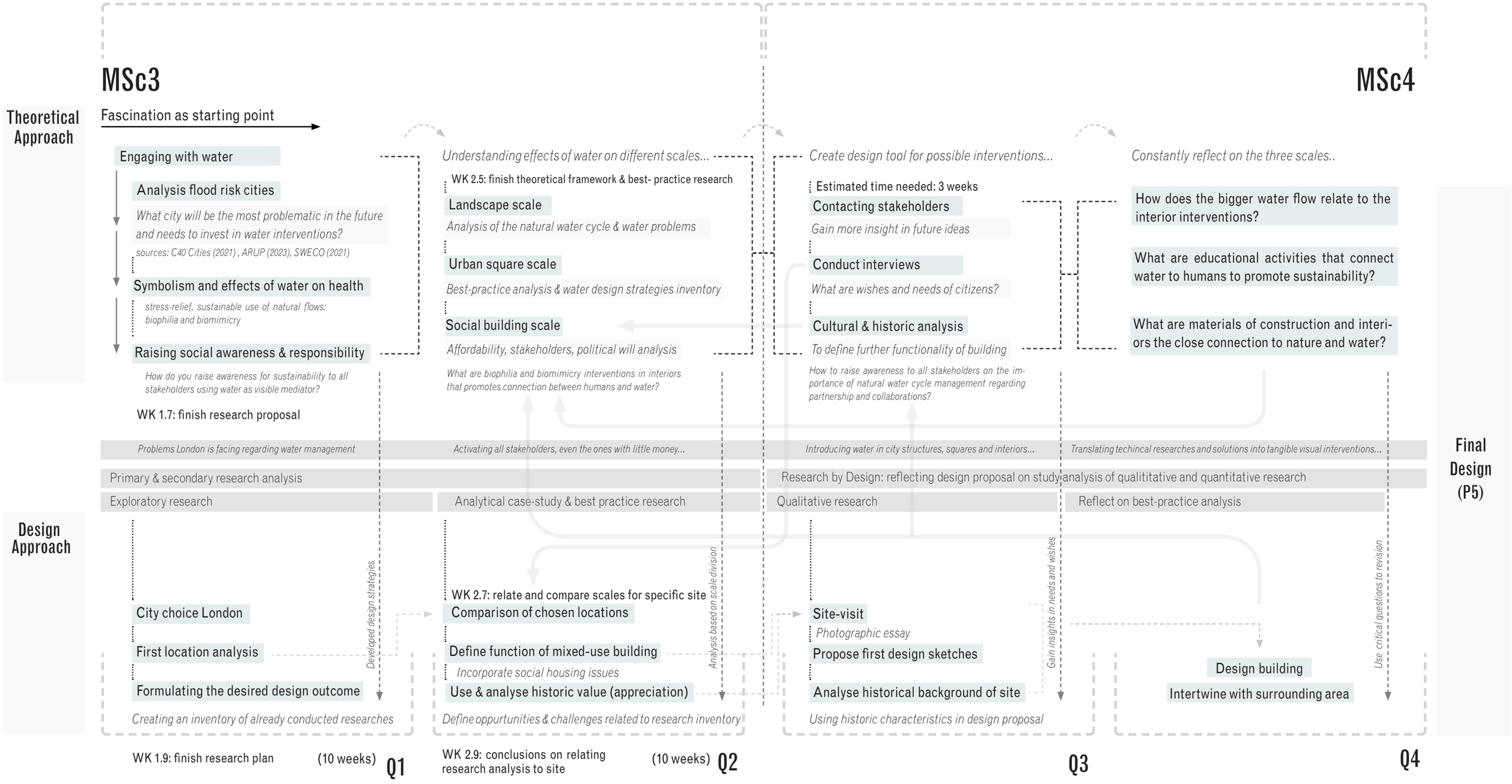


Figure 14: Expected schedule of research

Annotated bibliography

Climate change analysis

AghaKouchak, A., Breinl, K., Di Baldassarre, G., Garcia, M., Kuil, L., Rangecroft, S., Veldkamp, T., Van Oel, P., Van Loon, A. F. & Wanders, N. (2018). Water shortages worsened by reservoir effects. Nature Sustainability, 1(11), 617–622. https://doi.org/10.1038/s41893-018-0159-0. Accessed on October 21st 2023, from https://www.nature.com/articles/s41893-018-0159-0

