EARLY ADAPTATION OF WATER IN URBAN PLANS

IMPROVING WATER INCLUSIVITY IN EARLY DEVELOPMENT PLANS, LIKE SCHIEOEVERS NOORD IN DELFT, BY BRIDGING THE GAP IN DISCOURSE BETWEEN URBAN DESIGNERS AND CIVIL ENGINEERS IN URBAN WATER MANAGEMENT.

MASTER THESIS, INGRID STAPS

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Abstract

There is a gap in the discourse between urban designers and civil engineers, within the field of urban water management. This gap is caused by different educational backgrounds, perspectives, appproach and language used in the respective fields. It causes multidisciplinary projects like the redevelopment of Schieoevers Noord in Delft to be unnecessarily difficult or inefficient.

This thesis studies the effects that the gap in discourse has on the redevelopment plans of Schieoevers Noord, with the aim of bridging the gap and making the existing plans more water inclusive. To achieve that, the area and plans were thoroughly analysed and research was done into the principles behind healthy surface water systems in the Netherlands and climate adaptation measures. Using the data from these analyses, five evaluation criteria were set up.

Next, using the principles of water management and the climate analysis of Schieoevers Noord, four strategies for an improved water system in the area were made. The evaluation criteria helped define the strengths and weaknesses of these strategies. This made it possible to take the strong points and combine them into a final proposal for the water system in Schieoevers Noord. The proposal was also tested using the evaluation criteria and the results showed that it held up really well in all categories.

The lessons learned from going through this process for Schieoevers Noord, are that bridging the gap between urban designers and civil engineers within urban water management is achievable. But it requires effort from both parties to go back and forth between the two fields, while using existing tools to ease communication. A very useful tool for this would be the Climate Resilient Cities Toolbox. With some further research into quantifying design goals this toolbox can be improved even more, and therefore become a great tool for bridging the gap between the two fields.

Another important lesson learned from this research is the importance of thinking about the water system in a very early stage of the planning process. Surface water systems are often complex and adding to them will take up a large amount of space. However, a healthy surface water system is more efficient than only using climate adaptation measure, when combatting the negative externalities of climate change. Because the effects of climate change are rapidly increasing, it is imperative that developers, municipalities and other stakeholders prioritise healthy water systems in their development plans.

Motivation

My interest in the Dutch water system has been around for a long time. Even as far back as primary school when I gave a presentation on the Delta works.

In the master track of Urbanism, I was able to extend my knowledge of the water system in different courses. When we were selecting courses for our elective quarter I was pleased to learn about the possibility of following courses at the faculty of civil engineering. There was a very decisive moment during the course called water management in urban areas that I decided to dive into this topic for my thesis.

We were on a field trip, visiting a residential building in Amsterdam that had a specific rainwater collection system. The rainwater collected in a basin with filtering plants at the bottom of the building. Right above this basin were the balconies of the ground floor apartments. The civil engineering professor was explaining the technical aspects of this intervention and showed us it fulfilled its purpose very well. At the end of his explanation, one of the residents came up and told us that she and the other residents were absolutely not happy with it because it caused a lot of foul odours and it allowed mosquitos to reproduce.

This is a clear example of a project that met its technical goals but had unforeseen negative externalities for spatial quality and the social environment. I felt that these kinds of situations should not happen. Even though you can never fully understand how a plan is going to work out once realised, better communication between the different parties could have made a difference. That is why I decided to research the gap in discourse between designers and engineers within the topic of water management in urban areas.

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INDEX

READING GUIDE

This document consists of seven chapters.

The first chapter is the introduction, this chapter will first introduce the problem field, it will then introduce the case-study location and explain why this location is suitable to illustrate the issues that are explained in the problem field. Later, it will discuss the problem statement, aims and intended outcomes of this thesis. Finally, it will present the research questions used to guide this research.

The next chapter is the methodology, which presents the conceptual and the methodological framework. These frameworks formed the basis of this project. The conceptual framework shows the interrelation of concepts in this research and the methodological framework illustrates the steps taken and methods used to answer the research questions.

The third chapter is the case study analysis, this chapter will dive deeper into Schieoevers Noord, the case-study location of this thesis, by analysing the location in the surroundings, the sub-regions, the existing water system and the climate issues. After the physical analysis of the area, the existing redevelopment plan of Schieoevers Noord will also be analysed. From these analyses a space matrix calculation is done to show the available free space for the water strategy designs, which are discussed further along in this thesis.

The last research chapter is called principles of water management. This chapter will touch upon the general principles of surface water systems and the climate adaptation measures that are of importance for designing a water strategy in an area like Schieoevers Noord. It will also highlight some issues pertaining to the water system that are specific to Schieoevers Noord. These principles combined will form a strong base for evaluating any possible strategies later on in this thesis.

Chapter five is the chapter that will show the four strategies that were made for the water system in Schieoevers Noord. It will elaborate on different aspects of these strategies and compare them to each other using the evaluation criteria from the previous chapter. From the comparison of the four strategies one final water system design proposal will be made and elaborated upon.

The last chapters are the conclusion and reflection. The conclusion shows the answers to the research questions and the reflection shows the relevance of the research, the ethical considerations, a reflection upon the approach and methods used and the relation between research and design.

Glossary

N.F.B. - Nature friendly banks, banks of water ways that have a gentle slope outfitted with greenery, provides beneficial qualities for nature.

H.A.P. and L.A.P. - Higher and Lower Abtwoudse Polder (Hoge- en Lage Abtwoudse polder) two polders in the Delfland Water Authority management area. Their territory includes the part of Schieoevers Noord on the west side of the Schie.

NAP - Normaal Amsterdams Peil, a vertical datum used to reference height levels. Also used in the European Vertical Reference System.

Static water storage - In this thesis the term static water storage means the volume of water that can be stored on top of the existing surface water. This amount is therefore determined by using the height difference from the normal water level to the maximum allowable water level.

Delfland Water authority ledger - The official documentation of the water system within the management area of Delfland. This document holds the rules, regulations and dimensions of the surface water system.

Water inclusive urban plans, water inclusivity - These terms refer to the prioritisation of water in urban regeneration plans. Which will lead to an integrated and healthy surface water system, as well as good climate adaptivity.

If no source is indicated the figure was made by the author.

If not otherwise specified, the North direction of maps point towards the top of the page.

INTRODUCTION

This chapter will first introduce the problem field and the case-study location. After that it will show the problem statement and the aims and intended outcomes of this thesis. Finally it will show the research questions used to guide this research.

PROBLEM FIELD
Introduction

Looking at literature through time, even as far back as the beginning of the 20th century, shows that a gap in the discourse between design and infrastructure professionals exists (Neuman & Smith, 2010, p. 35). Communication between designers and engineers has been an issue for a long time. It is what makes multidisciplinary projects so complicated and time-consuming. However, if done right, they will enhance the final product of a project tremendously. (Sies & Silver, 1996) (Healy, 1999) Professionals in both infrastructure and urban design know that they cannot fix all the problems by themselves; they know that they have to work together. However as Neuman and Smith also write, recently the connection between design, planning and infrastructure has been “nonstrategic and noncomprehensive” (Neuman & Smith, 2010, p. 21)

“... endless rows of brick boxes, looking out on dreary streets and squalid backyards, are not really homes for people, and can never become such, however complete may be the drainage system, however pure the water supply, or however detailed the bye-laws under which they are built” (Unwin, 1909, p. 4)

This quote from Unwin from the early 20th century clearly describes part of the issue that this essay will focus on. However, this is only half of the problem. When turning it around, beautifully designed areas without proper drainage and other technical considerations will also never make for a qualitative living environment.

This paper will focus on the fields of urban design and infrastructure engineering, more specifically, urban water management, in which both of these fields are intrinsically connected. This connection is what makes research on the gap in discourse so important. Infrastructure is an undeniably important part of cities. (Neuman & Smith, 2010, p. 22) If a designer attempts to redesign a neighbourhood without taking infrastructure into account or if an engineer makes plans without taking into account the social environment, it would lead to unforeseen negative externalities for the inhabitants of a neighbourhood or even the city (Neuman & Smith, 2010, p. 36).

Research on adaptation to climate change in Dutch urban areas shows that on a local scale, the nuisance of excessive water after rain and urban heat stress are posing more economical, societal and health-related threats (Huynen, de Hollander, Martens, & Mackenbach, 2008; IPCC, 2007; Runhaar, Mees, Wardekker, van der Sluijs, & Driessen, 2012, p. 777). This trend means that well thought out multidisciplinary projects in this field are increasingly important. Even though the gap in discourse has been researched, a clear definition is still missing. In this essay, I will attempt to review the literature and combine existing knowledge in order to define the gap in discourse more clearly. Therefore, the question that will be answered in this essay is: How can the gap in the discourse between urban designers and infrastructure engineers be defined within the field of urban water management?

This question is divided into sub-questions which the different paragraphs of this essay will answer. The first paragraph will explain how and when the gap in discourse manifested itself. The second paragraph will show if there have been issues with a gap in discourse within other areas of urban development. The next paragraph will answer what the cause for the gap in discourse is and finally, what specific problems can be found within urban water management.

Figure 1 Use of the phrase “city planning” in literature (Google Ngam viewer, 2020)

The start of the diverging focus

Urban design, or city planning as it was also called at that time, started separating itself from infrastructure as early as the 19th century, according to Wiebe (1969) the two fields started splitting and forming their areas of expertise. However, as of 1864 architecture and thus urban design is still only a specialization inside the field of civil engineering and city architects come from a background of military engineering (Lintsen, 1994a, 201). Early in the 20th century city planning moved away from architecture, landscape architecture and engineering. This is when it started to be recognized as a separate profession (Neuman & Smith, 2010, p. 27). The shift can also be detected in the use of the phrase “city planning” in literature over time, shown in Figure 1, it started to rise only after the start of the 20th century.

From the time that city planning was established as a separate profession, the focus and area of expertise kept growing more distant from the field of infrastructure. This can be attributed to the fact that city planning was trying to strengthen and consolidate itself as a separate profession (Boyer, 1983). Physically this change meant that the city planning which was once done by architects, landscape architects and engineers now had shifted to new professionals. This new profession was called city planning, Their work was done in planning commissions with lawyers and government officials to create legally binding masterplans (Neuman & Smith, 2010, p. 28). These plans could direct the placement and type of buildings, green spaces and infrastructure in a specific way. Architects, landscape architects and engineers would still create the buildings and spaces but would have to follow the guidelines in the masterplan, this means they had less freedom in the placement of their projects.

When looking more specifically at the Dutch context, this paradigm shift was present as well. In the 19th century, the fields of urban design and engineering were combined into what can be described as urban engineering. An example of this, as Hooimeijer (2011 p. 77) shows, is Willem Nicolaas Rose (1801-1877). He was trained as a military engineer, but during his time as the city architect of Rotterdam, he showed that he can combine his knowledge of the technical aspects with the vision of creating a healthier and generally qualitatively better environment. However, this harmonious combination came to an end around the turn of the century. The Industrial Revolution and its rapid growth in scale had the two disciplines growing apart and focus on different perspectives (Hooimeijer, 2011, p. 9 and p. 76). Large scale projects like the dried lake, Haarlemmermeer, gave civil engineers the chance to go into a more technical direction. While the negative externalities of industrialization, like lack of hygiene and low-quality housing, caused the need for urban designers to make more coherent and organized plans for expansion of cities. Finally, Hooimeijer (2011, p. 120) writes that this shift also becomes apparent in education, interest groups, associations and governmental organizations.

So to answer the question, the gap in discourse between urban design and infrastructure started forming in the early 20th century in the Netherlands as well as abroad and has kept growing since then. It is mostly due to the increase in scale and change in necessities that came with the industrial revolution.

Shortening the commute

Urban water management is a relatively recent topic in the field of urbanism and infrastructure. To truly understand the nature and effect of the gap in discourse between the two disciplines, it is essential to learn from the past. In this chapter, research on the effect of the gap in discourse in another area of city planning is shown.

One field in which the miscommunication between urbanism and infrastructure has been very apparent is traffic engineering. Urban sprawl in mid-20th century American cities caused the need for more highways from the inner city to the suburbs. These immense projects had a lot of social impacts. Ellis (1996, p.262-279) explains that at this time, highway engineers planned many large interstate highway systems. They wiped out low-income communities to make way for these highways, like in figure 2 which shows the highways I95 and I395 going right through a neighbourhood in Miami called Overtown. This area was once home to a thriving black community but after the construction of the interstate highways, which forced thousands of people from their homes, it never recovered. Now, according to long-time Overtown resident General White, it is nothing but a big overpass (Toro, 2013).

The main goal of these plans was free traffic-flow, and the surrounding social and environmental context was not taken into account. The urban designers did not play a role in making these plans. The plans were based on federally funded plans for enhancing the suburbs of cities by shortening the commute for the inhabitants (Rome, Crosby & Worster, 2001).

When these plans were made public and executed, a group of activists, among who were some prominent urban designers of that time, (Jane Jacobs, Paul Davidoff and Chester Hartman) started a movement called "Freeway revolts" (Neuman & Smith, 2010, p. 30). Even though there was some pushback from parts of the urban design community, for the most part they did not or had no chance to interject.

Although not as widely known and well documented as the situation in America, the phenomenon of low-income housing being forced to make way for improving free traffic-flow also occurred closer to home. A great example of this is the Sebastiaansbrug in Delft shown in figure 3 & 4. This bridge was also constructed through a neighbourhood of working class housing. The bridge was supposed to create a quicker route for car traffic from the TU Delft in the south all the way to the market square in the city centre. However after the construction of the bridge the plan was changed and the road did not proceed further into the centre (Gemeente Delft, 2012).

This lack of cooperation between infrastructure and design professionals has resulted in situations where cities have grown only according to the transportation needs instead of the existing structure, social environment or characteristics of the area (Palmboom, 1987, p. 41). Palmboom also states that this should not happen this way and that the characteristics of a place have to be taken into account when designing or making new plans.

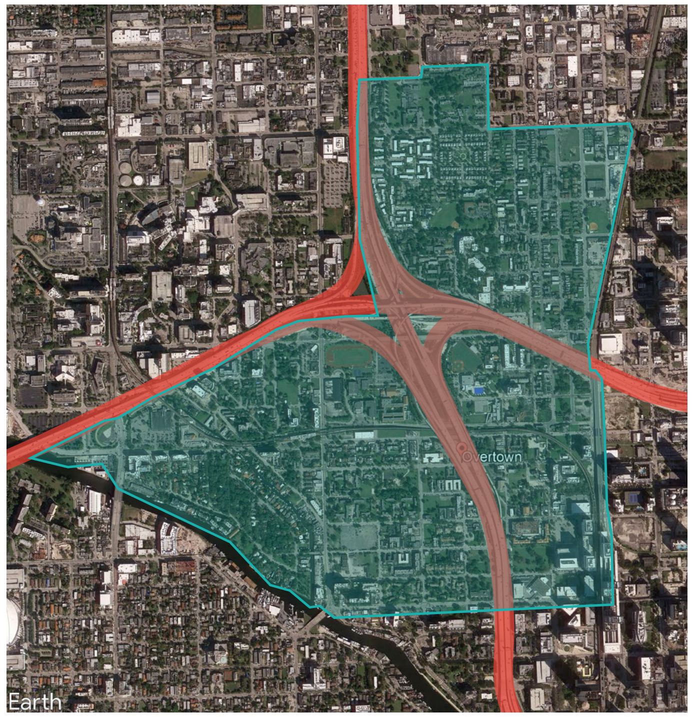


Figure 2 - I-95 through Overtown Miami
Edited from (Google Earth, 2020)

Figure 3
Situation before construction of Sebastiaansbrug Delft
(Kadaster, 1960)

Figure 4 - Komplan Delft 1956
(Gemeente Delft, 2012)

Missing language

Even though professionals in the respective fields are all aware of the necessity for a multidisciplinary approach, it is still not without its challenges (Neuman & Smith, 2010, p. 35). To find out why it is essential to look at what causes these problems in the first place. As seen in the last chapter, infrastructure and urban design come from the same starting point. They are intrinsically connected but have drifted apart over time. Because of this, the differences have become quite deeply rooted in several, if not all, of the facets that make up the two fields.

Even back when the education of both fields was quite similar, and they both followed roughly the same structure of courses with only some diverging specialisations, the students were already aware of the differences. The civil engineering students saw the design students as the artistic types that were able to make beautiful drawings (De Ruijter, 1983, p. 23). When the two fields were separated further, it soon started showing in the curriculum of design education. After the second world war, most of the technical courses were removed from the architecture educational program (Steenhuis, 2009, p. 55).

The gap between engineering and design is also very noticeable in the theoretical underpinning that both use to justify their decisions and plans. Like Marshall (2012) writes the theories of urban design are not solidly scientific. They mostly come from architecture, sociology, geography, demography and policy (Hooimeijer, 2011, p. 249). There are also some more scientific sources it draws from, like soil mechanics and hydrology and traffic engineering. However, most urban designers lack the technical understanding to use these theories to their full extent.

Another factor in the general gap in discourse is the perspective professionals have of each other and the projects. There is a set of roles each of the fields are expected to play and feel most comfortable with. Logically this means that the designers are in charge of the design while the civil engineers do the calculations and constructions. They interact with each other on a surface level but mostly focus on their own job (Lohuizen, 1942). This division is not a problem per se, but the truth is that designers might choose to implement a certain green structure that reduces heat, only the reasoning they would consider most important is the additional environmental and spatial quality. The heat stress would only be an additional benefit (Runhaar, et al, 2012, p. 785). This reasoning can lead to inefficiently implemented interventions because the technical aspects come secondary to the design aspects. It is then left to the engineer to solve those problems. This example shows that the perspective of both designers and engineers, even when solving the same problem, might still not match. Adding to that, according to van Berkum (2007, p.98) when working together, designers and engineers are often insecure about each other's approach. Engineers generally have a more conservative attitude towards problems while designers tend to be more reckless in their proposed solutions.

All these differences in education, theory, perspective and approach lead to what is actually the most significant cause of the modern-day gap in discourse between civil engineers and urban designers: The differences in their professional language. A clear example of this is found when looking at something as simple as the definition both fields have for the word "design". Both use this word to describe something they do in their professional environment, but the definition of each is very different (Hooimeijer, 2011, p. 299). When going deeper into the professional language used by both parties, it becomes evident that the scientific, analytical approach that engineers use results in a language that cannot compare to that of designers, whose language has emerged from art, architecture, sociology, and legal documents (Neuman & Smith, 2010, p. 34).

What about the water

We now know when and how the gap initiated, we know what effect it can have and we know what causes it. However, to truly answer the question of this essay, we will have to go deeper into the specific context of urban water management. This chapter will, therefore, show what is already known about the effects of the missing link within urban water management.

Specifically, in the Netherlands, water is and always has been very important. It is deeply rooted in our landscape and cultural identity. When approaching urban water management from the perspective of the gap in discourse, it shows that even in the earlier stages, there were already some issues. Hooimeijer (2011) states that in the 1960s, the building site preparation was done by civil engineers who found the water issues and fixed them. Even though this does not sound bad by itself, she also states that this caused the urban designer to never even know there were issues to begin with. At this time, the urban designers perspective on water was limited; it was considered a waste product that had to be dealt with underground or outside the city. This lack of cooperation between the civil engineers and designers is what caused the system to become illegible (Hooimeijer, 2011, p. 128).

More recently, the realization that the water system in the Netherlands has to be approached from different points of view will require compromises from both the urban designers and the civil engineers. This is why this research is important. Civil engineers have a very tight grip on the water system (Hooimeijer, 2011, p. 246), which makes it hard for designers to have any input on the matter. On the other hand, designers often fail to realize that they have no or minimal knowledge of the actual technical water system they are trying to work with (Hooimeijer, 2011, p. 251). This combination of facts can cause projects to be delayed in later stages, because the actual calculations do not match with the designed ideas.

Another effect of the miscommunication is the over-simplification of goals set by, for instance, the water authority. The water authority cannot trust the technical skills of urban designers and thus has to set specific rules (Van Berkum 2007, 32). A clear example of this as shown in the dissertation of Hooimeijer (2001, p. 252) is the waterboards rule of 10% surface water to compensate for closed surfaces, which is observed in squared metres. Due to this manner of goal setting, the options for designers are limited. If cooperation and interdisciplinary knowledge increase, these simplified rules can be let loose and give space for more creative and thought out solutions.

The situations explained previously show that there are in fact very real negative consequences on projects and their outcome because of the gap in discourse within urban water management. However, in urban water management, it is not too late to take steps in the right direction and work to bring the two disciplines closer together.

Conclusion

So, how can the gap in the discourse between urban designers and infrastructure engineers be defined within the field of urban water management? To answer this, we need to look at the answers to the sub-questions. We begin with the manifestation of the research gap in time. Literature shows that the fields of urban design and civil engineering stem from the same background before drifting apart. In the Dutch context, this paradigm shift was mainly caused by the changes in the scale of projects and the changes in the needs of the urban environment caused by the industrial revolution. From that point forward, the two fields only diverged more and became separate disciplines.

Next, if the gap is not bridged, it might negatively affect the outcome of projects, as is evident in the American example of urban traffic management in the 50s and 60s. Lack of cooperation between different disciplines caused the wipe-out of low-income neighbourhoods and caused a public and professional outcry. When looking back at the advances made at that time, it is now clear that the approach used then was not integrated and had severe negative externalities.

The gap in discourse cannot be defined without research into the cause of the problem. The existing literature presents the gap in discourse in many, if not, most of the aspects of civil engineering and urban design. Most of these issues can be linked to the simple lack of understanding of each other's points of view and methods. This, in turn, leads to the inability to form a common language.

All of the above translates directly into the more specific context of urban water management. The predicted increase of rainwater and periods of drought are the reason that integrated urban water management strategies are essential. Letting both designers and engineers do their job separately is no longer an option due to the demand for future-proof sustainable solutions. The perceived lack of technical knowledge leads to a lack of trust in designers from the water boards. This causes them to set strict and over-simplified goals for water management in plans. However, at the same time, innovative integrated solutions that might not exactly match those terms might actually resolve the problems more efficiently.

So the definition of the gap in the discourse between urban designers and civil engineers within the context of urban water management is:

There is a gap in the discourse between urban designers and civil engineering, within the field of urban water management. The gap is caused by the different educational background, perspective, approach and language used in the respective fields. The civil engineers lack a way to operationalise the design aspects while the urban designers lack the specific technical knowledge behind the urban water system. This knowledge gap causes multidisciplinary projects to be unnecessarily complicated and inefficient.

Discussion

The answer to the question set out in this essay shows that it is absolutely essential to move toward a more integrated approach to urban water management. Without cooperation of both civil engineering and urban designers it will not be possible to create truly successful sustainable solutions to the urgent problems related to urban water management strategies. In this thesis the goal is to make advances towards the bridging of the gap in discourse.

Existing knowledge from different sources and context came together to form the definition of the gap in discourse. This approach has a risk, old texts might be written under completely different circumstances and might not directly be transferable to the current situation. Also, the literature review method used in this theory essay is always limited in its scope. An attempt was made to gather existing knowledge in a broad spectrum, but eventually that always proves challenging.

CASE STUDY LOCATION
Schieoevers Noord

The case study location for this thesis is Schieoevers Noord. It is currently an industrial area located along the shores of the Schie in Delft. The municipality wants to transform it into a lively, diverse and colourful neighbourhood with mixed residential and small scale industrial functions. It will become a meeting place for sustainability and innovation. It is quite an interesting urban redevelopment because the whole area will be completely transformed. Hardly any of the buildings that are currently there will remain so after the transformation, this gives developers, designers and engineers an almost blank slate to create the new plan.

Fitting in new, or adapting existing water systems within existing neighbourhoods and mobility infrastructure is very challenging. Therefore, this blank slate is also what makes this area a great fit as a case study for this thesis. Research has already been done into the area and a development plan has been made, this provides a great opportunity to investigate and illustrate the possible effects of the problem field stated before.

The main ambitions for the transformation of Schieoevers Noord as set by the municipality are as follows:

1. Lively mixed urban area
Residential and business functions will mix. The central position and the opportunities for development will play a key role in this, by creating the right mix.

2. Socially and culturally diverse
Everyone should be able to feel at home in Delft, socially and professionally. A very crucial standpoint of the municipality of Delft. This area has potential to make for a very attractive and diverse scene for all residents of Delft.

3. Innovative manufacturing
Do, think, create and learn are central aspects of the 21st century economy of this area. To make sure that the Schieoevers Noord will keep doing justice to the industrial heritage the area will offer opportunity for innovative manufacturing that fit with the general paradigm of Delft: Capital of innovation and technology.

4. Mobility and Connection
The pressure on the traffic system of the area will increase drastically with the transformation. To make sure this will not cause problems it is important that car, bike and pedestrian routes are well connected to and through the area. Without causing disturbance for the inhabitants or businesses.

5. Sustainable and healthy environment
An appealing surrounding to live and work in will require attention for the environment of man, plant and animal. Greenery and water are very important ingredients for the area, a great example of this is the Schiepark that will go along the shore of the Schie.

The ambitions for this plan go along nicely with the broader ambitions from the municipality of Delft:

- 10.000 additional workplaces (by 2040)
- 15.000 additional residences
- Develop from knowledge city to technology capital of the Netherlands

Schieoevers Noord will account for almost 20% of the needed workplaces and almost 30% of the needed residences by 2030. At completion of the plan it should account for almost 55% of all workplaces and over 50% of all residences needed. So Schieoevers Noord will fulfill a very large share of the future growth of Delft.

(Gemeente Delft, n.d.)

Figure 6. Map of Schieoevers Noord and surrounding area >

Figure 5 View of the Schie and Schieoevers Noord (Minderhoud, 2006)

PROBLEM STATEMENT

There are 3 main factors that make up the problem statement for this thesis, they all consist of a cause and an effect. The first cause is climate change. Research shows that climate change comes with an increase of frequency and intensity of peak rain events and an increase in length and intensity of droughts (IPCC, 2015). Consequently, in the wet periods, the increase in rainwater will lead to more (and more severe) water nuisance. On the other hand, the extended dry periods will cause more severe droughts and therefore more heat stress.

The next cause is the gap in discourse between urban designers and civil engineers within the field of urban water management. As mentioned in the problem field, this gap in discourse is caused by a difference in educational background, perspective, approach and language used in the respective fields. The gap in discourse subsequently makes transdisciplinary projects unnecessarily complicated and inefficient, because it hinders effective communication in early stages of urban development.

The last factor of the problem statement is the fact that implementing water takes a lot of space. If water is not adapted early in an urban project, it will be inefficient, time consuming and expensive to fit in the existing frame of the project.

Together, these three factors make up the problem statement for this thesis. The problem statement shows the initial starting point of the research, the main problem, based in practise and theory, that this project will take on.

The increase in peak rain and extended droughts, caused by climate change, increases the need for water inclusivity in urban plans. However the gap in discourse between urban designers and civil engineers within urban water management makes early adaptation of water in urban plans more difficult. If water has to be worked into an urban plan at a later stage, it will be more expensive and time consuming, because water takes up a lot of space that might not be available anymore.

Figure 6 Water nuisance in Schieoevers Noord (van der List, 2018) >

AIMS AND OUTCOMES

The project aims to achieve the following within the realms of water-inclusive development plans and collaborative efforts between designers and engineers in carrying out these plans:

Highlight the importance of having water-inclusive strategies in early stages of urban (re) development plans.

Illustrate the negative effects of (re)development projects that do not include well defined strategies for water-inclusivity in initial stages of the project.

Delineate the principles of the Dutch water system that are important for surface water management and climate adaptation when devising a strategy for an area.

Illustrate the positive effects of integrating water-inclusive strategies in the development plan of Schieoevers Noord.

Investigate the reasons behind ineffective communication / collaboration between urban designers and civil engineers in urban redevelopment.

Provide a collection of knowledge that urban designers can use to better understand the more technical principles behind designing water systems.

The end results of this thesis will consist of three different outcomes, which will be directed at different stakeholders in urban water management. The first is a proposal for a possible water strategy, which could help the redevelopment of Schieoevers Noord become more water inclusive. The second are more general recommendations for early adaptation of water strategies in urban (re) development plans. And finally, an evaluation of the “Climate Resilient Cities Toolbox” including possible improvements to create a better digital environment for communication and cooperation between engineers and designers.

RESEARCH QUESTIONS

What lessons can be learned, regarding water inclusivity in urban regeneration plans, from Schieoevers Noord, by studying the gap in discourse between urban designers and civil engineers?

[DEFINITION OF THE RESEARCH GAP]

SQ 1: How can the gap in discourse between urban designers and infrastructure engineers be defined within the field of urban water management?

[ANALYSIS]

SQ 2: How does the gap in discourse affect the municipalities plans for Schieoevers Noord?

[GUIDING PRINCIPLES FOR PROPOSAL]

SQ 3: What are the design and technical principles of the Dutch surface water system and climate adaptation measures, and how can they be used to guide a proposal?

[PROPOSAL]

SQ 4: Building on the principles and analysis, what are possibilities for making the existing plans for Schieoevers Noord more water inclusive and do those options result in an overclaim of space?

[TRANSFERABILITY]

SQ 5: How can the principles of the strategy for Schieoevers Noord be applied in other cases of urban (re)development?

METHODOLOGY

This chapter presents the conceptual and the methodological framework, which formed the basis of this project. The conceptual framework shows the interrelation of concepts in this research and the methodological framework illustrates the steps taken and methods used to answer the research questions.

CONCEPTUAL FRAMEWORK

The conceptual framework shows the interrelation of key concepts of this project. It is a visual representation of the problem statement combined with the methodology. One might even refer to it as the projects DNA. There are different layers to the framework, which show the position of the project within its concepts.

The goal for this thesis is of course improving water inclusivity. To make projects more water inclusive, urban designers and civil engineers will have to come together and communicate better, the gap between them needs to be bridged.

Urban (re)development is a large domain, the focus for this project is on civil engineers and urban designers working within the field of urban water management, as can be seen by the inner most circle of the framework.

The next ring represents the whole field of urban (re)development, the project falls within this category, because making changes to the water system is very complex and therefore much easier when an area is already going through (re) development, like Schieoevers Noord.

Climate change is the weight pushing down and creating pressure in the field of urban (re) development and especially water management. It is the main motor that drives this project, the adaptation to climate change is a huge issue because it brings forth very concrete changes in the water system and the way it has to be managed.

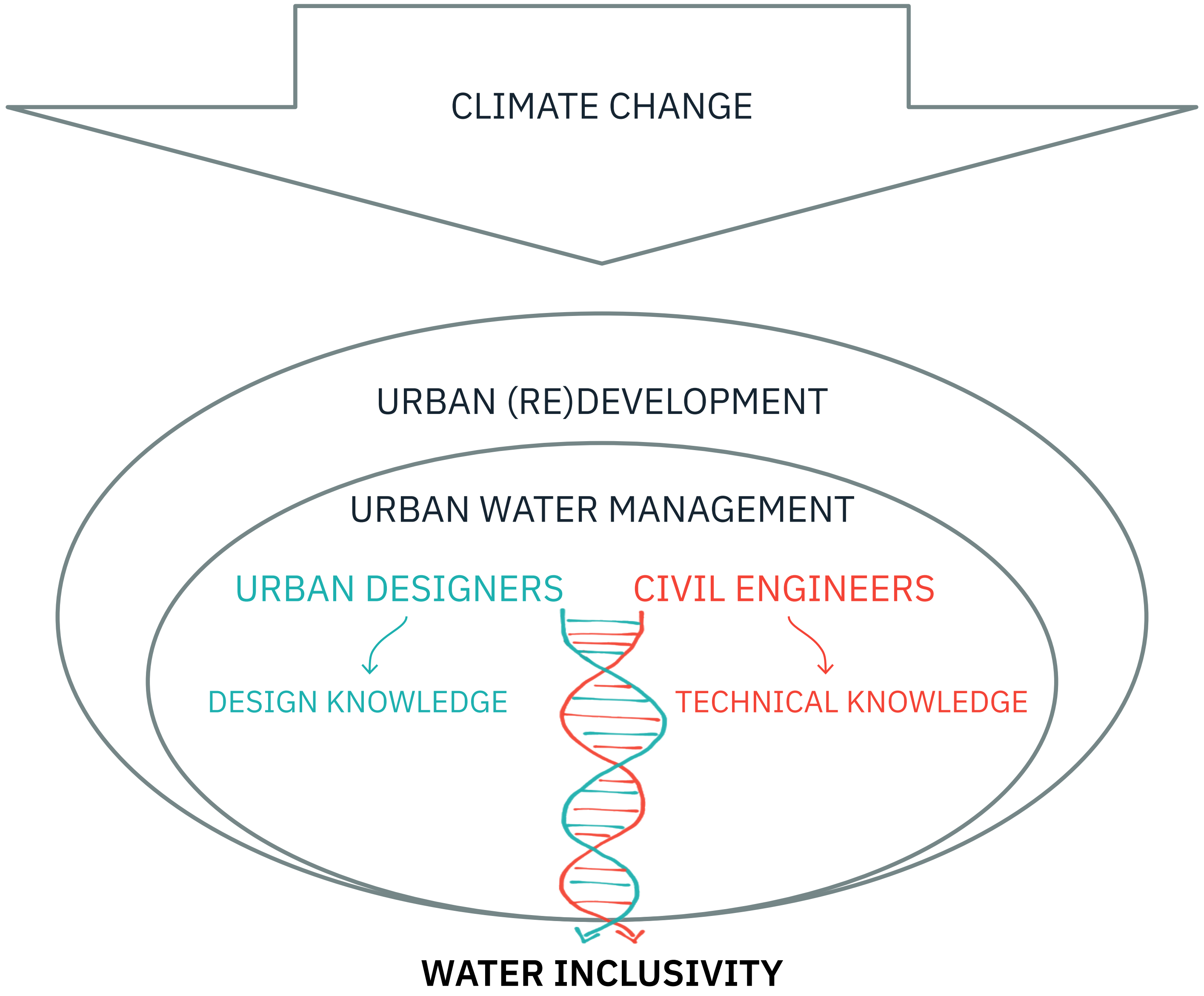


Figure 7. Conceptual framework

METHODOLOGICAL FRAMEWORK

The methodological framework shows the general rationale of this thesis. It aims to clarify the structure and justify the steps taken to reach the conclusion. It takes the form of figure 8 as can be seen on the right. It is based on the conceptual framework, the aims and outcomes and the research questions.

As you can see the methodological framework consists of roughly 5 sections. The first of which is of course the starting point of the project: The problem field and the definition of the knowledge gap. This relates to sub question 1 of the project, the method used to answer sub question 1 is theoretical literature research.

The second part of the framework is the case-study analysis. This step represents sub question 2, analysis of the existing area of Schieoevers Noord and analysis of the urban regeneration plans made by the municipality of Delft.

Next is the research into principles of surface water systems and climate adaptation measures. This step, reflected in sub question 3, together with the results from the case-study analysis creates a frame of reference to help form different water management strategies in Schieoevers Noord. It will also result in evaluation criteria that will be used to test the strategies in the next step.

The strategies and proposal are part four of the methodological framework. Within step four the different strategies will be evaluated according to the evaluation criteria set in step three. After the evaluation the best parts of the strategies will be combined into one final proposal for Schieoevers Noord. Eventually, sub question 5 will complete the feedback loop by extrapolating the transferability and thereby answering the main research question.

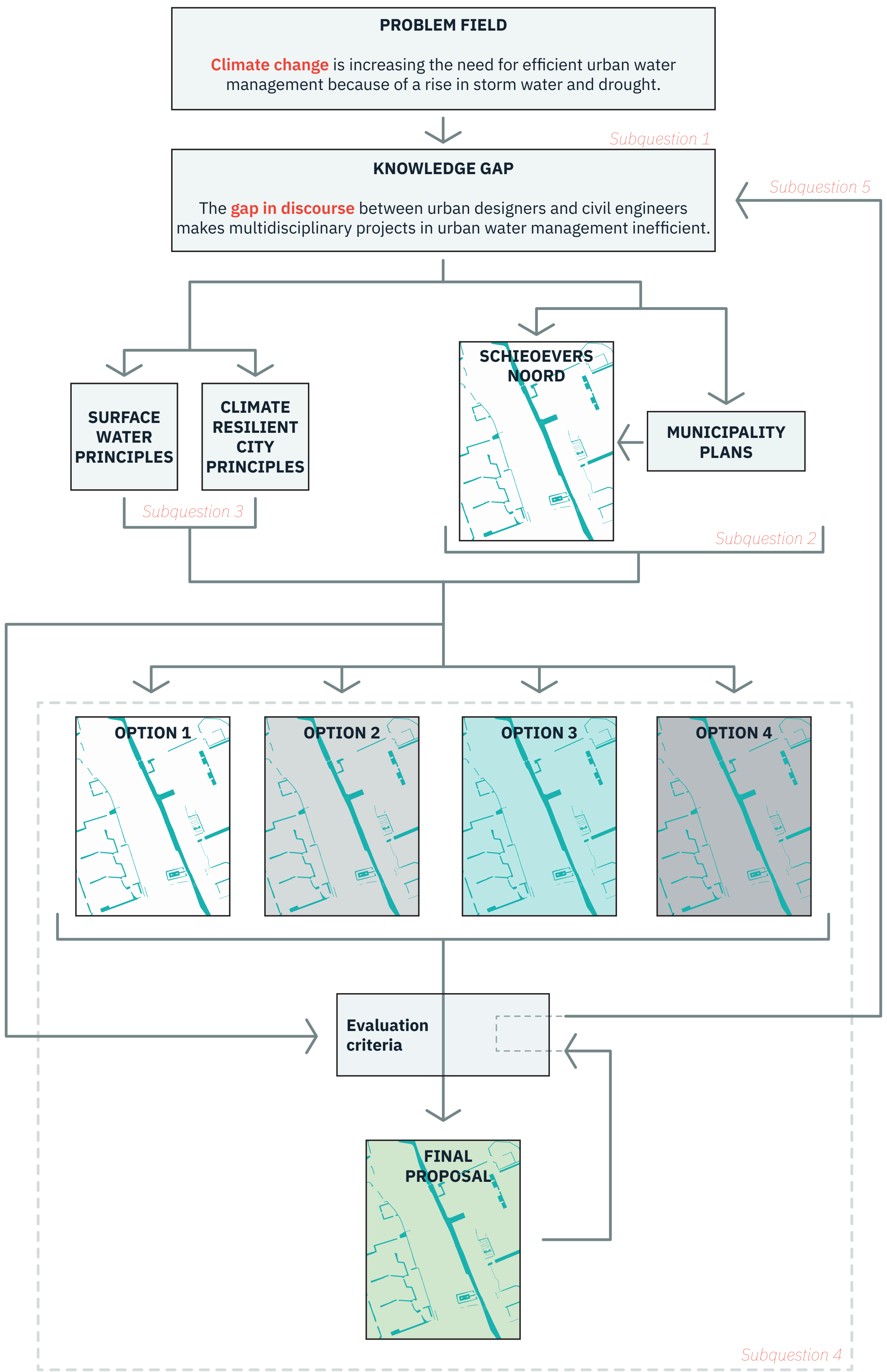


Figure 8. Methodological framework

CASE STUDY ANALYSIS

This chapter will dive deeper into Schieoevers Noord, the case-study location of this thesis, by analysing the location in the surroundings, the sub-regions, the existing water system and the climate issues. After the physical analysis of the area, the existing redevelopment plan of Schieoevers Noord will also be analysed. From these analyses a space matrix calculation is done to show the available free space for the water strategy designs, which are discussed further along in this thesis.

SCALES

Water authority Delfland, Municipality of Delft and the polders

Schieoevers Noord is part of three main systems. It is located in the management area of the Delfland Water authority, the municipality of Delft as well as three polder and one bosom system.

The Delfland Water Authority is one of twenty two water authorities in the Netherlands. Water authorities are in control of the water management of their respective management areas. In case of Delfland that is an area of 410km^2, including the municipalities of The Hague, Midden-Delfland and Delft. The water authority is responsible for safeguarding the water quality and quantity, maintaining dykes and dunes and running operations of waste water treatment facilities (Delfland Water Authority, n.d.).

One step down in scale is the municipality of Delft, in which Schieoevers Noord is located. The municipality of Delft is in control of the redevelopment plans for the area of Schieoevers Noord. They commissioned the development plan that is used in the analysis of this thesis as well.

Finally, when taking one last step down in scale, it shows that Schieoevers Noord is partly located in the Higher Abtwoudse polder (H.A.P.), the Lower Abtwoudse polder (L.A.P.), the Zuidpolder and the Schie bosom water system. This thesis will focus on the parts of Schieoevers Noord which are located in the Higher and Lower Abtwoudse polders, because that is the most significant part of the area and it also has the least amount of surface water in its current state. The higher and Lower Abtwoudse polder are two systems, but they are intrinsically connected to each other. Schieoevers Noord has the border of the two polders running right through its middle, which makes it a very interesting situation to study.

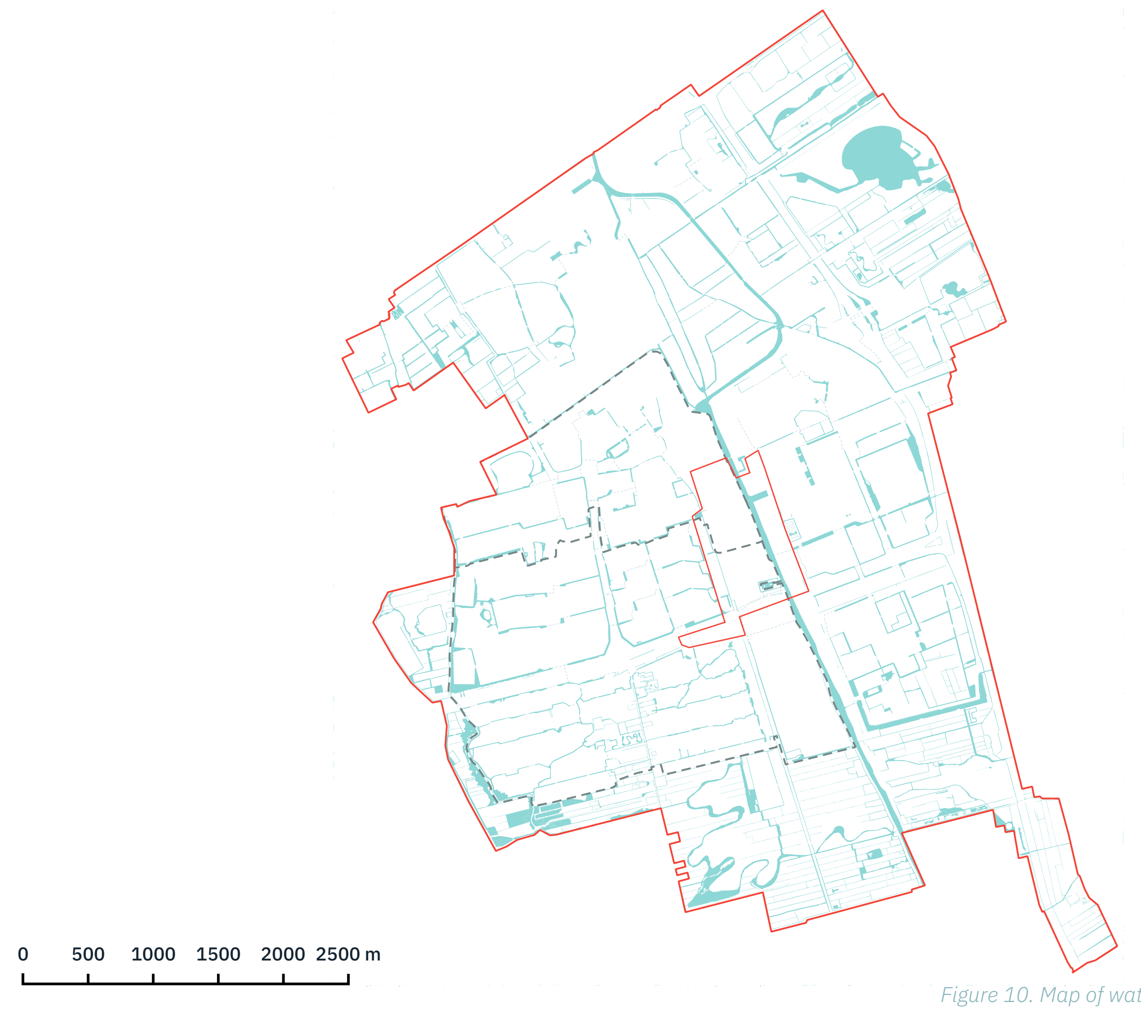


Figure 10. Map of water in the municipality of Delft

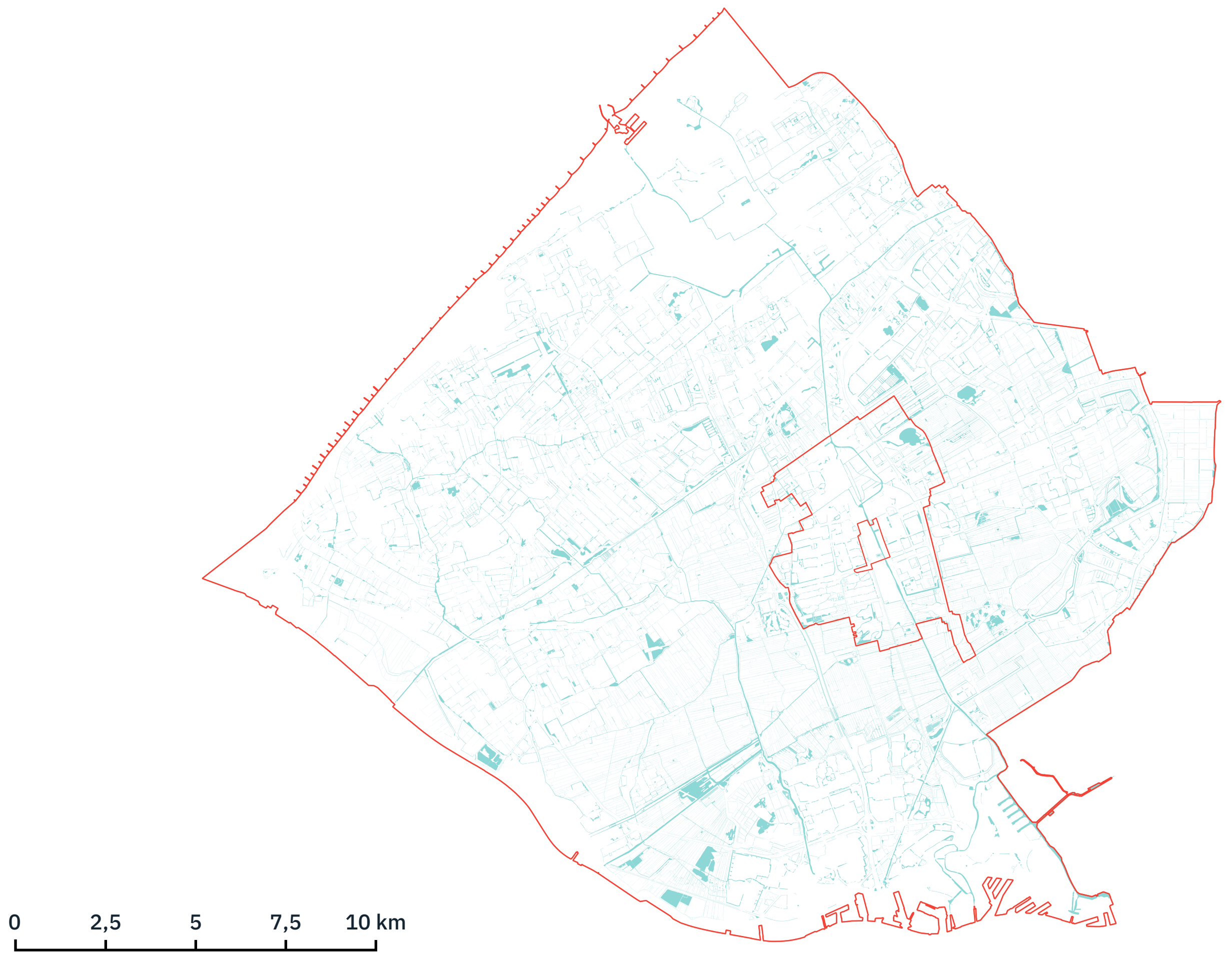


Figure 9. Map of water in the management area of Delfland

Figure 11. Map of water in the area around Schieoevers Noord

LOCATION AND SUBREGIONS

Within Delft, Schieoevers Noord is located between two large residential neighbourhoods in the west, the TU Delft campus in the east, the historical city centre in the north and an industrial area in the south (Figure 12). Schieoevers Noord is also located in range of two train stations; Delft and Delft Campus. In its current state Schieoevers Noord actually forms a huge barrier between the areas around it. One of the goals of the redevelopment is to integrate the area into the existing structure and improve the connections in both North-South and East-West directions.