Bin, L., Tian, F., Wang, C., Xu, K., & Zhuang, Y. (2023). Impact assessment of climate change on compound flooding in a coastal city. Journal of Hydrology, 617, 129166. https://doi.org/10.1016/j.jhydrol.2023.129166. Accessed on September 20th 2023, from https://www.sciencedirect.com/science/article/abs/pii/S0022169423001087?casa_token=Z8oJm-6uq-QAAAAA:mdvXi1yCGXqLajjh7MMHjoAe4OFhi9ZQ37V0IxoHB1jVlUwPniEA4Kqa5x7BABpuBa3RKgHsyQ

Chow, D. (2023, 12 September). Eight catastrophic floods in 11 days: What's behind intense rainfall around the world? NBC NEWS. Accessed on October 12th 2023, from https://www.nbcnews.com/science/science-news/eight-catastrophic-floods-11-days-s-intense-rainfall-world-rcna104620.

C40 Cities. (2022). Water Save Cities: How flooding and drought will impact C40 cities by 2050. ArcGIS StoryMaps. Accessed on 15 September 2023, from https://storymaps.arcgis.com/stories/75508f9fac8c43bda366ae545fb60ec8.

C40 has made an inventory of the possible risks' cities will have to deal with in the near future. They analyzed multiple aspects, such as riverine flooding, heavy rainfall risks, hydrological drought and agricultural drought. It is a primary tool to identify what cities need to be strengthened regarding water management and protection.

Hunt, A., & Watkiss, P. (2010). Climate Change Impacts and Adaptation in Cities: A Review of the literature. Climatic Change, 104(1), 13–49. https://doi.org/10.1007/s10584-010-9975-6. Accessed on September 20th 2023, from https://link.springer.com/article/10.1007/s10584-010-9975-6

In general, discusses what risks cities are facing and categorizes studies about the different cities and the flood prevention plans that are made. Here, findings about London can be used during the own research. Relatively old, so validation needs to be checked.

Leahy, S. (2021, 3 mei). From not enough to too much, the world's water crisis explained. Natural Geographic: Science. Accessed on September 14th 2023, from https://www.nationalgeographic.com/science/article/world-water-day-water-crisis-explained

Integrating technical sustainable water interventions in our cities

Armour, T., Hargrave, J. & Luebkeman, C. (2014). Cities Alive: Rethinking green infrastructure. ARUP. Accessed on 12 October 2023, from https://www.arup.com/perspectives/publications/research/section/cities-alive-rethinking-green-infrastructure

In this research ARUP writes about strengthening our cities by integrating nature or green infrastructures in our cities. The green infrastructure is here placed as an aspect that should replace grey infrastructure which is more cost effective, more resilient and more capable of meeting social, environmental and economic objectives. In the report different solutions in different cities are discussed. Moreover, they try to attract urban communities and other parties benefiting from these sustainable solutions.

Buurman, J., Hoekstra, A.Y., & Van Ginkel., K.C.H., (2018). Urban water security: A review: Environmental Research Letters, 13(5), 053002. https://doi.org/10.1088/1748-9326/aaba52. Accessed on 15 September 2023, from https://iopscience.iop.org/article/10.1088/1748-9326/aaba52/meta.

This review focusses on water security on urban scale. They divide subjects, such as equity, sustainability and water-related risks. Besides, an inventory is made of multiple perspectives on urban water security. Focus points of these are better sewerage and wastewater treatment, safety from flooding and water supply and sanitation.