To be able to zoom in on different areas of Schieoevers Noord the plan is divided into sub-regions. This thesis uses ten subregions (Figure 13, areas coloured in blue), the borders of which are the same as the first ten regions in municipal development plan. The municipal plan actually has fifteen sub-regions, the five that are on the East side of the Schie are not used in the strategies and proposal of this thesis, they were however, taken into account in the analysis.

Because the municipal plan was a guiding document in this thesis it was clear that using the same sub-regions would be most convenient. To add to that, the borders they set were very clearly defined and conveniently shaped, the borders are set according to logical, existing structures in the area. In the North-South direction the sub-regions are divided by the Vulcanusweg, the train tracks, the Schie and the Rotterdamseweg. In the East-West direction the sub-regions are mostly bound by current property lines, activities and position, in the south of Schieoevers Noord one sub-region is separated from the rest by the Kruithuisweg (natural borders shown in white in figure 13).

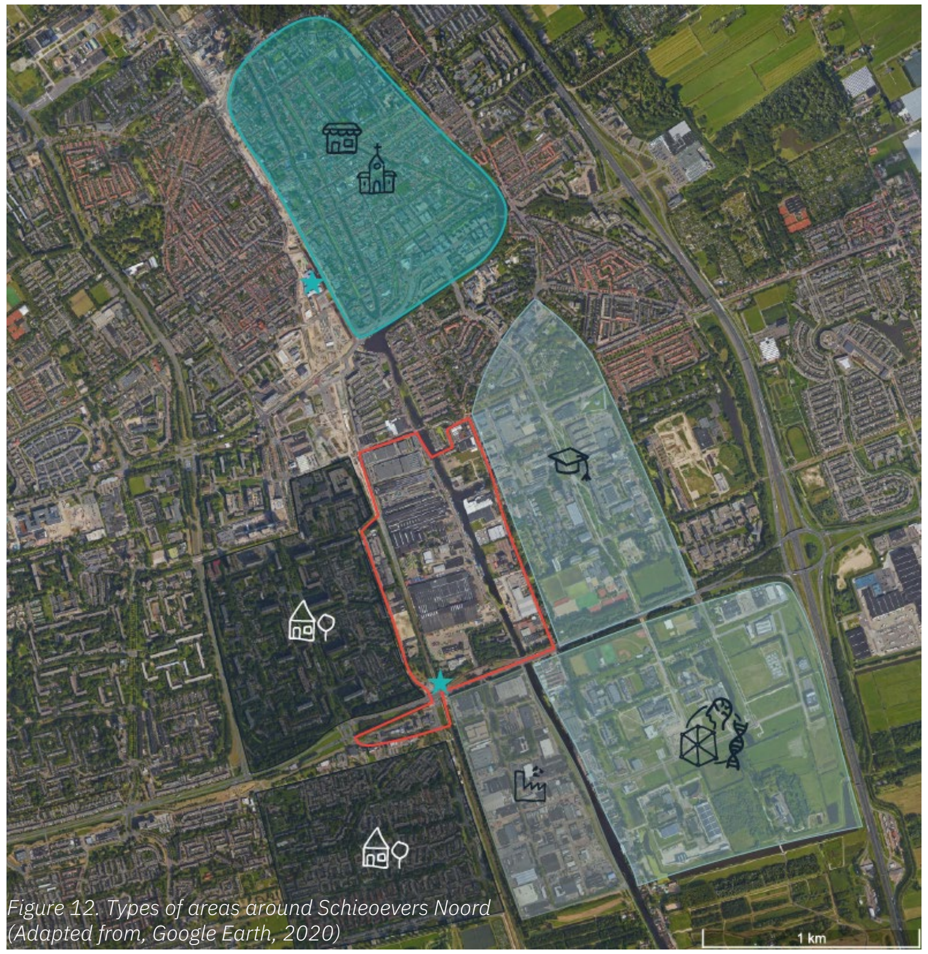


Figure 12. Types of areas around Schieoevers Noord (Adapted from, Google Earth, 2020)

Figure 13. Sub regions of Schieoevers Noord (Adapted from, Google Earth, 2020) >

Sub Region 1

The area is 27.500 m^2, the FSI is established as 1,00 and the maximum building height is not mentioned in the development plan.

Sub region 1 is located on the west side of the train tracks. The ground surface height is about 1,5 to 1,9 metres lower than the areas on the west side of the train tracks.

It lies on the border of the High and Low Abtwoudse polder systems and has existing surface water which is mostly part of the H.A.P. There is a small weir connecting the water from H.A.P. to L.A.P. in this area as well. The existing surface water is shown in figure 15 but it is mostly hidden behind thick foliage and therefore barely visible throughout the year.

An interesting building that can be found in this sub-region is the mosque shown in figure 14. (Moskee Al Ansaar)

Figure 15. View of area 1 (Google Earth, 2020)

Figure 14. Mosque Al Ansaar (Google Earth, 2020)

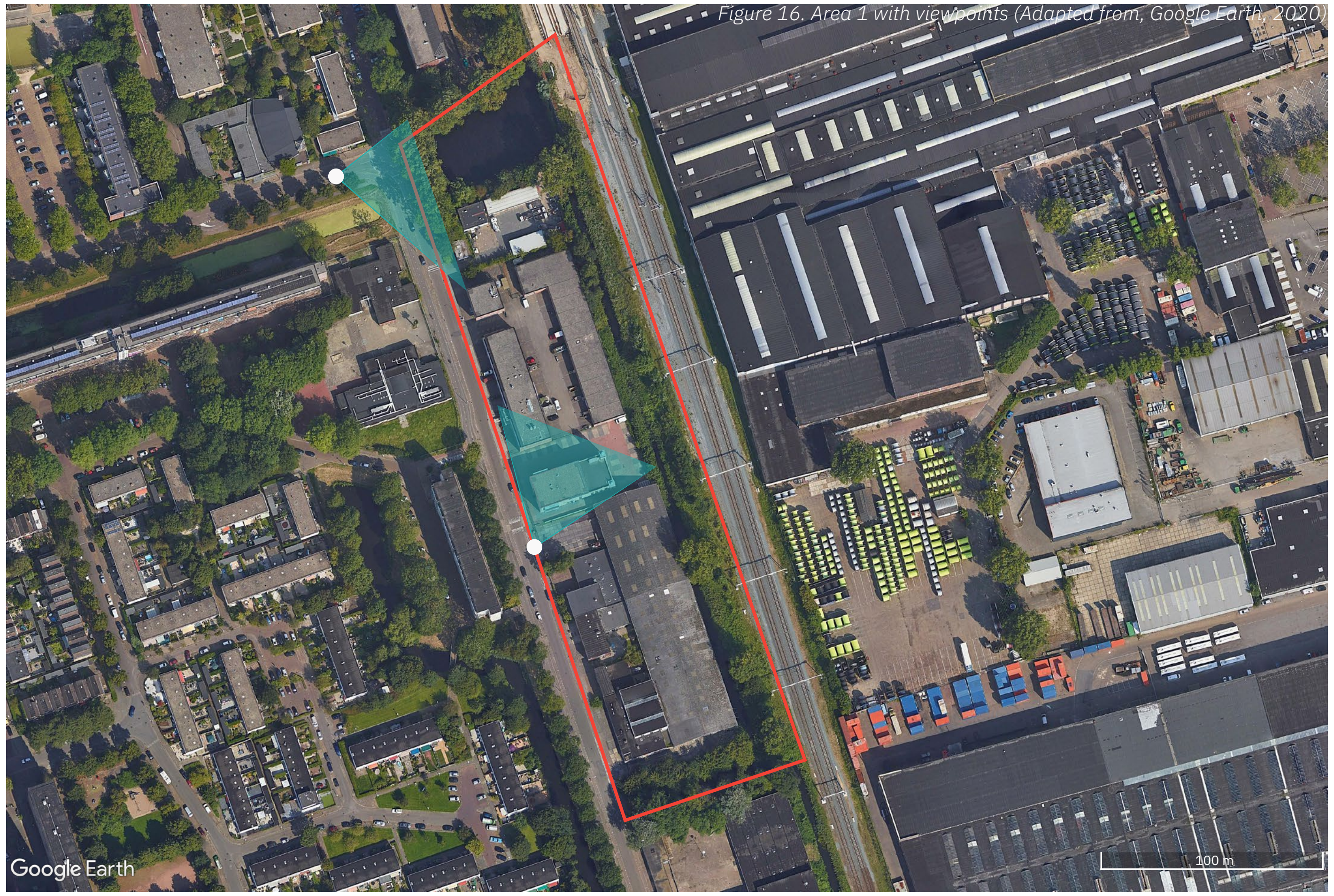


Figure 16. Area 1 with viewpoints (Adapted from, Google Earth, 2020)

Sub region 2

Figure 17. Area 2 with viewpoints (Adapted from, Google Earth, 2020)

Figure 18. Tiny houses (Pioniers Kwartier, n.d.)

The area is 28.000 m^2, the FSI is established at 1,00 and the maximum building height is not mentioned in the development plan.

Sub region 2 is also located on the west side of the train tracks and the ground surface height is the same as sub region 1, -1,5 to -1,9 NAP. It has a small stream of existing surface water within LAP, the water level is -2,70 m NAP.

Sub region 2 is also home to the temporary establishment of tiny houses. It's a collective called Pioniers kwartier and it houses around 21 people in 14 tiny houses. (Pionierskwartier, n.d.)

There is some greenery in this region, but it is not enough to actually use as a green space, since it is mostly trees planted to reduce sound and visuals from the train tracks.

Figure 19. View of buildings area 2 (Google Earth, 2020)

Sub Region 3

The area is 12.200 m², the FSI is established at 2,25 and the maximum building height will be 90 metres.

Sub region 3 is located on the west side of the train tracks and the ground surface height is the same as sub region 1 and 2, -1,5 to -1,9 NAP. It has some surface water within the Lower Abtwoudse polder, at a level of -2,70 m NAP.

This sub-region is also home to a pumping station that pumps water between the Schie and the Lower Abtwoudse polder with a capacity of 100 m³/min. This pumping station is an integral part of the water system.

The station (station Delft Campus) is also located in this sub-region. Construction of the station and the bicycle and pedestrian tunnel under the tracks is supposed to be finished by the end of 2021, which makes it one of the first developments in Schieoevers Noord, it will improve connectivity between the station and the TU Delft Campus.

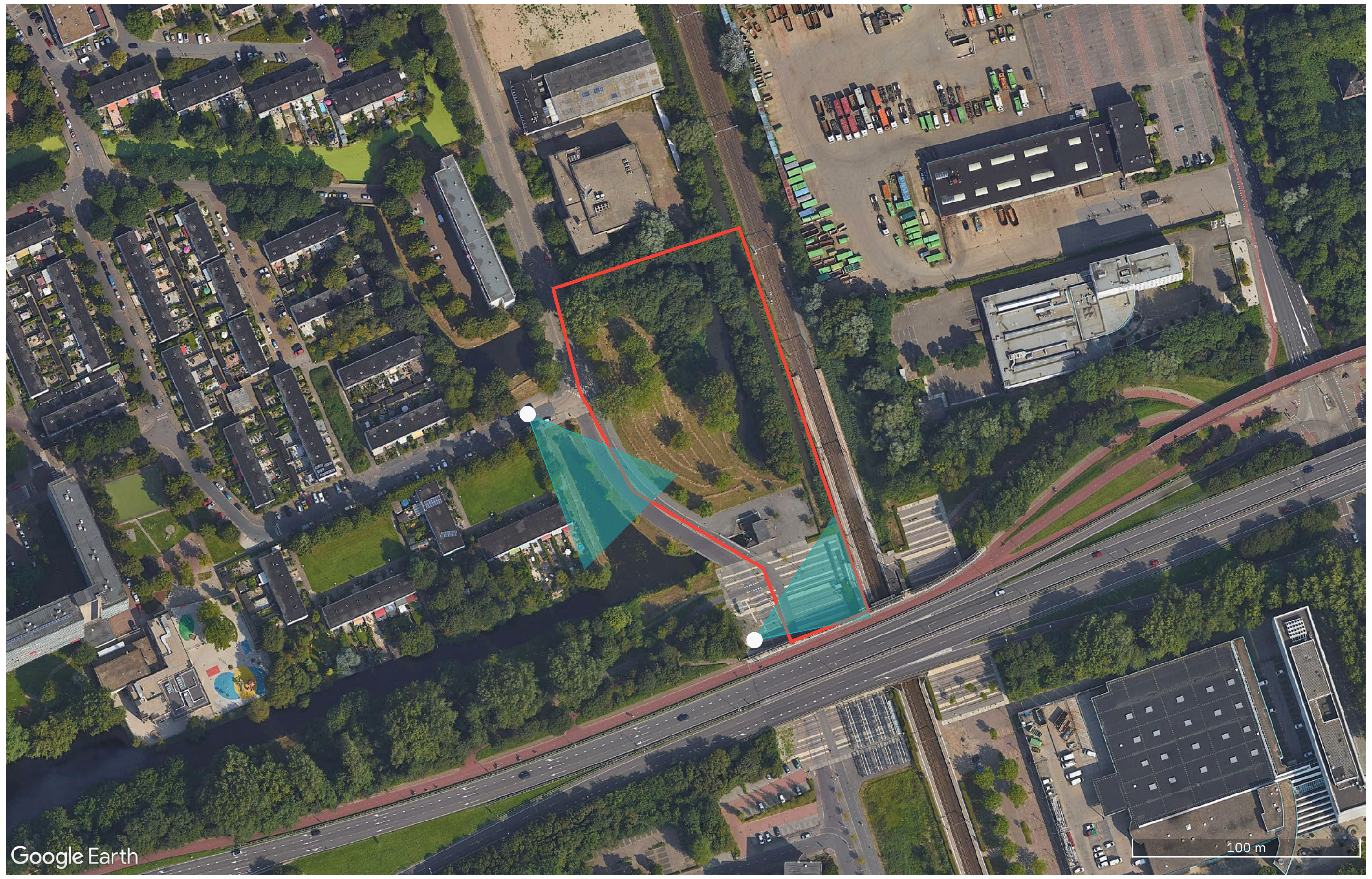


Figure 21. Area 3 with viewpoints (Adapted from, Google Earth, 2020.)

Figure 20. View of train station Delft Campus (Google Earth, 2020.)

Figure 22. View of water in area 3 (Google Earth, 2020.)

Sub region 4

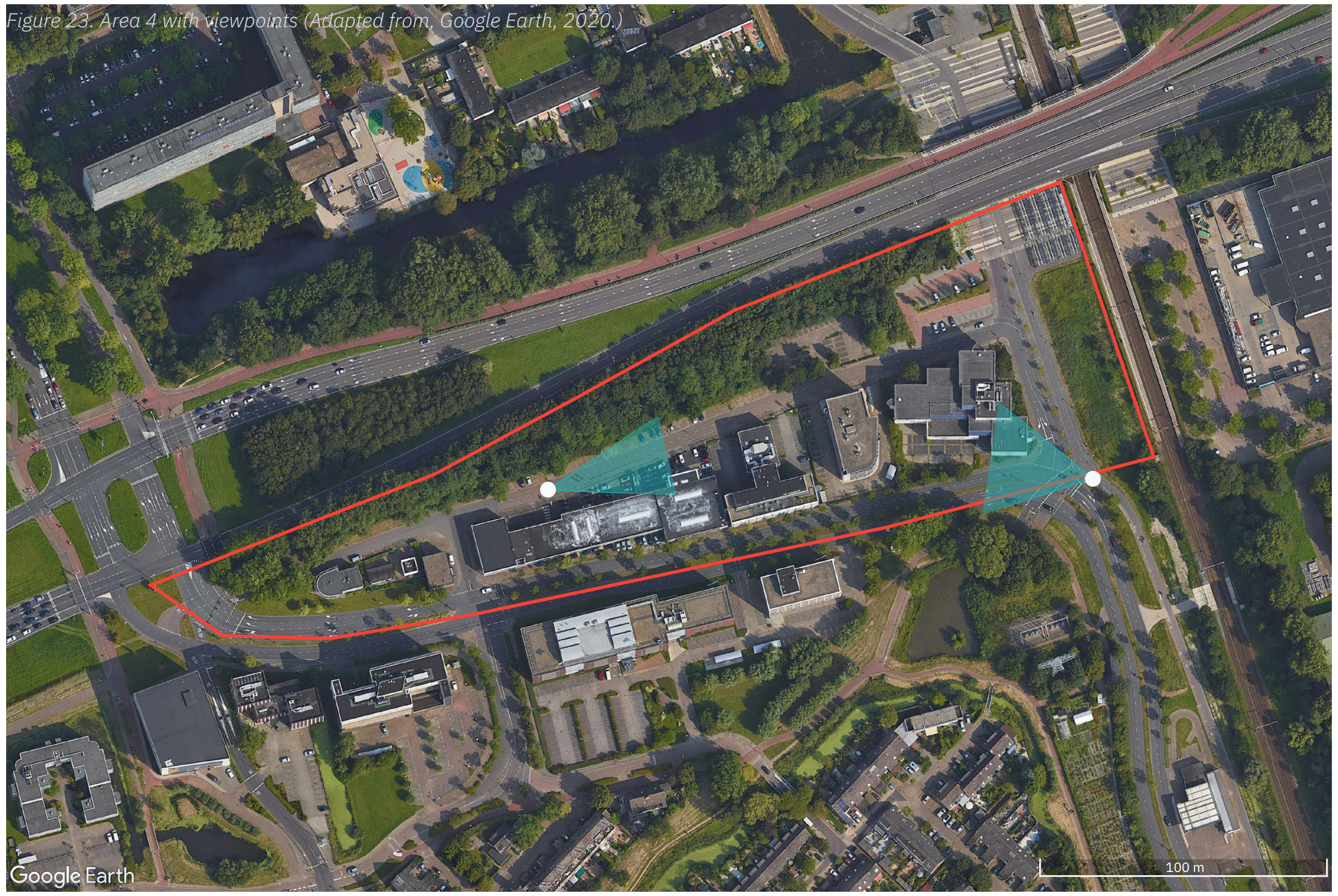


Figure 23. Area 4 with viewpoints (Adapted from, Google Earth, 2020.)


Figure 24. View buildings in area 4 (Google Earth, 2020.)

Out of the fifteen sub-regions, this region is the most susceptible to water nuisance from heavy rain (Gemeente Delft & marco.broekman, 2019, p. 54). There is some greenery separating the area from the busy road.

The area is 38.080 m^2, the FSI is established at 2,25 and the maximum building height will be 90 metres.

Sub-region 4 is the only one that is located south of the Kruithuisweg. It is connected with sub-region 3 via an underpass of Kruithuisweg. It is currently filled with a lot of industrial and office buildings, some of which are already empty. This region is one of the four that will be developed first.


Figure 25. View buildings in area 4 (Google Earth, 2020.)

Sub region 6


Figure 26. Schieweg in area 6

The area is 123.880 m^2, the FSI is established at 1,70 and the maximum building height will be 30-55 metres.

This sub-region is bordered by the train tracks on the east and the Schie on the west side. It has a ground level between +0,10 and + 0,30 m NAP. Just like sub-region 5 this area also has no green areas, it is completely paved.

This sub-region is home to Prysmian cables and systems B.V., their warehouse/factory building takes up most of this area. In the development of Schieoevers Noord only a small part of their buildings will remain as cultural heritage (figure 27).


Figure 27. Monumental building in area 6

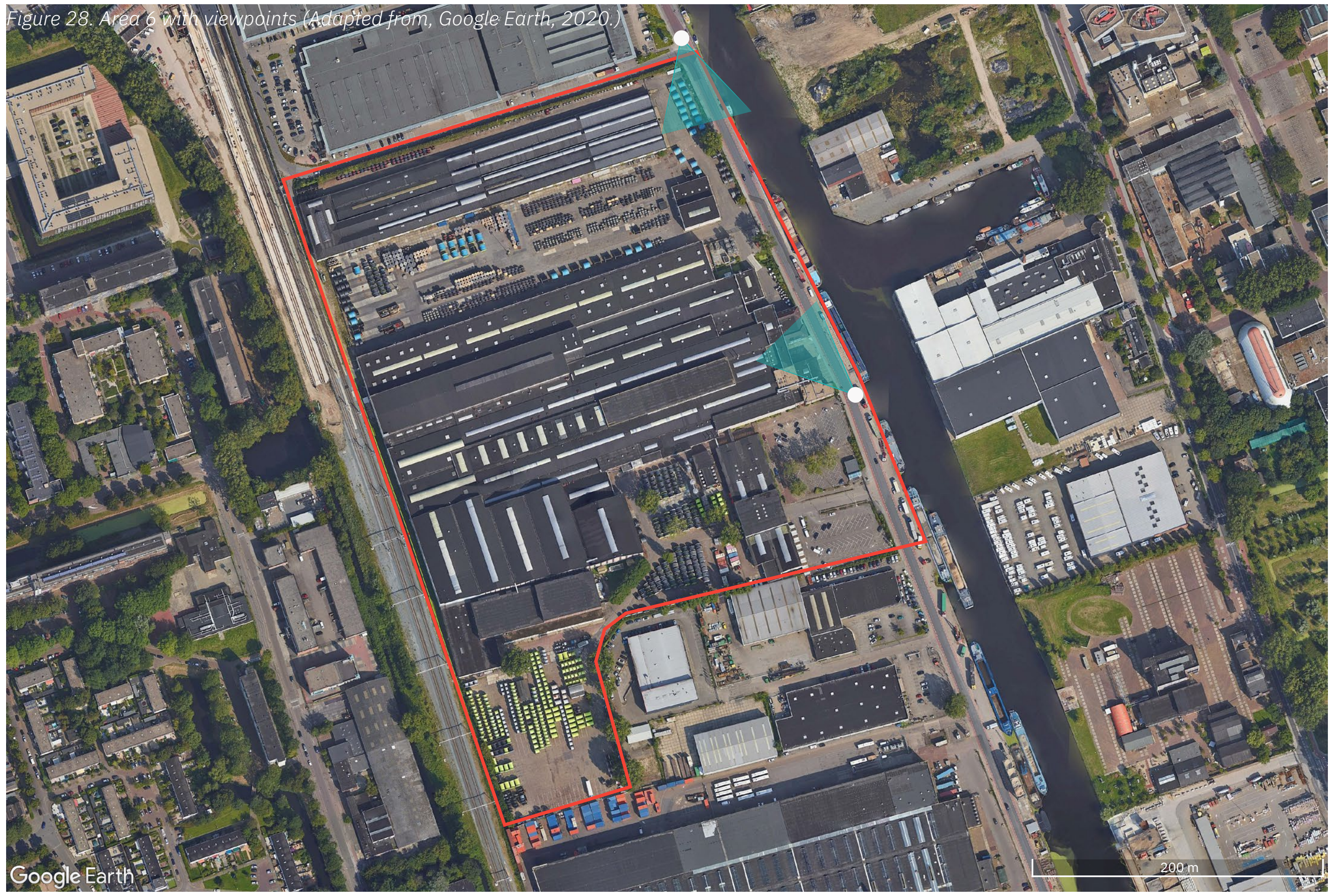


Figure 28. Area 6 with viewpoints (Adapted from, Google Earth, 2020.)

Sub Region 5

The area is 50.480 m², the FSI is established at 1,70 and the maximum building height will be 30 metres.

This sub-region is bordered by the train tracks on the east and the Schie on the west side. It is the northern most region on this side of the Schie. With a height of around +0,20 m NAP the ground level is significantly higher than the previous sub-regions. This gives it a height difference of around 0,60 m with the level of the Schie which is -0,43 m NAP.

The northern border of this sub-region is the Abtswoudseweg, which is a road connecting to the bridge. On weekdays, around 8:30 in the morning this road is usually extremely busy with cycling traffic going towards the TU Delft. Especially when the bridge is open it will have a bike traffic jam of several hundreds of people.

Right now it has a collection of large hardware and furniture stores. The region is completely paved, there is hardly any green space or water (except for the Schie).

There are a few residential buildings that will remain and be integrated with the new structure of the development in Schieoevers Noord.

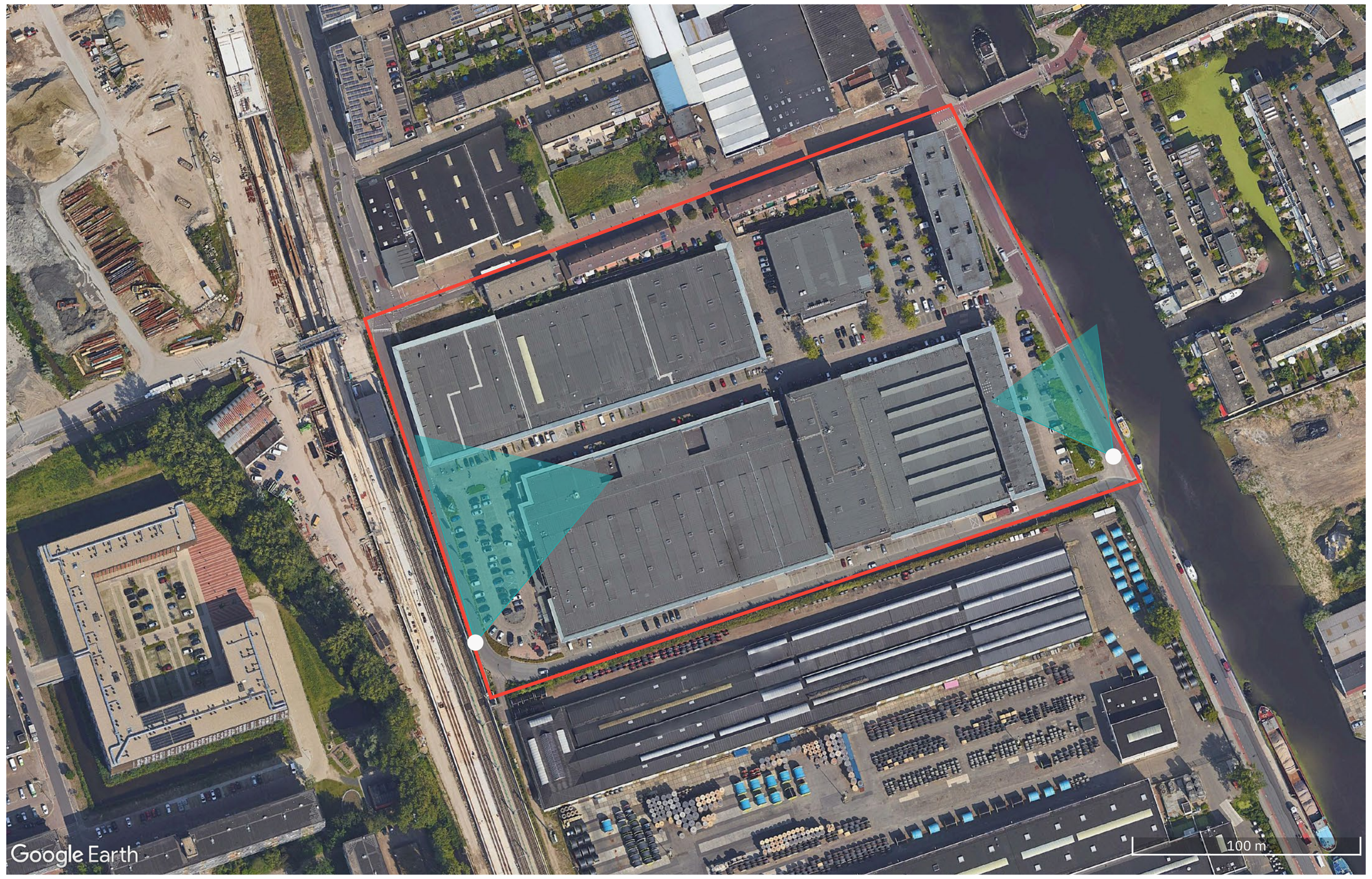


Figure 30. Area 5 with viewpoints (Adapted from, Google Earth, 2020.)

Figure 29. View of stores in area 5 (Google Earth, 2020.)

Figure 31. Schieweg in area 5 (Google Earth, 2020.)

Sub Region 7

The area is 29.000 m², the FSI is established at 1,70 and the maximum building height will be 50 metres.

There is one dead-end street with some industrial buildings and a hardware store, other than that, not much is happening in this region.

Figure 32. Hardware store in area 7

Figure 33. View of industry in area 7 (Google Earth, 2020)

Figure 34. Area 7 with viewpoints (Adapted from, Google Earth, 2020.)

Sub Region 9

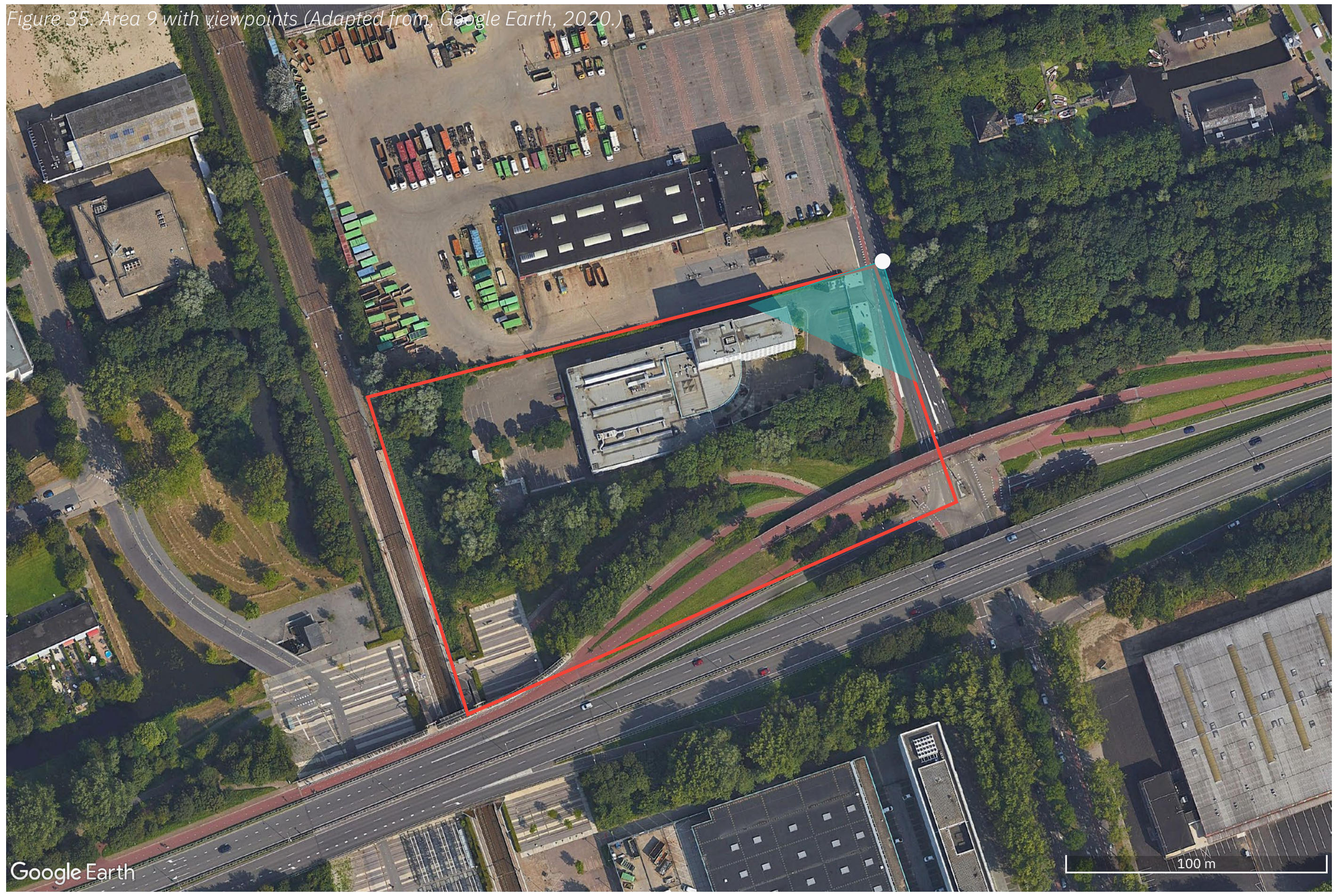


Figure 35. Area 9 with viewpoints (Adapted from, Google Earth, 2020.)

The area is 22.180 m², the FSI is established at 2,00 and the maximum building height will be 90 metres.

This area will connect to the tunnel that is being built underneath the station. This will be one of the few places where pedestrians and cyclists can pass the train tracks. It will improve the connection between the two sides of the train tracks.

Currently this region is home to an office building with a small parking lot, some greenery blocking sound and visuals to the road, and the train tracks. Further, there is an underpass under the Kruithuisweg with entrance and exit lanes to access the Kruithuisweg by bike and car, which will remain in place in accordance with the development plan.

Figure 36. View of building in area 9 (Google Earth, 2020)

Sub region 8

The area is 124.340 m², the FSI is established at 2,75 and the maximum building height will be 55-90 metres.

It has a ground level between +0,10 and + 0,30 m NAP, just like the other sub-regions on this side of the Schie. This area is also home to a very large paved parking site for waste collection trucks and cars.

This region has the Schiehallen building, the plan for this building is to retain as much as possible from the outer façade and integrate it with new developments.

This is one of the 4 sub-regions that is set to be developed in the first stage of the municipal redevelopment plans. This region already has a more specific plan made by Kondor Wessels and Amvest, the plan is called Kabeldistrict (figure 37).

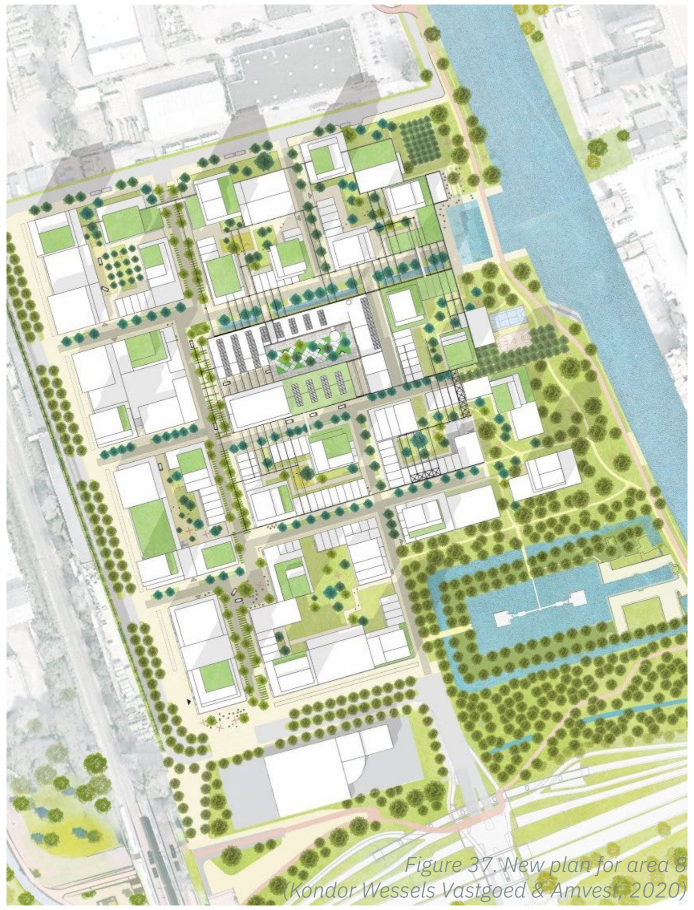


Figure 37. New plan for area 8 (Kondor Wessels Vastgoed & Amvest, 2020)

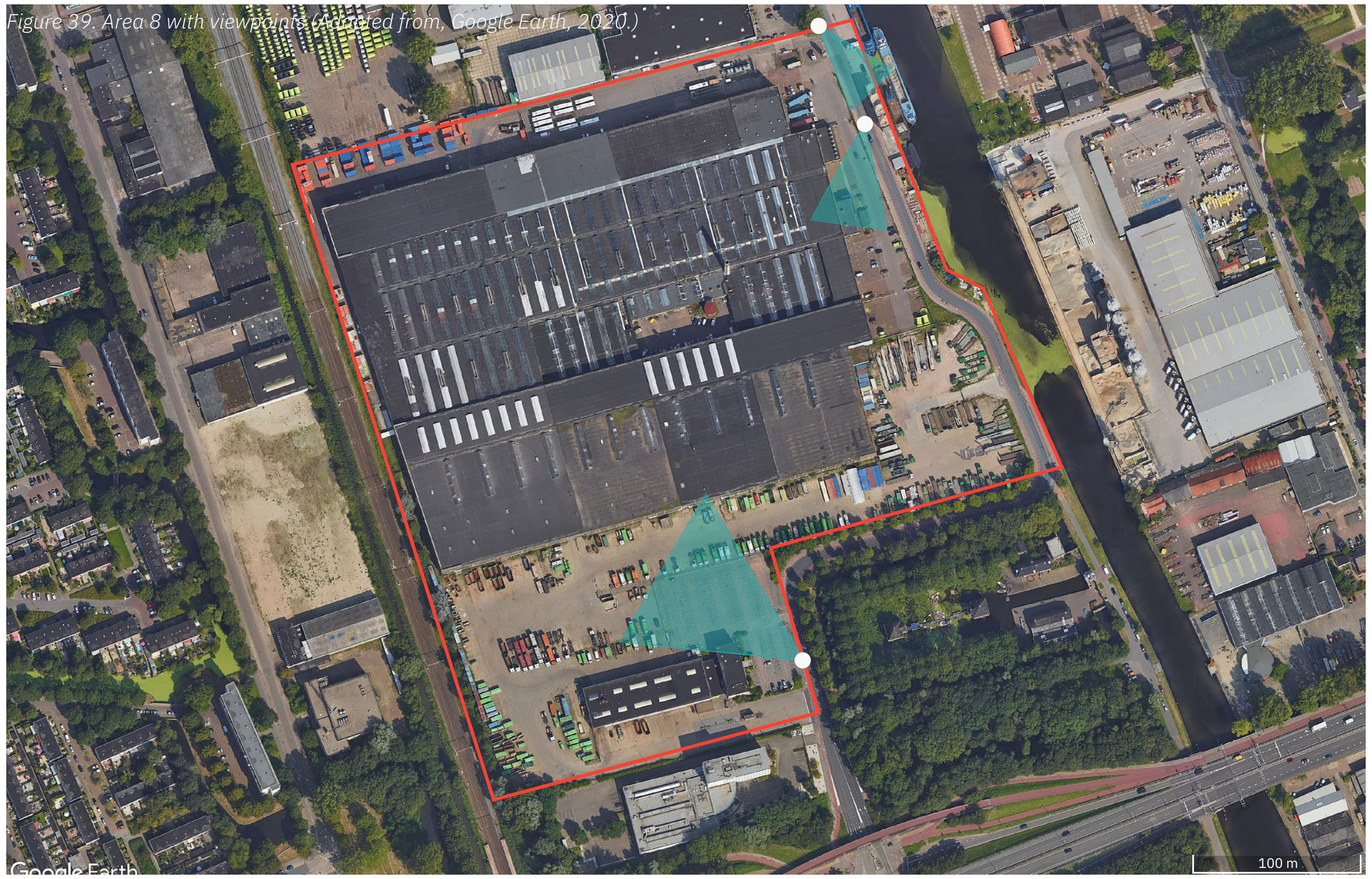


Figure 39. Area 8 with viewpoints (Altered from, Google Earth, 2020.)

Figure 38. Schiehallen in area 8

Figure 40. Parking lot area 8 (Google Earth, 2020)

Sub region 10

The area is 39.880 m², the FSI and the maximum building height are not mentioned in the development plan, because there will not be any building in this area.

A national monument called Kruithuis is located in this sub-region, it was built in 1660 and its function was military ammunition storage. It has a beautiful entrance with the coat of arms of Holland, which leads to a courtyard with two small storage houses surrounded by water. Currently this area is being used by scout groups.

Interestingly, this area has two different water levels. The water inside the courtyard is directly connected to the Schie and is therefore also at bosom level (-0,43 m NAP). Around Kruithuis is a moat at a height of -1,33m NAP, protecting the old foundation of the monument against fluctuating ground water levels.

This subregion is very different from all the others in Schieoevers, because it is almost completely covered in greenery and water as opposed to the pavement and lack of greenery in other sub-regions. The amount of trees and plants makes it a small urban forest.

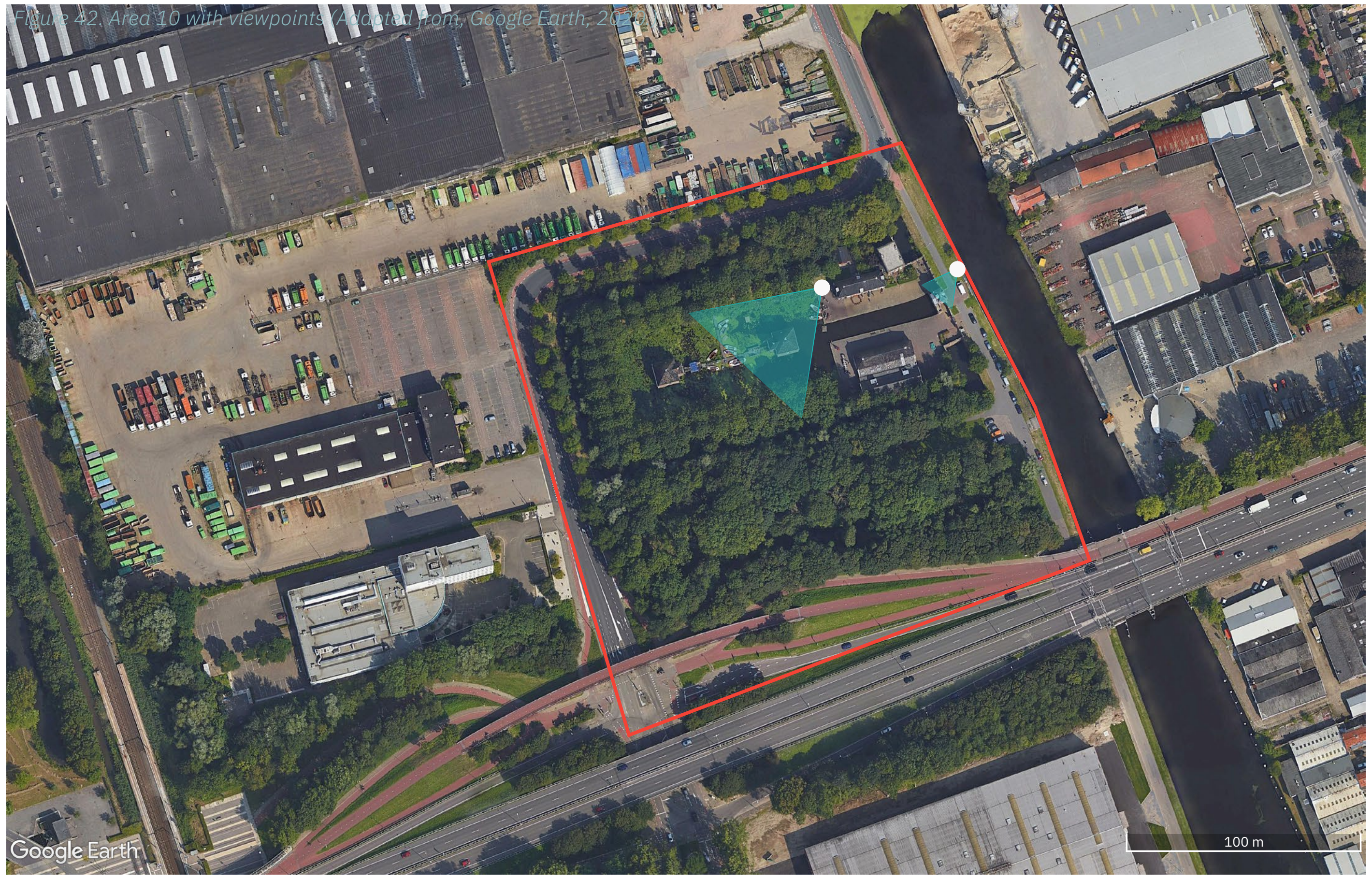


Figure 42. Area 10 with viewpoints (Adapted from, Google Earth, 2020)


Figure 41. Inside Kruithuis (Mastenbroek, 2016)


Figure 43. Kruithuis entrance

THE WATER SYSTEM
High and Low Abtwoudse polder

As mentioned earlier Schieoevers Noord is partly located in the Higher Abtwoudse polder (H.A.P.) and partly in the Lower Abtwoudse polder (L.A.P.). The systems of these two polders are intrinsically connected. Normally, polders are self-sufficient, separate systems, though in the case of the Abtwoudse polders they actually work together. Higher Abtwoudse polder is much smaller than Lower Abtwoudse polder, both in area and volume of water.

In total there are eight different water levels in the water systems of H.A.P. and L.A.P. (shown in figure 44). Within the area of Schieoevers Noord there are currently five different water levels according to the ledger of the Delfland water authority: The main water levels of H.A.P. and L.A.P., the adjusted water levels around Kruithuis and the bosom water level of the Schie. The water level for H.A.P. is -1,50m NAP, the main water level for L.A.P. is -2,70 m NAP and the bosom water level of the Schie is -0,43m NAP. The adjusted water level of the ring around Kruithuis is -1,33 m NAP; this is to stabilise the ground water level, protecting the old foundation of the monumental Kruithuis building. There is one other area with an adjusted water level measuring at -2,20 m NAP, the reason for this adjustment is unknown to the author. Having all these different water levels inside the area of Schieoevers Noord makes it very complicated to work with.

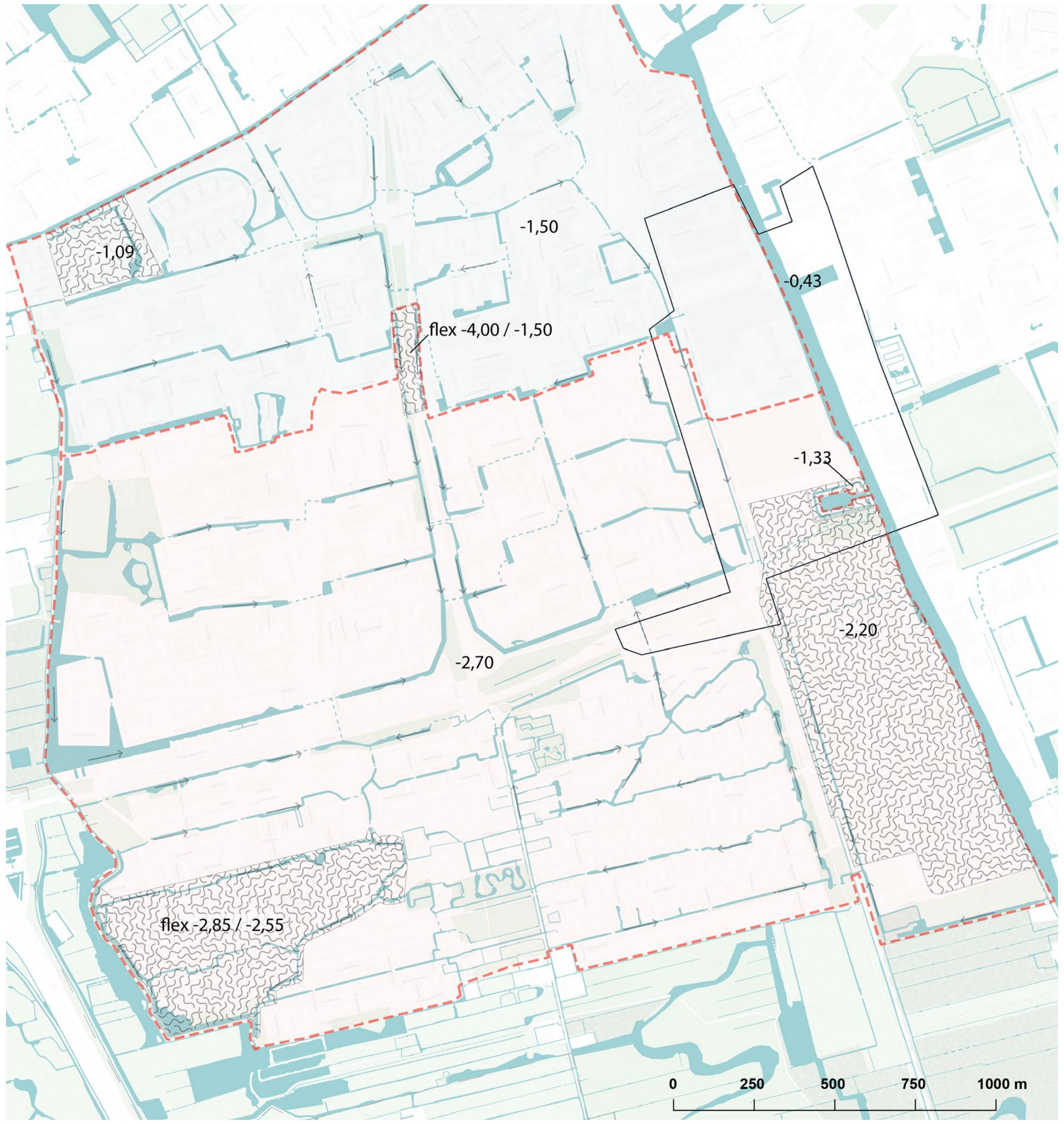


Figure 44. Higher and Lower Abtwoudse polder and their water levels

Figure 45 shows the direction of flow, as well as the pumps and weirs that control the flow of water through H.A.P. and L.A.P.. There are two pumping stations in figure 45, the first one is a relatively small pumping station located on the border of H.A.P. and L.A.P. with a maximum capacity of 1 m^3/min. The second one is much bigger and is located in area 3 of Schieoevers Noord. This pumping station is used for the exchange of water between the L.A.P. and the Schie, its maximum capacity is 100 m^3/min.

Schieoevers Noord is part of the surface area of both polders but there is hardly any water in Schieoevers Noord. This actually has a negative influence on the polders because the necessary water storage is calculated in cubic metres per hectare of land. This norm is harder to reach with Schieoevers Noord adding about 50 ha of space but hardly any cubic metres of water. Of course Schieoevers Noord has the Schie running through but since the Schie is part of the bosom system it won't affect the polders storage capacity.

Figure 45. Direction of flow, pumping stations and weirs

TECHNICAL SECTIONS

Adding to the complexity is that not only the water levels differ in height, but the ground levels also differ in height from east to west in Schieoevers Noord. The discrepancies in height of soil and water are clearly visible in the technical sections in figures 47 and 48.

The section in figure 47 is made at the height of area 6, cutting through the Schiehallen. Section 48 is made at the height of areas 9 and 10, cutting through Kruithuis.

Please note that the vertical scale of the soil is different from the vertical scale of the buildings and trees. To be able to illustrate the water and ground level differences for the full section of Schieoevers it was necessary to scale the ground accordingly. This is why a separate scale bar is shown for the subsoil. The horizontal scale is the same for both subsoil and above-ground structures.

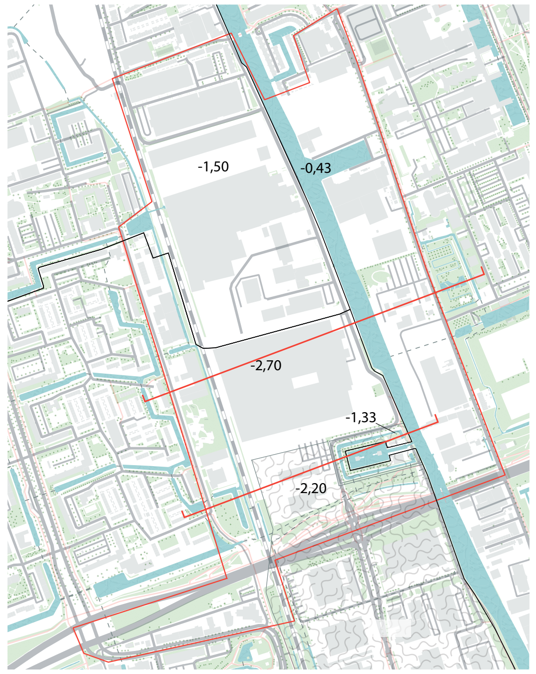


Figure 46. Section location map

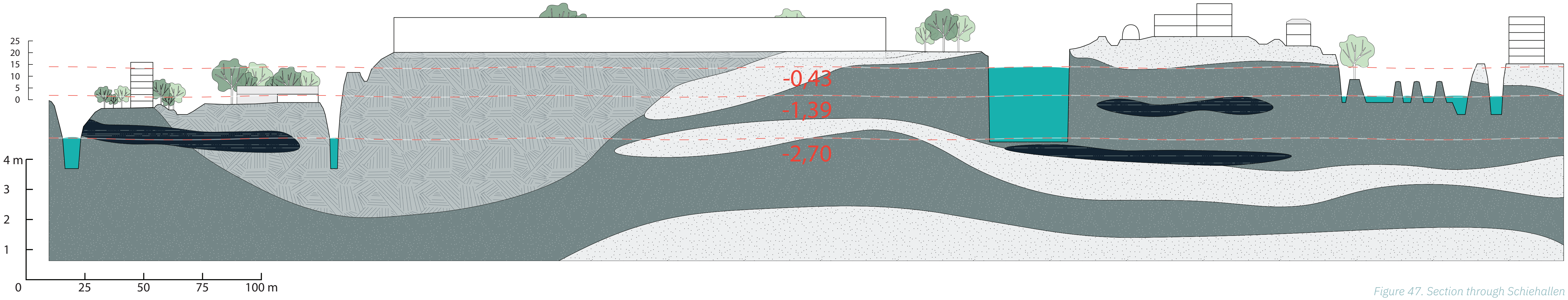


Figure 47. Section through Schiehallen

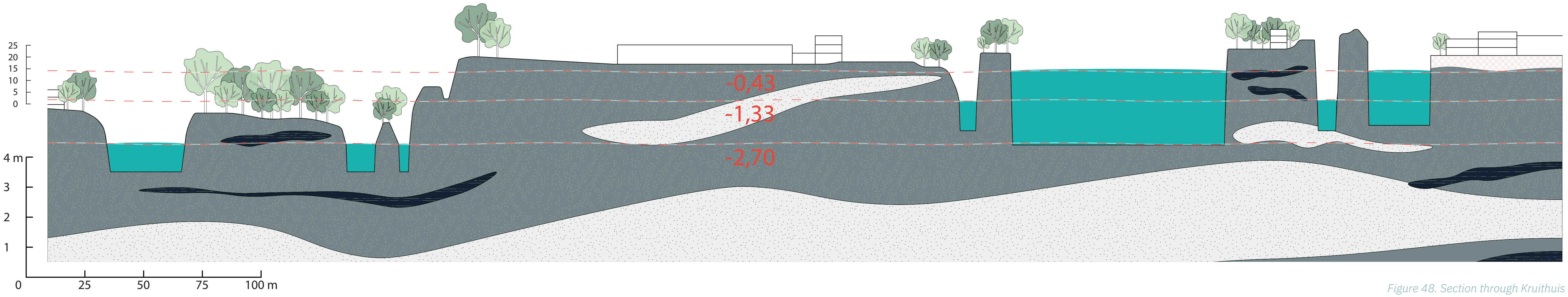


Figure 48. Section through Kruithuis

CLIMATE ANALYSIS OF SCHIEOEVERS NOORD

Quality and Quantity of Higher and Lower Abtwoudse polder

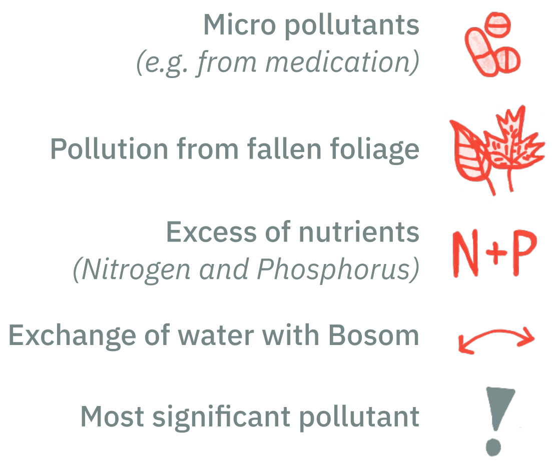
Both the higher and Lower Abtwoudse polder are dealing with issues in their water system. Some negative influences on the quality of the water in higher and Lower Abtwoudse polder are inlet of bosom water, sewage overflow, traffic, aquatic birds and fallen foliage from plants and trees. These negative influences affect the oxygen levels, the amount of nutrients, like phosphorus and nitrogen, and micro pollutants from for instance remnants of medication.

The Higher Abtwoudse polder has several problems in its water quality and quantity. As shown in figure 49 the main pollution in the Higher Abtwoudse polder comes from the exchange of water with the Schie. This exchange is necessary, because there is a shortage of static storage. This shortage means that the excess of water that falls in winter needs to be taken out of the system to prevent overflow. Also, any shortages of water in summer need to be solved by taking in water in from the Schie.

The Higher Abtwoudse polder has a surface area of roughly 218 ha with 37.500 m^3 of available storage. There is not enough storage available according to the 325-norm, which states that there should be at least 325 m^3/ha static water storage. Looking at the numbers, the Higher Abtwoudse polder only has around 172 m^3/ha, so it has a shortage of 153 m^3/ha. Higher Abtwoudse polder also has issues with micro pollutants, although the oxygen level is acceptable and the level of nutrients is good.

The Lower Abtwoudse polder does not have a shortage of static storage. Its area is 496 ha, with 191.900 m^3 available storage, which exceeds the 325-norm by 62 m^3/ha. The biggest quality concern in Lower Abtwoudse polder is actually falling foliage from trees and plants. A lot of the water in the Lower Abtwoudse polder is surrounded by trees and especially in fall it is hard to clear out the leaves falling in the water. This pollution is also a leading cause for the problems with nutrients, like phosphorus and nitrogen in this polder system. Other than the nutrients this polder also deals with micro pollutants. The oxygen levels here are acceptable, just like in the Higher Abtwoudse polder.

(De Ron & Van der Werf, 2005)



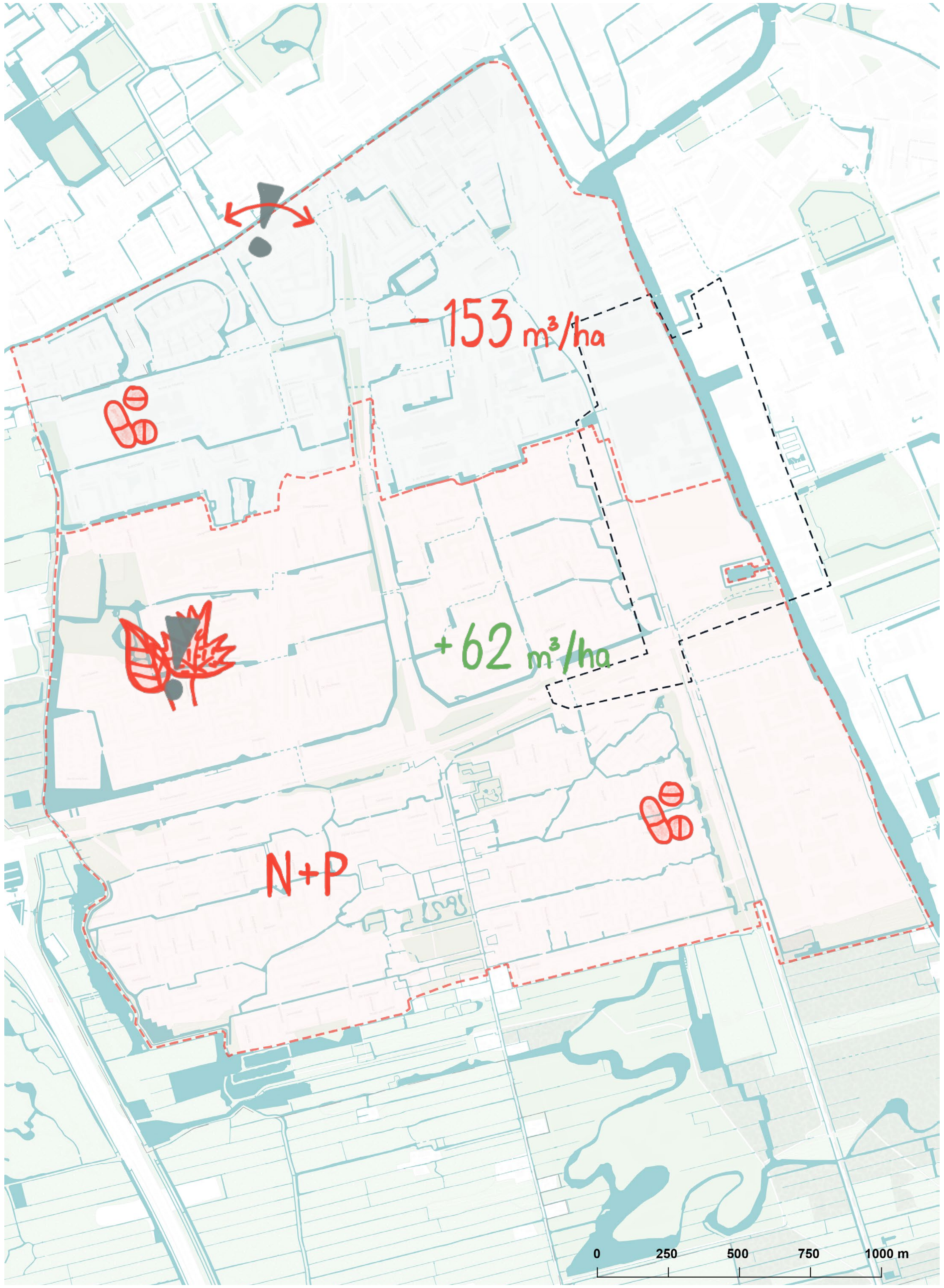


Figure 49. Quality and quanitity issues in H.A.P. and L.A.P.

Paved surface

Paved surfaces are impervious to water; Adittionally, the dark pavement materials have a low reflection factor (albedo), effectively making the stony materials a heat trap. These factors combined mean that a paved area suffers more severely from water nuisance after rain and heat stress. Schieoevers Noord is a very clear example of this.

As shown in figure 51 around 90% of the total area of Schieoevers is paved or built area. When comparing it to other neighbourhoods in Delft (figure 50) the percentage is even higher than the historical centre of Delft. This also corresponds very clearly with the heat stress map on the next page.

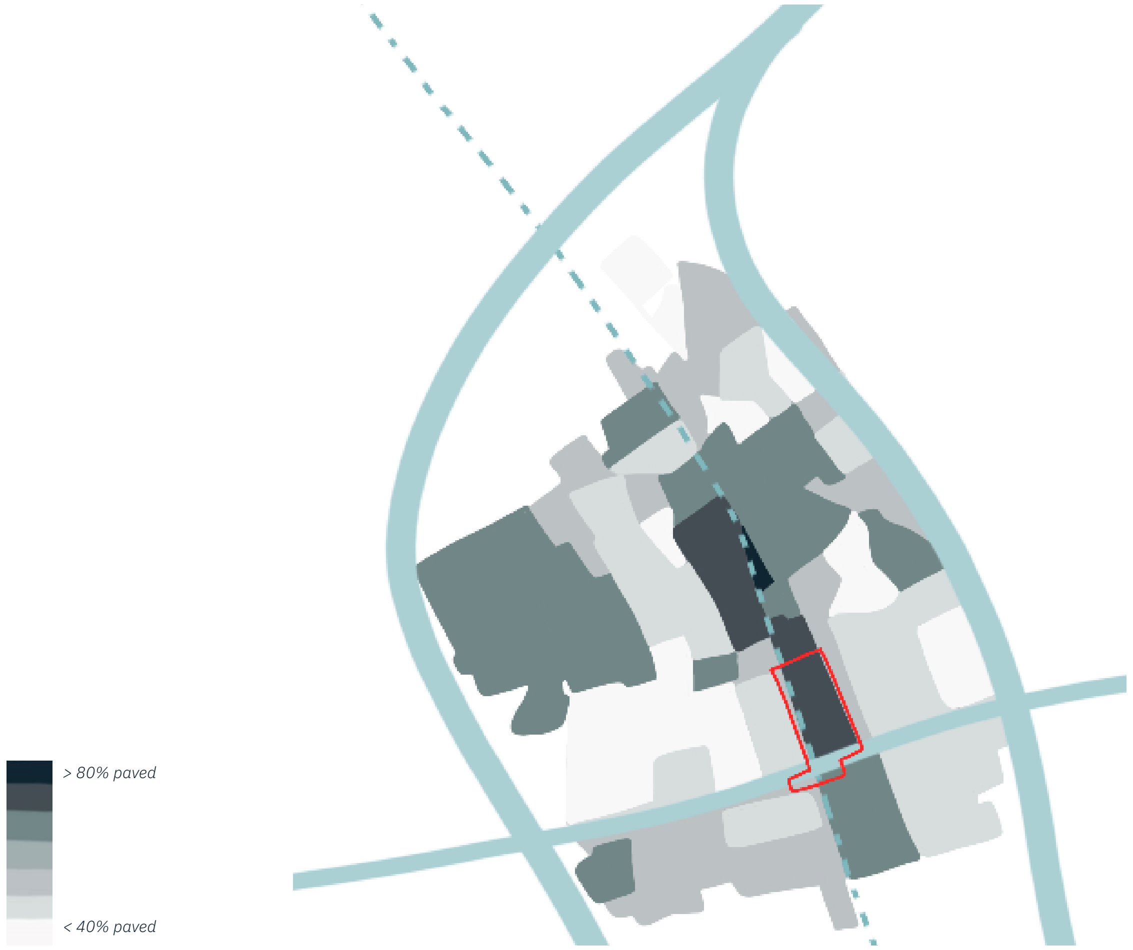


Figure 50. Percentage of paved area (Klimaateffectatlas, Top10NL)

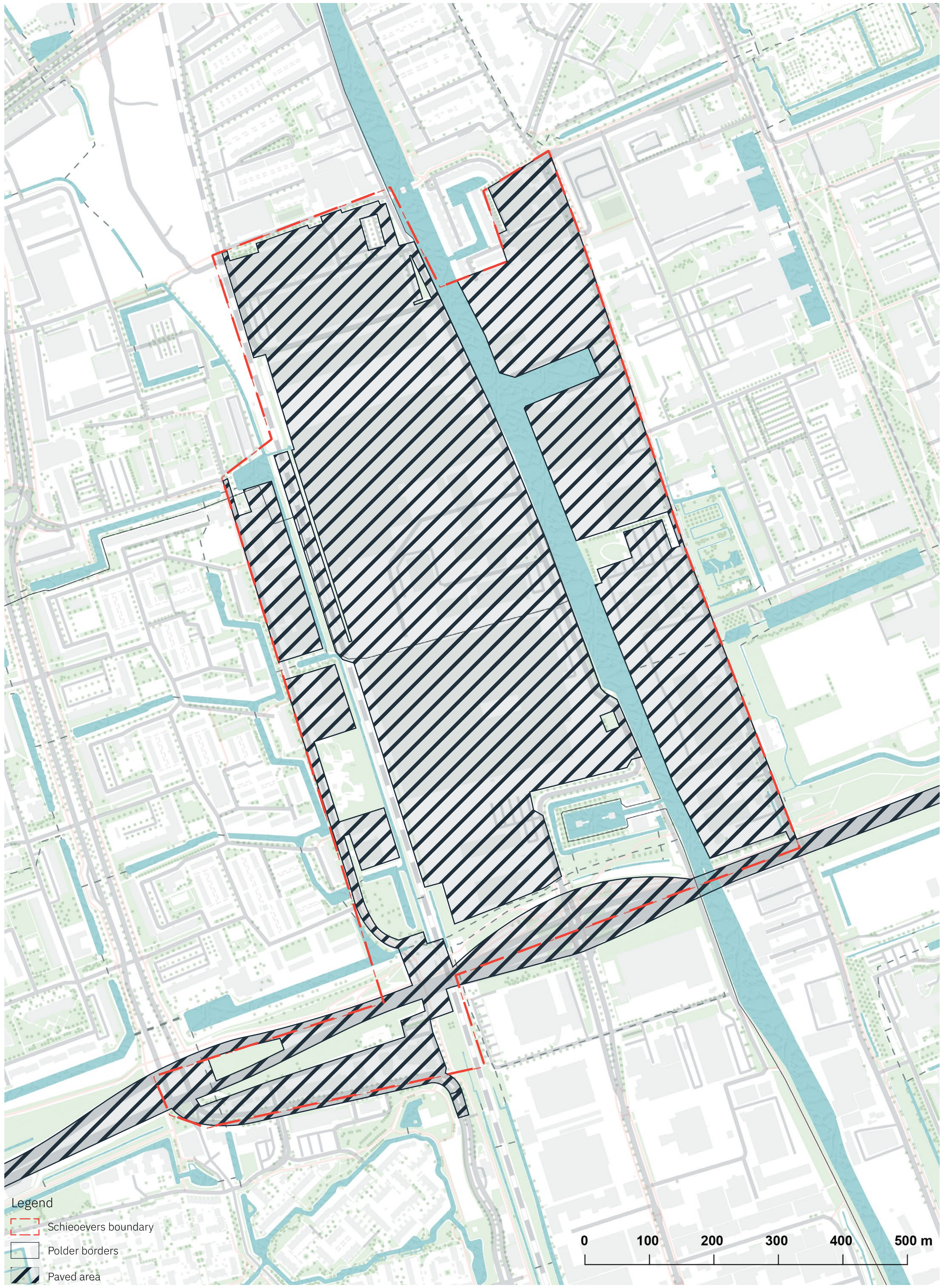


Figure 51. Pavement in Schieoevers Noord

Heat stress

When looking at highest average surface heat island (SHI), which is the difference in the air temperature and the surface temperature in an area, Delft has a very bad score. Delft has the worst SHI at night and the 13th highest SHI during the day out of 73 of the Netherlands biggest cities (Klok et al., 2012). When looking more specifically at Schieoevers Noord, figure 54 shows that the area actually has a higher temperature than most of the surrounding areas (except the city centre).

"Higher temperatures cause a higher mortality rate and affect the health, wellbeing and productivity of people, but also of flora and fauna. Higher temperatures are a direct cause of greater energy consumption for cooling and greater water consumption for cooling and for irrigating green areas. Higher temperatures have a direct impact on the quality of water."

(Pötz, 2016, p. 236)

This quote is a perfect summary of all the negative effects heat has on all aspects of sustainable development. Looking at the trend for heat in the Netherlands, figures 52 & 53 show a clear increase in the length of continuous days with temperatures over 25 degrees Celsius until 2050. This trend, together with the heat stress currently occurring in Schieoevers as shown in figure z, illustrates the importance of combatting heat stress in the development of this area.

Figure 52. Longest string of days with >= 25 C current climate (Klimaateffectatlas, KNMI)

Figure 53. Longest string of days with >= 25 C 2050 (Klimaateffectatlas, KNMI)

Figure 54. Urban heat island effect Schieoevers Noord

Water nuisance

Research shows that rain will increase due to climate change, which, naturally, will increase water nuisance as well, if not dealt with proactively. Figures 55 & 56 show the yearly precipitation in the current climate and in 2050. It can be seen that Delfland specifically will have a large increase in yearly precipitation. In its current situation Schieoevers Noord has a lot of water nuisance after heavy rain. Figure 57 shows the depth of water after a peak rain event currently happening once every 1000 years. It also shows hatched areas which already suffer from these depths of water after a more frequently occurring peak rain event (every 100 years).

Of course, the trend of increasing precipitation of course also means that these peak rain events will become more frequent in the future. Even if once every 100 years might not seem like much, in the future this fequency is going up quickly. One should also note that these peak rain events are not the only ones causing trouble. More frequent but lighter rain events will also cause water nuisance, just not (yet) reaching these depths.

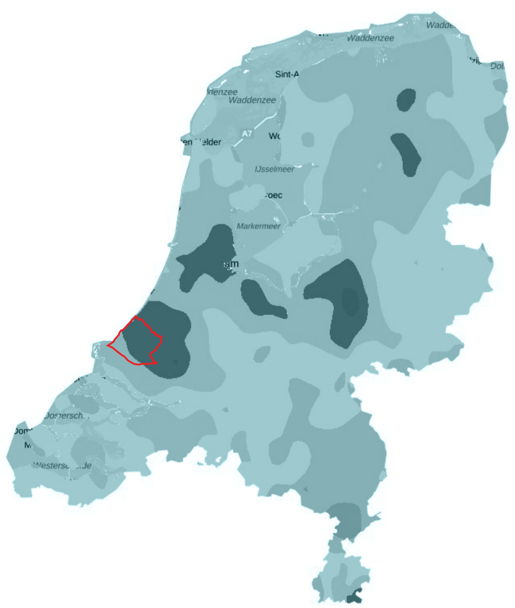


Figure 55. Yearly rainfall current climate (Klimaateffectatlas, KNMI)

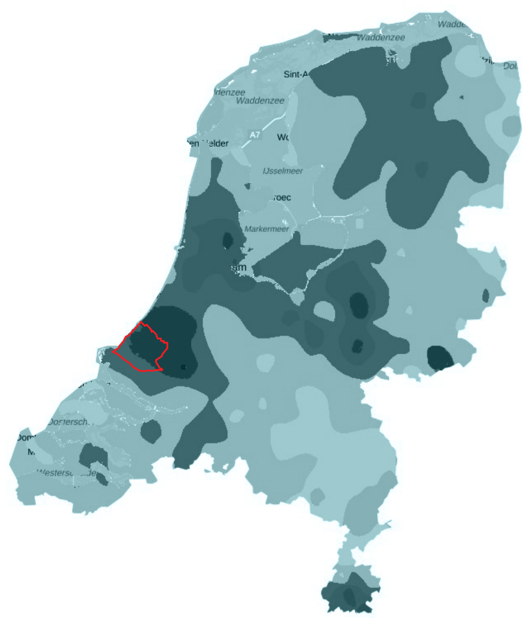


Figure 56. Yearly rainfall 2050 (Klimaateffectatlas, KNMI)

Figure 57. Water nuisance after heave rain

MUNICIPAL PLANS
Development plan Schieoevers Noord

The development plan called “Schieoevers Noord, Delft, Ontwikkelplan”, made by marco.broekman and commissioned by the municipality of Delft, is the main development plan for Schieoevers Noord. It was influenced by two earlier research reports. The first is “Duurzaam Schieoevers” (sustainable Schieoevers) by Metabolic.

“Duurzaam Schieoevers” is a sustainability study that precedes the municipal development plan of Schieoevers Noord. This study focusses on setting guidelines for sustainable development in the area. The municipality deems sustainability a very important issue for development so this plan sets ambitious goals for the energy transition, circular economy, climate adaptation, green environment and sustainable mobility.

The most important area development objectives from this document are:

- All banks of surface water need to be executed in a nature friendly fashion unless it is absolutely impossible.
- 99.5% of weather situations should not cause any nuisance or other problems.
- Schieoevers Noord should have substantial green infrastructure in order to mitigate heat stress and water nuisance.
- Collecting and buffering rainwater could satisfy up to 65% of the water demand (the suggestion is to collect rainwater in underground basins).

(Blok et al., 2018)

The second is the “Milieu Effect Rapportage” (environmental assessment) made by the Antea Group.

The environmental assessment is a mandatory study when making development plans for an area, like Schieoevers Noord. This study dives deep into the possible environmental ramifications of a project, which is done to ensure quality information on the environment will always be available for decision making. This environmental assessment covers five themes; program, mobility, quality of the environment and sustainable design.

The most important decisions of this environmental assessment are:

- The municipality needs to set guidelines for the FSI, FMI and building height in the development plan.
- The area should have enough green spaces to motivate movement, meeting and playing.
- Every development needs to account for reducing heat stress in the area.
- The area should have a intricate, robust surface water system that meets ledger requirements, has good circularity and, whenever possible, has nature-friendly banks.
- Public spaces should be designed in a rain-proof manner, heavy precipitation (up to 20mm)
  should not negatively impact uses of public space.
- The preferred order of dealing with rainwater is: Reuse, retain, store and lastly (delayed) drainage.

(Lindeboom & Verhoeven, 2019)

The municipal plan for Schieoevers Noord is a very crucial part of this thesis. In order to understand the steps taken in the next parts of this thesis it is important to know more about this development plan. This is why this chapter will touch upon the topics and decisions from the development plan that fall within the scope of this thesis.

The plan was made in cooperation with stakeholders like TU Delft, the province of Zuid-Holland, BKS (a group of companies in Schieoevers), developers and even the public, including residents and business owners. The document is meant as a starting point for a frame of reference for further development. It shows the direction the municipality wants Schieoevers Noord to goin, in the future. The municipality aims to let developers suggest innovative solutions within its guidelines, as they do not want to strictly control all developments and will therefore not purchase any land.

The document also shows the different planning steps in the development plan. The first areas to be developed until 2030 are sub-region 3, 4, 8 and 12.

Figure 58. Sustainable Schieoevers front page (Metabolic, 2018)

Figure 59. Environmental assesment front page (Antea Group, 2019)

Figure 60. Goals for Schieoevers Noord (Municipality of Delft and Marco.Broekman, 2019)

The other sub-regions will start development after that, because the existing uses need time to relocate. The areas planned for early development are either already mostly vacant, or in the case of area 3, the station is a very important part of development that will affect all other development in the area.

As mentioned in the introduction, this development plan has five main focal points. The one most important in this thesis is the fourth one: Healthy and sustainable surrounding. This chapter shows all guidelines for greenery, sustainability and water. The most relevant points of the development plan used in this thesis are divided into three categories: Greenery, Water and Infrastructure. These three categories are also illustrated in the green-blue framework in figure 62 and the infrastructure framework in figure 63.

Greenery

Greenery is a very well represented subject in the development plan. A lot of green structures and guidelines have been set up in the plan. This is supported by the statement that greenery (and water) are supposed to be implemented in order to help achieve the sustainability goals of Delft. The most obvious green structure is the Schiepark, which is a park stretching the entire length of the west bank of the Schie. Its varying width gives this park a diverse feel and allows for different activities. This park is one of the most important staples of the development of Schieoevers Noord. Apart from the large park there are also pocket parks spread throughout the area to ensure that users will always have green space close by. There are 9 requirements set up for these pocket parks shown in Figure 61;

1. There should always be a green space or park within 75 metres of any residence in Schieoevers Noord.
2. Pocket parks need to be at least 400 m^2 (20 m by 20 m)
3. The pocket parks need to be publicly accessible and easy to reach from roads and paths.
4. There should be as little pavement as possible.
5. At least 50% of parks should be designed as a shaded, cool area.
6. All parks should have seating available.
7. All parks should have a unique identity to increase diversity of green spaces.
8. Planting should be carefully chosen to serve one or more target species including specific biotopes natural to Schieoevers.
9. It is encouraged to improve ecological value by adding specific elements catered towards target species, for instance insect hotels or nesting sites for birds.

Buildings in Schieoevers Noord also have to be as nature-inclusive as possible. The plan states that 100% of the area of the footprint of a building should come back as green elements on the building itself; this could for instance be on the roof or the facades.

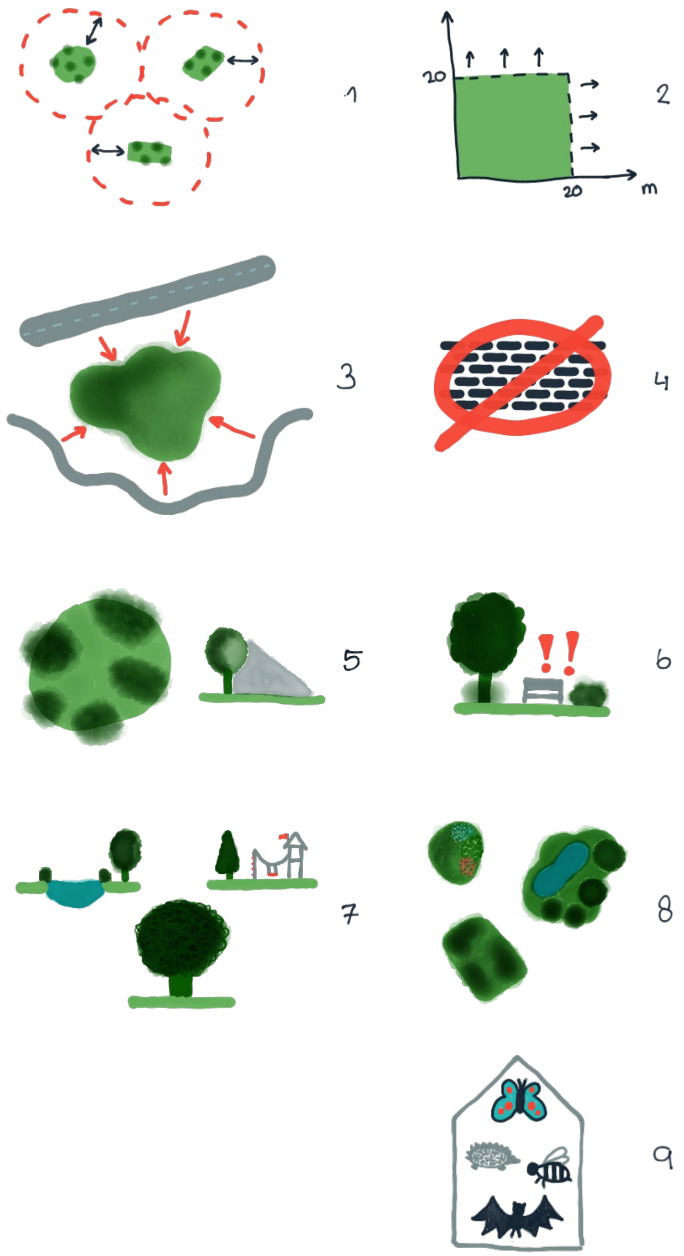


Figure 61. Rules for pocket parks

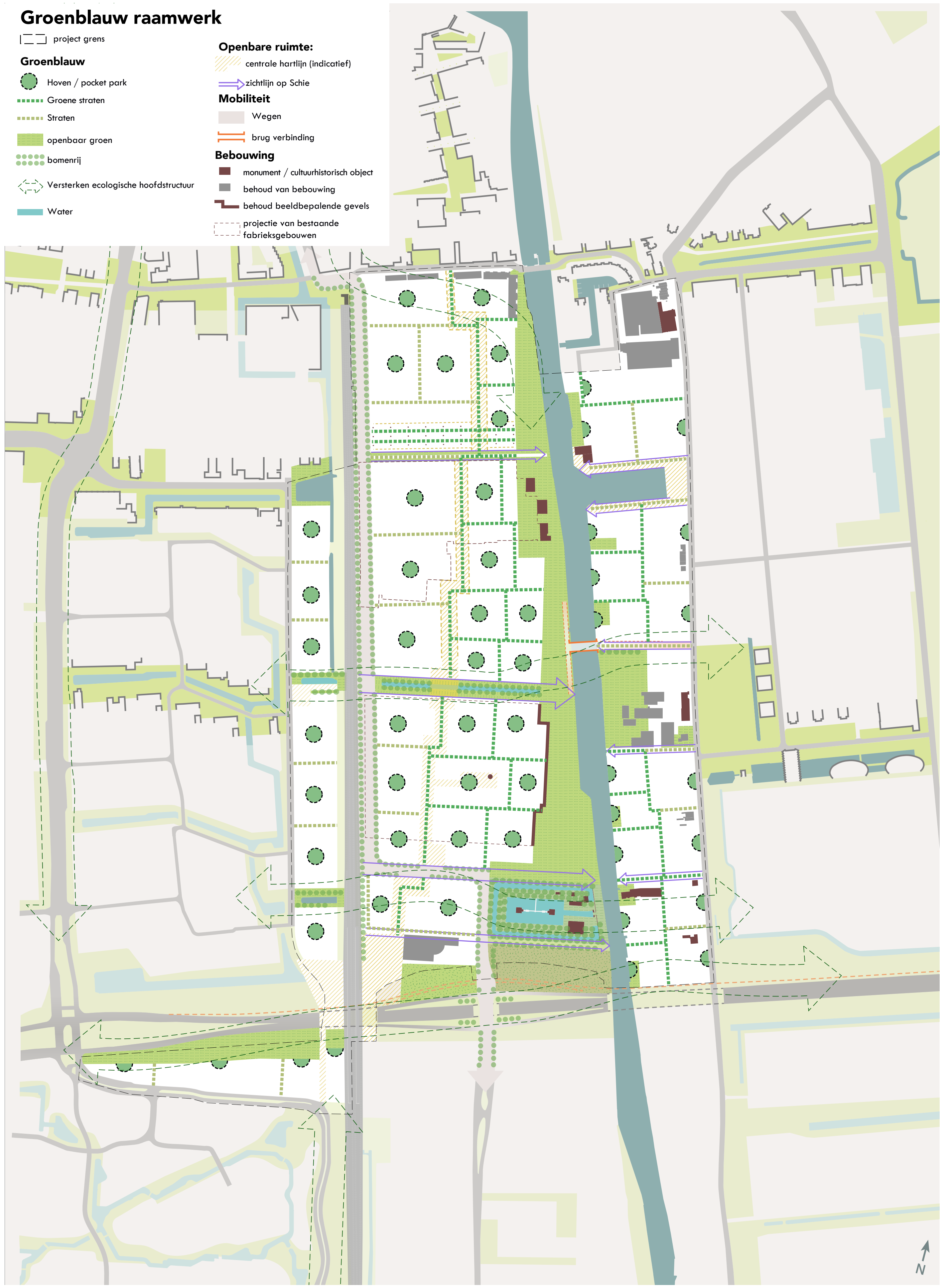


Figure 62. Blue Green Framework map (Municipality of Delft and Marco.Broekman, 2019)

Water

Even though the plan states that water and greenery should form the foundation of the development, water is actually not as well represented as expected. There are a lot of strong guidelines for climate adaptivity and rainwater retention, but hardly any guidelines for handling surface water in the area. Several guidelines form the basis of climate adaptivity in Schieoevers Noord. It is expected that rain will cause a lot of problems, if not properly handled. The municipality states that the focus is on retaining rainwater where it falls, with storage locations under and on top of buildings. They say that all roofs should have water retention and at least one other function. For lower (parts of) buildings the emphasis is on green or usable outside space, while for higher buildings the emphasis is on solar energy collection. To ensure the green spaces in Schieoevers Noord can withstand the dry summer months, at least 200 litres of water per squared metre of green space should be buffered.

In reference to surface water the municipal plan mentions that Schieoevers Noord shows promise and that the large-scale development provides the opportunity to add surface water to the area. It also notes however, that due to the complex nature of the water system achieving circularity in the water flow will be challenging. No further mentions are made on the topic of surface water.

Infrastructure

Infrastructure is not the main focus of this thesis, however, there are some points in the municipal plan which are important to mention in order to create a general figure of the structure of Schieoevers Noord. There is a strong emphasis on traveling on foot, by bicycle or using shared mobility instead of personal motor vehicles. The aim is to create the mobility infrastructure in such a way that it will instigate a paradigm shift in the decision process of the future occupants. They should be gently nudged towards more sustainable mobility options through the design of the public space, for instance by giving more room to pedestrians and cyclists. An important decision on this topic is to flip the busy Schieweg so that it will be located along the train tracks in the west of Schieoevers Noord, instead of along the bank of the Schie. The municipality has also established profiles for the different types of mobility infrastructure present in the plan. These profiles were used in the calculations in the next chapter.