CWRA Steering Group (2019). City Water Resilience Approach. ARUP. Accessed on September 20th 2023, from https://www.arup.com/perspectives/publications/research/section/the-city-water-resilience-approach

ARUP is an engineering firm that tries to reduce water floods in cities. The City Water Resilience Approach (CWRA) is developed to help leaders to tackle this locally with small interventions. The main theme that stands central is 'resilience' which refers to make cities less vulnerable to future water problems. For the own research it is a relevant study approach, since it divides different steps on how to work on creating water resilient cities: understand the system; asses urban water resilience; develop action plan; implement action plan; evaluate, learn and adapt. In the report, they also mention example projects (Cape Town, Manchester, Rotterdam) that could be used for the best-practice analysis.

Douglas, I., Fekete, B. M., Grimm, N. B., Grönwall, J., Hale, R. L., Revenga, C. & McDonald R.I. (2011). Global urban growth and the geography of water availability, quality, and delivery. AMBIO: A Journal of the Human Environment, 40(5), 437–446. https://doi.org/10.1007/s13280-011-0152-6. Accessed on 23 October 2023, from https://pubmed.ncbi.nlm.nih.gov/21848133/

IPCC (2007). Climate change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp. Accessed on October 17th 2023, from https://www.ipcc.ch/report/ar4/wg2/

Raes, S. & Savolainen, T. (2021). Report: Healthy water cities: From sewer to health booster. SWECO. Accessed on October 5th 2023, from https://www.swecogroup.com/urban-insight/health-and-well-being/report-healthy-water-cities-from-sewer-to-health-booster/.

In this report the health challenges of our quickly changing living environment regarding economic developments and climate change are being addressed. SWECO proposes strategies on how to restore the space for water and people. They use a lot of visuals of multifunctional spaces that function as both water basin and playground or another public function. They also discuss already realized projects in multiple cities. The strategy division can form an inspiration for the own theoretical framework approach to gather information. In the end, recommendations are given and integrated water management tools are mentioned, developed by SWECO.

Water flood problems and social challenges London

Bloomberg News. (2021, 3 February). How Chennai, one of the world's wettest major cities, ran out of water. Accessed on October 5th 2023, from https://www.bloomberg.com/news/features/2021-02-03/how-a-water-crisis-hit-india-s-chennai-one-of-the-world-s-wettest-cities

Cooper, L.A.M. (2019). Running out or flooded out – Londons water crisis. London Assembly Labour. Accessed on October 23rd 2023, from https://www.london.gov.uk/press-releases/assembly/leonie-cooper/london-facing-water-crisis-warns-new-report.

Cooper writes about the problems London is facing regarding water management. She also gives recommendations on how to tackle the problems and prevent floodings for the mayor of London. The information she writes could be used to specify the possibilities of water management in London and what the ambitions are.

Environment Agency. (2018). The state of the environment: water resources. GOV.UK. Accessed on 23 October 2023, from https://www.gov.uk/government/publications/state-of-the-environment

The pressures and impacts of water in London are here categorized and mentioned. The water cycle is being explained and the focus for the future is pointed out. For the own research, the information can be used to create understanding of the water network in London.

Macrotrends. (2023). London, UK Metro Area Population 1950-2023. Accessed on 23 September 2023, from https://www.macrotrends.net/cities/22860/london/population

Raising sustainable awareness

ARUP (n.d.). Design with Water 2.0: Collaborative Tools for Place Based Outcomes. ARUP. Accessed on 12 October 2023, from https://www.arup.com/perspectives/design-with-water-2-collaborative-tools-for-rethinking-the-water-environment.

ARUP has developed a collaborative tool for integrating water management in city planning. They try to work towards better outcomes and try to combine creative thinking with social and environmental value through a whole-system approach. They use four categories in their approach that should help to get clarity on the problems the cities are facing: integrated, smart, resilient, and regenerative. The research can be used as a base on how to implement the water systems in the existing city structure of London on multiple scales.

Berting, N. (2023). Memberful design is about creating a sense of belonging. WHAT DESIGN CAN DO. Accessed on 5 September 2023, from https://www.whatdesigncando.com/stories/memberful-design-is-about-creating-a-sense-of-belonging/

About memberful design, where designing with the needs, contributions, and experiences of members in mind stands central. Answers question involving communities to address climate change.