Buildings in Schieoevers Noord will be mixed industrial, commercial and residential, which means that the sizes of buildings needed vary a lot. The absolute maximum size of industrial buildings will be 3000 to 5000 m^2, of which only a few (less than a handful) are allowed to exist. The rest of the building sizes are divided as follows; 20% 1000 to 3000 m^2, 40% 500 to 1000 m^2 and 40% 150 to 500 m^2. Intricate building blocks with multiple smaller buildings are preferred, because they result in a more dynamic public space with crossings and meeting places for pedestrians.

Building heights have also been set, ranging from 25 m to 90 m between the different sub-regions. Important to note is that all buildings higher than 4 or 5 stories are required to have an offset in their higher segment. This is done to conserve the human scale in the public space. Lastly the municipality has also decided that the plinth, or ground floor, of buildings should be between 6 m to 8 m high to establish an open character towards the street and allow for flexible use of space.

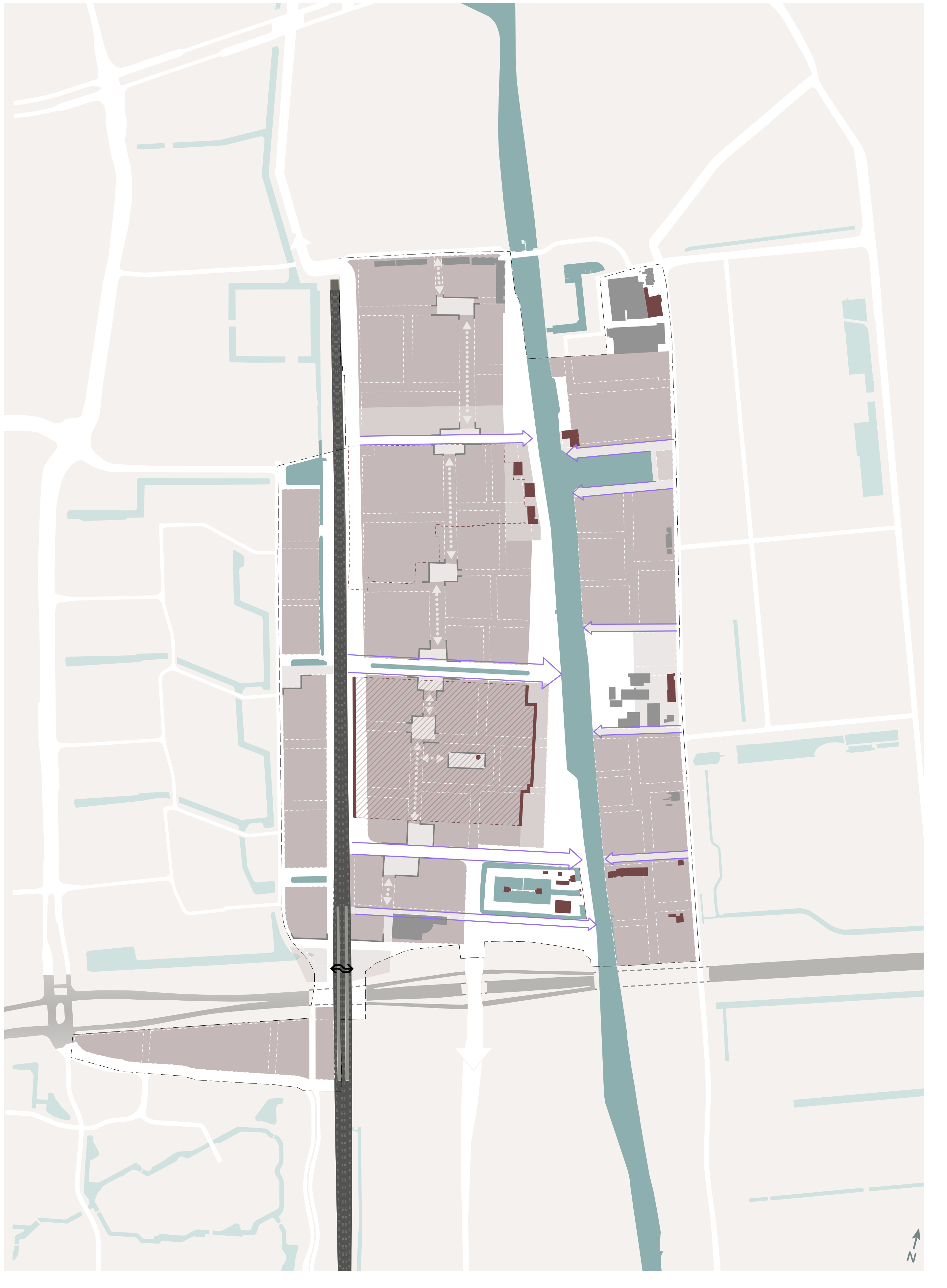


Figure 63. Map with building block borders (Municipality of Delft and Marco.Broekman, 2019)

SPACE MATRIX
Example calculation sub region 5

The space matrix is a visual calculation meant to show the amount of available space in the sub regions of Schieoevers Noord. This calculation will stretch to the limits of the guidelines set by the municipality by, for instance, using the maximum building height and therefore the minimal footprint for new buildings.

To illustrate the space matrix calculation this is a step by step showcase of the calculation for sub-region 5, the region marked in figure 64. The total surface area of this region is 50.480 m².

The space matrix calculation is done in several steps. First the total area of a sub region is displayed in 50,5 squares (Figure 65). Then the minimal surface area for the footprint of buildings will be marked on the squares to show how much space they will take up. A 20% buffer was used to account for inaccuracies. Next, the footprint of the mobility infrastructure and existing structures are also calculated and marked in the squares.

In some sub regions there is also existing water that is taken into account. Finally an area of 10% of the entire area of the sub-region is marked for unforeseen other elements that need to be added. The leftover empty squares will illustrate the available space per sub region.

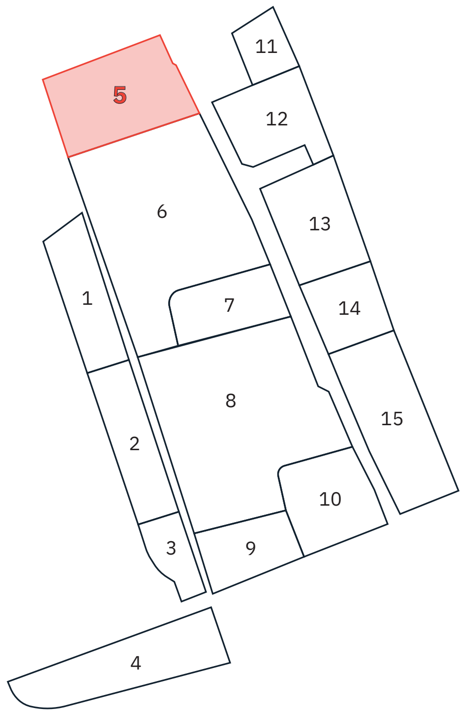


Figure 64. Highlighted sub region 5

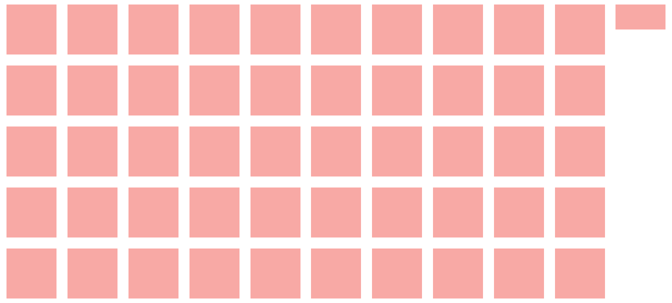


Figure 65. Blocks representing area of sub region 5

10% Buffer

A_{buffer} = 5048 m² **-> 5.1 Squares**

Maximum building height

H_{max} = 30 m

Number of floors

$N_v = 1 + ((H_{max} - 7) / 3 = 8$

Floor space index

FSI = 1,70

Total area of builings

A_b = FSI x A_{reg} = 85.816 m²

Minimal footprint new buildings

$A_{foot} = A_b / N_v$ = 10.727 m² **-> 10,7 Squares**

Footprint mobility infrastructure

1. Schieweg	- 30 m wide
2. Working street	- 15 m wide
3. East-West Narrow	- 15 m wide
4. Heart street	- 20 m wide

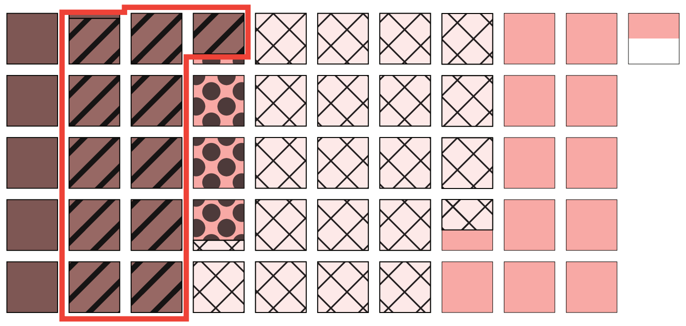
[30 m] x [175 m long] =	5250 m²
[15 m] x [380 m long] =	5700 m²
[15 m] x [300 m long] =	4500 m²
[20 m] x [215 m long] =	4300 m²

A_{mob} = 19.750 m² **-> 19.8 Squares**

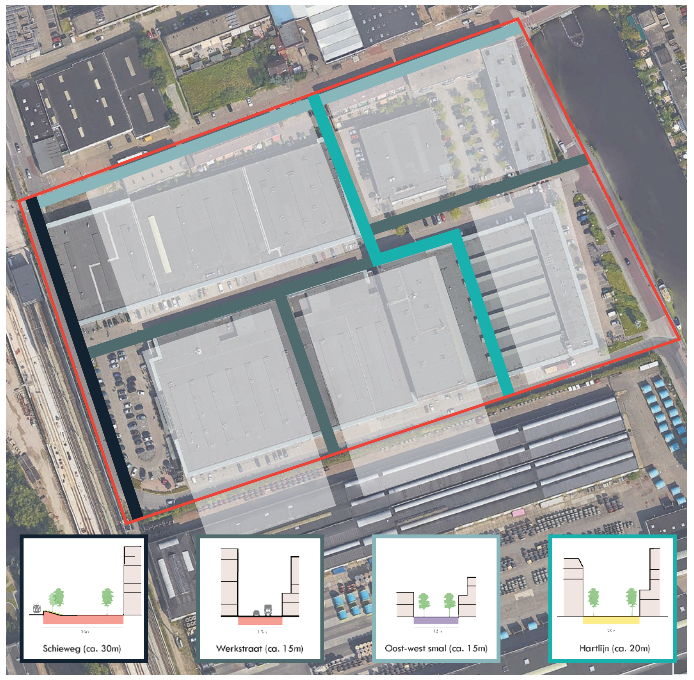
Total footprint existing structures

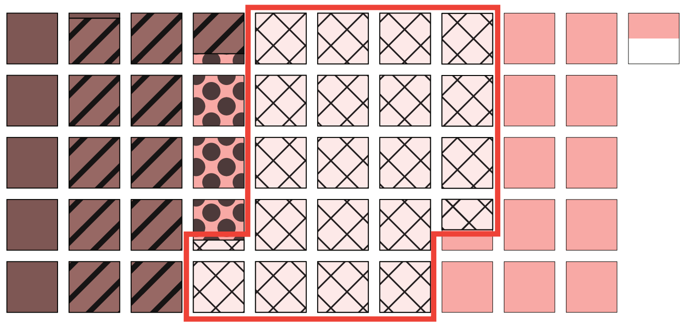
A_{built} = 2.957 m² **-> 3,0 Squares**

New buildings

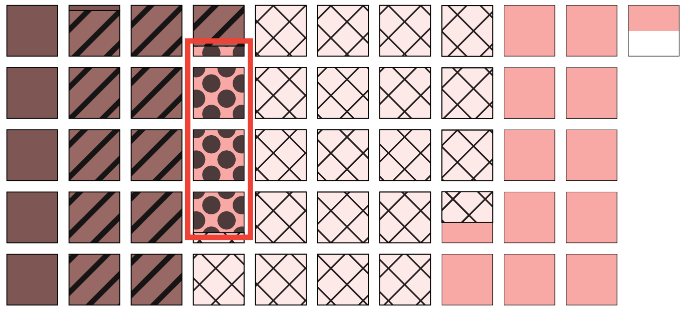


Mobility infrastructure





Existing structures



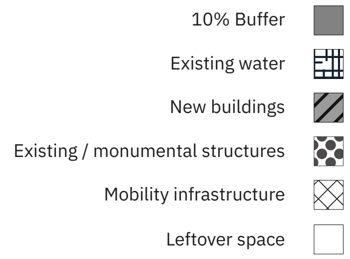
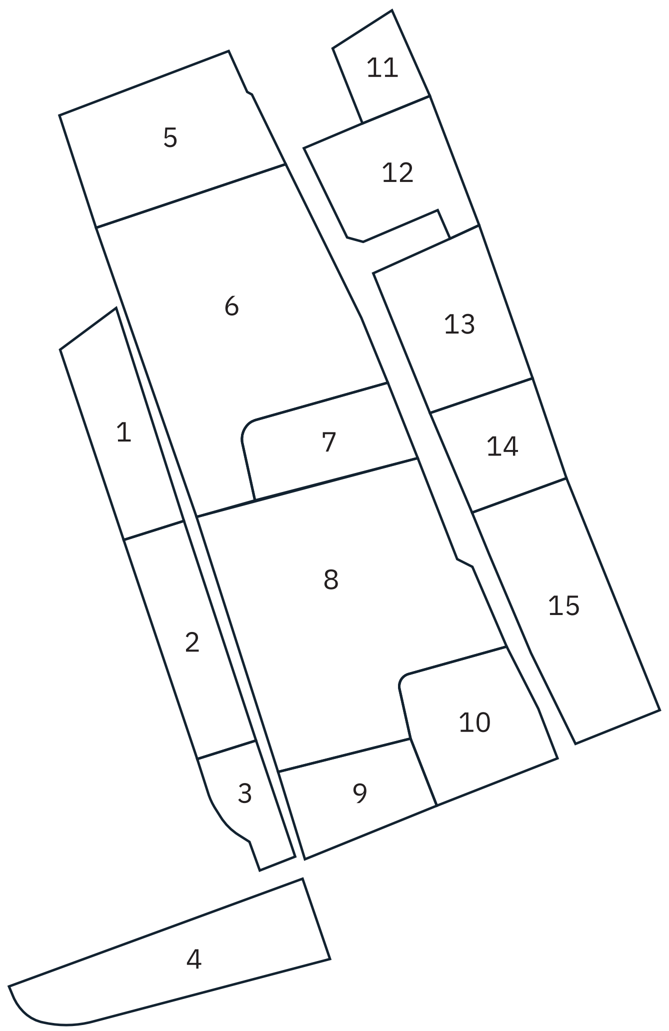


Figure 66. New building footprint representation
Figure 67. Mobility infrastructure area representation
Figure 68. Existing structures area representation

SPACE MATRIX
Conclusion

Illustrated here are the results of the space matrix calculations for the other sub-regions. This data will be used as a basis to test the feasibility of the water system strategies and final proposal at the end of this thesis.

Even when following the building guidelines stipulated in the current municipal development plan, it can be concluded that most sub-regions have a sizeable amount of open space to work with, after all variables are taken into account. The available ground identified by the calculations represents an opportunity for the implementation of surface water, among others, which would mark an opposition to the municipal plan discussed in an earlier chapter of this thesis.



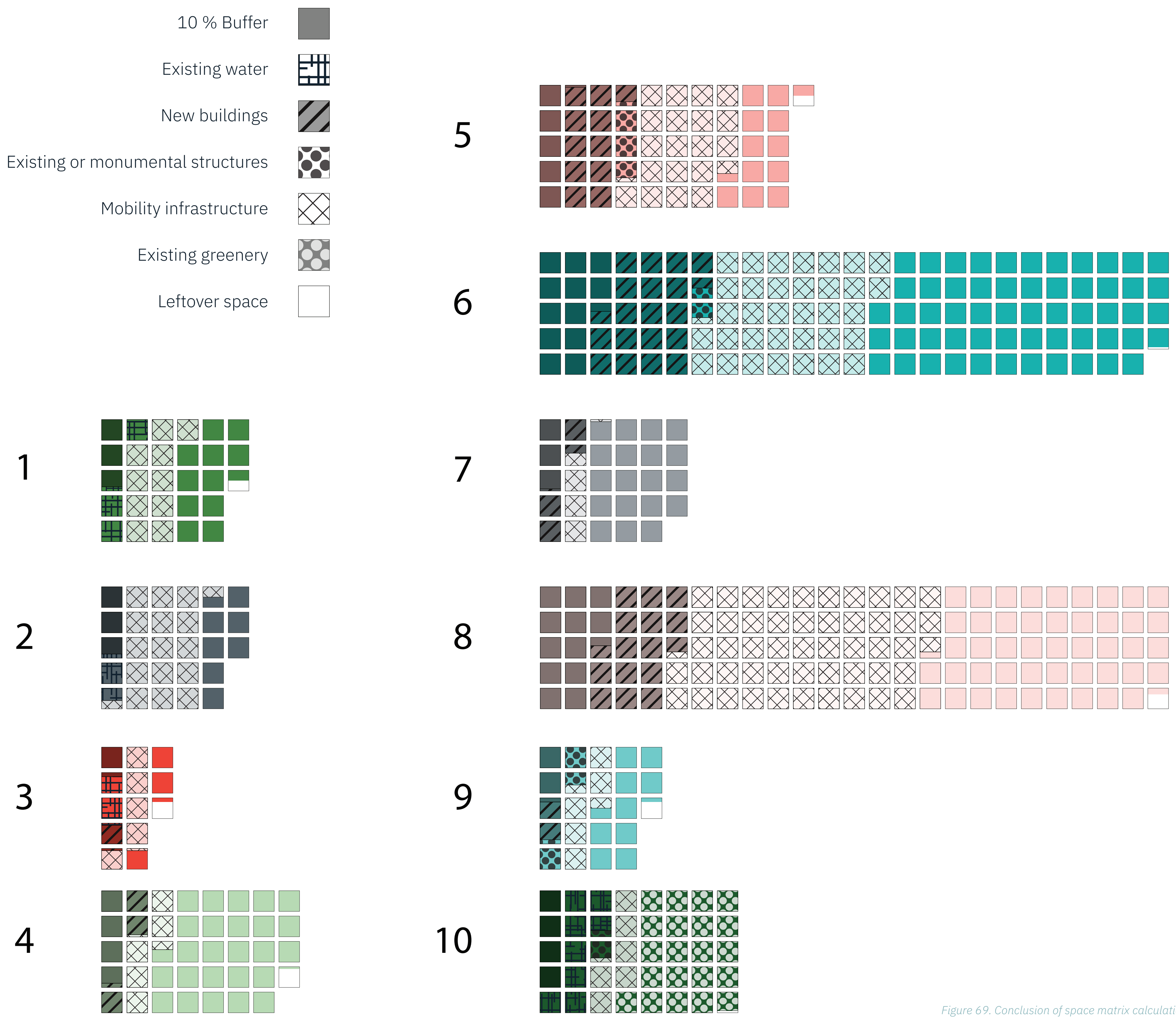


Figure 69. Conclusion of space matrix calculation

REFERENCES AND VISUALISATION
Lower density - higher buildings

In the development plan for Schieoevers the municipality states they want Schieoevers Noord to become a metropolitan area. In some sub-regions the maximum building height goes up to 90 metres. They also illustrate this in the birds-eye visualisation of the area. However, when looking at the references they show, the building height hardly goes above 15 stories. When looking at the density with which the buildings are drawn in the maps there wouldn not be a lot of space left for incorporating a surface water system. That's why the space matrix calculation was an important tool to show there are other options.

The space matrix calculation was done based on the minimal possible footprint of buildings, which means they are built as high as possible, sometimes going up to 28 stories. By making the buildings a bit higher more space is left for greenery and water, without losing the metropolitan building style. To give an impression of the types of buildings this page shows some references that match the building heights used in the space matrix calculations.

Figure 70 is a render of twin skyscrapers for Vancouver, which are a little higher than towers in Schieoevers Noord (168m), but they do illustrate the green yet metropolitan style that Schieoevers should have. They were designed by Büro Ole Scheeren. They are supposed to be vertical villages, with the irregular shapes creating spaces for terraces and greenery.

Figure 71 and 72 show impressions of the Sluisbuurt plan from the municipality of Amsterdam. Sluisbuurt has a lot of aspects in common with Schieoevers Noord, which makes it a great reference project. It is an area with a very high demand for housing, it is mixed use, it has a park on a water defense structure and is thus also located along the water. They decided to use high, slender towers in order to leave a lot of open space and greenery. (Beaufort, n.d.)

Figure 70. Reference Barclay Village (Büro Ole Scheeren, n.d.)

Figure 71. Sluisbuurt (Gemeente Amsterdam, BOOM Landscape, & BurtonHamfelt Urban Architecture. 2018)

Figure 72 - Sluisbuurt (Gemeente Amsterdam, BOOM Landscape, & BurtonHamfelt Urban Architecture. 2018)

PRINCIPLES OF WATER MANAGEMENT

This chapter will touch upon the general principles of surface water systems and the climate adaptation measures that are of importance for designing a water strategy in an area like Schieoevers Noord. It will also highlight some issues pertaining to the water system that are specific to Schieoevers Noord. These principles combined will form a strong base for evaluating any possible strategies later on in this thesis.

IMPORTANT IN SCHIEOEVERS NOORD

The train tunnel

When adding surface water to Schieoevers Noord the train tunnel entrance can be a limiting factor. The tunnel structure needs to be heavy enough and stable enough to counteract any upwards force from water. This is because, if the ground water level increases the pressure on the structure also increases.

Other than that, the surface should also be designed in such a way that rainwater falling near the train tunnel entrance does not flow into the tunnel. Even if most of the rainwater flows away from the tunnel, the tunnel should still have sufficient pumping capacity, so the water that falls directly into the entrance of the tunnel, can be pumped out.

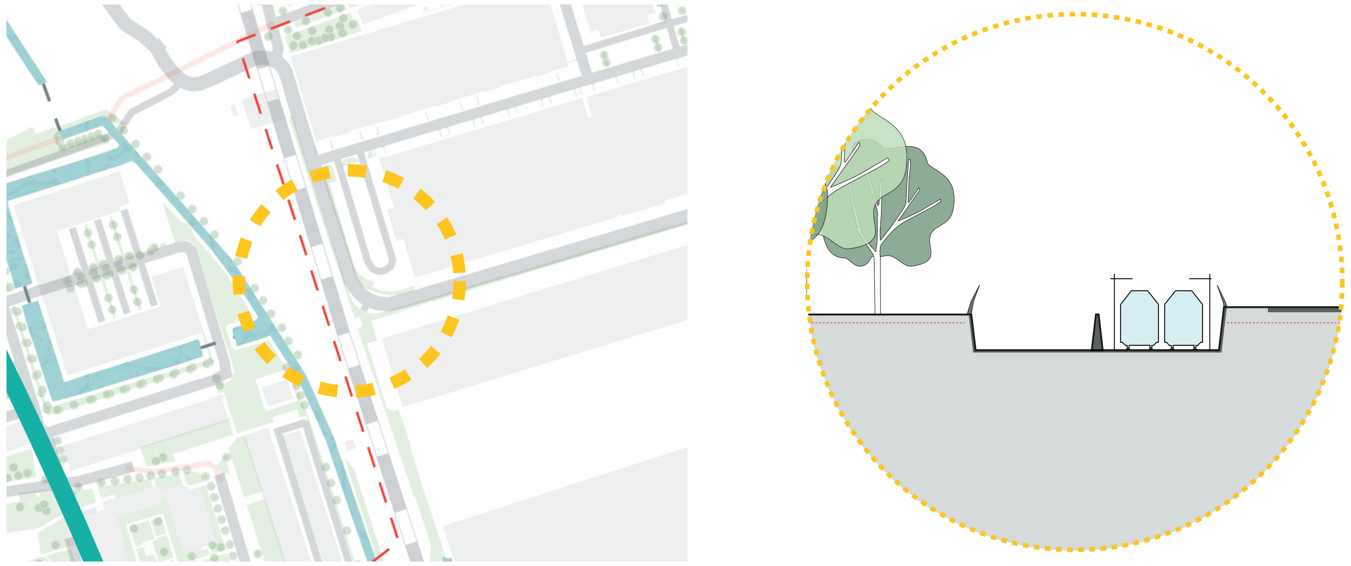


Figure 73. Train tunnel zoom-in

The height differences

The ground level difference was mentioned earlier in the water system analysis and the sections of Schieoevers Noord. When designing a strategy for surface water in Schieoevers Noord, the height difference makes it more complex to connect any future surface water in Schieoevers Noord to that in the rest of the higher and Lower Abtwoudse polder. Even if the design of the surface water system has enough static storage to solve the shortage in Higher Abtwoudse Polder, it will still need a pumping station that has a high enough capacity to exchange the water between the level differences.

Figure 74. Height differences zoom-in

The protection zone of the flood defences

A regional water protection structure like in Schieoevers Noord has three distinctive zones: The structure itself, the protection zone and the free space profile. These zones all have degrees of restriction in their use of the land. The structure itself is the main dike, like shown in ledger profile; the protection in this area is very high, because the stability of the dike is essential. The protection zone is a strip right along the actual dike. This zone has protections to ensure no activities that might harm the stability of the dike can take place here. Finally, the free space profile is the space around and also above the dike that is protected to ensure access for potential future expansion of the dike. This last zone is not always used, it is usually just there, if the water authority expects that an expansion of the dike will be necessary in the foreseeable future (Hoogheemraadschap Delfland, 2014).

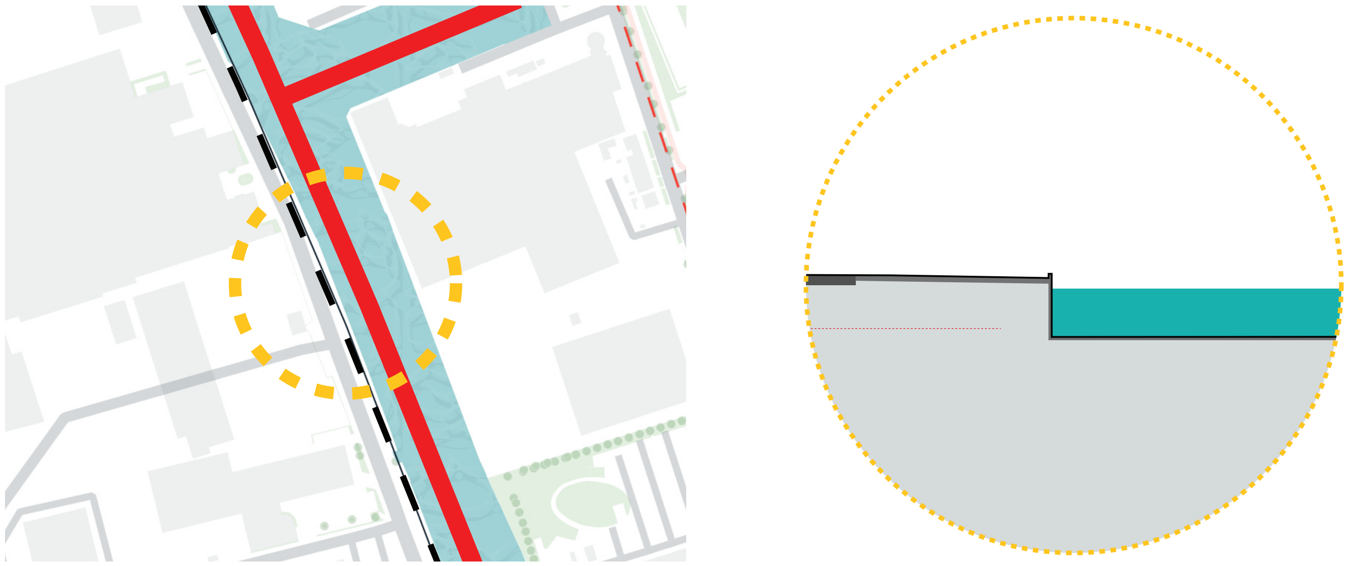


Figure 75. Regional water defenece structure zoom-in

SURFACE WATER PRINCIPLES

Retain, Store, Drain

The end of the 20th century has shown that the Dutch water system was not in order. Heavy rains put the system under pressure. The Dutch government realized that a new water plan needed to be made. To find ways to deal with water in the future, a committee on water management in the 21st century was created.

A key conclusion for handling water at polder scale from the advisory report made by the committee is retain, store, drain. This is now one of the most important principles in the design of surface water systems. When rain falls, the first thing that should happen is retaining water where it falls in groundwater or surface water systems. If there is a shortage of static storage, water can temporarily be stored in seasonal buffers of buffer spaces like wadi's, retention ponds or under buildings. If all of these are full or fail the last and least preferred option is to drain water into the sewer system or from the polder system into the bosom system.

(Stumpe & Tielrooij, 2000)

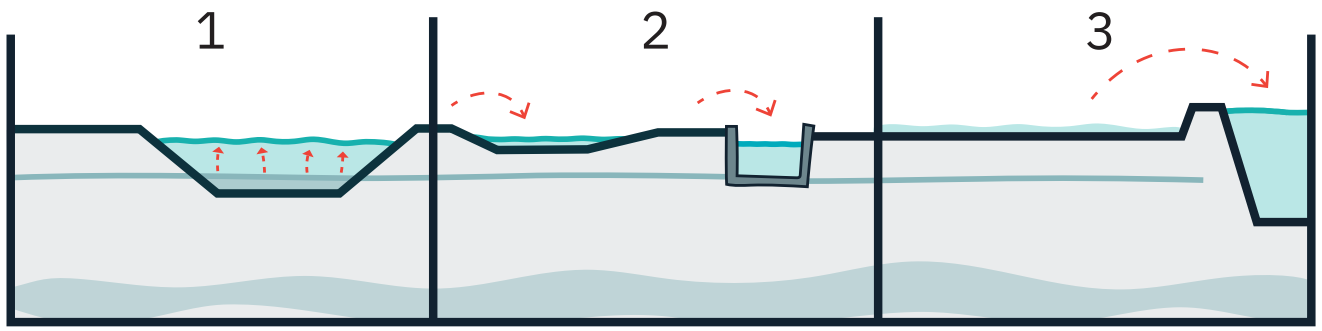


Figure 76. Retain, Store, Drain

Circulating, integrated system

The surface water system should always be circular. There should never be dead ends in the system, because that would lead to the water being stagnant in some places.

Any new water that is supposed to belong to either the Lower or Higher Abtwoudse polder should connect to the rest of the system using the existing structure of weirs and pumps. However, it should also be a selfsustaining system and it should not negatively affect the rest of the polder system.

The system should be designed in a way which ensures minimal exchange of water from the bosom, because that would negatively affect the water quality. If possible, it would be good to allow for a flexible water level, which would greatly increase buffering capacity. If the new water system exceeds the necessary buffering capacity of its own area, it could function as a temporary buffer for surrounding areas that have less buffering capacity. In that way these surrounding areas will also become less dependent on exchange between the polder and bosom water.

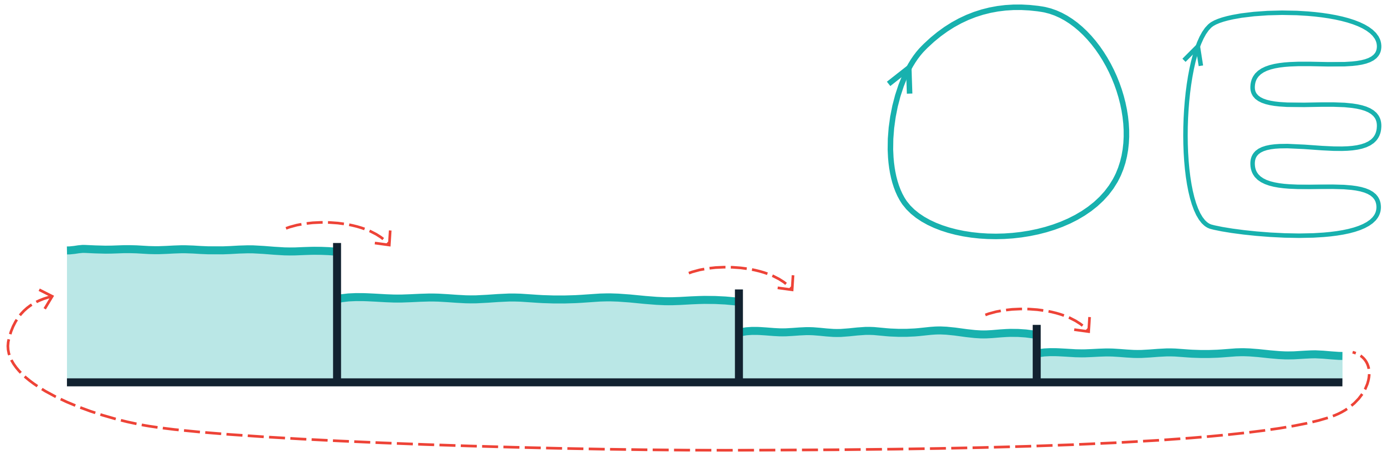


Figure 77. Circulating water system

Nature-friendly banks

Nature-friendly banks are those that have a very gentle slope. The ratio should be at least 1 to 4, but preferably even longer. This way of designing the banks of a waterway improves the water quality and adds ecological benefits.

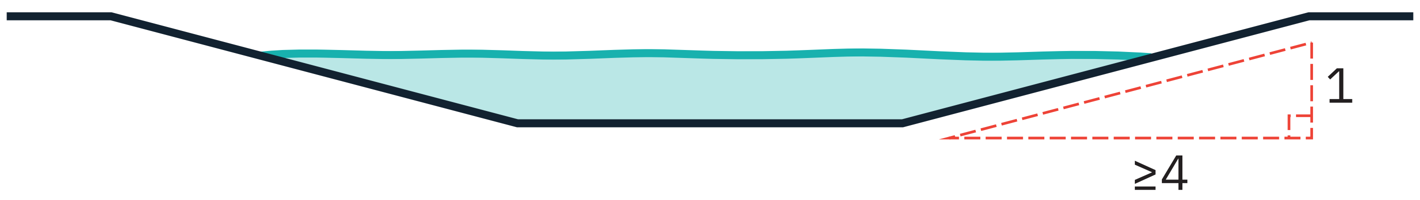


Figure 78. Angle of nature friendly banks

SURFACE WATER PRINCIPLES

Wet berms

An alternative type of eco-friendly banks is a wet berm, like shown in figure 79. Apart from the opportunity to add helophyte filtering plants in the shallow stretch, this option is also safer for small children.

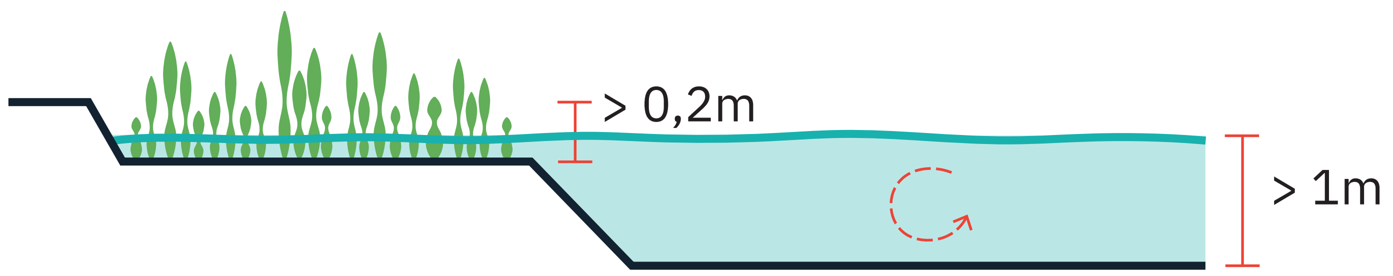


Figure 79. Wetberm system

Sun facing side

In case there is just enough space to realize an eco-friendly bank on one side of the water, the preference should usually be the side that gets the most sunlight. This side will be the best for sustaining the plant and animal life.

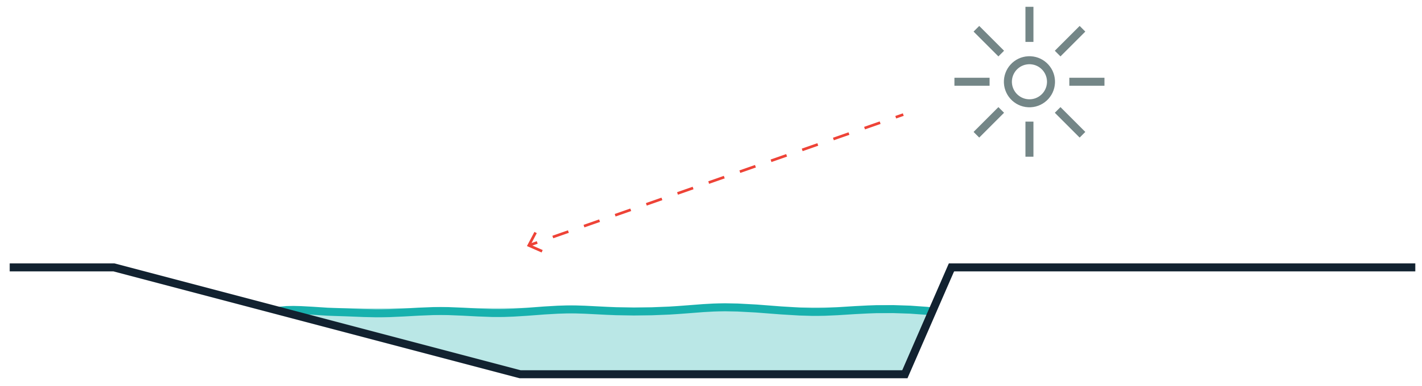


Figure 80. Sun facing nature friendly bank

Connected ecosystems

Additionally, it is also important for small creatures to be able to travel around. If the eco-friendly banks would alternate from one side of the water to the other, like in figure 81, this would be a lot more challenging.

Even though this would theoretically be considered the best system, in this case it could be better to change the eco-friendly bank to the other side or, even more preferable, have both sides be eco-friendly.

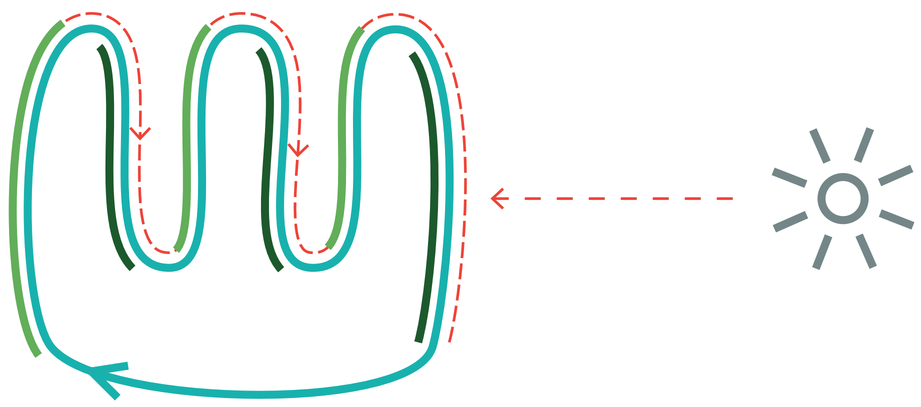


Figure 81. Connected ecosystem

SURFACE WATER PRINCIPLES

Minimal width

To allow maintenance vessels access to the waterways, the width of the water should be at least 6 metres. This way it is easier for the vessels to manoeuvre and undertake the periodic maintenance.

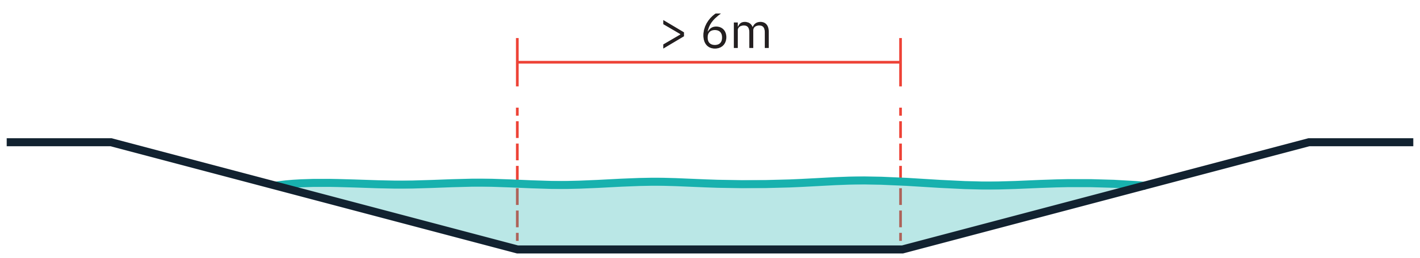


Figure 82. Minimal width of the water

Levee protection zone

In Schieoevers Noord the west embankment of the Schie is actually also a regional flood barrier. This means there is a protected zone around it.

First there is a strip called the "core zone", which is about 7 metres from the water edge. After that, there is a strip of about 15 metres called the protection zone (Hoogheemraadschap Delfland, 2014). There are limited possibilities for building or changing this zone, because its preservation is important for the flood protection system.

If, for instance, a surface water stream is dug too far inside the protection zone, water might seep from the bosom through the ground and into the polder system. This phenomenon is called seepage. If the seepage becomes too strong sand could start welling up (piping). And in turn when the sand under the levee disappears, it could lead to the collapse of the levee.

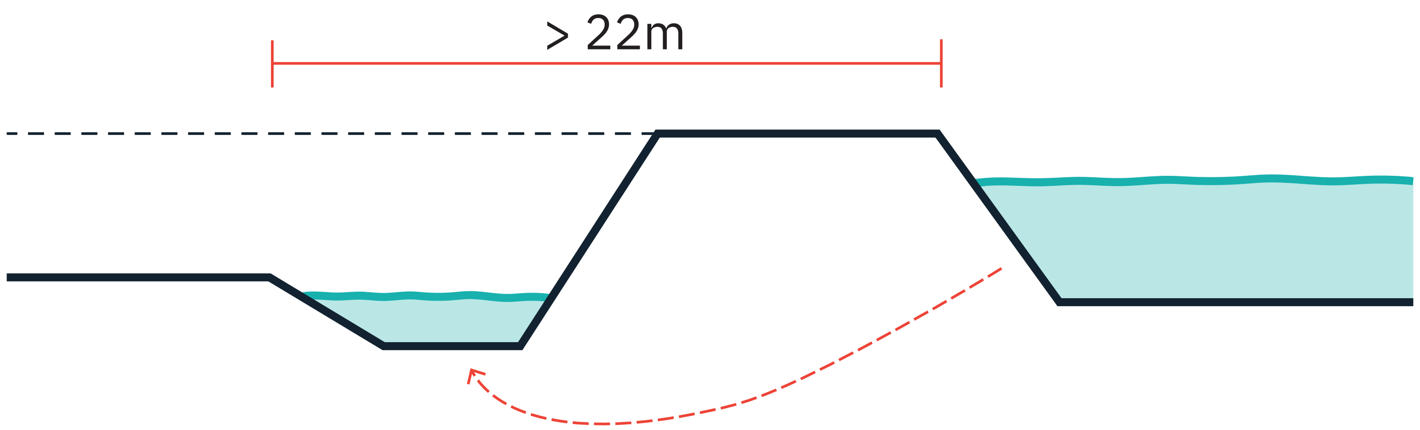


Figure 83. Preventing seepage

High bridges

When designing bridges it is important to leave as much of the eco-friendly bank intact, from one side to the other. This will help the ecosystems to stay connected and allows small animals to migrate through it.

It is also important that the water under the bridge still gets as much light as possible, in order to sustain the ecosystem.

This means that bridges should be as narrow as the function allows them to be and should preferably arch over the water. If an arch is absolutely impossible, the second option is to build the bridge straight across. If even that is not possible, the final, and least desirable, option is to build a diver under the road instead of a bridge over the water. This last option has a negative effect on the water quality and aquatic ecosystems, so it should only be used, if there are no other options.

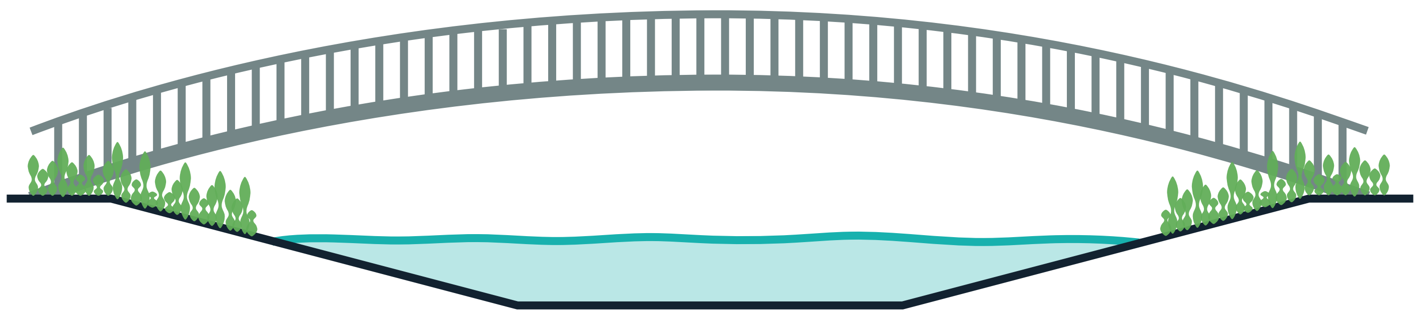


Figure 84. High, arching bridges

CLIMATE ADAPTATION MEASURES
Green-Blue Grids and the Climate Resilient Cities Toolbox

The other set of principles for water in Schieoevers Noord are climate adaptation measures. Technically they are more than just measures for water, but the focus in this project is on the measures that deal with water and heat. The other topics for are: Biodiversity, urban agriculture, air quality and energy. Green-Blue Grids (2016) has combined all these measures and scored them on efficiency, social importance, multifunctional space usage and costs. A selection of the measures from Green-Blue Grids will be used in this chapter.

Aside from the ranking by Green-Blue Grids, the measures will also be looked at in a software called “Climate Resilient Cities Toolbox”. This is an online software that allows users to input measures into their project area and study the effects. The software has been developed in collaboration of Deltares, Wageningen University, Atelier Groenblauw, TNO, Bosch Slabbers, Tauw and Hogeschool van Amsterdam.

The software is meant to be used in the exploratory / planning phase of a climate adaptation strategy on the neighbourhood or street scale. The toolbox holds 40 different measures, which are all interventions against pluvial flooding, river flooding, drought or heat stress. The tool can be used in the risk dialogue between stakeholders with different backgrounds, like professionals and residential representatives. It shows how to make the project area more climate-proof by, for instance, creating scenarios with different combinations of the interventions. The toolbox will show the effectiveness of a scenario, the amount of space needed and the costs for construction, management and maintenance. All the outcomes are based on numbers that come directly from practice, but are adjusted for the Dutch climate. These scenarios can then be set against previously set adaptation goals.

(Ruimtelijkeadaptatie/Deltares, 2019)

The measures that are currently available in the software are:

- Adding trees to streetscape
- Increasing surface water area
- Storage by realizing extra height
- Hollow or slanted roads
- Water squares
- Infiltration fields or lanes with surface storage
- Temporary levee
- Rainwater detention ponds
- Green roofs
- Green roofs with drainage delay
- Urban forests
- Cooling with water elements (ponds)
- (small) Quays
- Creation of shaded areas
- Permeable pavement with storage
- Softening of the surface
- Permeable pavement
- Blue roofs / water roofs
- Cool materials (High albedo)
- Drought resistant species
- Drainage-infiltration-transport (DIT) sewer
- Green façade
- Fountains, waterfalls or water facades
- Deep groundwater infiltration
- Urban wetlands
- Building as levee
- Infiltration boxes
- Wadi’s / bioswale with drainage
- Underground storage basement
- Gravel trunks
- Rain barrels
- Dikes
- Ditches
- Smart irrigation
- Lowering terrace
- Smart irrigation measures

Technical values available in the software:

Climate
- Storage capacity [m^3]
- Return time factor
- Groundwater recharge [mm/year]
- Evapotranspiration [mm/year]
- Heat reduction [°C]
- Cool areas [number]

Costs
- Construction [€]
- Maintenance [€/year]

Water quality
- Pathogen reduction [%]
- Nutrient reduction [%]
- Adsorbing pollutants [%]

A selection of adaptive measures is made to fit the needs of Schieoevers Noord. The selected measures will be elaborated upon further in the rest of this chapter. The selection is based on the municipal development plans. In these plans multiple options for climate adaptation measures came forward and were discussed.

For the comparison and ranking of the principles that are selected for Schieoevers Noord, a combination of both the software and the Green-Blue Grids results will be used.

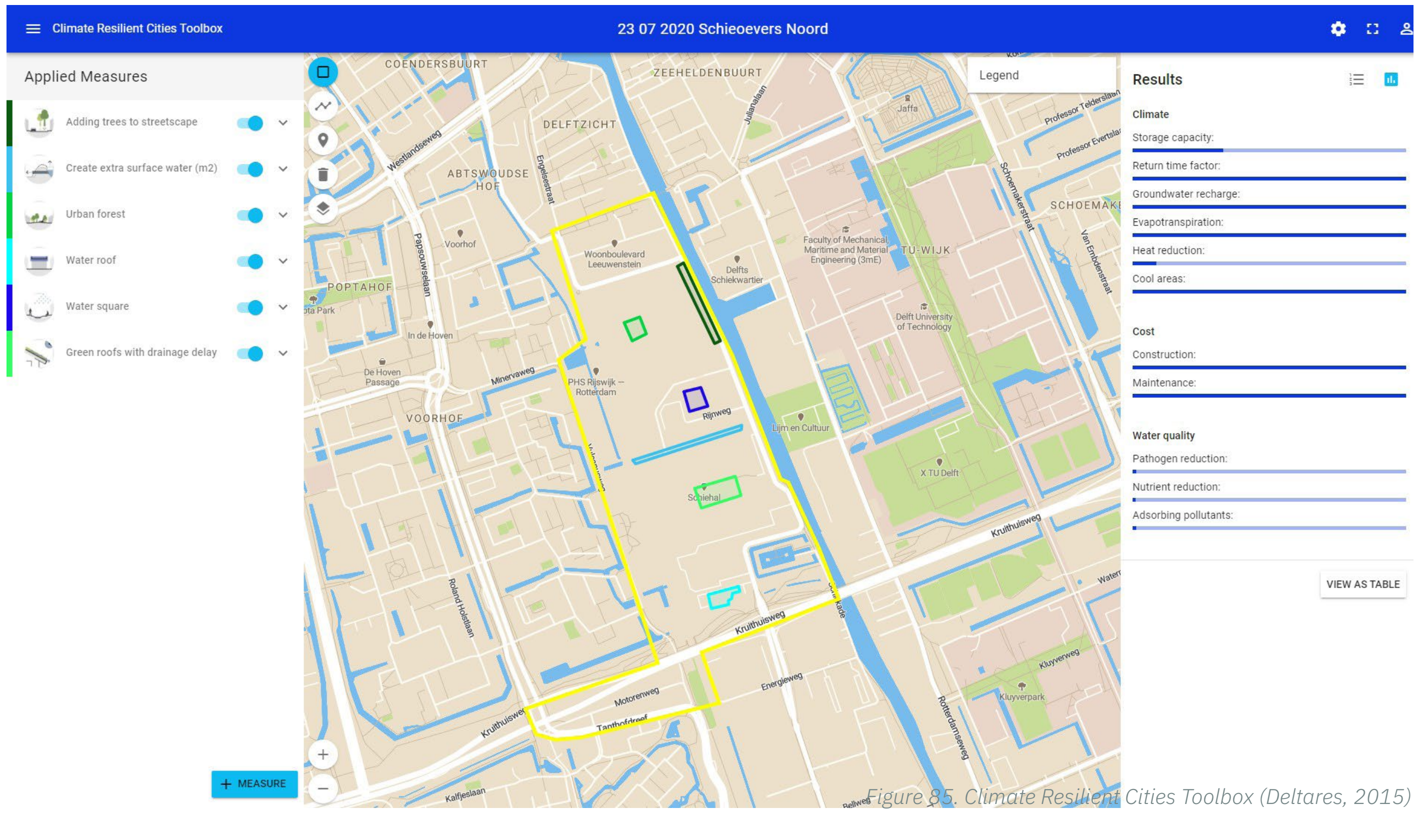


Figure 85. Climate Resilient Cities Toolbox (Deltares, 2015)

Main measures for Schieoevers Noord

Figure 86. Blue roofs (Reiling n.d.)

Blue roofs

Using roofs of buildings to capture rainwater will help to store water for later use in the area. Instead of having the drain situated at the lowest point of the roof it will be installed a bit higher. This way the water will buffer on the roof. When adding blue roofs to buildings, the load bearing capacity of the buildings should be taken into account. When water is present on the roof, it will also help cool the building, however in hot periods, when cooling is needed, water on the roof cannot always be guaranteed.
(Pötz, 2016, p. 108, 260-263)

Figure 87. DIT Drain (terricola, n.d.)

DIT drains and gravel layers

This measure can consist of a layer or a tube packed with gravel, with the runoff infiltrating into the ground through the gravel. This measure can be used when there is little space, because it is located underground and functions similarly to a ditch. Maintenance may be tough, because problems are hard to spot early on in the underground system. (Pötz, 2016, p. 105)

Figure 88. Water permeable pavement materials (atelier GROENBLAUW, 2016)

Reducing pavement

Having a lot of pavement will decrease infiltration and increase heat stress. When replacing paved areas with greener surfaces (the rougher the better), water will more easily infiltrate into the soil and less heat will build up. Another option, for instance for parking spaces, is permeable pavement. This pavement will have better infiltration of water, but will still be accessible for vehicles and pedestrians. Most used materials for these types of pavement are open cell concrete blocks, grass concrete pavers, woodchips, shells or gravel. The openings in the material will vary from 15% to 40% permeability, compared to normal pavement. These types of paving materials are less durable than normal pavement and can therefore not be used in intensively used roads or parking spaces. The ideal place for these pavements are footpaths, playgrounds and service roads.
(Pötz, 2016, p. 80-81, 256-258, 423)

Figure 89. Green facades (de Winter, n.d.)

Green facades

Having plants on facades of buildings will attract and reduce heat by evapotranspiration and even improve air quality. It will not have a huge effect on water ,but when the plants are growing from the ground up, they do have a strip of open earth to grow from, through which some rainwater can infiltrate into the ground.
(Pötz, 2016, p. 275, 334)

Figure 90. Ditch (Vaxelaire, n.d.)

Ditches

Small channels, which collect water runoff from paved areas. They create temporary water retention, transportation and infiltration. Ditches usually have a green appearance, which is good for biodiversity. When creating ditches, care has to be taken in selecting the plants, as they will have to survive both wet and dry conditions. Maintenance is needed to prevent silting up in ditches. (Pötz, 2016, p. 74)

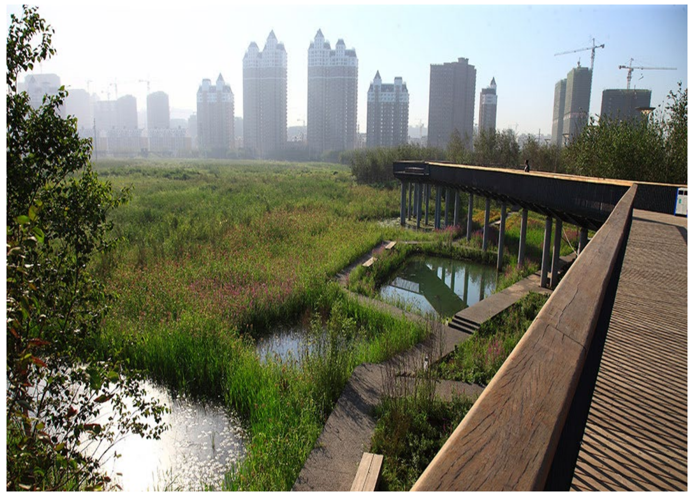


Figure 91. Urban wetland (Turenscape, 2014)

Urban wetland

Urban wetland is an area where the water and ground level are roughly the same, which creates parts of semi-submerged soil. These types of areas usually occur along rivers and deltas. Urban wetlands are capable of handling fluctuation in the water level, so they make for good rainwater buffer areas. Because of this fluctuation and the semi submerged ecosystems, these areas tend to be home to large populations of amphibians, dragonflies and birds. The plants that thrive in these types of areas are also good at filtering the water, which increases its quality. The water purification in urban wetlands can be as effective as more expensive, high tech purification systems. (Pötz, 2016, p. 131)

Bioswale

A low-lying green area that collects excess rainwater from surrounding areas. It creates temporary water retention and infiltration. Rainwater can temporarily be stored here, but it should drain within about 24 hours. This measure works best in porous soil and low ground water levels like in the east of the Netherlands. When combined with helophyte plants, the water will get filtered before being drained or infiltrated, which improves the quality of the surface/ground water. A bioswale should have an overflow prevention drain, but it should be designed in such a way that it will only have to be used a maximum of once every 2 years.
(Pötz, 2016, p. 95)

Figure 92. Bioswale / Wadi (Atelier Dreiseitl, n.d.-b)

Hollow roads

Roads can be designed with a strip that is lower than the rest of the road. This strip collects and guides the water to drain it to collection areas. The road has to have a light slope to ensure the water does not end up in stationary puddles. This measure might cause splashing from bikes and cars, so should be used carefully.
(Pötz, 2016, p. 73, 192)

Figure 93. Hollow road (Atelier Dreiseitl, n.d.-a)

Rainwater detention pond

Ponds can be used to collect and store rainwater. If the ponds are not connected to the surface water system, there is no circulation and water quality can decrease. The quality can also decrease, if the temperature of the water rises, or if foliage or animal faeces fall in the water. These issues need to be taken into account when designing a water retention pond. However, if the banks are planted with helophyte plants, the water quality can improve, because the plants filter the water before infiltration or drainage. Ponds can be used to collect polluted water and purify it. If this is the case, the pond should be sealed from the ground with a membrane under the soil so the pollution cannot infiltrate into the ground water. After going through purification from a soil filter and filtering plants, the water can go into the surface water system.
(Pötz, 2016, p. 90-93)

Figure 94. Rainwater detention pond (Picture of a Wet Pond 2, 2012)

Adding trees in the city

Trees generally have a positive impact on heat stress and air quality. When planting trees along roads in cities, there are a few things that are important. First, when placed on both sides of a street, they should not merge together or cover more than one third of the street. This would prevent exhaust gasses from going up and mixing with clean air, which would then lead to worse air quality on the street level. It is also important to carefully choose the type and placement of the trees, because they have to have enough space in the soil to grow and reach their potential.
(Pötz, 2016, p. 284, 337, 419)

Figure 95. City trees (Perrin, n.d.)

Water squares

Specifically designed lower areas in squares that can collect and retain water in case of heavy rainfall. This measure can be combined with other types of spaces, like playing areas, but they need to be easy to clean, because water leaves behind a lot of waste and mud. These water squares have large buffering capacities and can be designed to fill up in stages, where for instance the most used functions of the square fill up last. (Pötz, 2016, p. 116)

Figure 96. Water square ('Water Square' in Benthemplein, 2020)

Green roofs

Green roofs come in different varieties. They range from sedum or moss roofs to green roofs with whole city parks on them. In general, the rougher and higher the greenery, the more effect it has on water and heat, but also the higher the costs. When a green roof is planned, a balance needs to be found between the costs, the construction possibilities and the goals. Sloping roofs up to 35 degrees are best suited for having green roofs, because it will not require extra support to prevent sliding. Some green roofs can also buffer water (drainage delay). These work best at a slope of 7 degrees. Green roofs that are on lower buildings need to be checked for unwanted seedlings of large plants and trees, because the roots could cause damage to the roof. (Pötz, 2016, p. 107, 261-274, 383)

Figure 97. Greeen roofs (Optigroen, n.d.)

Figure 98. Urban forest (Vyncke & SeniorenNet.nl, n.d.)

Urban forest

A collection of trees planted closely together provides shade and therefore cooler areas. As with other measures that use trees, urban forests also positively affect air quality and biodiversity and combat heat stress. Urban forests can be combined with water, but it is important to prevent too much foliage from falling into the water and polluting it. These small forest areas also make great parks for walking dogs and for kids to play. (Pötz, 2016, p. 286, 342, 418-419)

Figure 99. Infiltration strips (atelier GROENBLAUW & d'Ersu, n.d.-a)

Infiltration strips and fields

Infiltration fields or strips are similar to ditches and can be used next to roads, where there is less space. The main difference is that these infiltrations strips are just meant for delayed drainage and infiltration; they do not transport the water like ditches can. The layers of soil and the plants filter the water before it can infiltrate. These strips and fields can only be implemented if the soil is suitable for infiltration. When placed next to a road or other paved area, the infiltration field or strip should be lower than the pavement so that water naturally collects there. (Pötz, 2016, p. 87, 104)

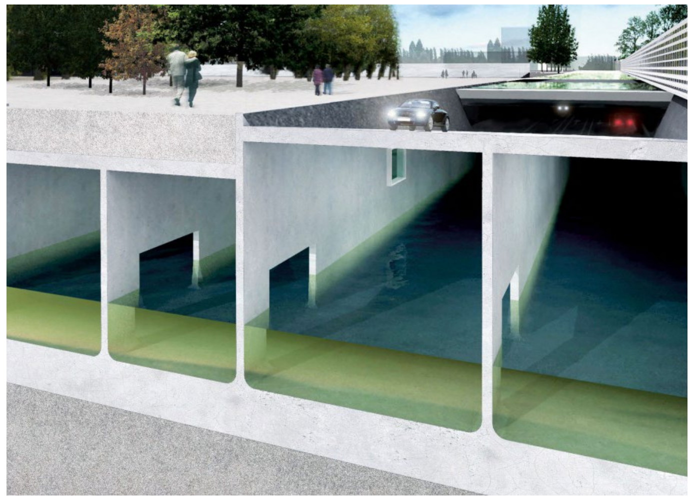


Figure 100. Underground storage (Gemeente Rotterdam, n.d.)

Underground storage

Some basements of buildings or underground parking garages can be used for temporary water storage. The volume of these spaces is usually very high, which means a lot of water can be stored there. This measure reduces water nuisance in the case of peak rain events, but it is invisible to the public. Making theses spaces can be very expensive, but if they are already there and currently unused it could be a beneficial use for the spaces. (Pötz, 2016, p. 110)

Figure 101. Flexible water level (atelier GROENBLAUW & d'Ersu, n.d.-b)

Flexible water level

Surface water is a great place to buffer excess rainwater. In order to create a greater buffering capacity in the surface water system, it should allow for fluctuation of the water level. The most important thing to watch out for, is that the difference in height between the ground and water remains great enough to be safe and prevent nuisance. Having nature friendly banks with light slopes are one of the best ways to design for a fluctuating water level. Great care should be taken when deciding what kind of plants are used, because they would have to be able to withstand dry and wet conditions. Having a flexible water level is the most direct measure to improve water quantity and quality in polder systems. The water that is added in the wet winter months, will evaporate in the hot summer months. This means shortages are less likely and taking in water from the bosom system is not necessary as often. (Pötz, 2016, p. 114-115, 193, 231)

Figure 102. Infiltration boxes (Indra b.v., n.d.)

Infiltration boxes

This measure consists of boxes placed underneath a road or sports field. The boxes have a 95% storage capacity, which allows for a lot of water to be stored. The infiltration boxes are very flexible in their sizes and they require no space above ground and are therefore invisible. A special filter cloth is wrapped around the boxes to prevent them from silting up.
(Pötz, 2016, p. 106)

Figure 103. Rain barrels (Tuinbranche Nederland, n.d.)

Rain barrel

A very simple and low-tech measure for collecting rainwater are rain barrels. They usually catch rainwater from roofs of small residential buildings. The water collected in them can then be used for, for instance, watering gardens. Rain barrels can also collect water from larger buildings and the water from those bigger tanks could even be used for flushing toilets. Using rain barrels like that is only feasible, if there is a large enough volume of water coming to the tank. (Pötz, 2016, p. 163-171)

CLIMATE ADAPTATION MEASURES - COMPARISON

Figure 104. Climate adaptive measures comparison matrix (explained on the next page)

Measures	Effect on water	Multifunctionality	Biodiversity	Storage capacity	Evapotranspiration	Water quality effect	Water awareness	Heat stress reduction		Costs		Maintenance	
Source	Green blue grids	Green blue grids	Green blue grids	Climate resilient cities	Climate resilient cities	Climate resilient cities	Created by author	Green blue grids	Climate resilient cities	Green blue grids	Climate resilient cities	Green blue grids	Climate resilient cities
Scale	0 - 3 no effect - large effect	0 - 3 no effect - large effect	0 - 3 no effect - large effect	0 - 4 very small to no result - large result	0 - 4 very small to no result - large result	0 - 4 very small to no result - large result	0 - 4 completely invisible - experience difference	0 - 3 no effect - large effect	0 - 1 no difference - 0,05 C difference	1 - 3 neutral - high cost	0 - 4 very small to no result - large result	0 - 3 no effect - large effect	0 - 4 very small to no result - large result
Blue roofs	3	2	0	2	2	0	1	1	1	2	3	1	-
Gravel layers - maybe remove	3	2	0	2	0	4	0	0	0	2	3	1	3
Hollow roads	1	1	0	2	2	0	3	0	0	1	2	1	2
Green facades	1	2	3	1	0	0	2	3	0	2	3	?	4
Ditches	1	1	2	1	0	1	3	1	0	1	1	1	1
Water squares	3	3	1	3	0	0	4	1	1	3	4	3	2
Bioswale with drainage	3	2	3	2	0	4	4	2	1	2	2	2	1
Remove pavement to plant green	2	2	2	1	4	4	2	2	1	1	1	1	2
Rainwater detention pond (wet pond)	3	3	3	2	0	2	3	2	1	3	1	3	1
Adding trees to the streetscape	2	1	3	1	4	1	1	3	1	2	1	2	1
Urban wetland	3	3	3	2	1	3	2	3	0	1	2	2	2
Green roofs with drainage delay	2	2	2	1	2	4	1	2	1	2	2	1	3
Urban forest	3	3	3	1	3	1	1	3	1	2	1	2	1
Infiltration boxes	3	3	0	2	0	4	0	0	0	3	3	2	4
Storage tank or underground water storage	2	1	0	4	0	3	0	0	0	3	3	2	4
Infiltration fields and strips with surface storage	2	2	1	2	0	4	3	1	1	2	2	2	1
Drainage infiltration transport drains / Gravel layer	3	2	0	1	0	1	0	0	0	2	1	2	1
Rain barrel	1	1	0	1	0	1	1	0	0	1	2	1	-
Surface water	3	1	1	3	3	2	2	1	0	2	3	2	1
Supplemental water retention by flexible water level	3	2	2	3	3	2	4	1	0	3	-	2	-

CLIMATE ADAPTATION MEASURES - COMPARISON
Table discription

The table on the previous page shows the comparison matrix for the effects of all the climate adaptation measures mentioned in this chapter of the thesis. Two main sources were used, the Green-Blue Grids and The Climate Resilient Cities Toolbox, and one aspect is created by the author. The Climate Resilient Cities Toolbox has an underlying calculation from which the author extruded the score. To compare the different scales the colour blue highlights the largest effects.

Green-Blue Grids
The Green-Blue Grids measures the effect on different aspects of the climate. They show 0 - no effect, 1 - minor effect, 2 - substantial effect, and 3 - large effect. Except for cost which they show on a 1-3 scale where 1 - low to neutral cots, 2 - additional cost and 3 - high cost.

The Climate Resilient Cities Toolbox
Other aspects were calculated by putting them into the Climate Resilient Cities Toolbox with areas of corresponding dimensions for each intervention. The results ranked 0 to 4 where 0 is very small to no result and 4 is a large result. One exception: The heat stress reduction. The Climate Resilient Cities Toolbox only showed a very small difference in temperature with some measures. Therefore, there are only two scales, 0 - no difference and 1 – 0,05 °C difference.

Water awareness
This aspect is created by the author. The visibility of water fluctuations is important to increase uses' understanding of water issues. If people never know there are any water issues, the social platform will always be limited. This category is included because the water issue is growing in size and importance. The visibility of dealing with water nuisance should increase understanding in users. The ranking goes from 0 – the water is completely invisible, 1 – slightly visible, 2- visible to 3 - very visible, 4 - experience the difference. The 4th rank is about those measures where people can experience the difference after rainfall. This is a necessary rank. It makes a big difference if the water is just there and people do not realize it is more or less water than the day before or if after heavy rain the entire square is filled with water which educates people on the effects of heavy precipitation.

EVALUATION CRITERIA

Five criteria to evaluate the strategies and help form the proposal

All the principles and measures described in this chapter are important aspects of a water system design for Schieoevers Noord. They are the principles behind the water system and can be used to compare the design strategies to each other, so a final proposal with a solid underlying foundation can be created. To ensure the process of evaluating the design strategies is clear, this chapter will elaborate on the evaluation criteria that will be used in the next chapter to compare the strategies with each other.

Criterion 1 – Amount of space used
This criterion will compare the space needed for the different strategies and the proposal. It might be that all the strategies fit in the available space from the space matrix calculation, but using less space is preferential.

Flexibility is always important when developing an area, because when working in a team, compromises need to be found. The calculation was done using the maximum building height, therefore the minimal footprint, so it leaves almost no room for variation. It should be used to prove a point, but not as a set amount of space that can be completely filled with water. Therefore, weighing the needed space against the results of other criteria will improve the chances of success in the strategies and proposal.

Criterion 2 – Static storage capacity
Another important evaluation criterion is the amount of static water storage in the area. This is based on the 325-norm that states there should be, at the very least, 325 cubic metres of static water storage per hectare of space in any polder area. Static water storage is the amount of water that can be retained on top of the existing water in an area, so it is dependent on the maximum allowable fluctuation in the water level. It is important to keep in mind that the 325-norm is a minimum, so the more cubic metres of storage the better. What is also important here is that the 325-norm is a rule of thumb used for estimating the amount of storage needed.

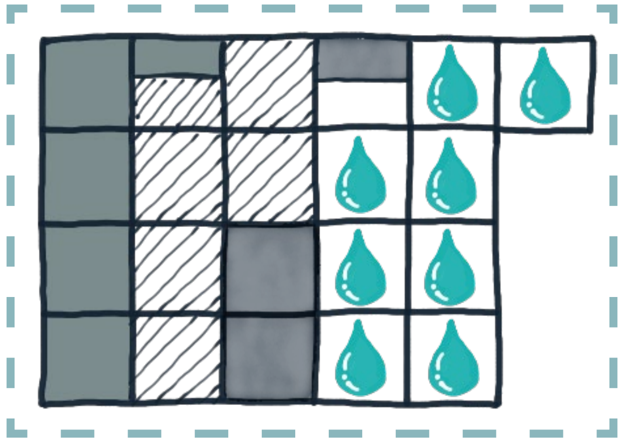
The area of Schieoevers Noord that will actually be part of the design strategies is around 50 ha, meaning there should be at least 16.250m^3 of static water storage. This criterion will only apply to the space for retention within the surface water system since that is what the norm was created for. Other storage of rainwater, for instance in climate adaptation measures, that are not connected to the water system will not be taken into account here.

The calculations for this criterion will show the difference in static storage between the different strategies and the proposal. Because the strategies are not very refined, the calculation cannot be carried out yet. That is why the formulas will be used with a fictive amount of water, which is the same in all strategies. By doing this, the amount of static storage can be compared between the strategies. A more realistic calculation was carried out for the proposal. Because it was a more detailed plan, actual data was available to use in the calculation, and the results show the possible amount of static storage.

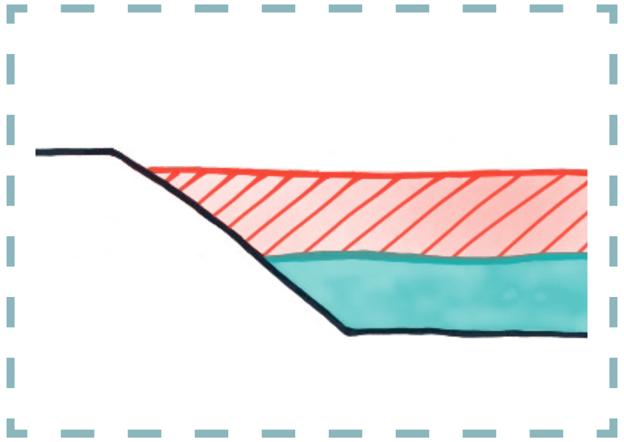
All calculations will depend on the height of the maximum allowable fluctuation and the width of the banks. Additionally, if the banks are nature friendly, the static storage goes up much faster than without nature friendly banks.

Criterion 3 – Effect on the polders
As described in the analysis of the area, higher and Lower Abtwoudse polders have some water quality issues and Higher Abtwoudse polder also has a water quantity issue. That is why in the third evaluation, the strategies will be held accountable for their effect on the two polder systems. This will be done using a rating system from ++, for a very positive effect, to --, for a very negative effect [++, +, 0, -, --]. The effect on both quality and quantity of water will be mentioned here for Higher and Lower Abtwoudse polder.

Criterion 1



Criterion 2



Criterion 3

Figure 105. Icon for criterion one - Amount of space used
Figure 106. Icon for criterion two - Static storage capacity
Figure 107. Icon for criterion three - Effect on the polders

EVALUATION CRITERIA

Criterion 4 – Spatial quality
Most of the criteria are based on calculations or other technical aspects of the strategies, which are all important factors to consider. There is however another very important aspect to test the strategies and proposal on: Spatial quality. Adding any type of green-blue structure in an otherwise urban area will increase the spatial quality. This evaluation criterion aims to differentiate between the added spatial quality in the different strategies. Important criteria when evaluating the spatial quality for users are the experience of and the possibility for interaction with the water and greenery. However, not all green-blue structures are meant to be interacted with. A mix of different types of green-blue structures forms the best balance between users and the ecosystem.

Therefore, before being able to evaluate the spatial quality of a green-blue structure, it is important to look at the type and the purpose of greenery and water added in the plans. The municipality of Delft (2004) divides greenery and water into three different classes, “cultural assets”, “experiential assets” and “natural assets”.

“Greenery and water as cultural assets” describes the type that brings about a cultural sense of a location. In this class the actual ecological value of the green-blue structure is secondary to the cultural value. Good examples of this in the case of Schieoevers Noord are the Schie and the green-blue structure around Kruithuis. These structures are intertwined with the cultural heritage of the site. In case of the Schie the natural value of the water is not predominant. Historically, but also recently, it is used as a means of transportation, not so much as a place to enjoy nature. In case of Kruithuis, the natural value is significant, because it is a larger patch of urban forest that holds purpose for biodiversity, though its function to protect the monumental structures is more important.

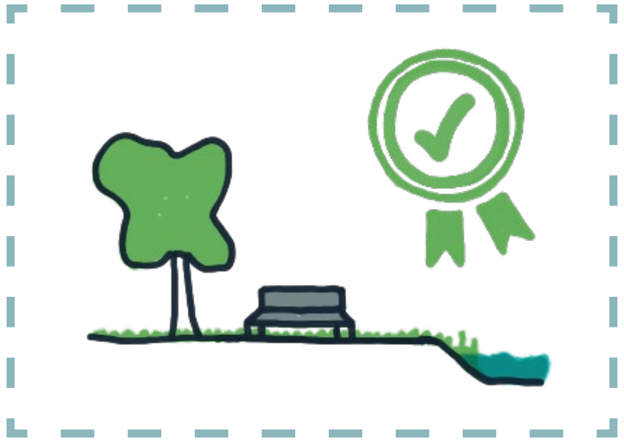
“Greenery and water as experiential assets” describes the type that provides users the chance to experience and interact with nature. This might mean that the water is of sufficient quality for swimming, or that a park is accessible and maintained, so it can be used for walking, cycling, or other sports and leisure activities. The municipality of Delft describes this type of green-blue structure as a continuous strip going through an area, intertwined with its recreational mobility structure.

“Greenery and water as natural assets” describes the type that is mainly meant to safeguard or improve ecological value, such as biodiversity. The main focus of these areas is the natural system, and they have less intervention by people. They create safe spaces for the most delicate species and allow them to thrive.

By dividing the green-blue structures into these three classes, it will be easier to evaluate them on spatial quality. Depending on the type of asset a green space is classified as, there are different values to take into account. An evaluation can be made on the added value specific to the type of asset. The balance between the different classes of green-blue structures is also an important criterion.

Criterion 5 – Adaptive measure effects
The last criterion is a combination of different aspects. Looking at the adaptive measures used in the strategy design, how does it score in the categories of biodiversity, heat reduction (and evapotranspiration), multifunctional space usage, water awareness and cost of construction and maintenance. This will be compared by putting the different strategies into the Climate Resilient Cities Toolbox and using the comparison matrix from the previous chapter.

Criterion 4



Criterion 5

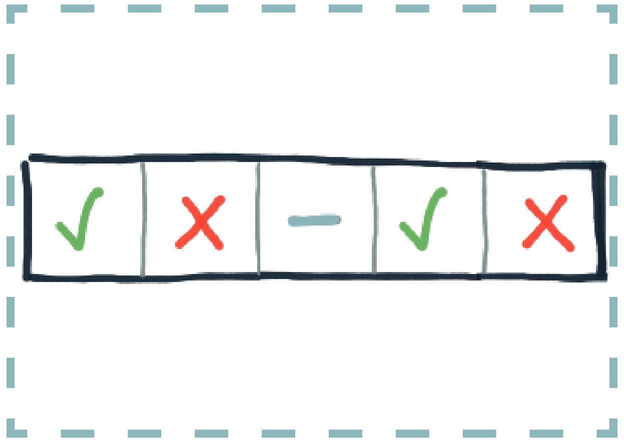


Figure 108. Icon for criterion four - Spatial quality
Figure 109. Icon for criterion five - Adaptive measure effects

STRATEGIES AND PROPOSAL

This chapter will first show four strategies that were made for the water system in Schieoevers Noord. It will elaborate on different aspects of these strategies and compare them to each other using the evaluation criteria from the previous chapter. From the comparison of the four strategies one final water system design proposal will be shown.

STRATEGIES

Strategy 1 - Connecting to both polders

The first strategy is actually derived from the status quo; what if we bring in water using the higher and Lower Abtwoudse polder systems the way they are. This strategy follows the current borders set in the ledger of the Delfland Water Authority. This means the water in the northern part of the area connects to the Higher Abtwoudse polder with a water level of -1.50 m NAP and the southern part of the area connects to the Lower Abtwoudse polder with a water level of -2.70 m NAP.

There are some issues that might arise with this strategy. The first is the amount of times the water needs to go across the train tracks. Using divers under the train tracks is always risky because the trains running above it might damage the divers or the divers might destabilise the ground underneath the train tracks if they leak or break. The construction of these connections under the train track might also hinder train traffic, which is something that will become expensive very fast. Something else to consider is the water around Kruithuis. The level of this water is at -1,33 m NAP in order to protect the old foundation of the monumental buildings. With the water around it being at -2,70 m NAP it will not be possible to integrate it into the water system of the area easily.

The final issue that needs to be taken into account is the height difference between the water and the ground. The average ground level is about 0.10 m NAP, so the height difference in the southern area will be around 2,80 metres. This means the difference between the public space and the water will be about a story of a building. It will take considerable planning to keep the public place safe.

The next page will show how this strategy scores in the five different evaluation criteria.

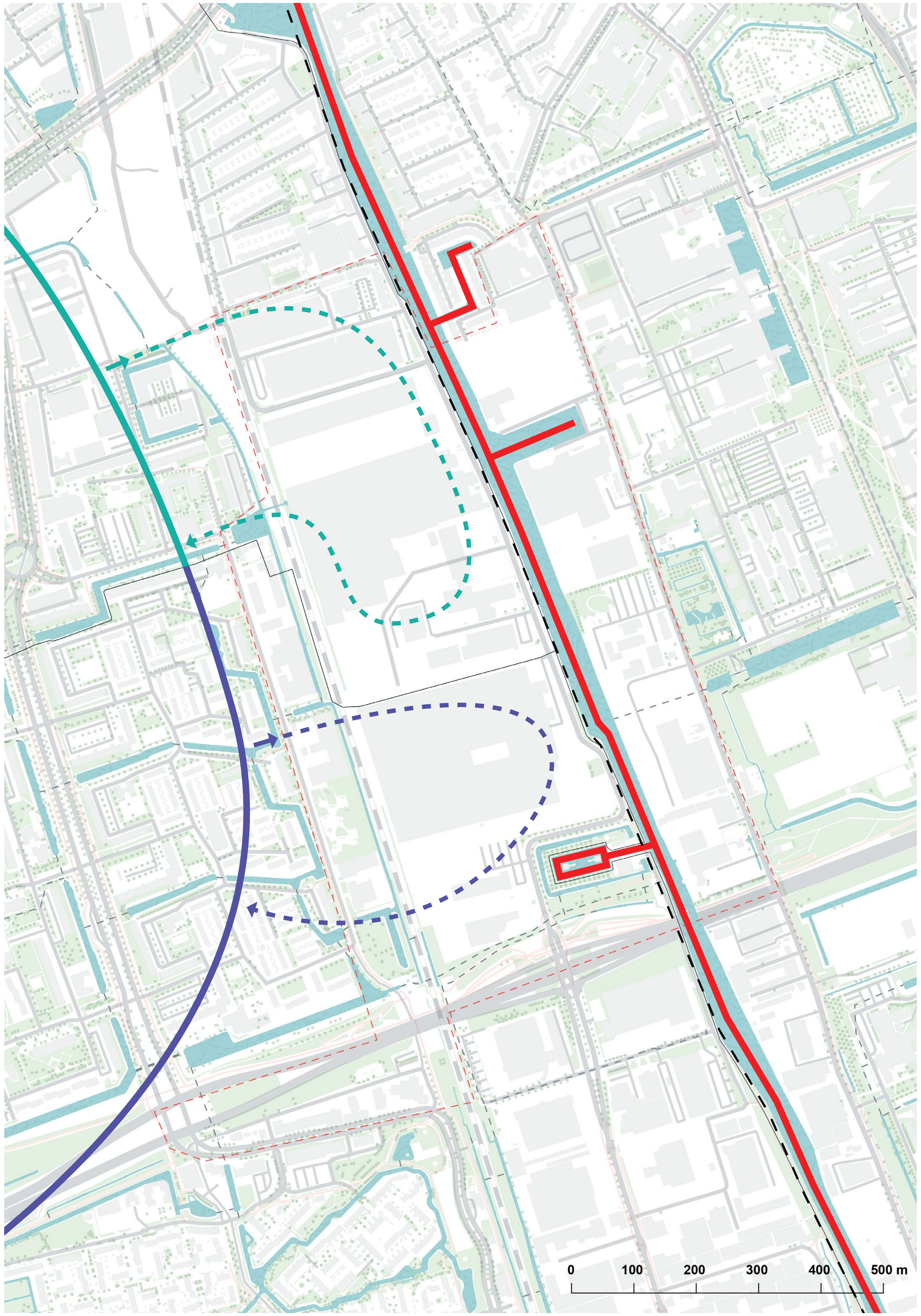


Figure 110. System of the first strategy

Criterion 1

When looking at studies into the sustainability of Schieoevers Noord, it became clear that nature friendly banks (NFB's) are highly preferred over steeper banks. This has a large impact on the space needed. Therefore this evaluation criterion will look at how much space the water takes up with one and two nature friendly banks when using the higher and Lower Abtwoudse polder water levels.

Figure 112 shows the amount of space needed for H.A.P., one NFB is 16.4 m^2 per linear metre of water and for two NFB's it is 26.8 m^2 per linear metre of water.

Looking at the same calculation for L.A.P. shows that the necessary space is much higher, one NFB needs 21.2 m^2 per linear metre of water and two NFB's need 36.4 m^2 per linear metre of water (Figure 113). This difference comes from the height difference between the water and ground level. This means that bringing in the L.A.P. water level is not beneficial in regards to this criterion.

Figure 111 shows the amount of space that is left after fitting in the water. It shows that in area 5, area 8 and area 9 fitting in water with 2 NFB's will be complicated or even impossible.

	Space left [m2]	Space left with one NFB [m2]	Space left with two NFB [m2]
Area 5	7800	223	-4582
Area 6	49900	22584	8659
Area 7	17400	9974	6189
Area 8	39100	13688	-401
Area 9	9400	4790	1789

Figure 111. Table with leftover space for criterion 1

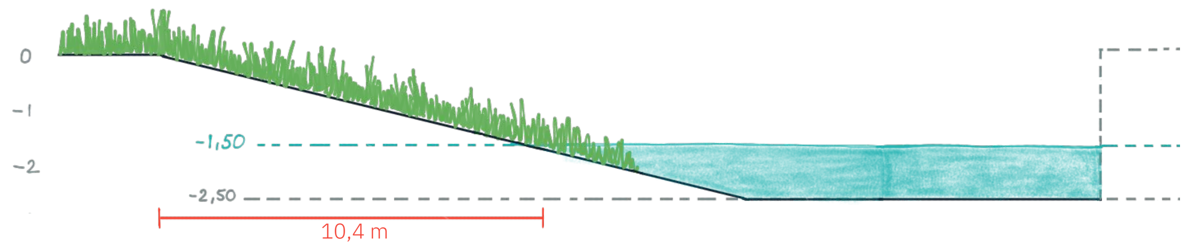


Figure 112. Section of water at -1,50 m NAP

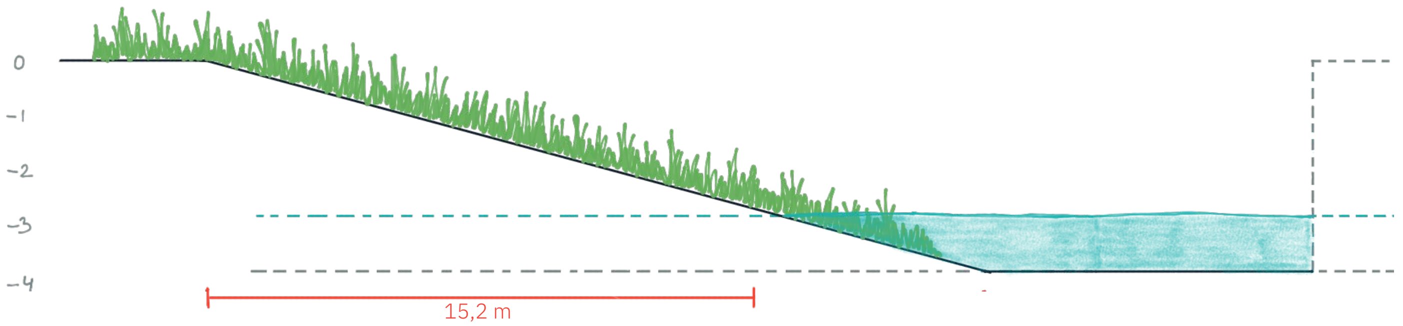


Figure 113. Section of water at -2,70 m NAP

Criterion 2

The height difference in this strategy would actually be beneficial for the static storage capacity because it can allow for more water level fluctuation. However, it will only be beneficial when there is enough space for nature friendly banks because as the formulas below illustrate, the nature friendly banks greatly increase the amount of storage.

Static storage [m^3]:

Per linear metre of water without NFB $= \Delta h_{water\ level} * l_{width\ bottom}$
Per linear metre of water with 1 NFB $= (\Delta h_{water\ level} * l_{width\ bottom}) + (2 + (4 * \Delta h_{water\ level}))$
Per linear metre of water with 2 NFB's $= (\Delta h_{water\ level} * l_{width\ bottom}) + (2 * (2 + (4 * \Delta h_{water\ level})))$

For filling in the formulas for this strategy the width of the bottom will be 6 metres and the allowable fluctuation of water level in H.A.P. will be 1 metre (from -1,5 to -0,5 m NAP) and for L.A.P. it will be 2 metres (from -2,7 to -0,7 m NAP).

$l_{width\ bottom} = 6$ m
H.A.P. -> $\Delta h_{water\ level} = 1$ m
L.A.P. -> $\Delta h_{water\ level} = 2$ m

H.A.P.
Per linear metre of water without NFB = 1 * 6 = **6 m^3**
Per linear metre of water with 1 NFB = (1 * 6) + (2 + (4 * 1)) = **12 m^3**
Per linear metre of water with 2 NFB's = (1 * 6) + (2 * (2 + (4 * 1))) = **18 m^3**

L.A.P.
Per linear metre of water without NFB = 2 * 6 = **12 m^3**
Per linear metre of water with 1 NFB = (2 * 6) + (2 + (4 * 2)) = **22 m^3**
Per linear metre of water with 2 NFB's = (2 * 6) + (2 * (2 + (4 * 2))) = **32 m^3**

So for a stretch of 100 (linear) metres of water, with a width of 6 metres, the static storage would be:

H.A.P.
Without NFB = **600 m^3**
With 1 NFB = **1200 m^3**
With 2 NFB's = **1800 m^3**

L.A.P.
Without NFB = **1200 m^3**
With 1 NFB = **2200 m^3**
With 2 NFB's = **3200 m^3**

Schieoevers Noord is about 50 ha, so to satisfy the norm of 325 m^3/ha in the polders there should be at least 16.250 m^3 of static storage.

Criterion 3

Adding water in both polder systems will have a beneficial effect on the water quantity in both higher and Lower Abtwoudse polder. Especially in Higher Abtwoudse polder less water will have to be exchanged with the Schie so it will help the quantity and quality since the Schie is the biggest polluting factor in H.A.P..

Since L.A.P. already has sufficient water the effect will not be as great. Something that might affect L.A.P. positively, is creating nature friendly banks, planted with helophyte plants, which filter water and with that increase the quality of the water. However as we found out in the first criterion, this strategy takes up a lot of space and might therefore not always have nature friendly banks.

Criterion 4

Because the nature friendly banks in this strategy take up a lot of space, there is less space left for other types of green and blue structures, like pocket parks and the Schiepark. This means that the water structure will be the main blue-green structure in the area. This is undesirable because by definition the variety will be lower and therefore the balance between the three different classes of green-blue space will be distorted.

Another issue with the interaction and experience of the water, in this strategy, is the height difference between the ground and water levels. In the southern part of the Schieoevers the difference in height is about 2,80 metres. This means that actual interaction with the water will be hard. Figure 114 clearly shows that such height difference will limit the field of view when walking along the water, especially when the banks are steeper due to lack of space.