Dickinson., M. (Host). (2022, 26 July). Can nature prevent flooding? [S1 A4]. In: ARUP Sustainable Forces. Accessed on 20 September 2023, from https://www.arup.com/perspectives/sustainable-forces-podcast-episode-4-can-nature-prevent-flooding

ARUP makes podcasts about the sponge qualities of cities. They discuss how the natural infrastructure can be implemented in the city structure again. In the podcast three types of infrastructure are divided into blue, green, and grey areas. The blue green spaces help to manage the flood risk for the region. Interesting for the research is how they try to connect it to communities.

Dedekorkut-Howes, A., Howes, M., Khatibi, F.S., & Torabi, E. (2021). Can public awareness, knowledge and engagement improve climate change adaptation policies? Discover Sustainability, 2(1). https://doi.org/10.1007/s43621-021-00024-z. Accessed on 20 September 2023, from https://link.springer.com/article/10.1007/s43621-021-00024-z

Research that created an inventory of available information about public participation in climate change. A very good example on how to involve people into developing creative sustainable solutions about climate change in general. For this research, the information could be used to specifically focus more on the engagement of people with water regarding climate change. The research also points out the barriers and challenges of involving people in the climate change approach.

The effects of water on our health

Angelaki, A., Koutsoyiannis, D., Tchobanoglous G., & Zarkadoulas, N. (2008). Urban Water Management in Ancient Greece: Legacies and Lessons. Journal of Water Resources and Planning Management; 134:45–54. DOI: 10.1061/(ASCE)0733-9496(2008)134:1(45). Accessed on October 17th 2023, from https://www.researchgate.net/publication/248880244_Urban_Water_Management_in_Ancient_Greece_Legacies_and_Lessons

Arpitha, S. (2023). Nature-Inspired Design: Biomimicry in Architecture. Parametric Architecture. Accessed on 25 September 2023, from https://parametric-architecture.com/nature-inspired-design-biomimicry-in-architecture/

Arsénio, A.M., Biswas, R., Chakravarty, J.G., Chaatterjee, A., Rietveld, L.C., & Siri, J.G. (2016). Environmental Health. 15(Suppl 1):31 DOI 10.1186/s12940-016-0107-2. Accessed on October 23rd 2023, from https://ehjournal.biomedcentral.com/articles/10.1186/s12940-016-0107-2

The research focusses on the links between water and healthy cities and proposes methods on how to deal with the multi-scale thinking of doing so. They also mention examples from India and Austria.

Calabrese, E.F. & Kellert, S.R. (2015). The practice of Biophilic Design. Accessed on September 26th 2023, from https://www.biophilic-design.com/

A study about implementing nature in designing again, learning from hospitals and offices. It teaches what influence biophilic designs have on the human well-being, but also how the implementation of nature leads to better sustainable designs.

Mikhailova, R. (2018). The element of water in the architecture of archaic societies. Środowisko Mieszkaniowe. https://doi.org/10.4467/25438700sm.18.046.9211. Accessed on September 27th 2023, from http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-0f646bf9-29fe-45b6-ae13-474fe77c6417

Interesting is how the connection of water is related to our ancestors and early settlements, but also to art and architecture. Describes what symbolisms water has regarding the historical, cultural and artistic interpretation of water.

SageGlass. (2016). Seven Principles of Biophilic Design. Industry Insights. Accessed on September 23rd 2023, from https://www.sageglass.com/industry-insights/seven-principles-biophilic-design.

Verma, S. (2023). Biomimetic Design in Architecture: Origin, Pros, Cons, and its Application. NOVATR. Accessed on 25 September 2023, from https://www.novatr.com/blog/biomimetic-design-in-architecture

Appendix A.

Overview Research Framework as a research design guideline

RESEARCH QUESTION	KNOWLEDGE NEEDED	DATA COLLECTION METHOD	ANALYSING COLLECTED DATA	EXPECTED OUCOME
LANDSCAPE What areas in cities are currently dealing with high-risk flooding and water scarcity? How does the natural sponge function (regarding release and absorption) of a city work?	Understanding the natural water cycle, surface water flood-risks and flood-prone areas in the existing city structure using quantitative and qualitative data. Also to map water design ambitions of municipality. **Since the research will be a guideline for future projects, the chosen city of the design project (London) will form a base to see what kind of knowledge needs to be gathered to be able to form a guideline.**	- Governmental data base collection depending on specific city London specific data collection: - Report by SWECO and ARUP that are both engineering companies - Government of London (gov.uk). - City flood-risk by 2050 by C40 cities	Analysing what flood-risk area maps are needed within chosen city to analyse and point out potential, challenging areas. Inventory of possible water design interventions on landscape scale. Indicating parcs and green areas to understand the sponge qualities and to find weak grey infrastructure spots.	On the landscape scale an overview and summary of what flood-risk maps are necessary to figure out problem areas that need attention will be made to see where oppurtunities of these areas lie regarding the regulating water systems. Since the research will be a guideline, the type of needed analysis maps will be categorized in order to be able to compare them and identify problem areas.
URBAN SQUARE What design interventions can be taken to restore grey infrastructure to a more connected natural environment to stimulate people to participate in water management design as a community? How can the usage of biomimicry and biophilia in a building design enhance our living environment? What type of neighborhood needs attention, regarding affordability?	The possible applicable water interventions in the public sphere and building scale. The effects and symbolism of biomimicry and biophilia on well-being, and the visual translation possibilities on how to implement these concepts into a design approach. Indicating other, more social, factors in defining the design location area.	Case-study of example projects that incorporate water sensitive design interventions from for example The Netherlands and Denmark. Inventory of research about water management design strategies indoors and outdoors (SWECO, ARUP and other engineering companies) Literature research about health effects of biomimicry and biophilia. Gathering news articles about neighborhood developments.	Trying to categorize the possible water interventions in the public sphere and building scale, such as streets, squares, playgrounds. Overview of best-practice project analysis (case-study). Understanding the effects and symbolism of biomimicry and biophilia to visuale possible intervention methods by applying and combining the collected knowledge.	The urban square scale should help understand and indicate what would be the best water intervention method to apply to a certain area. Is the area for example dealing with only flooding, so the water absorption quality needs to be improved? Or, is the area also dealing with water scarcity and is it important to retain the water for a longer time period? The categorization and best-practise analysis should help forming this. The same goes for the indoor quailty using biomimicry and biophilia design translations.
SOCIAL BUILDING How to raise awareness to all stakeholders on the importance of natural water cycle management in politics, investing strategies and communities regarding partnership and collaborations? How do you teach people about sustainable solutions? What type of public building will enrich the chosen neighborhood?	Find underdeveloped amenities that people appreciate, while simultaneously indicating missing functions within the area. Stakeholders involved within the to be developed area. Types of educational sustainablility activities.	Local newspaper about buildings that had to be shut down. Gathering maps on vacant amenities. Since London is used as a demonstration example, conducting interviews with citizens living close to the chosen site combined with a site visit. Governmental data regarding development projects to determine involved parties.	Mapping different location options regarding historic and cultural value. Summarizing interviews and newspapers to determine public function for the chosen site. Creating an overview of involved stakeholders and target groups within the to be developed area.	In this stadium the landscape and urban square scale will also be involved to determine challenging areas. If for example a vacant historic site is chosen, are there water risks within the neighborhood? And have the municipality already invested in water interventions close-by? Therefore, it is a constant process of reflecting on the different scales. This switchting between scales will also play a prominent role in the design process.

Appendix B.

City comparison combatting floods and droughts

Outcome city comparison

The better the score, the better the city is doing...