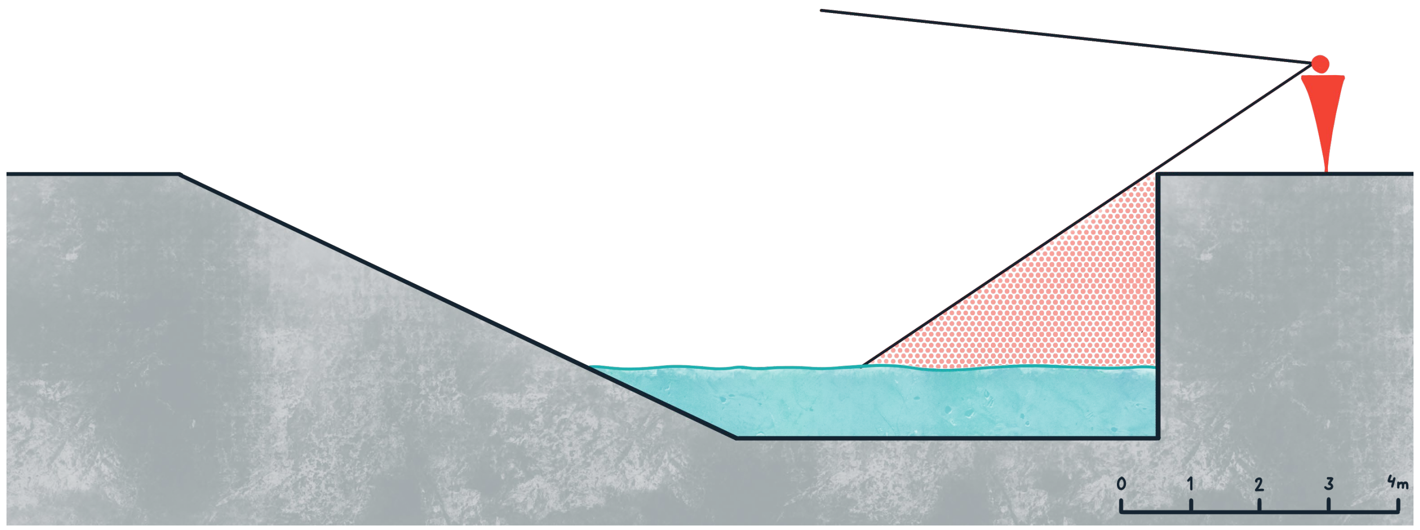


Figure 114. Blocked view with water at -2,70 m NAP

Criterion 5

Water awareness +

Adding a solid surface water system in an urban area is of course beneficial to the visibility and water awareness of the users. Nonetheless, having water with such a height difference will actually impair the user's ability to tell the difference in water levels easily. Making it less obvious when there is an excess or shortage.

Biodiversity +

The biggest measure in this strategy is adding surface water with as many nature friendly banks as possible. The NFB's are beneficial for the biodiversity, but because of the lack of space there might not be much opportunity for adding other types of green spaces. Since variety of habitats is the best thing for an ecosystem this strategy actually does not score great when it comes to biodiversity.

Heat reduction 0

Adding a surface water system does not affect the heat stress of an urban area very much. What does affect the heat stress is the types of grass, plants and trees planted along the banks of the water system. since nature friendly banks cannot be ensured in this strategy it scores neutral on the topic of heat stress reduction.

Multifunctional space +

Looking at multifunctional space usage the lightly sloping, nature friendly banks can be used for different activities apart from the biodiversity one could also create places to meet, walking routes and playgrounds in these green areas.

Costs --

A downside of adding surface water in this strategy is the cost, the construction and maintenance costs of surface water and its banks, at this height level, are quite high.

STRATEGIES

Strategy 2 - Using only the Higher Abtwoudse polder

Because the difference in the water level of L.A.P. and the ground level in Schieoevers Noord is so big and has such a negative effect on the space impact of a water system, this second strategy shifts the entire area of Schieoevers Noord into H.A.P.. This eliminates the 2,80 m height difference because the water level is now at – 1,50 m NAP in the whole area, apart from the moat around Kruithuis.

This strategy also reduces the need for connections running under the train tracks, there is one existing connection that could be used and one additional connection might need to be made.

Something that has not changed regarding the first strategy is the difference in height between the new system and the existing water around Kruithuis. In this strategy it is still not possible to integrate the existing water with the new system without the use of pumps and weirs.

The next page will show how this strategy scores in the five different evaluation criteria.

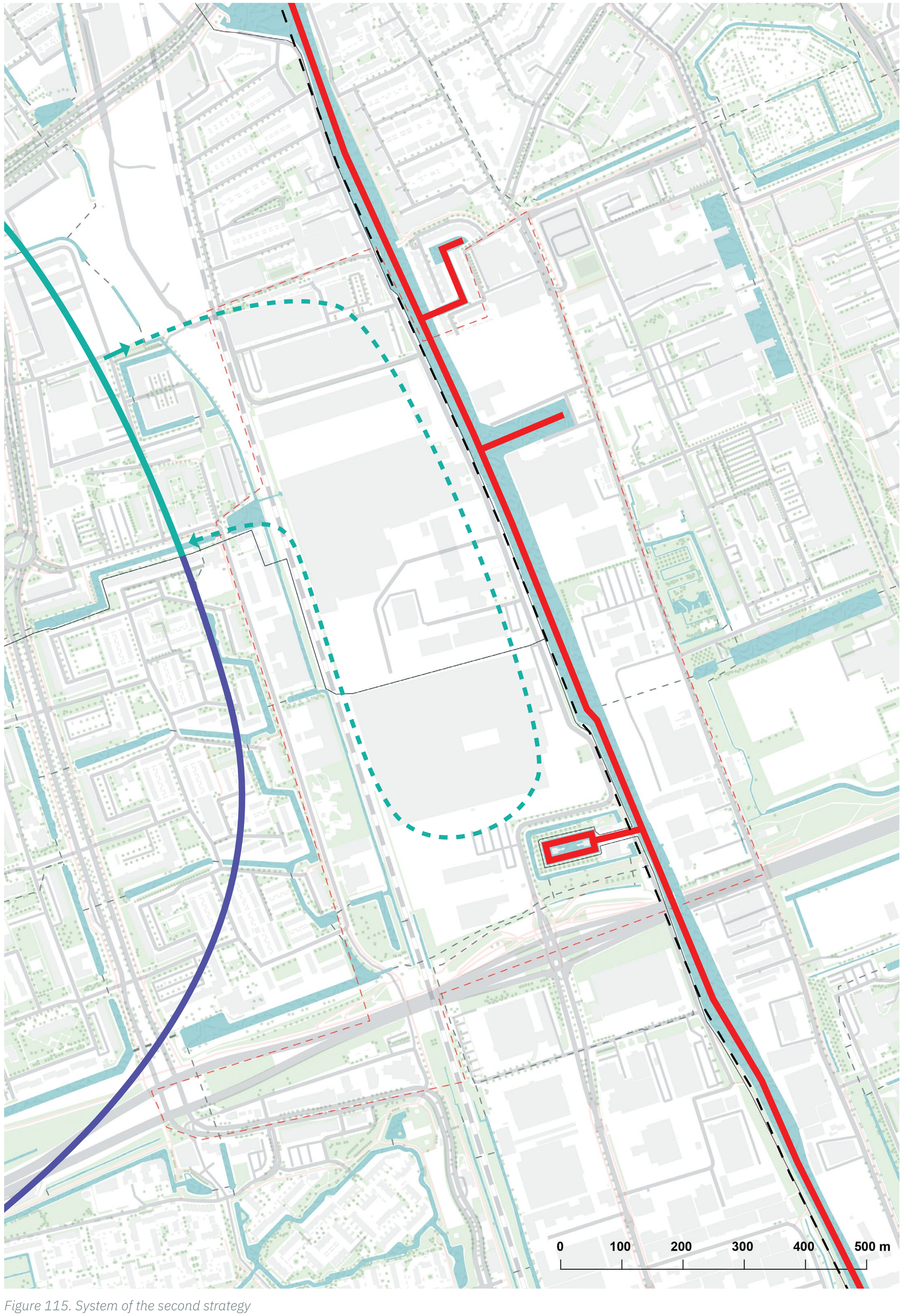


Figure 115. System of the second strategy

Criterion 1

When looking at studies into the sustainability of Schieoevers Noord, it became clear that nature friendly banks are highly preferred over steeper banks. This has a large impact on the space needed. Therefore this evaluation criterion will look at how much water can fit with one nature friendly bank and with two nature friendly banks when using only the Higher Abtwoudse polder water level.

As shown in figure 117 within the H.A.P. the space needed for 1 NFB is 16.4 m^2 per linear metre of water and 2NFB's is 26.8 m^2 per linear metre of water.

Figure 116 shows the amount of space left after fitting in the water. It shows that in area 5 it will still be impossible to fit the entire system using two nature friendly banks, however, looking at the other areas, it has improved a lot compared to the previous strategy.

	Space left [m2]	Space left with one NFB [m2]	Space left with two NFB [m2]
Area 5	7800	223	-4582
Area 6	49900	22584	8659
Area 7	17400	9974	6189
Area 8	39100	14695	1612
Area 9	9400	5005	2218

Figure 116. Table with leftover space for criterion 1

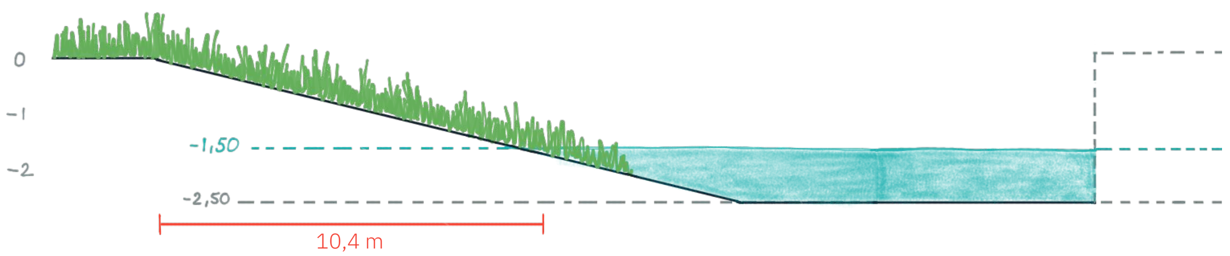


Figure 117. Section of water at -1,50 m NAP

Criterion 2

The calculation for the static storage in this strategy is very similar to the previous one, except that in this one the L.A.P. water level is not used. With the lower allowable fluctuation the water storage will be less in this strategy compared to the previous one.

Static storage [m^3]:

Per linear metre of water without NFB $= \Delta h_{water\ level} * l_{width\ bottom}$
Per linear metre of water with 1 NFB $= (\Delta h_{water\ level} * l_{width\ bottom}) + (2 + (4 * \Delta h_{water\ level}))$
Per linear metre of water with 2 NFB's $= (\Delta h_{water\ level} * l_{width\ bottom}) + (2 * (2 + (4 * \Delta h_{water\ level})))$

For filling in the formulas for this strategy the width of the bottom will be 6 metres and the allowable fluctuation of water level in H.A.P. will be 1 metre (from -1,5 to -0,5 m NAP).

$l_{width\ bottom} = 6$ m
H.A.P. -> $\Delta h_{water\ level} = 1$ m

H.A.P.

Per linear metre of water without NFB $= 1 * 6 =$ **6 m^3**
Per linear metre of water with 1 NFB $= (1 * 6) + (2 + (4 * 1)) =$ **12 m^3**
Per linear metre of water with 2 NFB's $= (1 * 6) + (2 * (2 + (4 * 1))) =$ **18 m^3**

So for a stretch of 100 (linear) metres of water, with a width of 6 metres, the static storage would be:

Without NFB = **600 m^3**
With 1 NFB = **1200 m^3**
With 2 NFB's = **1800 m^3**

Criterion 3

Adding water and area to the Higher Abtwoudse polder system is not necessarily beneficial, by adding area to the polder the requirements for water quantity also go up. This means that when adding area to a polder with a water shortage the added area should exceed the quantity requirements in order to improve the situation in the polder.

The other side of that is that removing area from the L.A.P. polder system will increase its surplus even more but it will not do anything for the water quality of the water in the polder system.

Criterion 4

The height difference between the water and the ground is much lower in this strategy than the previous one. When designing water with nature friendly banks the difference in height between the ground and water will decide the space needed. A smaller amount of space for the water system leads to more space for other types of green and blue structures. For instance having the Schiepark could add an experiential element to the Schie, instead of just the cultural element. It would also leave more space for pocket parks, the diversity that pocket parks bring can improve the balance between the cultural, experiential and natural classes. Overall this means that this strategy has higher promise for achieving a balanced green-blue system that will benefit both the ecological aspect and the spatial quality aspect in Schieoevers Noord.

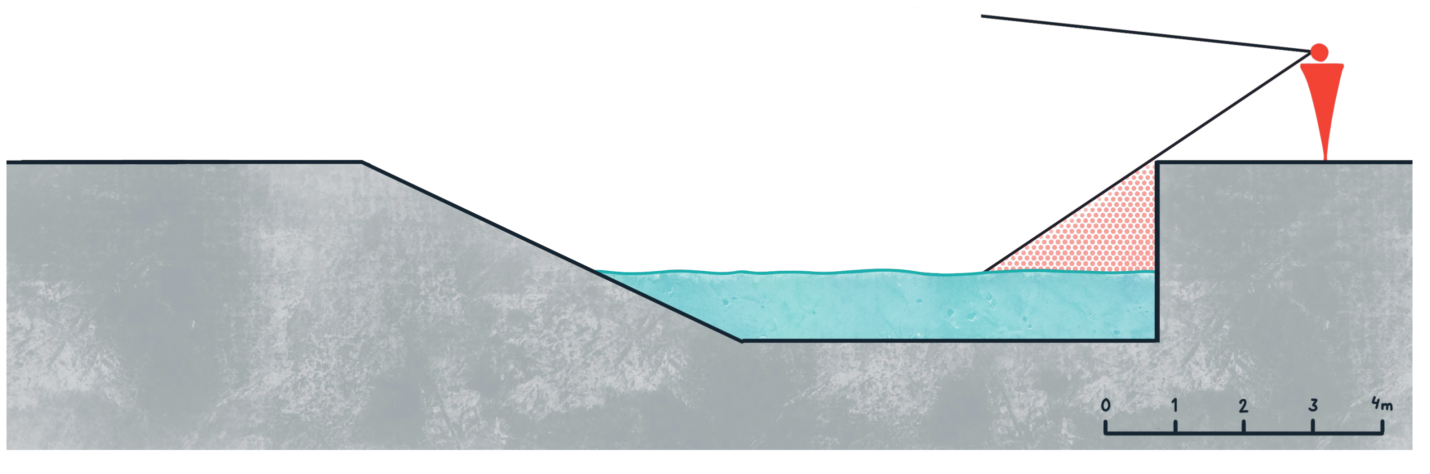


Figure 118. Blocked view with water at -1,50 m NAP

Criterion 5

Water awareness ++

Adding a solid surface water system that allows for fluctuation in an urban area is of course beneficial to the visibility and water awareness of the users. The possibility to combine the surface water system with different pocket parks that also have a water storage function will improve water awareness even more.

Biodiversity ++

The biggest measure in this strategy is adding surface water with as many nature friendly banks as possible. The NFB's are beneficial for the biodiversity, especially in combination with other types of greenery, in pocket parks, that will be specifically designed to cater to different species and provide nesting spots.

Heat reduction +

Adding a surface water system does not affect the heat stress of an urban area very much. What does affect the heat stress is the types of grass, plants and trees planted along the banks of the water system and in the pocket parks. Since the municipality stated that at least 50% of the pocket parks need to be cool, shaded places, they will definitely reduce heat stress.

Multifunctional space +

The chance for multifunctional space usage is the same as in the previous strategy. The lightly sloping, nature friendly banks can be used for different activities apart from the biodiversity one could also create places to meet, walking routes and playgrounds in these green areas.

Costs -

Because the surface water in this strategy is not as far down, construction costs are less than in the previous strategy. However, adding surface water in any area is expensive so the costs are still a negative feature.

STRATEGIES

Strategy 3 - Inlet from the Schie

Another source of surface water in Schieoevers Noord is the Schie. The Schie belongs to the bosom water system. In the municipal development plan they mentioned that another option for bringing surface water into Schieoevers Noord might be the Schie. To test that idea and see how it measures up to the other strategies, it is also tested using the same evaluation criteria.

There is a regional water defence structure imbedded in the eastern quay of the Schie, so creating inlets into the area of Schieoevers will certainly come with complications. The levee should be safeguarded and recreated around all the inlets to ensure the safety of the system. As mentioned before, regional water defence structures also come with a protection zone that only allows for minimally invasive activities. This means that the amount of space left for building will be limited in this strategy.

There is only a difference of 0,50 m between the water level of the Schie (-0,43 m NAP) and the ground level of Schieoevers (0,10 m NAP). The levee function combined with the small difference in height between the water and the ground, will make it difficult to create nature friendly banks in this strategy.

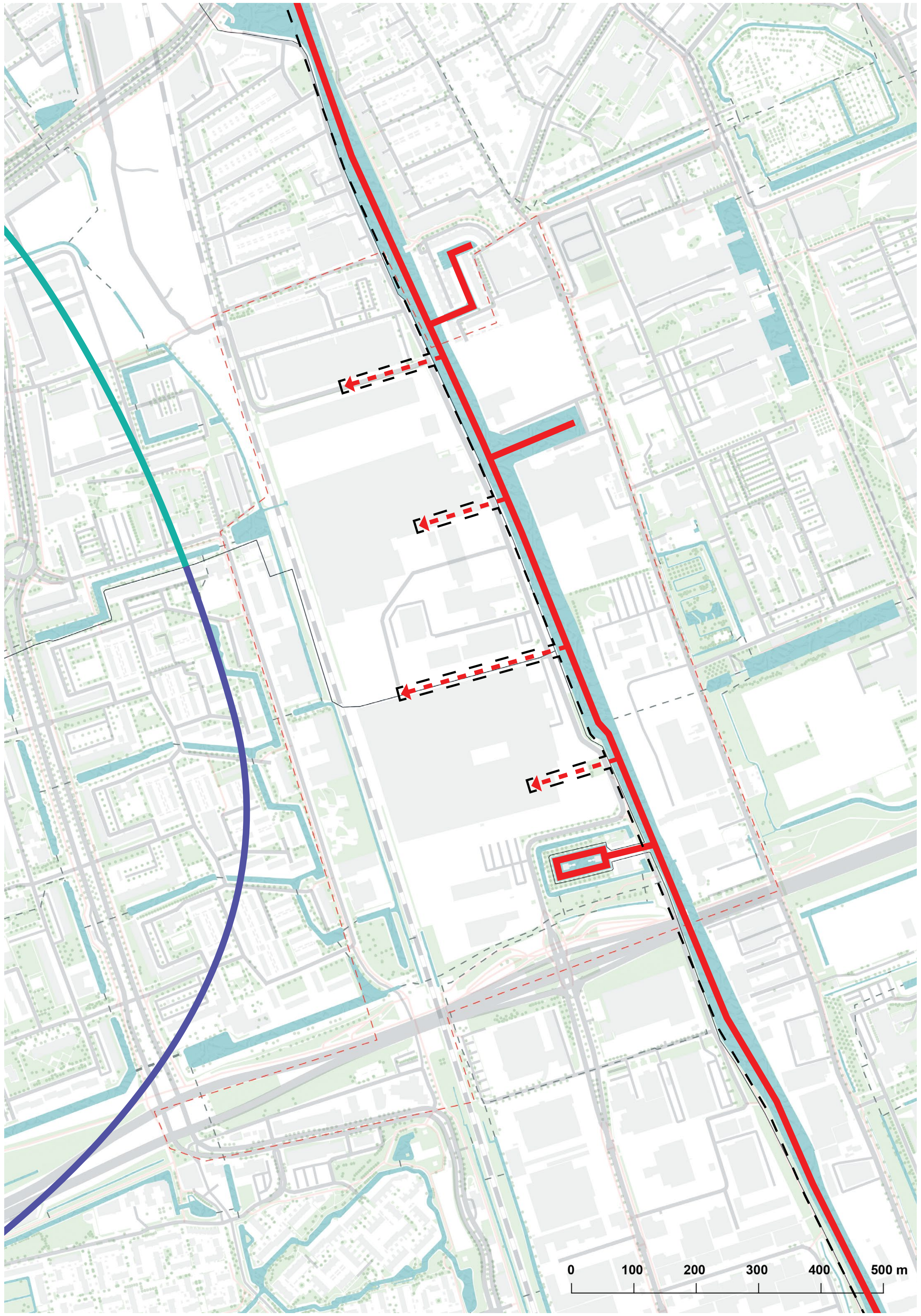


Figure 119. System of the third strategy

Criterion 1

As shown in figure 121 the Schie has a core and a protection zone measuring 21 metres from the start of the quay. Letting the Schie further into the project area will greatly impact available space without adding the beneficial qualities of nature friendly banks. The space needed per linear metre of water with the protection zone is the width of the water plus two times the width of the protection zone, that amounts to around 48 m^2 of space per linear metre of water.

Figure 120, calculated using the following formula; $A_{empty\ space} - l_{water} * (l_{width} + 2 * l_{protection\ zone})$, shows that space will be tight in area 5 and area 7, it also shows that it is not even possible to get water into area 9 because, that is because it does not border the Schie. In the other areas there is enough space to let the Schie in, however, this calculation has completely disregarded any circulation issues that might arise when having an inlet from the Schie going that far into Schieoevers Noord.

	Space left [m2]	Length of water [m]	Space left [m2]
Area 5	7800	80	2520
Area 6	49900	300	30100
Area 7	17400	230	2220
Area 8	39100	300	19300
Area 9	9400	0	9400

Figure 120. Table with leftover space for criterion 1

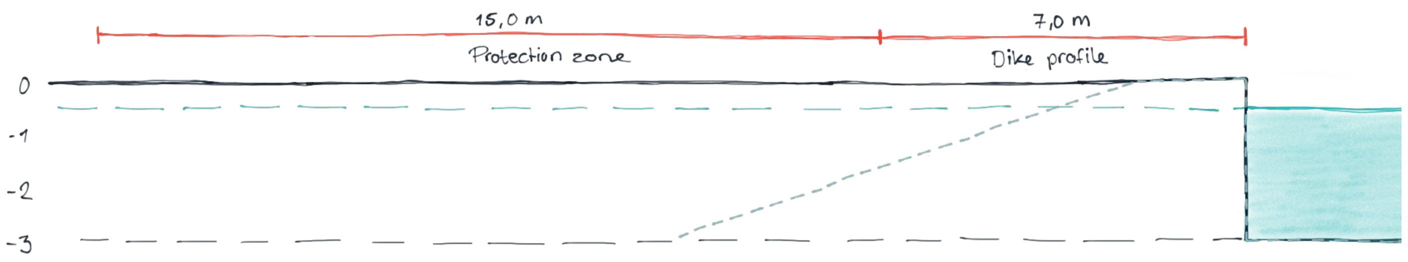


Figure 121. Section of levee protection zone

Criterion 2

The calculation for the static storage in this strategy is very simple, the assumption is that nature friendly banks will hardly be possible so the calculation for the static storage per linear metre of water is just the width of the water multiplied by the possible fluctuation height.

Static storage [m^3]:
Per linear metre of water without NFB -> $\Delta h_{water\ level} * l_{width\ bottom}$

For filling in the formulas for this strategy the width of the bottom will be 6 metres and the allowable fluctuation of the water level in the system will be 0,20 m (from -0,40 to -0,20 m NAP).

$l_{width\ bottom} = 6$ m
Schie -> $\Delta h_{water\ level} = 0{,}20$ m

Schie
Per linear metre of water without NFB = 0,2 * 6 = **1,2 m^3**

So for a stretch of 100 (linear) metres of water, with a width of 6 metres, the static storage would be:

Without NFB = **120 m^3**

This calculation is not very accurate, the 325-norm is something made for polder areas and since the Schie is not actually a polder it does not quite fit in this calculation. The Schie is not a water system that is contained at the same scale a polder water system would be. Since the inlets of the Schie into Schieoevers would be in direct contact with the Schie water system the rain that would fall, would not stay in the Schieoever area. In order to raise the water level of the Schie, much more water is necessary. This would actually go against the principle of retain, store drain because that states that retaining water in the area it falls is the first and most important step to creating a healthy and resilient local water system.

Criterion 3

This strategy will reduce the size of the H.A.P. and L.A.P. systems. This will have a beneficial effect on their quantity of water but no effect on the quality of the water in the system.

Criterion 4

Bringing the Schie into the area takes a lot of space, the banks can be designed like parks to create green-blue strips but they have a very limited reach. This means that the west side of Schieoevers, nearer to the train tracks, will have no interaction with the water. If the space allows it, other green structures can be realised there but the system will not be integrated throughout the whole area.

Additionally, creating nature friendly banks in this system will be very complicated because its function as a regional water protection element. This means that species that commonly reside on the border between water and greenery will not have a place in the system. This will drastically limit the biodiversity in Schieoevers Noord, compared to the other strategies.

All these factors combined are making it very hard to achieve a balance between green spaces as cultural, experiential and natural assets. This lack of balance will translate directly to the spatial quality because an unbalanced ecological system will reduce the variety of species and therefore make the green spaces more monotone.

One small positive aspect about this strategy can be seen in figure 122. Compared to the other strategies, the water is really close to the surface and that makes it easier to see. However, the lack of green space surrounding it, makes it harder to actually experience and interact with.

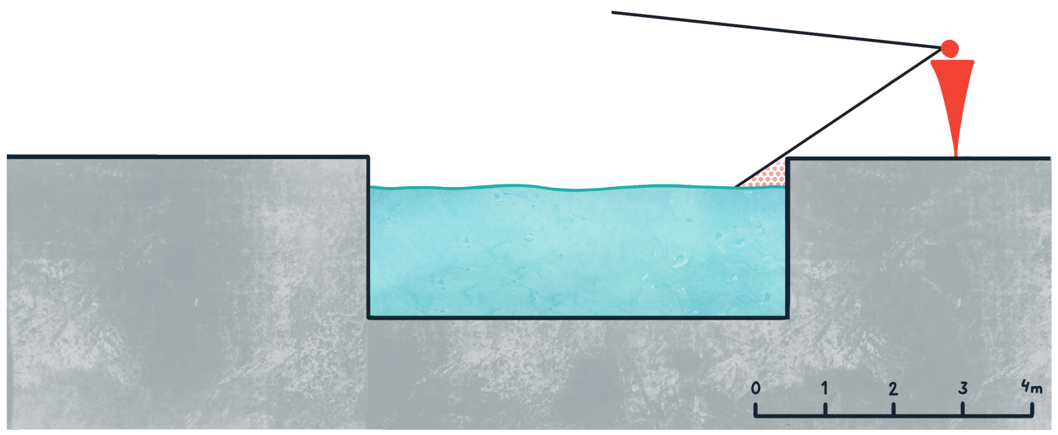


Figure 122. Blocked view with water at -0,43 m NAP

Criterion 5

Water awareness 0
The mass of this water body is so big that fluctuations after heavy rain will barely be visible, this means that users will not become more aware of the water issues.

Biodiversity 0
Adding water from the Schie is not very beneficial for biodiversity because nature friendly banks are very complicated. It therefore eliminates the ecological hotspots that exist in the gradient between dry and wet space in nature friendly banks. Bosom water is also generally lower in quality so bringing it into the area might not be ideal.

Heat reduction +
Surface water does not impact heat stress very much. However this water body is much deeper and therefore stays cool longer. So the water might have a bigger, positive, effect on heat stress compared to the previous strategies. Because activities in the protection zone are limited, the most likely space usage there would be a park. Depending on the design, it could positively impact heat stress.

Multifunctional space -
Looking at multifunctional space usage the banks of the Schie have a lot of restrictions. The east bank of the Schie is part of the regional water defence system so it has a core and protection zone of 21 metres in which construction and activities will be limited.

Costs --
Creating inlets from the Schie into Schieoevers includes lengthening the regional water protection structure. This will require a lot of legal hassle with the waterboards and research, both of which will probably cost a lot of money. Apart from that, the construction of these inlets and levees will also need a lot of specialized attention which in turn translates to more money. Realizing this strategy will be very expensive.

STRATEGIES

Strategy 4 - Pocket parks and climate adaptation measures

The final strategy to evaluate is the strategy by the municipality. Like mentioned earlier in this thesis, the municipality chose to use mainly climate adaptation measures to handle water issues in Schieoevers Noord. The main point for this strategy, regarding green-blue structures, are the pocket parks. These pocket parks all have a green function and some can also have an additional blue function in them. They are at least 400 m² (20x20) and should vary in their function, identity and appearance.

In the green-blue framework drawn in the municipal plan there is also a small area with what seems to be surface water, but there are not further details or descriptions of that in the document so it will not be taken into account for this evaluation.

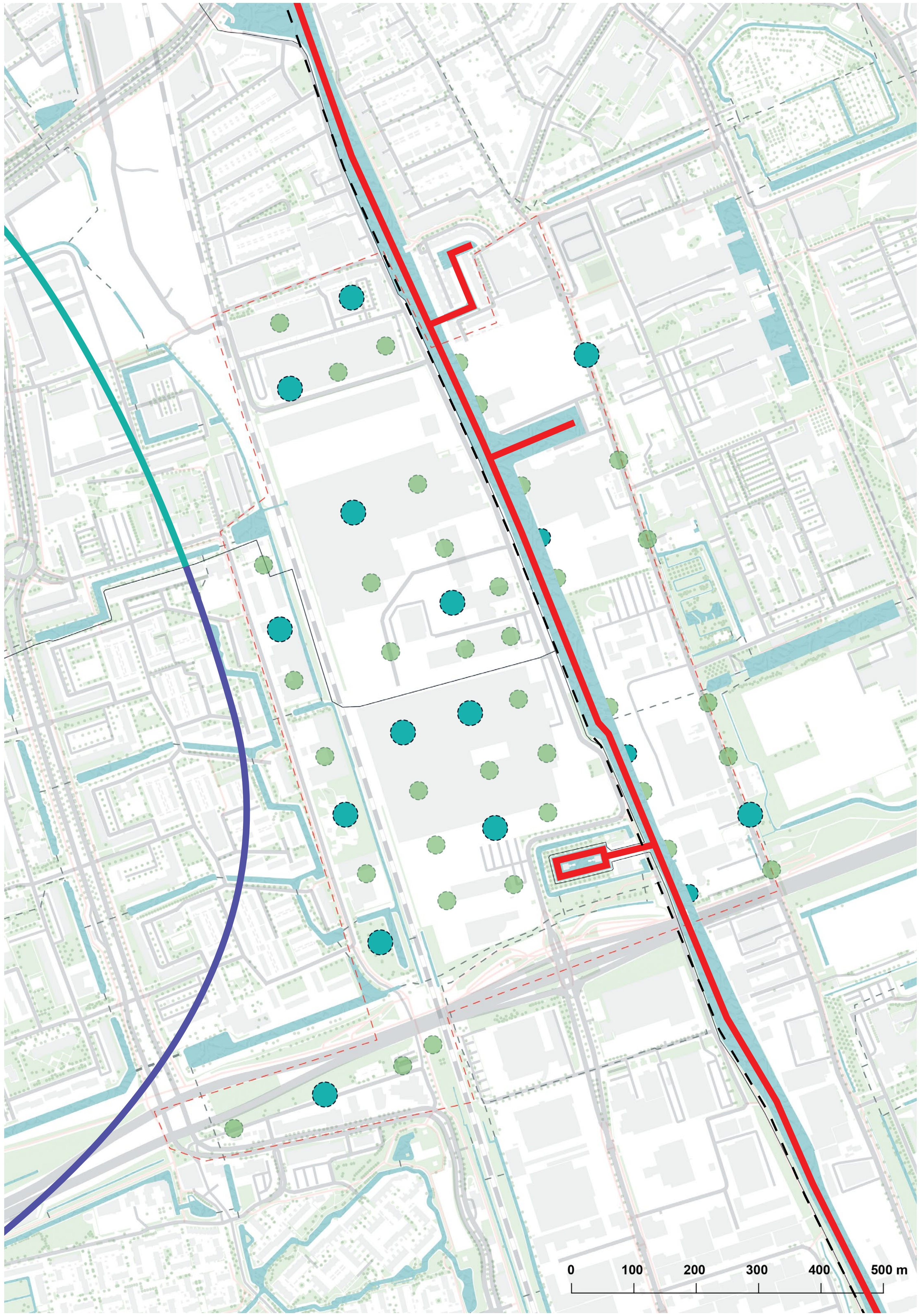


Figure 123. System of the fourth strategy

Criterion 1

This strategy has a very low space impact, figure x shows the amount of space left after all pocket parks shown in the plan have been taken into account. The calculation used was:

$A_{empty\ space} - n_{parks} * A_{park}$

Figure x shows the measurements and a possible illustration of what a pocket park might look like.

	Space left [m2]	Space left with parks [m2]
Area 5	7800	5800
Area 6	49900	46700
Area 7	17400	16600
Area 8	39100	35500
Area 9	9400	8600

Figure 124. Table with leftover space for criterion 1

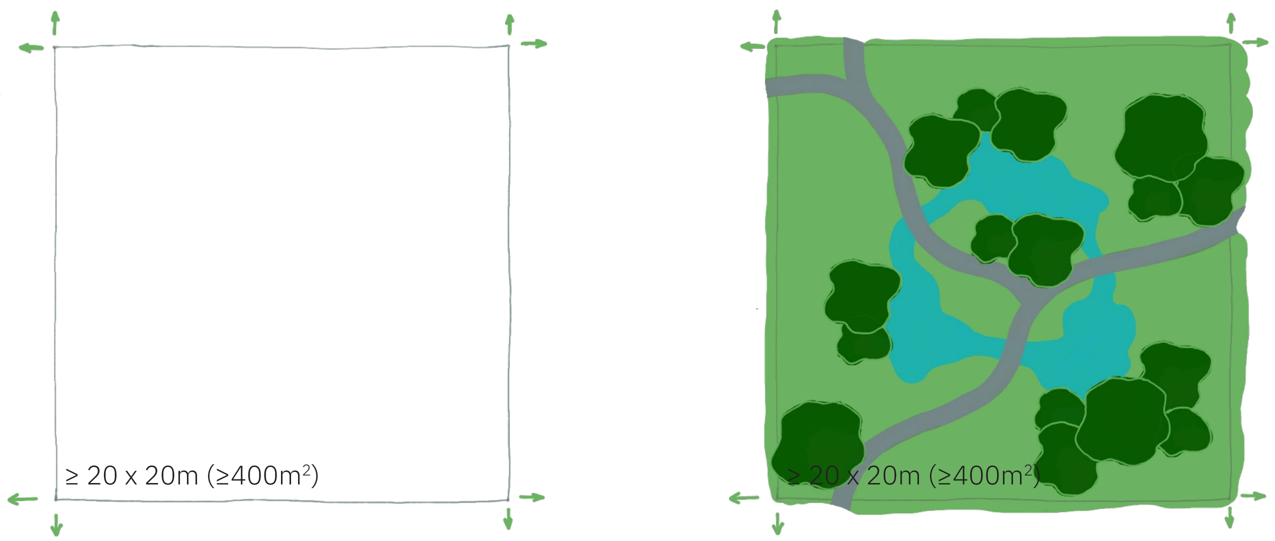


Figure 125. Pocket parks size and scale

Criterion 2

Since the 325-norm is made to evaluate static storage in polder areas, it does not apply to the measures in this strategy. Static storage is the amount of (rain)water that can additionally be retained in the surface water system. So it is basically the volume of the allowable water level fluctuation. Since this strategy does not add surface water to Schieoevers Noord it also does not add any static storage.

The area of Schieoevers looked at for these strategies is about 50 ha. This means there should be about 16.250 cubic metres of static water storage. Using this strategy would not satisfy the 325-norm for static storage in polder areas.

Criterion 3

Adding no surface water to the area of Schieoevers will technically not affect the H.A.P. and L.A.P. since it is just a continuance of the status quo. However, when comparing it to the other strategies it does get a lower in this criterion because the other strategies at least improve some components of the polder systems.

Higher Abtwoudse polder might indirectly be negatively impacted if this strategy was used because it takes away a large chunk of space that will not be available for any other development in the foreseeable future. Meaning that improving the situation in Higher Abtwoudse polder to reach the norm will be harder.

Criterion 4

Having a large number of unique and diverse pocket parks, in addition to the Schiepark, is good to create a diverse public space. The parks can technically be designed to fall within all three of the asset categories. However, depending on the size and other guidelines for these pocket parks, designing them to be well-functioning natural assets will be complicated.

The pocket parks are disconnected green systems which means that migration between the different parks will be difficult, to impossible, for some species. This drastically decreases their habitat. Having smaller habitats and therefore less interaction with other species and potential mates might lead to negative mutations within species and maybe even local extinction. If the ecological structure falls out of balance due to the decrease of natural assets, it can have a huge impact on the other types of green-blue assets in the area.

Another important factor that impacts the spatial quality of this strategy, also has to do with the disconnected nature of the parks. When users walk or bike through a green-blue environment that stretches along their path, they can get immersed in it. In the case of these smaller structures it will be much harder to achieve that. It will not evolve into a continuous green-blue network that integrates with the public space and mobility infrastructure of Schieoevers Noord.

Criterion 5

Water awareness *++*
The different pockets parks provide Schieoevers with an opportunity for educating the public. They can showcase all sorts of different climate adaptation measures and show users what they do with for instance educational signs. They could even introduce walking tours for school groups or other interested parties. The opportunities for utilizing the pocket park water measures are endless.

Biodiversity *0*
Having a high number of different pocket parks uniquely catered to specific species and providing nesting places is good for biodiversity. Like mentioned before, the issue is that animals might not be able migrate from one pocket park to another. This migration is very important for the local survival of some species. The uncertainty of this is why this strategy scores lower on biodiversity.

Heat reduction *++*
A lot of climate adaptation measures are effective against heat stress. Specifically trees that create shady areas and provide evapotranspiration will help cool Schieoevers Noord down.

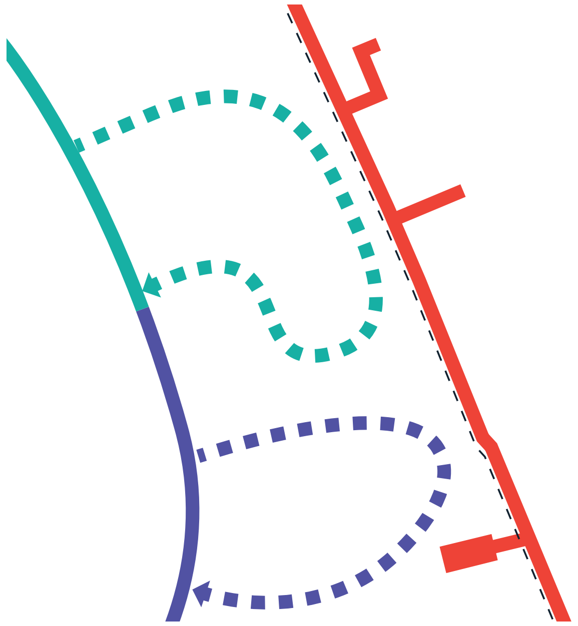
Multifunctional space *++*
Looking at multifunctional space usage the possibilities are again endless, depending on the type of measures used in the pocket park, every single one can have its own combination of functions and allow for all sorts of activities.

Costs *+*
The costs for construction will differ greatly depending on the design of the different parks. Compared to adding a complete surface water system to the area the costs will most likely be a lot lower.

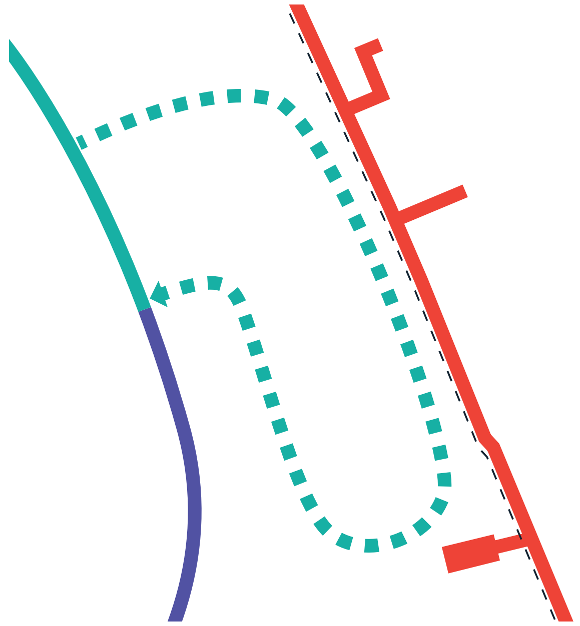
STRATEGIES COMPARISON

Overview of the evaluation criteria scores for all strategies

STRATEGY 1

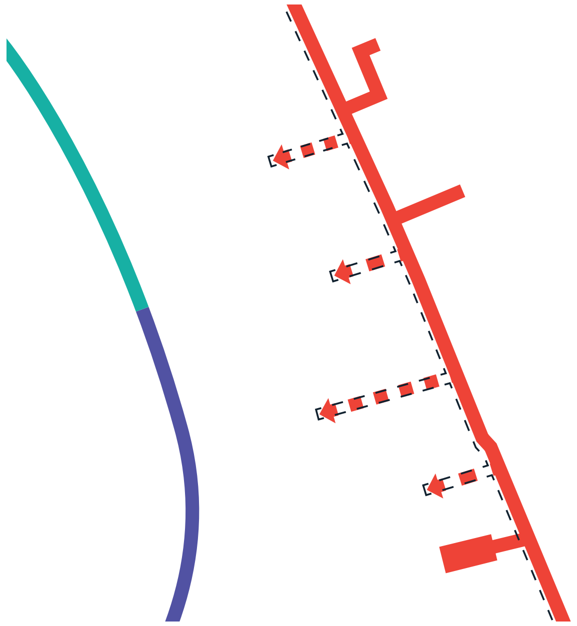


STRATEGY 2

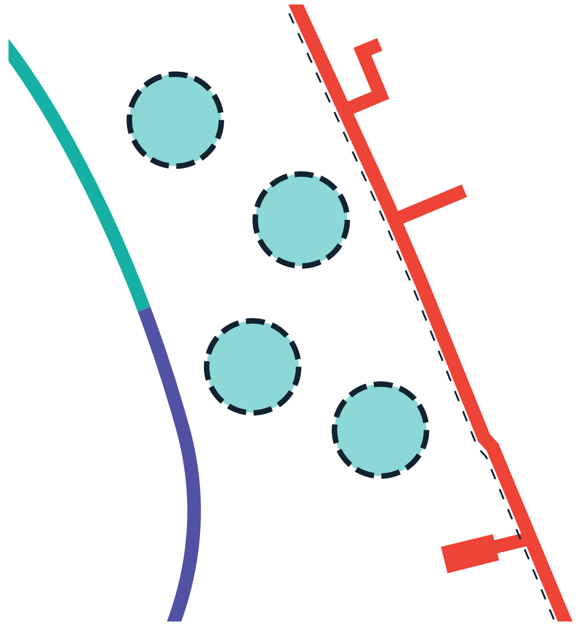


	Strategy 1	Strategy 2
Criterion 1	– –	–
Criterion 2	+ +	+
Criterion 3	+	+
Criterion 4	– –	+
Criterion 5	O	+

STRATEGY 3



STRATEGY 4



	Strategy 3	Strategy 4
Criterion 1	– –	+ +
Criterion 2	–	– –
Criterion 3	O	O
Criterion 4	– –	–
Criterion 5	–	+ +

Figure 126. Comparison matrix for evaluation results per strategy

FINAL PROPOSAL
Sub-polder

This final proposal aims to take the best parts of the strategies and combine them into a strong system. Having five different water levels in Schieoevers Noord was not a problem until now. But now that this redevelopment brings the opportunity for creating a new water system, having all these different levels makes it very complex. That is why this proposal suggests a sub-polder system, meaning that the water level in Schieoevers Noord, sub-region five through ten, should be equalised. This will create a sub polder separate from Lower Abtwoudse polder, but still connected to Higher Abtwoudse polder using a pumping station.

The step from strategy one to strategy two showed that shifting the water level in the area to a higher level was very beneficial. This proposal goes even further on that and brings the water even higher. With a level of -1,33 m NAP the new water system would be at the height of the existing water around Kruithuis. This means that opposed to the other strategies this water can now also be integrated into a the rest of the system. More circulation will be possible and the quality of the water in the Kruithuis area will improve. To preserve the old foundation of Kruithuis, -1,33 m NAP should be the minimal water level in the entire system.

Because the ground level in Schieoevers Noord (between the train tracks and the Schie) is so high (0,10 m NAP), it is still possible to create a system with a very flexible water level. With the minimum level at -1,33 m NAP the maximum allowable fluctuation can still be one metre. This creates a very good amount of static storage in the area.

As Figure 127 shows, this water level saves space so that the Schiepark and some of the pocket parks also have a place in this proposal. By giving the area diversity in the type of greenery it builds upon the positive aspects that strategy four brought without having the negative aspects.