THE EFFECTS OF WATER FLOOD / DROUGHT IN CATEGORIES BY 2050	RIVERINE FLOODING (in $ per capita)		HEAVY RAINFALL		COASTAL FLOODING	HYDROLOGICAL DROUGHT	AGRICULTURAL DROUGHT (m3/km2/year)
CITY							
AMSTERDAM	$0 to $0	6	0%	5	50 - 100%	2	4 (no flood)	4 (10 m3)	2
ROTTERDAM	$0 to $0	6	0%	5	50 - 100%	2	4 (no flood)	2	2
OSLO	$66 to $87	3	32%	4	50 - 100%	2	4 (no flood)	4 (10 m3)	2
STOCKHOLM	$26 to $44	4	70%	2	>50%	3	4 (no flood)	3	2
LONDON	$4 to $18	5	x4	1	>50%	3	2	3	1
VENICE	$0 to $0	6	0%	5	50 - 100%	2	1 (350 k m3)	5	1
MELBOURBE	$71 to $117	2	67%	2	50 - 100%	2	4 (no flood)	5	1
SYDNEY	$138 to $195	1	41%	3	>100%	1	3 (5 k m3)	1	3 (<1)

HIGHEST RISK

12	SYDNEY
15	LONDON
16	MELBOURNE
18	STOCKHOLM
19	OSLO
20	VENICE
21	ROTTERDAM
23	AMSTERDAM

LOWEST RISK

Sydney has the lowest score, which means that it is the problematic city regarding the water systems in the city. By 2050, its citizens will have to pay 40% more (per capita) to be able to build-up the destroyed areas as a result of the riverine flooding when no actino would be taken regarding water management. Of the five measured impacts, Sydney scores as the number one problem city. London has the second lowest score with only 15 points. Compared to where Rotterdam and Amsterdam score, with 21 and 23 points, this is extremely low.Therefore, the city of choice will be London, since it is both combatting floods and droughts and is asking for new interventions regarding water sensitive designs.

Appendix C.

Research Cities Alive examples of design strategies by ARUP

Figure 3: Benefits of green infrastructure All city stakeholders benefit from green infrastructure. This chart shows some typical groups involved and the economic, social and environmental benefit to each. © Arup

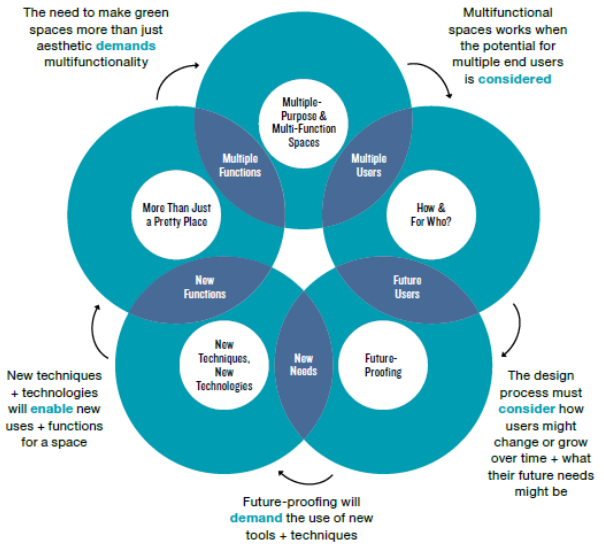
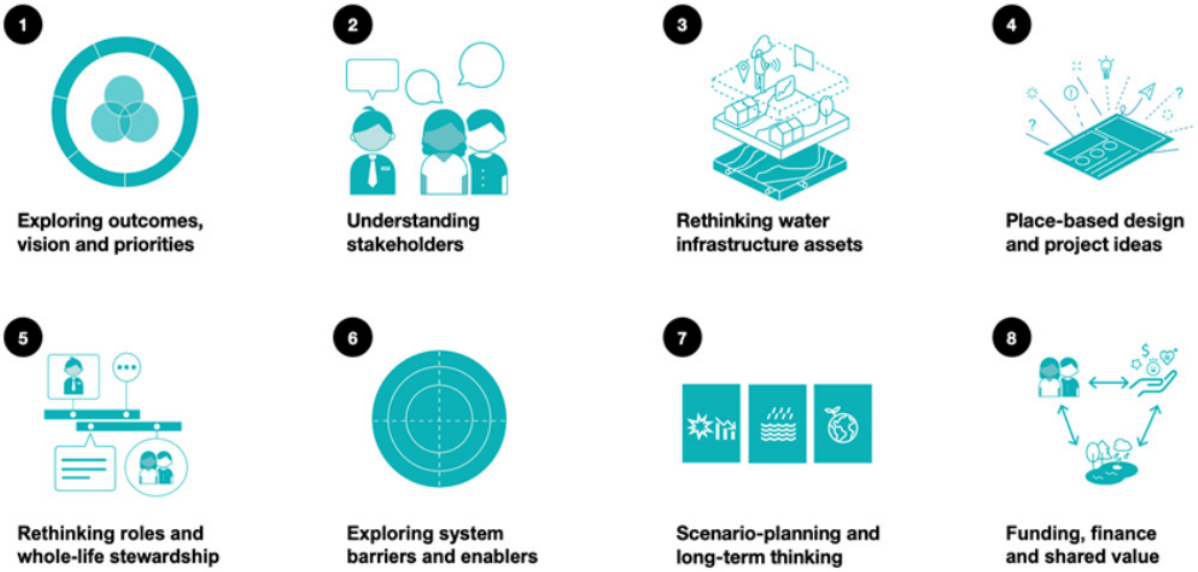