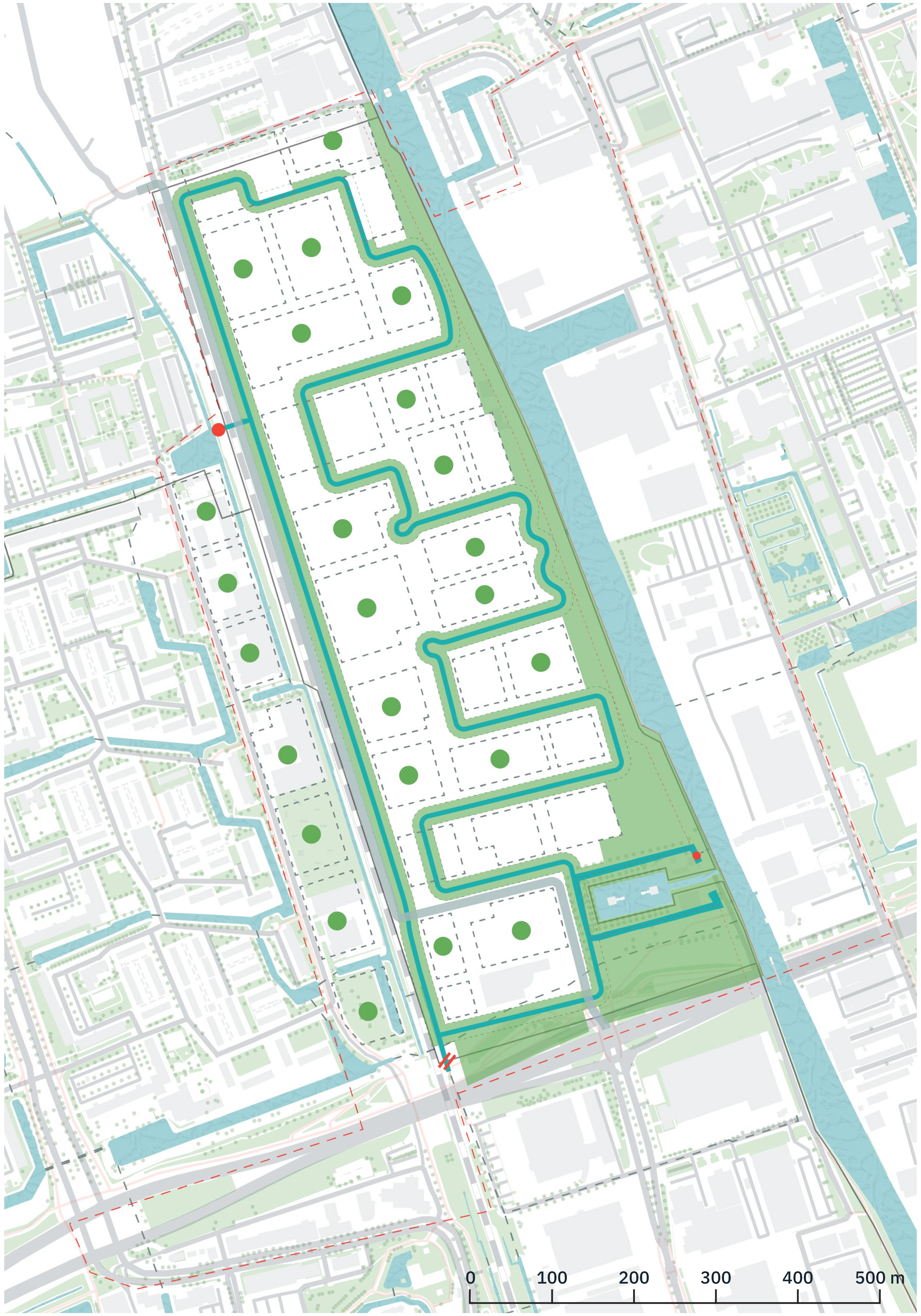


Figure 127. Proposal map

FINAL PROPOSAL

Guiding map - calculations and rules

The map made for this proposal is scaled and has some important technical details, that require elaboration, in it.

1. This map shows the minimal width of the water at 6 metres, according to the principles mentioned before. As well as the space needed for the standard nature friendly banks with a slope of 1:4. (section in figure 128)

2. It also shows the protection zone (section in figure 129) for the levee structure in the Schie quay. No water can be dug inside this zone, to prevent seepage problems.

3. Because the system is at a separate water level from the Higher Abtwoudse polder, it needs its own circulation. There is a pumping station that has two types of pumps in it. One, the circulation pump, ensures the water in the new system can circulate in a maximum of 10 days. The other one, the evacuation pump, allows excess water from the H.A.P, to be transported into Schieoevers within 2 days, in case of emergency.

   Circulation pump
   10 days = 14.400 min
   $V_{\text{water in S.O.}}$ ≈ 35.000 m^3
   Minimum capacity of circulation pump
   35.000m^3 / 14.400 min ≈ **2,5 m^3/min**

   Evacuation pump
   2 days = 2880 min
   $V_{\text{shortage H.A.P.}}$ = 33.354 m^3
   Capacity of evacuation pump
   33.354 m^3 / 2880 min ≈ **11,6 m^3/min**

4. There is a second pumping station for exchange with the Schie. It prevents unnecessary connections under the train tracks, prevents an increase of pressure on the pump in area three and prepares Schieoevers for heavy rainfall situations. This is a redundancy for when there is an unacceptable surplus or shortage of water in the system. This measure is important for a well-functioning and safe system.

   This pump should be able to pump 1,5 L/s per hectare, which, for 50 ha, amounts to a capacity of: **4,5 m^3/min**

   By placing this pumping station at the closest point to the Schie the distance of the diver is as short as possible. And because the water around Kruithuis actually needs to stay at or above the minimal level placing the pumping station there will make sure that it will always be protected.

5. Finally this map also shows the borders of the building blocks. Like the space matrix calculation showed, the blocks are slightly smaller in some places but they still fulfill the FSI and maximum building height set in the municipal plan.

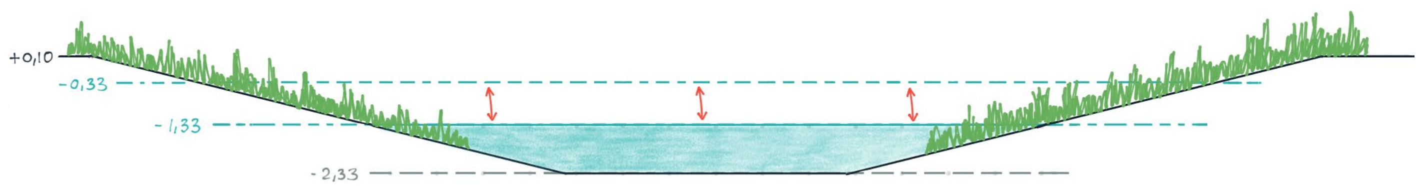


Figure 128. Section with two NFB's water level -1,33 m NAP

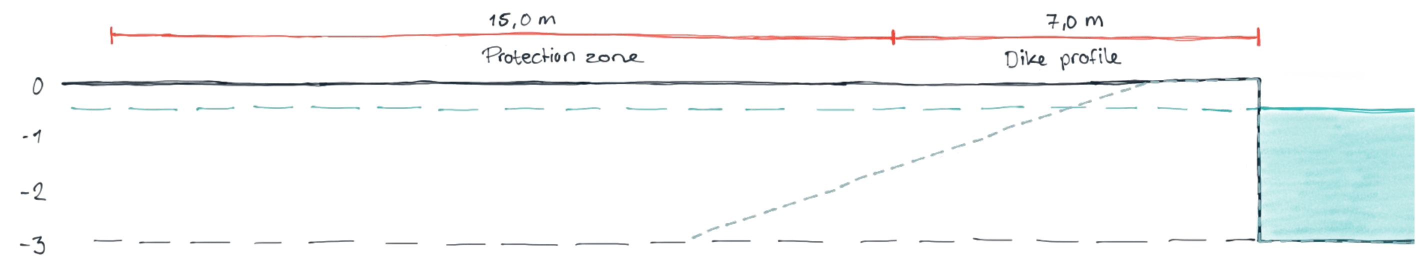


Figure 129. Section with levee protection zone

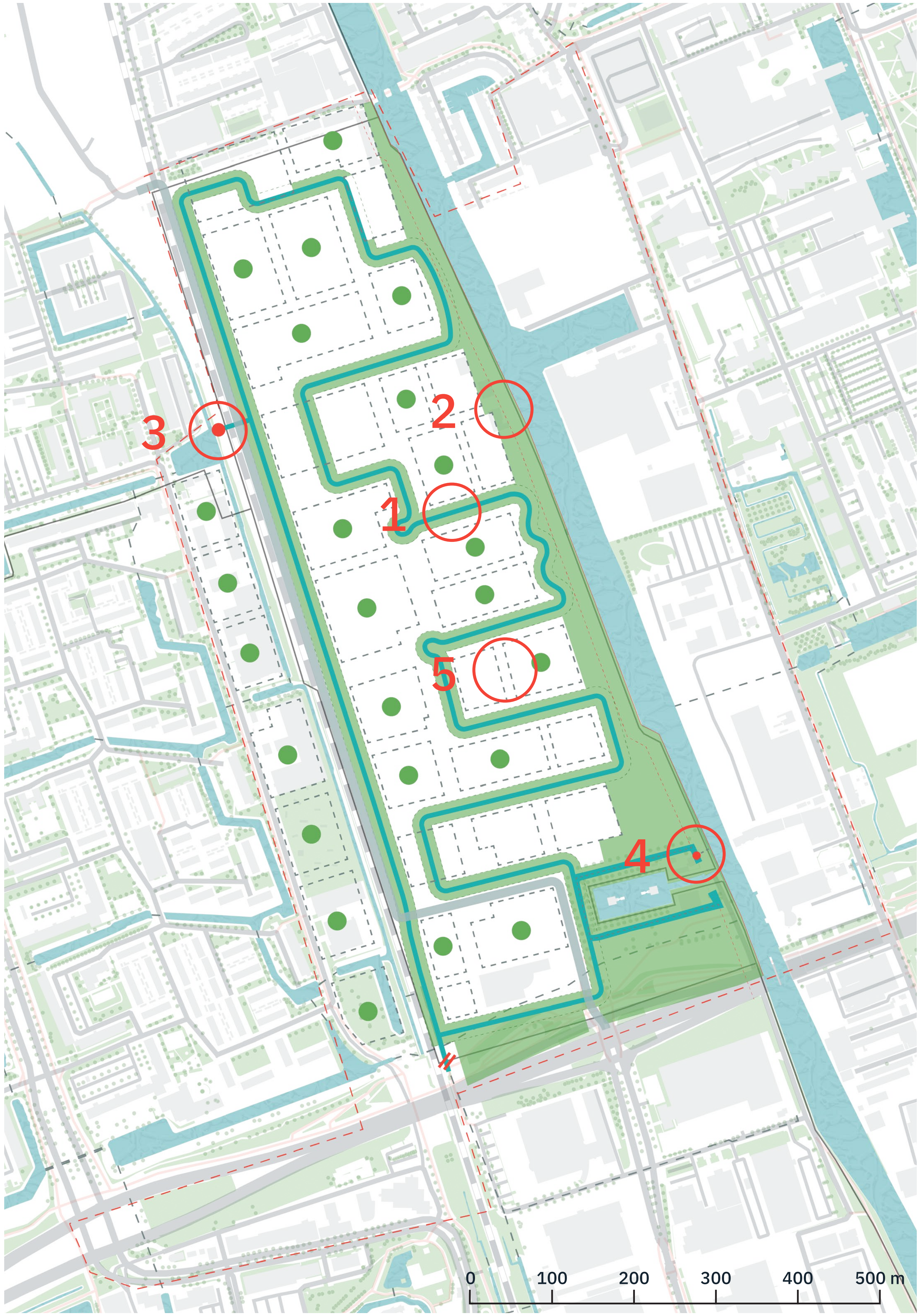


Figure 130 . Proposal map with indication of guidelines

FINAL PROPOSAL

Criterion 1

When looking at studies into the sustainability of Schieoevers Noord, it became clear that nature friendly banks are highly preferred over steeper banks. This has a large impact on the space needed. Therefore this evaluation criterion will look at how much water can fit with one nature friendly bank and with 2 nature friendly banks when using the new Schieoevers water level.

As shown in figure 132 within Schieoevers the space needed for 1 NFB is 15.3 m^2 per linear metre of water and 2NFB's is 24,6 m^2 per linear metre of water.

Figure 131 shows the amount of space left after fitting in the water. It shows that in area 5 it will still be im-possible to fit the entire system using two nature friendly banks, however, looking at the other areas, the full length could have two nature friendly banks. This is an improvement compared to the strategies.

	Space left [m2]	Space left with one NFB [m2]	Space left with two NFB [m2]
Area 5	7800	731	-3565
Area 6	49900	24057	11605
Area 7	17400	10375	6990
Area 8	39100	16079	4379
Area 9	9400	5300	2807

Figure 131 . Table with leftover space for criterion 1

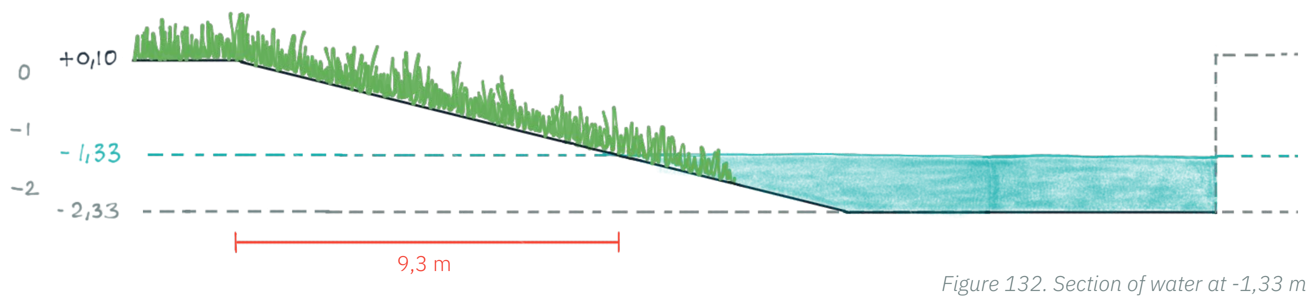


Figure 132. Section of water at -1,33 m NAP

Criterion 2

The calculation for the static storage in this strategy is very similar to the previous one, except that in this one the L.A.P. water level is not used. With the lower allowable fluctuation the water storage will be less in this strategy compared to the previous one.

Static storage [m^3]:

Per linear metre of water without NFB $= \Delta h_{water\ level} * l_{width\ bottom}$

Per linear metre of water with 1 NFB $= (\Delta h_{water\ level} * l_{width\ bottom}) + (2 + (4 * \Delta h_{water\ level}))$

Per linear metre of water with 2 NFB's $= (\Delta h_{water\ level} * l_{width\ bottom}) + (2 * (2 + (4 * \Delta h_{water\ level})))$

The static storage calcultion for the proposal is very similar to the one from strategy two, exept the water level fluctuates from -1,33 to -0,3 m NAP, which still makes the difference in water level 1 metre. In the calculation the minimal width of the water (6 metres) is used, in reality the width will probably vary.

$l_{width\ bottom}$ = 6 m

$\Delta h_{water\ level}$ = 1 m

Schie

Per linear metre of water without NFB $= 1 * 6 = 6\ m^3$

Per linear metre of water with 1 NFB $= (1 * 6) + (2 + (4 * 1)) = 12\ m^3$

Per linear metre of water with 2 NFB's $= (1 * 6) + (2 * (2 + (4 * 1))) = 18\ m^3$

Because this is just a proposal, it cannot yet be determined how much of the water system would actually have two completely nature friendly banks. That is why for the static storage calculation of this system 1,5 NFB's were used.

Per linear metre of water with 1,5 NB's $= (1 * 6) + (1,5 * (2 + (4 * 1))) = 15\ m^3$

l_{water} = 3691 m

$V_{static\ storage} = 15 * 3691 = 55.365\ m^3 \approx 1100\ m^3 / ha$

With the norm being 325 m^3/ha, this proposal scores very well on static storage.

Criterion 3

This proposal has a positive effect on the static storage capacity of both the Higher and the Lower Abtwoudse polder. Shown in the following calculation is the effect of taking away 50 ha of space on the storage capacity. Higher Abtwoudse polder still wont quite reach the 325-norm but it does get closer to it. Lower Abtwoudse polder already has a surplus of storage capacity, which becomes even larger. For comparison, the calculation also shows the storage capacity of this proposal.

Schieoevers = 50 ha
(H.A.P. = 20 ha & L.A.P. = 30 ha)

H.A.P.
A = 218 ha
$V_{static\ storage}$ = 37.500 m^3
Current static storage — 172 m^3/ha
H.A.P. (- S.O.) = 198 ha — **189 m^3/ha**

L.A.P.
A = 496 ha
$V_{static\ storage}$ = 191.000 m^3
Current static storage — 386 m^3/ha
L.A.P. (- S.O.) = 496 ha — **411 m^3/ha**

Schieoevers
A = 50 ha
$V_{static\ storage}$ ≈ 55.000 m^3
Static storage — **1100 m^3/ha**

This proposal will not have a direct effect on the water quality of the Lower Abtwoudse polder. It will however, have a positive effect on the water quality in the Higher Abtwoudse polder. The biggest polluting factor in the H.A.P. is the exchange with the Schie. Because this proposal has such a large static storage capacity it can actually support the Higher Abtwoudse polder when it has an excess or shortage of water and therefore (mostly) remove the need for exchange with the Schie.

Criterion 4

Because the height difference between the ground and water level is smaller, more interaction with the water is possible and there is enough space for creating nature friendly banks. These gently sloped strips of green surrounding the water provide ample opportunity for integration with the pedestrian or cycling routes for instance by way of pier paths, or by creating usable green spaces for waterfront picnics or other activities. Thus creating a lot of experiential green and blue spaces.

Because there will be so much water in the area, in addition to the experiential areas, in other parts, the nature friendly banks could for instance be outfitted with higher or wilder planting which will allow for better habitats and nesting places for small creatures. The rough plants will ensure these green areas are not suitable for use by people, which in turn creates safer environments for biodiversity to flourish.

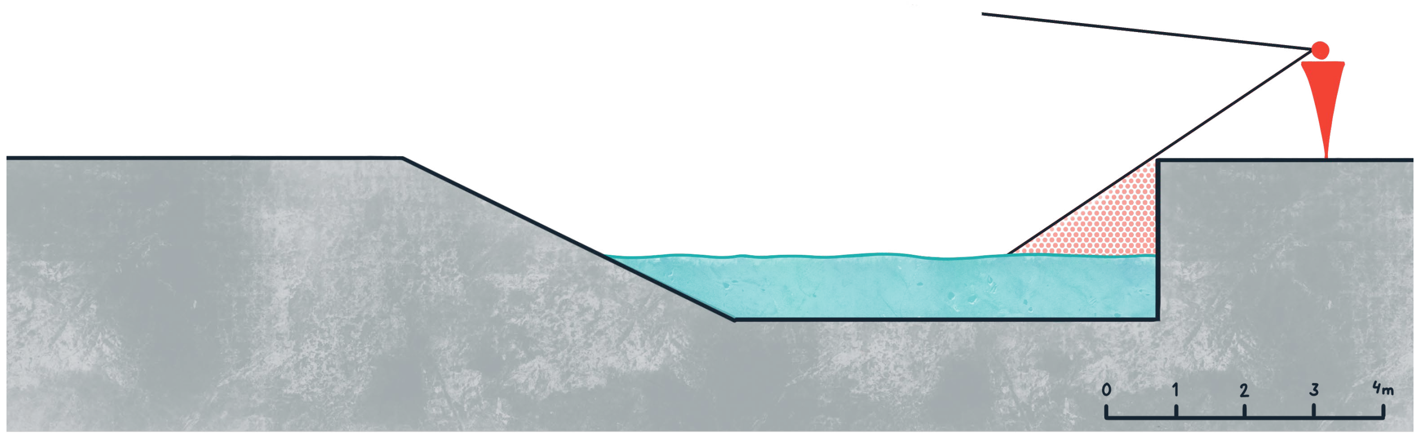


Figure 133. Blocked view with water at -1,33 m NAP

The space saved by lowering the difference in height can be used to implement some pocket parks. All pocket parks, as stated by the municipality, should be diverse and unique. This means they can be designed for any of the three classes mentioned in this evaluation criterion. Depending on the need they could be experiential greenery, like a green playground that doubles as a wadi. They could also be cultural greenery, if located close to a monumental building and giving them an industrial character to highlight the cultural and historical origin of Schieoevers Noord. Or they could have a rougher character to cater to the natural system and ecological diversity.

To summarize, creating a balance between the three different classifications of greenery and water will be easier in this proposal because of the diversity of the system. The spatial quality of the existing cultural green and blue spaces will be enhanced by adding accompanying experiential greenery and water, and the ecosystem will be strengthened by more diverse natural blue-green spaces that will cater to a wider variety of species.

Criterion 5

Water awareness ++
Adding a solid surface water system that allows for fluctuation in an urban area is of course beneficial to the visibility and water awareness of the users. Additionally, the different pockets parks provide Schieoevers with an opportunity for educating the public. They can showcase all sorts of different climate adaptation measures and show users how they work, with for instance educational signs. They could even introduce walking tours for school groups or other interested parties. The opportunity for utilizing Schieoevers Noord for increasing awareness is endless.

Biodiversity ++
The balanced implementation of different types of green-blue structures will provide a multitude of nesting spots, habitats and safe zones for all sorts of species. The ribbon structure that the water system provides will allow for safe migration and therefore increase territory sizes and mating opportunities.

Heat reduction +
Adding a surface water system does not affect the heat stress of an urban area very much. What does affect the heat stress is the types of grass, plants and trees planted along the banks of the water system and in the pocket parks. Since the municipality stated that at least 50% of the pocket parks need to be cool, shaded places, they will definitely reduce heat stress.

Multifunctional space +
The opportunities for multifunctional space usage are very broad, the lightly sloping, nature friendly banks can be used for a range of different activities. The pocket parks can also be designed for a multitude of uses, apart from their green-blue function, they could double as meeting places, playgrounds, sports fields or anything else.

Costs -
Because the surface water in this proposal is not as far down, construction costs are less than in the first two strategies. However, adding surface water in any area is expensive so the costs are still a negative feature. Also the diversity of types of greenery require specialist attention. All the pocket parks, the Schiepark and the water system need to be separately designed, this will take time and therefore also money.

FINAL PROPOSAL
Suggestions for design

1. Building above water

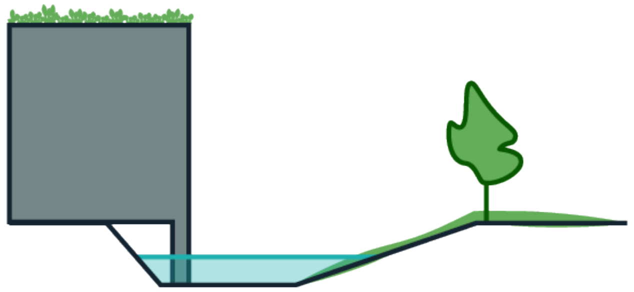


Figure 134.

Because space is limited in area 5, the suggestion for this area is to integrate the buildings more with the water system. Building a building above the water saves space and also creates interesting variation in the public space.

2. Example of a building block

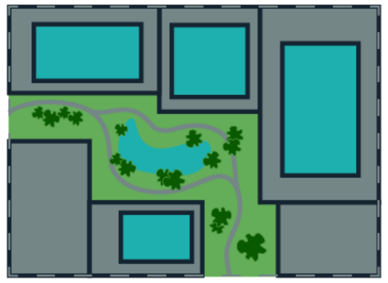


Figure 136.

The building blocks in the development plans are outlines for a collection of buildings. In this proposal they are the same. Having different buildings with a green space in the middle creates another interesting addition to the public space.

3. Filtering urban wetland

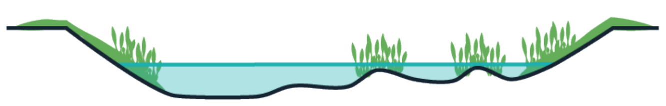


Figure 135.

Preserving the water quality in any polder system is important. The location indicated by number 3 in figure 138 shows the ideal location for implementing an urban wetland in this proposal. Urban wetlands have filtering plants that help improve the quality of the surface water.

4. Suggestion for water through a building block

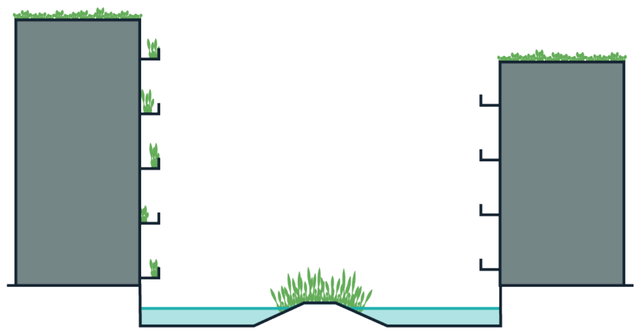


Figure 137.

When the water goes through a building block, like in location 4 in figure 138, there could be another nice variation of public space by bringing the buildings closer to the water like in figure 137. This eliminates the possibility of implementing nature friendly banks, so instead an island with gently sloping green banks might also function to replace the nature friendly banks.

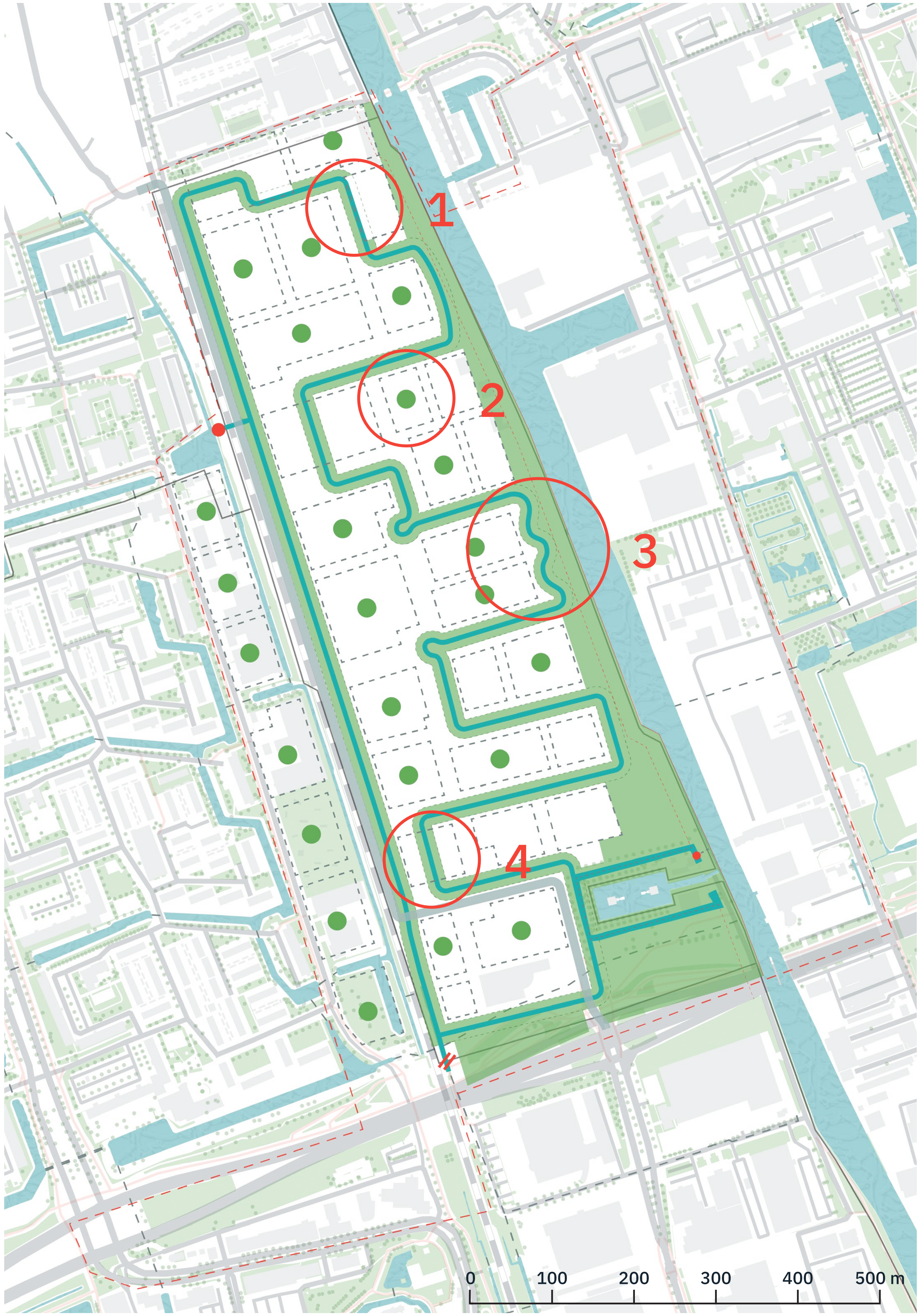


Figure 138. Proposal map with indications for design suggestions

FINAL PROPOSAL

Zoom-in areas

To showcase the quality of the public space for this proposal a few areas were chosen to zoom in on. Each of these areas will have a more detailed map and a perspective visualisation sketch. The drawings are possible options for designs focussing on the public space within this proposal. The areas chosen to zoom in on either elaborate on the suggestions for designs mentioned earlier or have a specific character which is interesting to showcase.

1. Zoom-in of area 5 where the proposal suggested building on the water

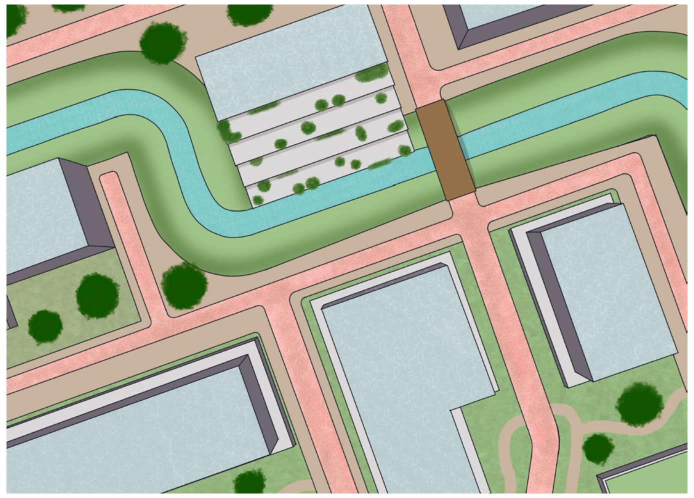


Figure 139.

2. Zoom-in of a public square with a bend of the water system.

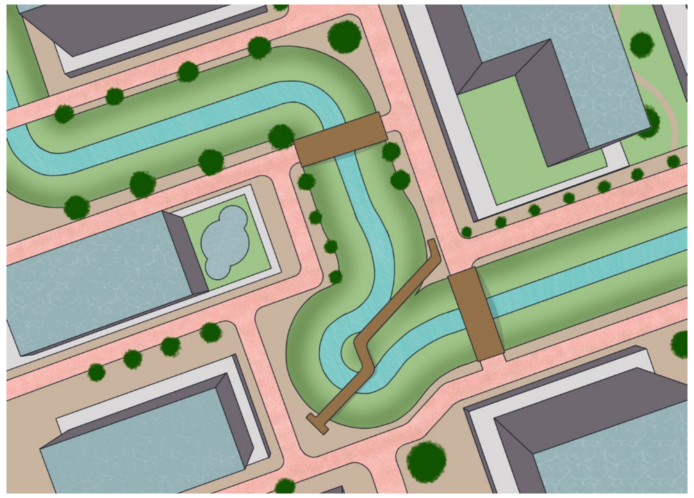


Figure 140.

3. Zoom-in showcasing the urban wetland.

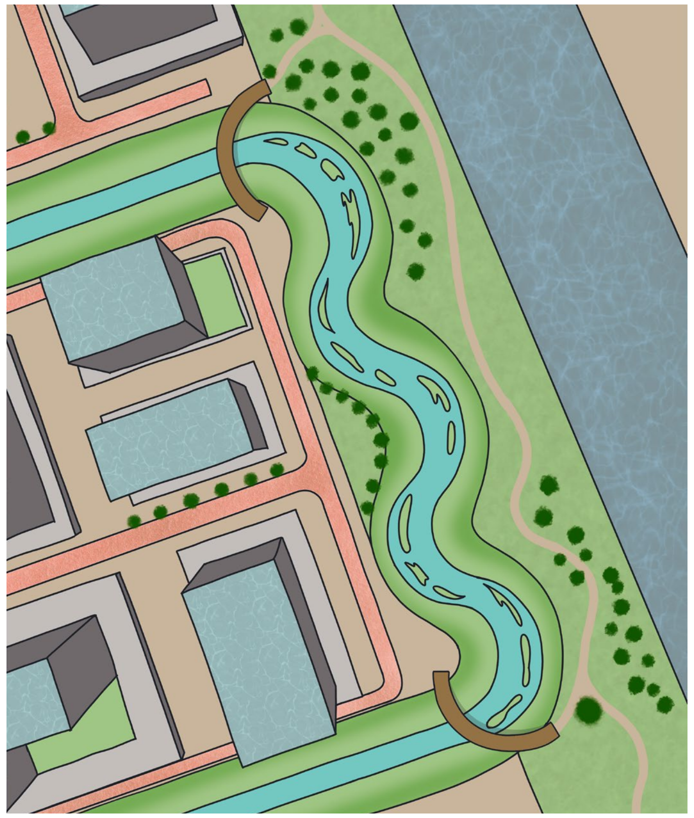


Figure 141.

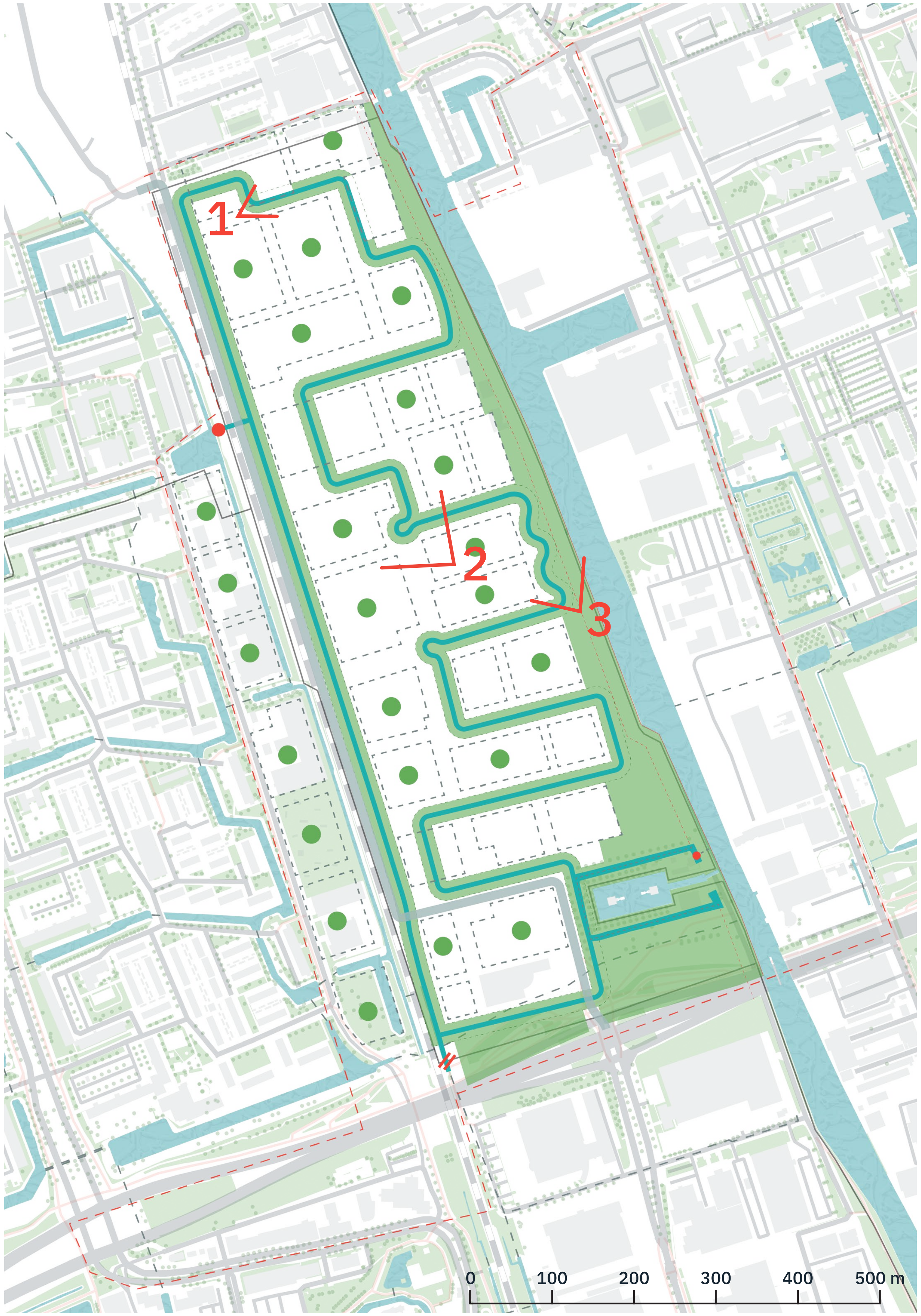


Figure 143. Proposal map with viewpoints of zoom-in locations

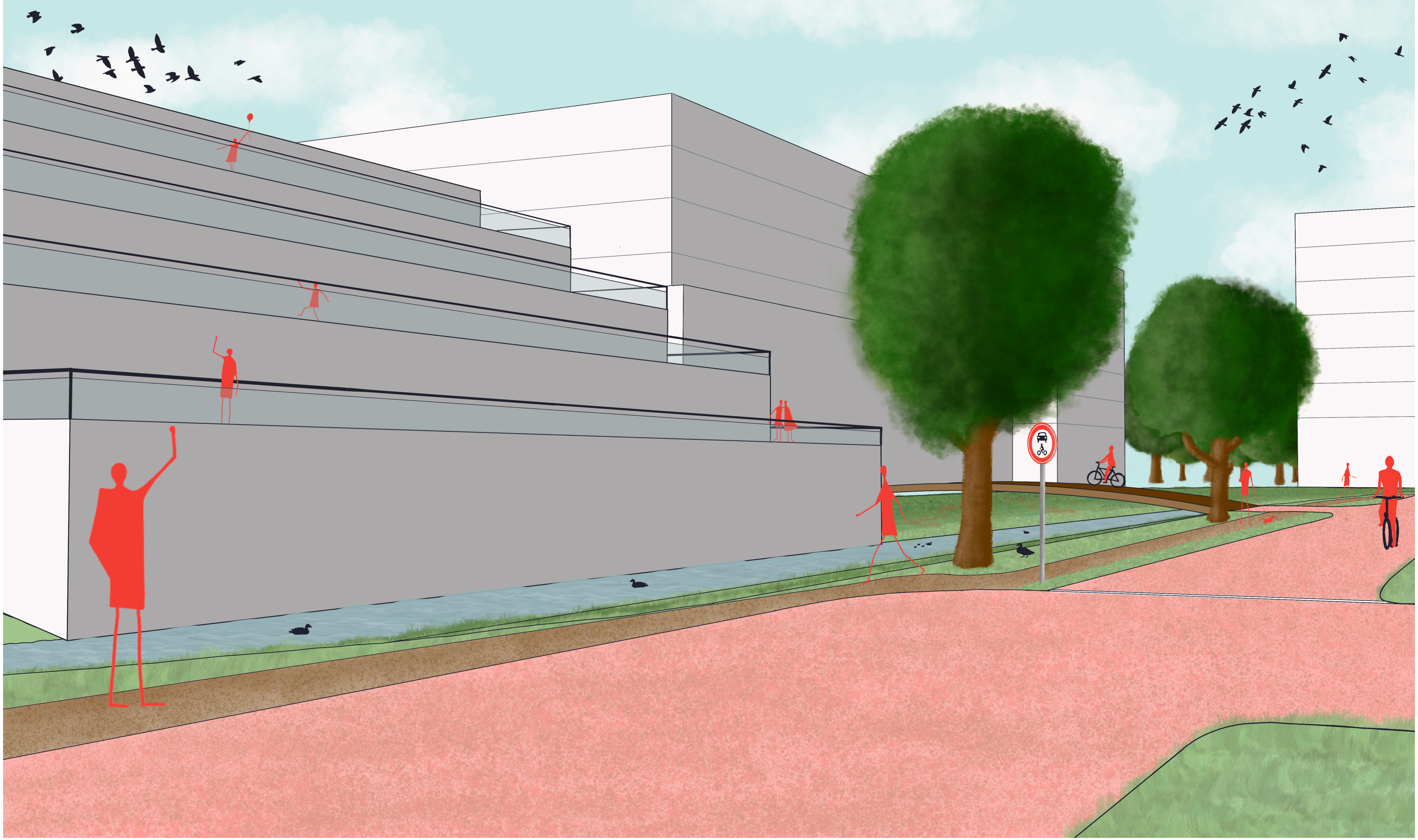


Figure 144.

PUBLIC SQUARE WITH WATER

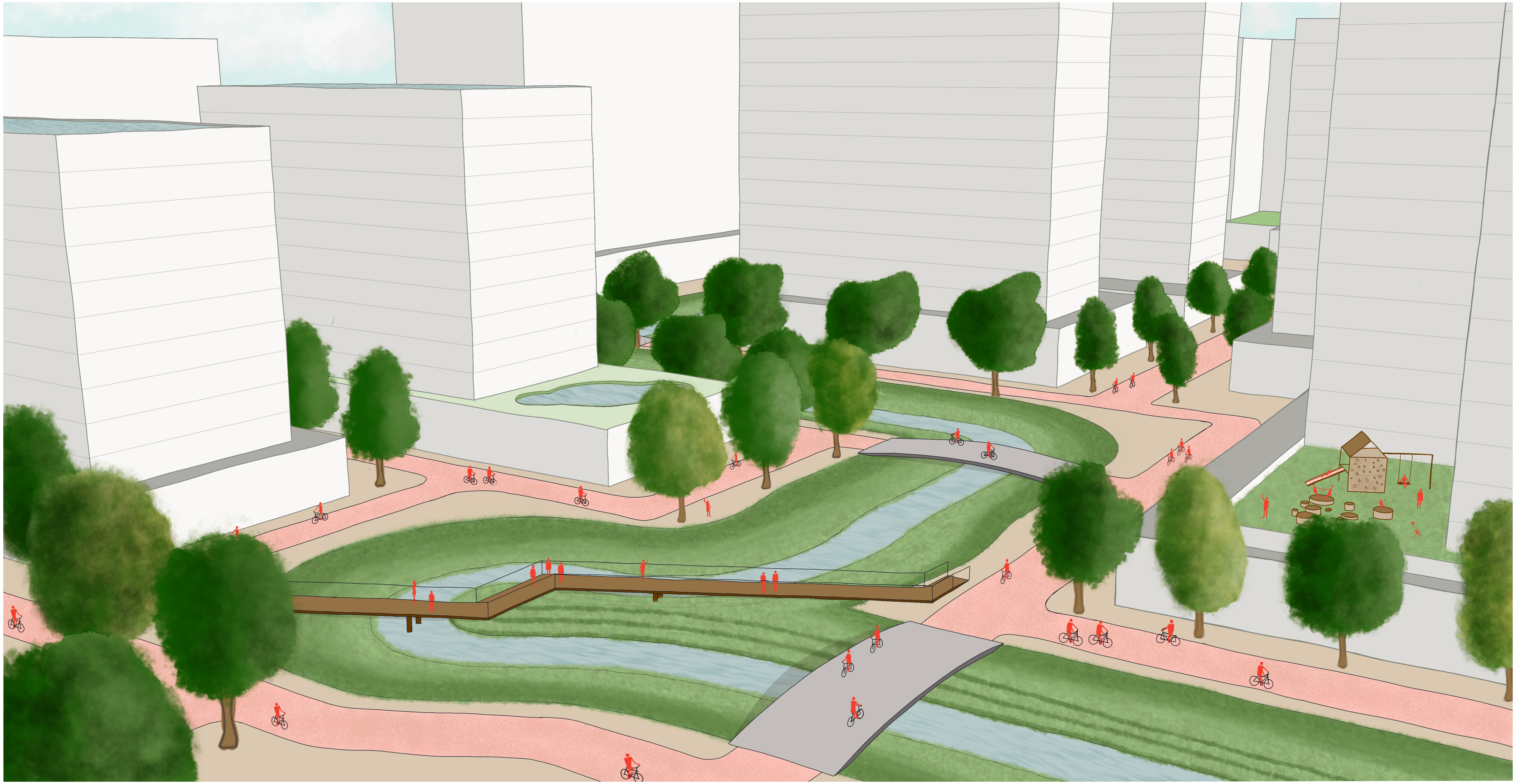


Figure 145.