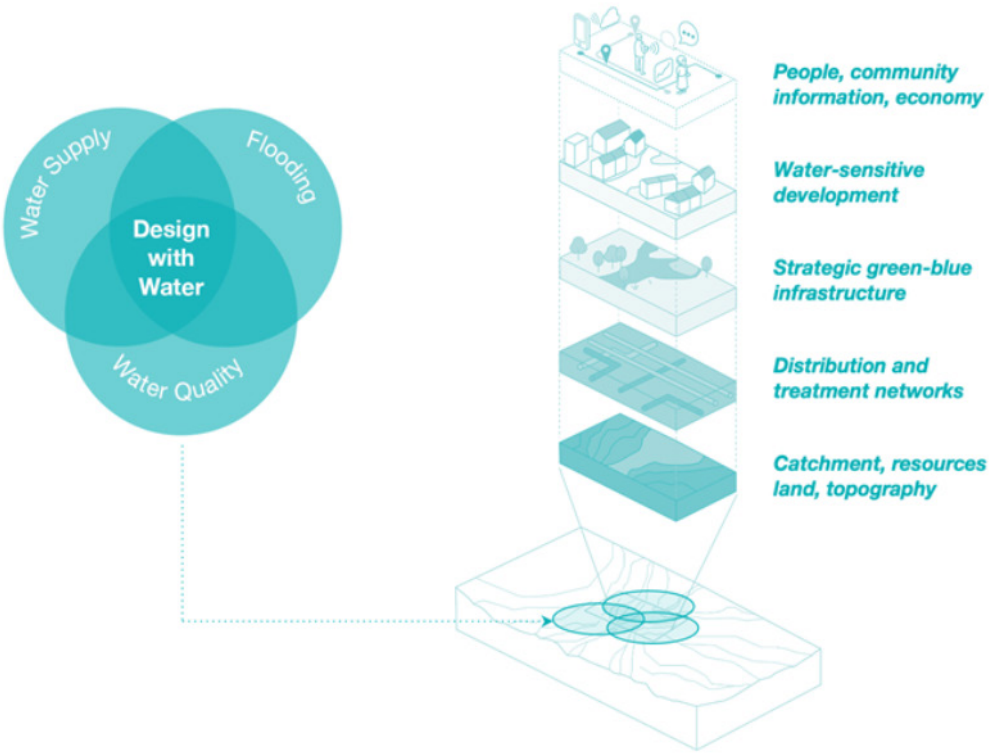
Figure 5: Strategies Diagram This chart maps the relationships and flow between the design strategies outlined in this report. The strategies not only affect and are affected by each other, but also have identifiable crossover points where more specific needs can be drawn out. © Arup

Appendix D.

Research Design with Water examples of design strategies by ARUP



Design With Water is supported by flexible collaborative tools to support outcomes-led design and implementation.



Design With Water rethinks water-cycle assets as a series of linked place-based systems that can be applied at a range of scales, from households and communities to cities and catchments

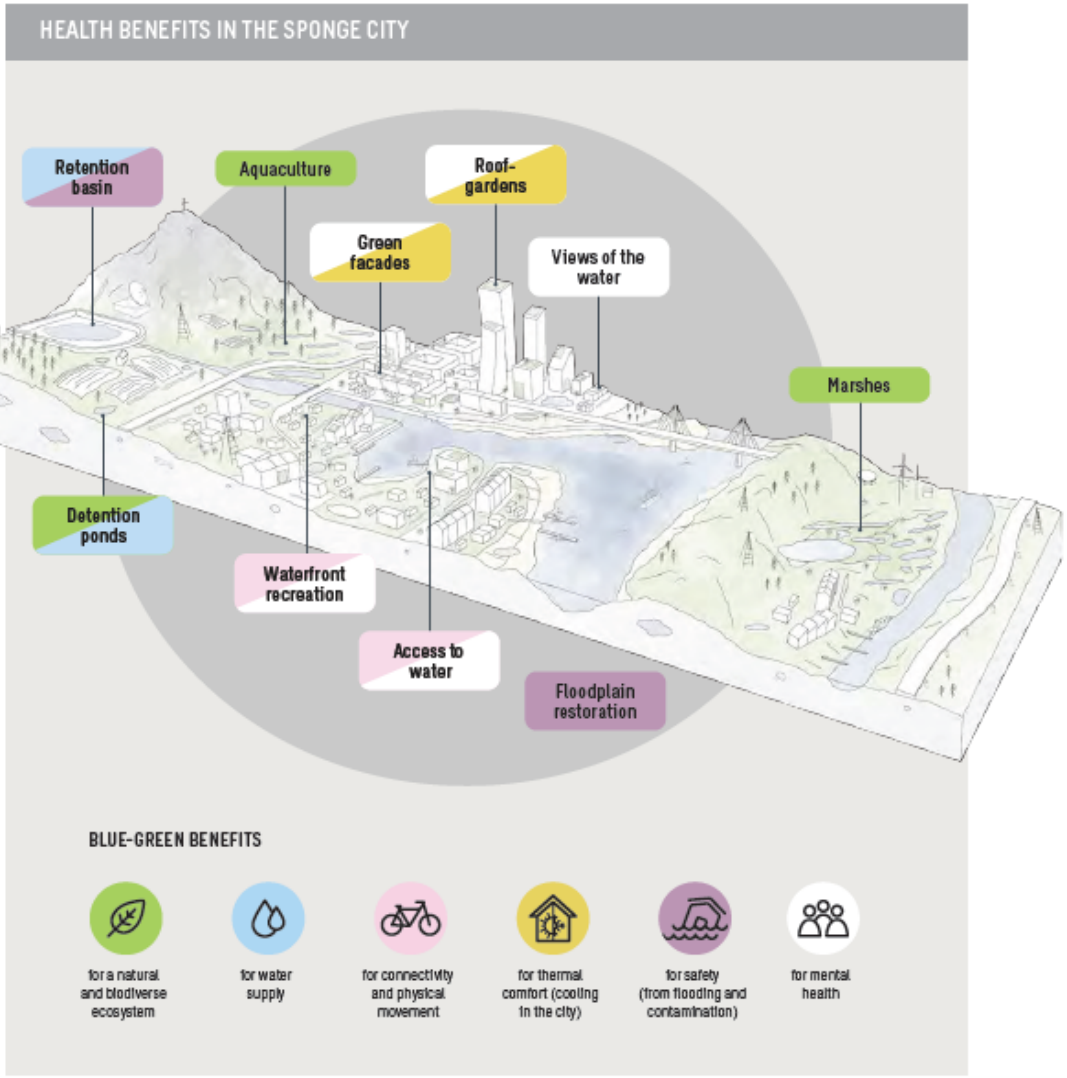
Appendix E.

Research Healthy Water Cities examples of design strategies by SWECO

STRATEGIES:

Reintroduce nature in cities

This second strategy is about using nature and soil in urban planning processes to remedy drought and flooding issues. A thorough understanding and a sustainable use of the natural water cycle and natural processes not only benefits nature, but has a positive impact on people and their health. An example of this is the popular concept of sponge cities.



Appendix F.

Design and research tool