URBAN WETLAND

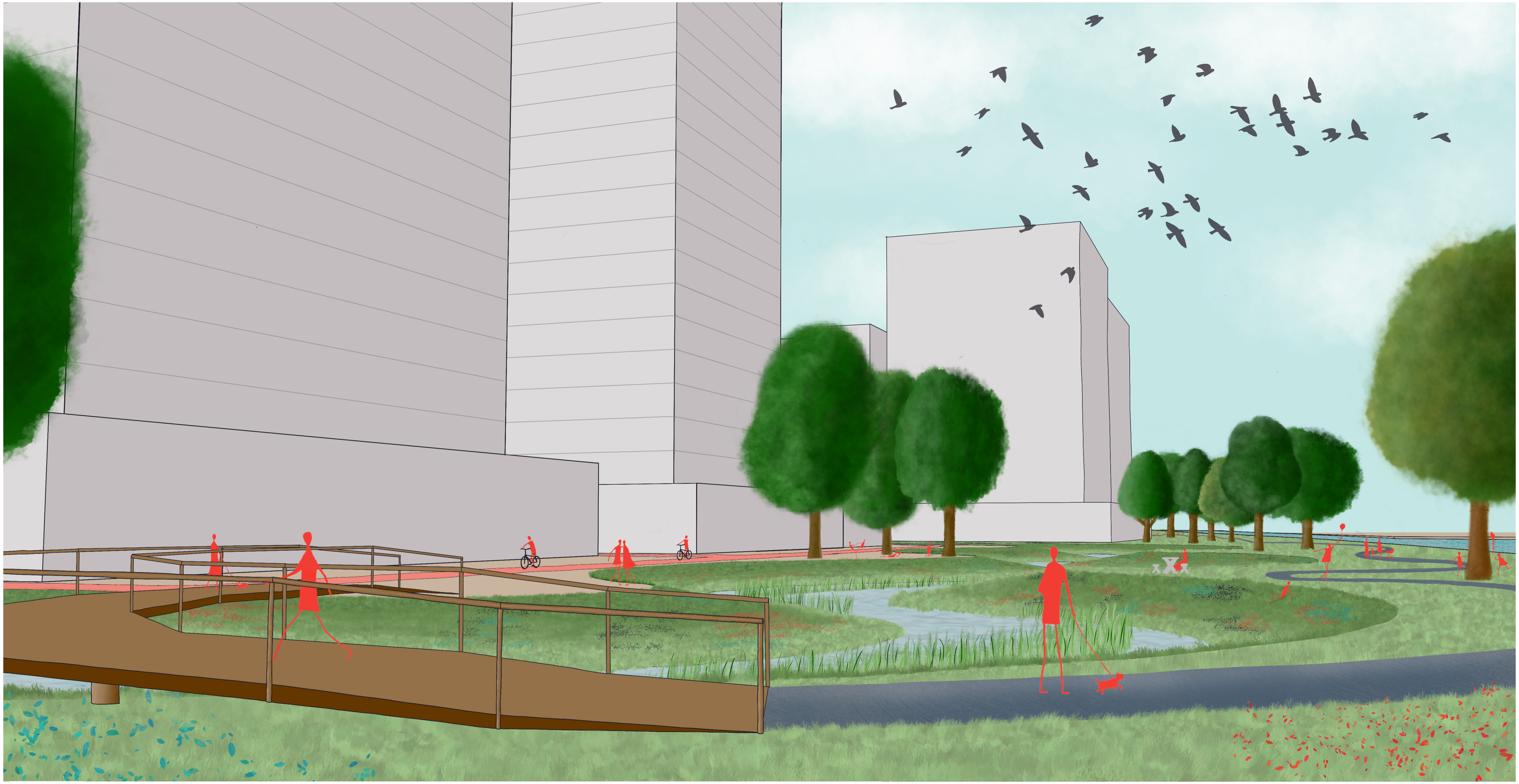


Figure 146.

CONCLUSION

This chapter has the conlusion, the recommendatios for Schieoevers Noord, elaboration on the transferability of the results, recommendations for the Climate Resilient Cities Toolbox and the reflection.

CONCLUSION

The gap in discourse

The research into the problem field in the introduction gave the answer to sub-question one; how can the gap in discourse between urban designers and civil engineers be defined within the context of urban water management? After studying when the gap originated, how it affected other areas of urban planning, the differences in language of the two fields and finally the situation within water management the definition of the gap in discourse was defined as follows:

There is a gap in the discourse between urban designers and civil engineering, within the field of urban water management. The gap is caused by the different educational background, perspective, approach and language used in the respective fields. The civil engineers lack a way to operationalise the design aspects while the urban designers lack the specific technical knowledge behind the urban water system. This knowledge gap causes multidisciplinary projects to be unnecessarily complicated and inefficient.

Knowing the causes and reasons behind the gap in discourse has helped to guide the research to bridge the gap. Literature showed that the gap has been steadily developing since the early 20th century and that it has had negative effects on different areas of urban development.

The effect on Schieoevers Noord

In order to prevent the negative externalities a gap in discourse may cause, it is essential to study where these impacts are felt for water strategies in urban development plans. The second sub-question – How does the gap in discourse affect the municipalities plans for Schieoevers Noord? – guides this analysis.

While studying the very extensive document that is the municipal development plan, one may have the impression the authors have forgotten about water strategies, since surface water is mentioned only once. Even though it is stated that Schieoevers Noord has great potential for the addition of surface water and all its benefits, the report falls short on providing any solutions or even guidance as to how this could be realised.

Further, the municipality has no intention of acquiring land in the area, but rather have the 15 sub-regions be developed separately by various developers. The developers are expected to follow the general municipal guidelines when detailing their plans for the respective areas. However, since the municipal plan lacks guidance regarding surface water, this topic cannot be prioritised by the developers. Having this many independent parties involved in the development of the area will make the creation of an integrated water system near impossible to begin with. Without strong guidance and a comprehensive set of rules set by the municipality, neither party will be motivated to work together either.

A redevelopment of the size such as Schieoevers Noord represents a rare opportunity and will probably not be a common occurrence in the near future, making it a waste to not take full advantage. Moreover, since Schieoevers is a very climate sensitive area, the redevelopment has an enormous potential to deliver a positive impact to the system of the involved polders and climate adaptation of the area.

Summarising, the communication gap has led to an important aspect for the future proof redevelopment of Schieoevers Noord to be overlooked. The positive potential, which the area definitely has, will not be able to be used with the current lack of guidance on surface water management.

Principles and evaluation

To understand the input needed to formulate a plan for a strong and integrated urban water system, the third sub question aimed to dive deeper into what the design and technical principles of the Dutch surface water system and climate adaptation measures are and how these can be used to guide a proposal.

The chapter on principles of water management showed that there are many things to keep in mind when designing a climate-proof area. The surface water needs circulation and filtration to stay healthy and different measures can be used to reduce water nuisance, heat stress and other negative externalities of climate change.

These principles help set limitations and provide stepping stones for the creation of a healthy system. Additionally, climate adaptation measures exist to further the climate adaptivity of certain areas, though it should be noted that the positive impact of a healthy surface water system would be greater. Therefore, provided there is space within the area in question, these measures should not be applied instead of a comprehensive surface water system, but rather serve as an addition to the same.

All existing principles combined can form the basis for the development of a set of evaluation criteria. These criteria are merging design and technical goals, so as to provide a holistic evaluation of the proposal in question. In addition to being used to evaluate scenarios and strategies, the criteria can also be of use when going through feedback loops further on in the design process. Here the criteria are especially useful to confirm that proposed strategies still match with the originally stipulated goals for the project.

Possibilities and strategies

The fourth sub-question was as follows: Building on the principles and analysis, what are the possibilities for making the exiting plans for Schieoevers Noord more water inclusive, and do those options result in an overclaim of space? As the question itself stipulates, its answer will stem from a combination of the analysis and principles discussed in sub-questions two and three.

The subject matter of this question turned out to be rather delicate, as technically adding surface water does not have to lead to an overclaim of space. However, some changes and concessions in other areas will be necessary, which adds complexity to this specific topic.

Generally speaking, there are a lot of possibilities for Schieoevers Noord, especially when building the buildings in the area higher than originally planned (while still within the limits of the municipal plan). With an adjusted building strategy, the area offers more than enough space to include a very extensive and healthy surface water system. With this said, fitting the system, especially with all other parts of the design having progressed further along, presents quite a puzzle, as can be concluded from earlier chapters of this thesis. Nonetheless, looping through multiple stages of the design process while implementing feedback and analysis outcomes, results in a solid design for the water system.

The effect on Schieoevers Noord

The final question aimed to use the knowledge gained in all the previous questions and extract it in such a way that the results can be used in other (re)development plans. In order to be able to do that first we need to know what general conditions need to be present in an area so it can be helped with the outcome of this thesis.

Overall, the evaluation criteria put forth in this thesis are based on principles for the Dutch water system. This means, as long as other (re) development projects have a comparable water structure, these criteria can be applied to test strategies for the project in question. Naturally, some minor adjustments may have to be applied to fit the individual case ad its specific conditions.

Another important insight is that for any (re) development project it is imperative to start the process of creating a sound water system as early as possible. This is mainly because water structure often take up a lot of space and are therefore not suited for retrofitting.

In case a development project already has a water system in place prior to (re)development, the evaluation criteria can still be applied to illustrate the status quo and consequently compare the proposed strategies and changes, to conclude their effect on the existing situation.

Evaluation of the Climate Resilient Cities toolbox

The Climate Resilient Cities Toolbox can be a very useful utensil to jump-start a conversation between designers and engineers. It should be taken into consideration though, that for designers this tool can be quite intimidating. It has a lot of purely technical background information that designers are not normally taught about.

The documentation of the toolbox states that it can be used in design workshops or individually by professionals of different backgrounds. After using the tool in the research on principles and the design of the water system in Schieoevers Noord there are some things that the author thinks might make the software more accessible.

The tool in its current state consists mostly of the technical principles and numbers behind climate adaptation. As described earlier in this thesis this is something which urban designers sometimes struggle with because of the difference in educational background. This tool makes it more accessible for designers to see the numbers behind their designs. However that is only part of the problem, the gap in discourse also goes the other way, designers often struggle explaining their decisions and designs to their more technically schooled engineering colleagues. This is why the toolbox would greatly benefit from adding more of the design aspects in its system.

For a start the water awareness, visibility, biodiversity effects, could be useful in the tool. An evaluation as simple as the scale from 0-3, 0 being no effect and 3 being a large effect, could already help designers bring their point across when using this software tool with professionals from different backgrounds. They would be supported by the software when explaining why for instance a bioswale would be more beneficial for ecology and biodiversity even though it might have a lower storage capacity or be more expensive than infiltration boxes.

Lessons learned

The main research question asked what the development of Schieoevers Noord teaches us about water inclusive urban regeneration, when looking at the gap in discourse between urban designers and civil engineers. The answers to all the sub questions combined give a clear figure of these lessons.

A good analogy representing the preferable interaction between urban designers and engineers in urban water management is looking at urban redevelopment as a bakery trying to improve their product. The first thing that needs to be done is to define the current state of the product, where the design aspect are like looking at customer reviews and the technical aspects are like looking at the composition of the product. In urban development this translates to the analysis. The area needs to be thoroughly analysed on both technical and design aspects. These analyses can be done by both parties separately, as long as the results get combined afterwards.

Both the designer and the engineer bring forth their list of ingredients that will improve the product. The technical ingredients are based on the needs of the water system that came forward in the analysis. The design ingredients are based on the requirements of the client (in this case the municipality), the wishes of potential users, and the quality of the public space.

In order to move forward in this process, these two ingredient lists need to be combined into a recipe, this is where the gap in discourse starts causing problems. Going through this process for Schieoevers Noord showed that it can be possible to bring the designer and engineer closer together by using tools, like the Climate Resilient Cities Toolbox and the Green-Blue Grids evaluation system. The aim of these tools is to make understanding of each other's points of view easier. By using these types of tools to discuss and visualise all ingredients, it can be made legible for both parties. These discussions and visualisations eventually turn into a recipe, using the ingredients from both parties. In this thesis the recipe was the map of the proposal.

This map visualised all rules and requirements for the area, as well as giving suggestions for further design.

The next step is to evaluate the recipe. The set of evaluation criteria developed in this thesis can be used to test the recipe and see if it addresses the issues that came forward in the analysis. If it satisfies all requirements the designer can now become the baker and finish the product. Before actually selling this improved product it needs to go through the feedback loop again to see if any unexpected changes happened while developing the design, or the baking of the cake. Finally, when all is well the designer can decorate the cake so it will be appetizing for the client and users.

In reality, after making the design for the water system there is a lot more work to be done. This comes in the shape of discussing with professionals in the other fields of urban regeneration who have gone through similar processes of creating their own ingredient lists, recipes and baking their cake. This step was not within the scope of this project and therefore requires further research.

The baker analogy shows that only having the technical ingredients will not satisfy the client, the users or the public space, and only having the design ingredients will not make a sustainable and strong water system. They need to come together and make a clear recipe to support the designer when working up the final design.

In conclusion, the lessons learned from going through this process for Schieoevers Noord, are that bridging the gap between urban designers and civil engineers within urban water management is achievable. But it requires effort from both parties to go back and forth between the two fields, while using existing tools to ease communication. This project also shows that if the designers and engineers do not come together, creating an integrated water system will be too complex and will not get the priority it deserves.

Another, and maybe even more important, lesson is the importance of thinking about the water system in a very early stage of the planning process. Surface water systems are often complex and adding to them will take up a large amount of space. However, a healthy surface water system is more efficient than only using climate adaptation measure, when combatting the negative externalities of climate change. Because the effects of climate change are rapidly increasing, it is imperative that developers, municipalities and other stakeholders prioritise healthy water systems in their development plans.

REFLECTION

Societal, professional and academic relevance

Well implemented water strategies and systems form an opportunity for inhabitants of neighbourhoods to have a more liveable area where water and heat pose less of a problem. Even better is when the water is implemented without having to compromise public space and with that the spatial quality that makes the area their home.

The current interventions and solutions within the water management discipline do not always take precedent in early stages of design strategies. This can cause a lack of space in later stages of the projects. In that case more time and resources need to be spent on fitting them in the existing structure of the plans. This thesis gives recommendations on how the urban water management strategies can be adapted more easily into strategies for urban regeneration.

This will on the one hand save time and resources in transdisciplinary projects and on the other hand ensure a better living environment for inhabitants.

The main issue of this thesis – the gap in discourse between designers and engineers – has been around for a while, looking as far back as the beginning of the 20th century there have been mentions of this phenomenon in literature (Neuman & Smith, 2010, p. 35). It is becoming even more important when looking at the current trend of climate change.

The gap in discourse and its cause and effect were researched in this thesis. Hopefully the results of this research will set in motion even more research into this topic so the gap can be bridged further in the future. It would be very good for the efficiency of transdisciplinary projects if the engineers and designers found ways to communicate better.

Ethical considerations

The threat of climate change and with that the rising of the water level and the increase of storm water is not yet something accepted by everyone. Discussions are still going on about the existence of climate change and its effects. I think it is the duty of urban designers and water management engineers to create new areas in such a way that its users become aware of the water. Instead of immediately letting it get flushed away into invisible underground storage tanks the priority should be on using natural, visible and accessible solutions. In my opinion it would increase awareness and with that increase its support in society. This also corresponds with Clayton et al. (2015) saying that human behaviour and perception of climate change are an integral part of successful adaptation.

Approach, methods and methodology

The focus of the project has changed a lot over time. Initially the goal was to find a way to connect designers and engineers within the field of urban water management, in order to help make transdisciplinary projects more feasible and more adapt to climate changes. The intention was to get together with designers, engineers and residents / stakeholders to find out how they could work together in early design processes, for instance through the use of the Climate Resilient Cities Toolbox. However, partly due to Corona and partly due to the research taking me into a different direction, this plan changed. After a while, the results were disconnected from the initial goal, it was then decided that the project focus was too broad. Subsequently, the project was restructured to have a sharper focus.

From that point onwards the project became more case-study oriented and the aims and outcomes became much clearer. This well laid-out plan made it a lot easier to find order and make logical progress in the research.

The approach that this project eventually had, like mentioned above, was more case-study oriented. The research consists of a critical analysis of the location and the development plan for the location made by the municipality of Delft. I tried to look at it from a designer and engineering point of view. My research included something I called a space-matrix which aimed to show the unused space according to the parametres set in the development plan. By pushing the parametres more towards the limits set in the development plan, I was able to show a flexibility in the use of space not visible in the maps provided by the municipality. One downside of this method was definitely the lack of precision, as a lot of (carefully weighed) assumptions had to be made in order to complete the space-matrix.

Another thing that has to be mentioned here is that the development plan is a document about the very early decisions taken by the municipality to show all stakeholders the general direction the municipality wants to go in, in the development of Schieoevers Noord. A lot more precise plans will be made before actual building will start. This means that the plans shown in the document are not binding and a lot may still change. However, this type of document was used in the research to illustrate that, specifically in this very early stage of planning, there still is enough flexibility for all parties to adapt their components. It would be possible and desirable to show a clearer and more structured plan for the water management in the area.

Looking back on the approach and methods used in the project, I think the outcome could have benefitted from more interaction with the municipality of Delft and, more specifically, someone working on the water strategy in the area of Schieoevers Noord. Near the end of the project, I was able to get in touch with someone from the Schieoevers team, and I shortly discussed the findings and outcomes of my project with them. I asked them why the municipality chose not to provide guidance for surface water in the area of Schieoevers Noord. They mentioned that due to a large number of stakeholders with diverging interests, the complexity of the current water system and the phased development of the area, the municipality simply did not give priority within the planning process for a structured surface water system, and instead attempts to solve the water nuisance and climate adaptivity by using the climate adaptation measures only. The conversation we had was short and very late in this thesis, but hearing that my findings were touching a nerve within the municipality, did provide validation for my project.

Improving the software
One of the aims of the project is to deliver recommendations for improving the software "Climate Resilient Cities Toolbox" made by Deltares et al. I aim to add a design perspective to this tool because I think it will help designers and engineers to understand each other better in early stages of brainstorming, which is what the tool is made for. However, giving recommendations about improving the software without more than a basic understanding of coding and the general internal structure of the toolbox might make the recommendations less functional. Further research might need to be

done in order for the toolbox to actually include the recommendations that I made.

The financial side
In the space matrix and proposals made in this project one of the biggest considerations is the fact that the financial side of developing this area was not taken into account at all. There was unfortunately not enough time to do reliable research to form a good understanding of the financial implications.

Data collection
Data is very readily available in the Netherlands so it was mostly easy to find what was needed. There were some older municipality documents with missing or illegible pages but after contacting the municipality they provided with better versions or alternatives.

Relation between research and design

Two types of theoretical research can be found in this thesis. first is the literature review which helped me identify the gap in discourse between urban designers and engineers which in turn helped define the problem field and problem statement. The second type is research into the principles of surface water systems and climate adaptation measures. This second aspect of the research is the basis of all proposals made in this thesis, it is the guiding theme of all the decisions and the recommendations made for the area of Schieoevers Noord.

Initially the design of the water system in Schieoevers Noord was meant to test the results of this thesis. Along the way however, it became clear that the design aspect of this thesis was more than just a testing opportunity. It became a tool to illustrate the results in a visual way, to prove that the gap in discourse did in fact have an effect on the plans for Schieoevers Noord and that it could still be adapted to have a better water system if designers and engineers came together. The design also became one of the final products, it holds recommendations for the water system of the area of Schieoevers Noord following the research done in this thesis.

The relation between graduation topic, studio topic, master track topic

The master track of urbanism in the Architecture, Urbanism and Building Sciences master programme has a focus on multiscalar urban design and planning dealing with issues like climate change, mobility, densification etc. The goal is teaching academic skills which will enable students to perform critical analyses of urban environments and propose new solutions to improve efficiency, sustainability, liveability, organisation and management in the urban environment. (TUDelft, 2020a) Within this master track the graduation studio of Urban Metabolism and Climate specializes in analysing, designing and engineering essential flows (water, energy, materials, food, waste and data) in order to create a more sustainable environment(TUDelft, 2020b).

This thesis is a project based on an urban regeneration case-study, the plans for the area and the area itself were carefully analysed and principles of urban water systems were researched. Resulting from the analysis and research, proposals were set up to improve the water inclusivity of the area for future plans.

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APPENDIX

1. SUBREGIONS 11 THROUGH 15
2. EXCEL FILES OF CALCULATIONS

APPENDIX 1

Sub-regions 11 through 15

Sub Region 11

The area is 14.000 m², the maximum building height will be 25 metres. There is no FSI established for this area because no new buildings will be added.

This area, together with most other areas on the east side of the Schie, is located outside of the protection zone of the Rotterdamseweg dike. This means they are not part of the polder system of Zuidpolder.

This is the northern most region of Schieoevers Noord. It is located on the east side of an inlet of the Schie, however the view of the water is blocked by a row of houses and the area therefore has almost no interaction with the Schie.

The region is almost completely filled with existing buildings, some of which are residential, but most, like Octatube and Royal Delft, are industrial. The existing companies and buildings are allowed to remain in the development of Schieoevers, because they fit the type of small scale industry that the municipality is looking for in Schieoevers Noord.

Royal Delft is the last remaining 17th century earthenware factory where they hand-make traditional Delft Blue. The Porceleyne Fles (figure A) is a monumental building located in this sub-region that houses the museum part of Royal Delft.

Figure B. (Google Earth, 2020.)

Figure A. Royal Delft. (n.d.). Porceleyne fles [Photo]. Royal Delft. https://royaldelft.com

Figure C. (Google Earth, 2020.)

Sub region 12

Imgae D. (Google Earth, 2020.)

Figure E

The area is 30.880 m², the FSI is established at 0,80 and the maximum building height will be 25 metres.

This area, together with most other areas on the east side of the Schie, is located outside of the protection zone of the Rotterdamseweg dike. This means they are not part of the polder system of Zuidpolder.

This region is located on the north side of the Nieuwe Haven, an inlet of the Schie. Currently its terrain is mostly vacant and undeveloped. There is one building that has been categorized as culturally and historically important (figure E).

Figure F. (Google Earth, 2020.)

Sub Region 13

The area is 36.120 m², the FSI is established at 1,00 and the maximum building height will be 25 metres.

This area, together with most other areas on the east side of the Schie, is located outside of the protection zone of the Rotterdamseweg dike. This means they are not part of the polder system of Zuidpolder.

(Google Earth, 2020.)

Figure G. (Google Earth, 2020.)

This area has some houses that are categorized as culturally and historically significant, other than that, there are industrial buildings and a camper and caravan store and parking area.

Some greenery can be found around the houses and next to the caravan parking, but it is not publicly accessible. Other than that, this sub-region is mostly filled with paved areas and buildings.

Figure H. (Google Earth, 2020.)

Sub region 14

Figure I. (Google Earth, 2020.)

Figure J. (Google Earth, 2020.)

The area is 23.390 m², the FSI is established at 1,00 and the maximum building height will be 25 metres.

This area, together with most other areas on the east side of the Schie, is located outside of the protection zone of the Rotterdamseweg dike. This means they are not part of the polder system of Zuidpolder.

This area is mostly part of Lijm & Cultuur, which is a cultural and festival terrain that hosts a range of different activities. The buildings in this area used to be part of a glue- and gelatine factory built in 1885. The remaining buildings are now protected by their monumental status.

The region has some grassy areas, but a lot of the ground is still paved.

This area will be connected with the other side of the Schie by the Gelatingebrug, a pedestrian and cyclist bridge going from sub-region 7 to here.

Figure K. (Google Earth, 2020.)

Sub Region 15

The area is 52.040 m², the FSI is established at 1,00 and the maximum building height will be 25 metres.

The northern half of this sub-region is located outside of the protection zone of the Rotterdamseweg dike. This means it is not part of the polder system of Zuidpolder. The official regional protection cuts through the middle of this region from the Rotterdamseweg to the bank of the Schie. This means the southern half of this sub-region is part of the Zuidpolder.


Figure L. (Google Earth, 2020.)

This region is home to student rowing club Proteus-Eretes with their boat storage halls and their clubhouse. Other than that, there are some industrial buildings and some buildings like figure M that have been categorized as historically and culturally significant or monumental.


Figure M. (Google Earth, 2020.)

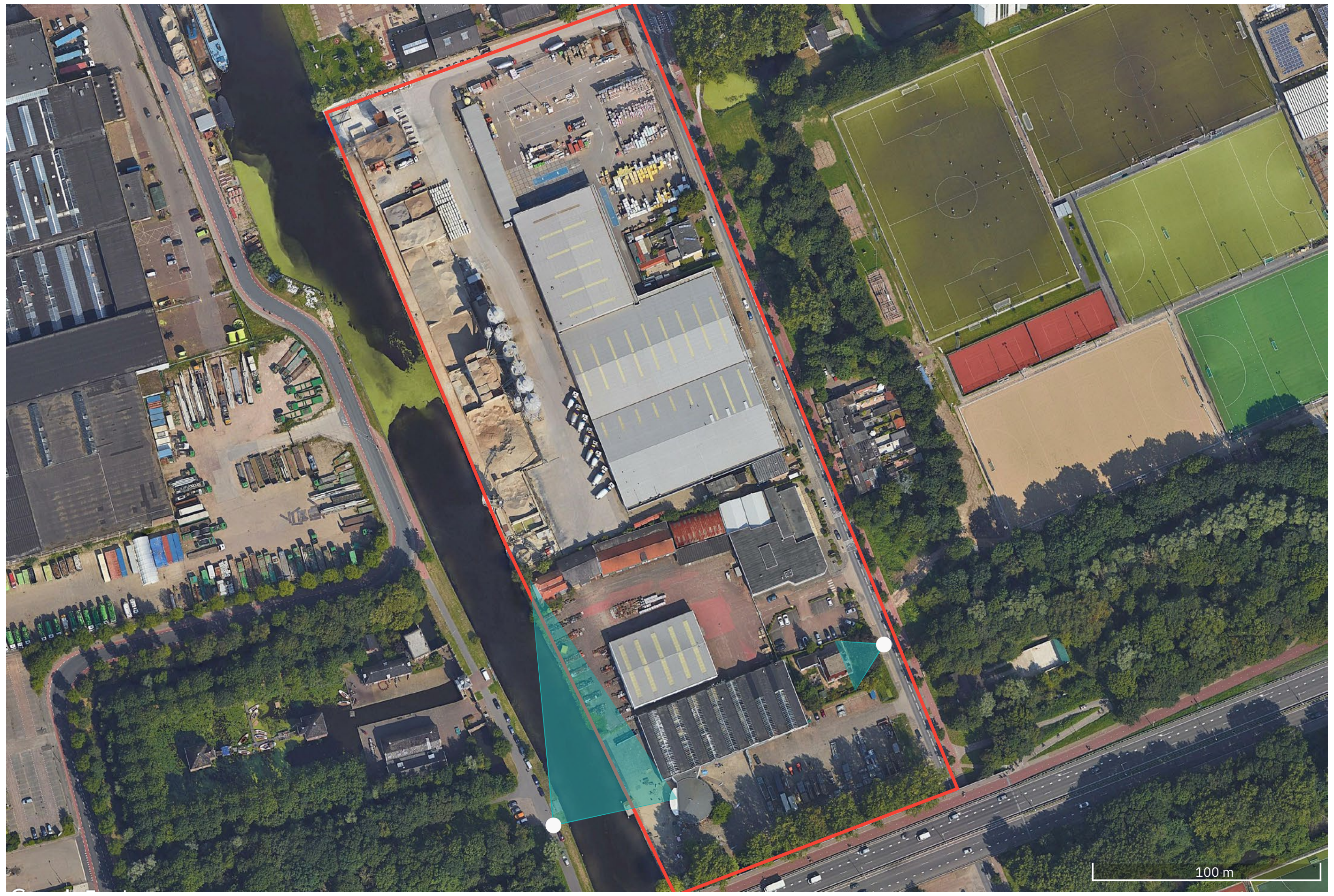

Figure N. (Google Earth, 2020.)

APPENDIX 2

Excel calculations

Space matrix calculation Excel sheet

		Vakjes	m2
Area 1	100%	27,5	27.500
	10%	2,8	2.800
	Mobility infrastructure	10	10.000
	New buildings	0	-
	Monumental/existing buildings	0	-
	Existing water	3,2	3.200
	Leftover	**11,5**	11.500
Area 2	100%	28	28.000
	10%	2,8	2.800
	Mobility infrastructure	15,9	15.900
	New buildings	0	-
	Monumental/existing buildings	0	-
	Existing water	1,8	1.800
	Leftover	**7,5**	7.500
Area 3	100%	12,2	12.200
	10%	1,2	1.220
	Mobility infrastructure	5	5.000
	New buildings	1,4	1.400
	Monumental/existing buildings	0	-
	Existing water	1,9	1.900
	Leftover	**2,7**	2.680
Area 4	100%	38,1	38.100
	10%	3,8	3.810
	Mobility infrastructure	5,5	5.500
	New buildings	3,7	3.700
	Monumental/existing buildings	0	-
	Existing water	0	-
	Leftover	**25,1**	25.090
Area 5	100%	50,5	50.500
	10%	5,1	5.100
	Mobility infrastructure	19,8	19.800
	New buildings	12,8	12.800
	Monumental/existing buildings	3,0	3.000
	Existing water	0,0	-
	Pocket parks	2,0	2.000
	Leftover	**7,8**	7.800
Area 6	100%	123,9	123.900
	10%	12,4	12.400
	Mobility infrastructure	34,3	34.300
	New buildings	22,9	22.900
	Monumental/existing buildings	1,2	1.200
	Existing water	0,0	-
	Pocket parks	3,2	3.200
	Leftover	**49,9**	49.900

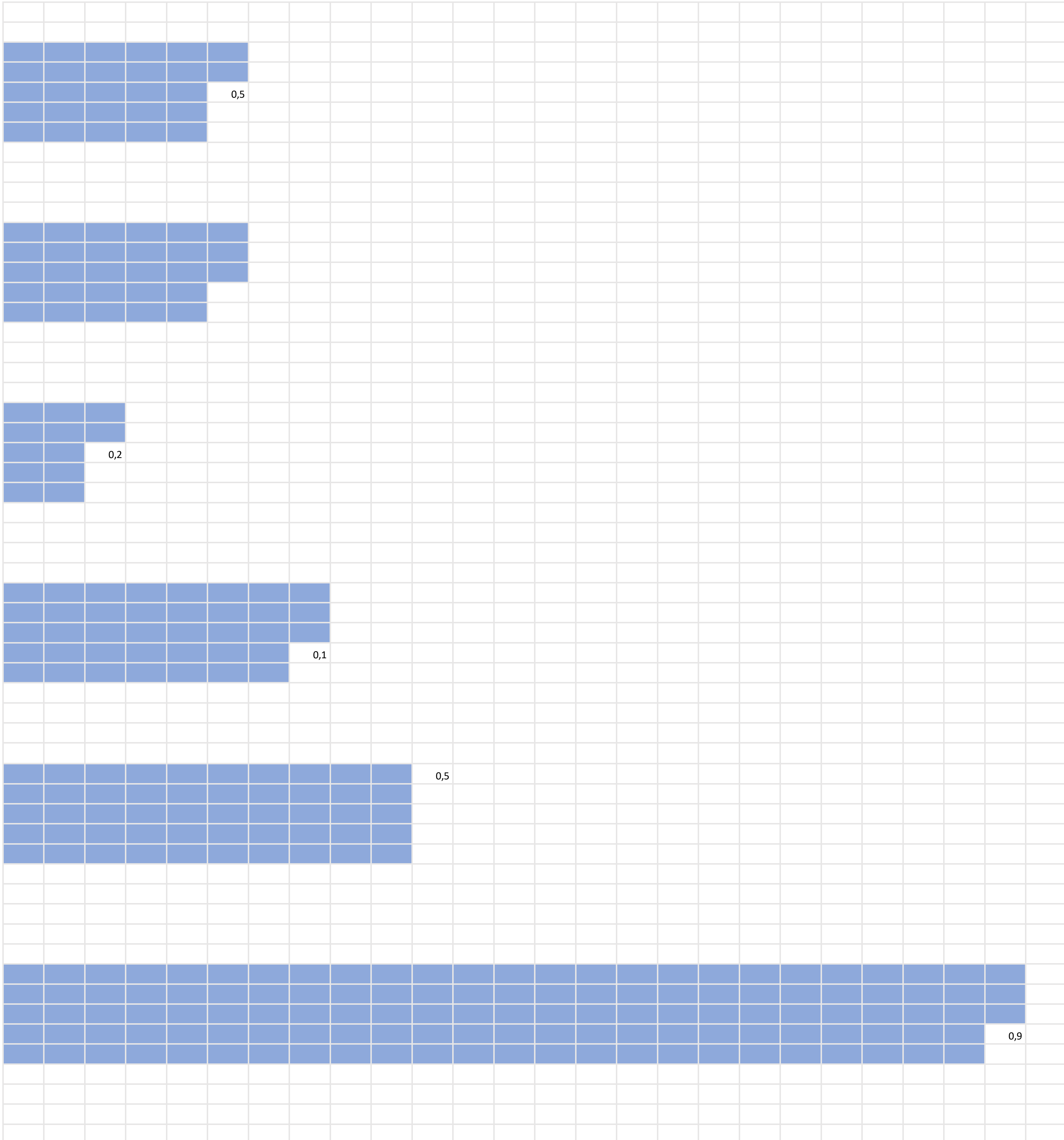

Figure O

Space matrix calculation Excel sheet

Area 7	100%	29,0	29.000
	10%	2,9	2.900
	Mobility infrastructure	3,7	3.700
	New buildings	4,2	4.200
	Monumental/existing buildings	0,0	-
	Existing water	0,0	-
	Pocket parks	0,8	800
	Leftover	**17,4**	17.400
Area 8	100%	124,3	124.300
	10%	12,4	12.400
	Mobility infrastructure	50,0	50.000
	New buildings	18,4	18.400
	Monumental/existing buildings	0,0	-
	Existing water	0,0	-
	Pocket parks	4,4	4.400
	Leftover	**39,1**	39.100
Area 9	100%	22,2	22.200
	10%	2,2	2.200
	Mobility infrastructure	5,9	5.900
	New buildings	1,9	1.900
	Monumental/existing buildings	2,8	2.800
	Existing water	0,0	-
	Pocket parks	0,0	-
	Leftover	**9,4**	9.400
Area 10	100%	39,9	39.900
	10%	4,0	4.000
	Mobility infrastructure	6,2	6.200
	Monumental green	**20,9**	**20.900**
	Monumental/existing buildings	1,1	1.100
	Existing water	7,7	7.700
	Leftover	**0,0**	-
Area 11	100%	14	14.000
	10%	1,4	1.400
	Mobility infrastructure	4,3	4.300
	New buildings	0	-
	Monumental/existing buildings	5,4	5.400
	Existing water	0	-
	Leftover	**2,9**	2.900
Area 12	100%	30,9	30.900
	10%	3,1	3.100
	Mobility infrastructure	11,4	11.400
	New buildings	7,4	7.400
	Monumental/existing buildings	1,7	1.700
	Existing water	0	-
	Leftover	**7,3**	7.300

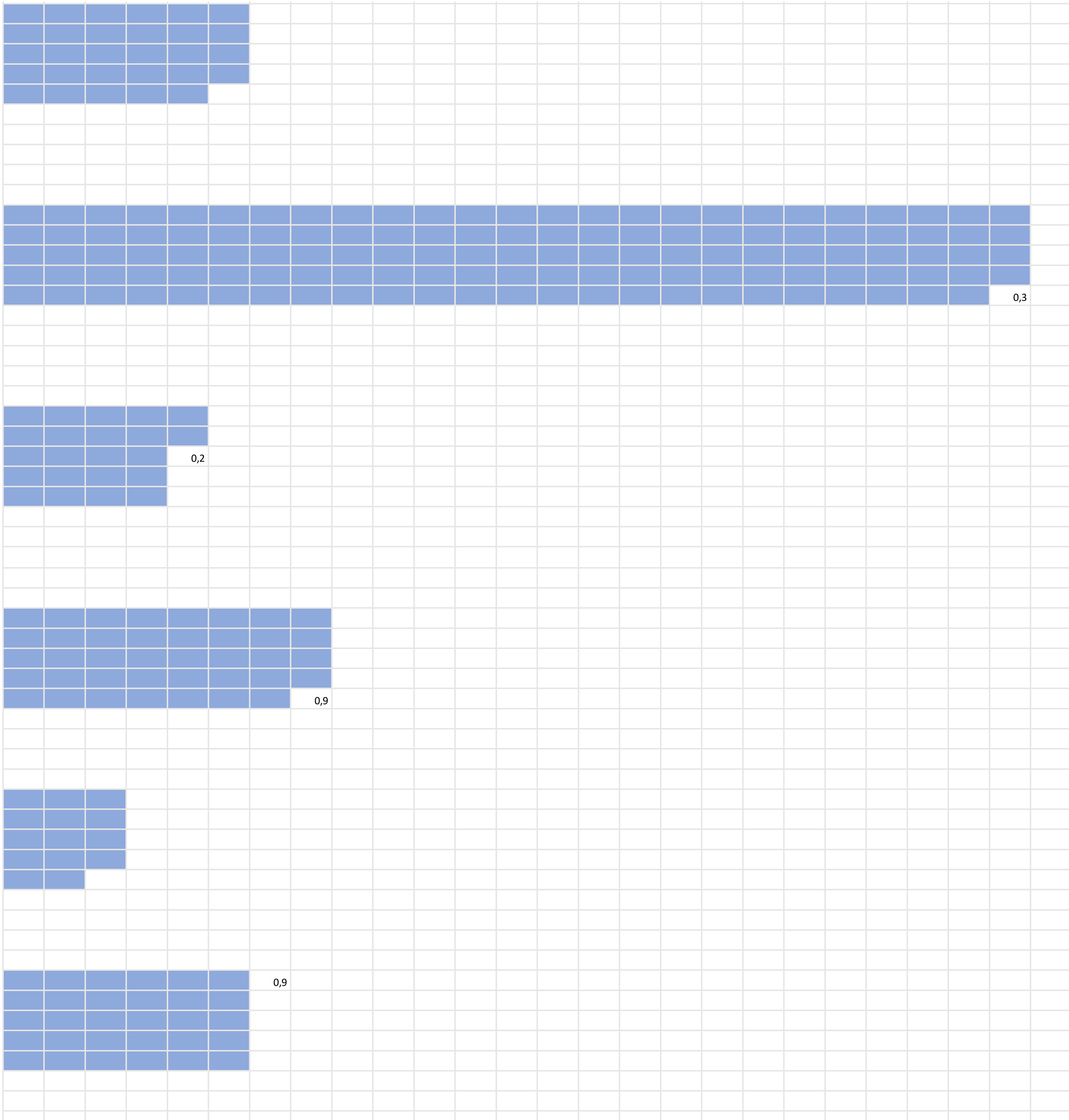

Figure P

Space matrix calculation Excel sheet

Area 13	100%	36,1	36.100
	10%	3,6	3.600
	Mobility infrastructure	10,7	10.700
	New buildings	8,6	8.600
	Monumental/existing buildings	0	-
	Existing water	0	-
	Leftover	**13,2**	13.200
Area 14	100%	23,4	23.400
	10%	2,3	2.300
	Mobility infrastructure	10,7	10.700
	New buildings	5,6	5.600
	Monumental/existing buildings	4	4.000
	Existing water	0	-
	Leftover	**0,8**	800
Area 15	100%	52	52.000
	10%	5,2	5.200
	Mobility infrastructure	19,2	19.200
	New buildings	12,5	12.500
	Monumental/existing buildings	1,2	1.200
	Existing water	0	-
	Leftover	**13,9**	13.900

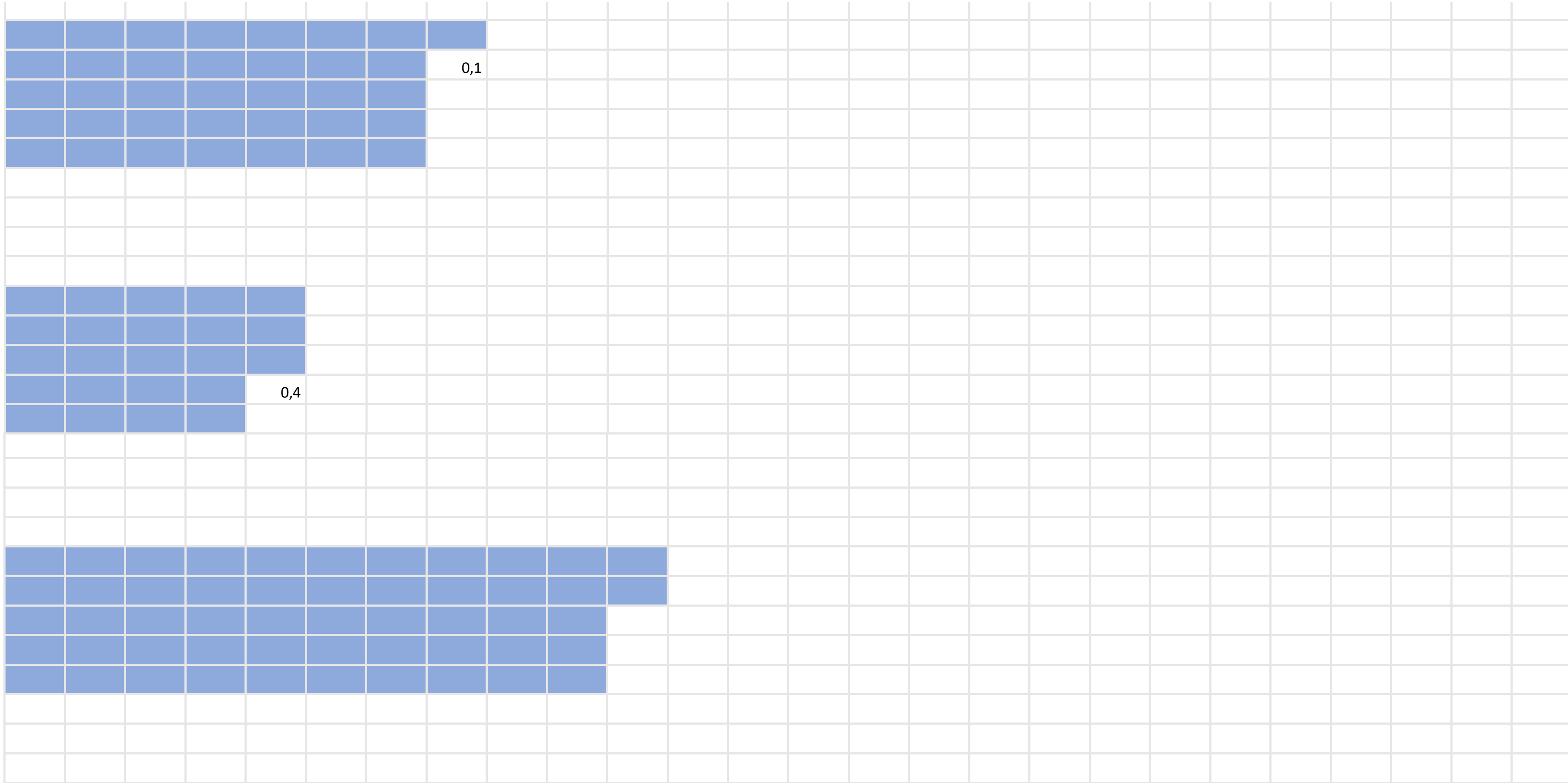

Figure Q

Criterion 1 calculation Excel sheet

	Space left	Length of water	avg. width of water	width of NFB	Oppervlakte 1 NVO	Oppervlakte 2 NVO	Space left with one NFB	Space left with two NFB	min Diepte	max Diepte	Oppervlakte water	min Volume water	max volume water
	[m2]	[m]	[m]	[m]	[m2]	[m2]	[m2]	[m2]	[m]	[m]	[m2]	[m3]	[m3]
Area 5	7800	462	6	9,3	7069	11365	731	-3565	1	2	2772	2772	5544
Area 6	49900	1339	10	9,3	25843	38295	24057	11605	1	2	13390	13390	26780
Area 7	17400	364	10	9,3	7025	10410	10375	6990	1	2	3640	3640	7280
Area 8	39100	1258	9	9,3	23021	34721	16079	4379	1	2	11322	11322	22644
Area 9	9400	268	6	9,3	4100	6593	5300	2807	1	2	1608	1608	3216
Totaal	123600	3691			67058	101385	56542	22215			32732		65464

Maaiveld	min Waterpeil	max Waterpeil	Verschil
[m NAP]	[m NAP]	[m NAP]	[m]
0,1	-1,33	-0,33	1,43

STRATEGY 1

	Space left	Length of water	avg. width of water	width of NFB	Oppervlakte 1 NVO	Oppervlakte 2 NVO	Space left with one NFB	Space left with two NFB	min Diepte	max Diepte	Oppervlakte water	min Volume water	max volume water
Area 5	7800	462	6	10,4	7577	12382	223	-4582	1	2	2772	2772	5544
Area 6	49900	1339	10	10,4	27316	41241	22584	8659	1	2	13390	13390	26780
Area 7	17400	364	10	10,4	7426	11211	9974	6189	1	2	3640	3640	7280
Area 8	39100	1258	9	11,2	25412	39501	13688	-401	1	2	11322	11322	22644
Area 9	9400	268	6	11,2	4610	7611	4790	1789	1	2	1608	1608	3216
Totaal	123600	3691			72339	111946	51261	11654			32732		65464

Maaiveld	min Waterpeil	max Waterpeil	Verschil
[m NAP]	[m NAP]	[m NAP]	[m]
0.1	-1.5	-0.5	1.6
0,1	-2,7	-1,7	2,8

STRATEGY 2

	Space left	Length of water	avg. width of water	width of NFB	Oppervlakte 1 NVO	Oppervlakte 2 NVO	Space left with one NFB	Space left with two NFB	min Diepte	max Diepte	Oppervlakte water	min Volume water	max volume water
Area 5	7800	462	6	10,4	7577	12382	223	-4582	1	2	2772	2772	5544
Area 6	49900	1339	10	10,4	27316	41241	22584	8659	1	2	13390	13390	26780
Area 7	17400	364	10	10,4	7426	11211	9974	6189	1	2	3640	3640	7280
Area 8	39100	1258	9	10,4	24405	37488	14695	1612	1	2	11322	11322	22644
Area 9	9400	268	6	10,4	4395	7182	5005	2218	1	2	1608	1608	3216
Totaal	123600	3691			71118	109505	52482	14095			32732		65464

Maaiveld	min Waterpeil	max Waterpeil	Verschil
[m NAP]	[m NAP]	[m NAP]	[m]
0.1	-1.5	-0.5	1.6

Figure R

Criterion 1 calculation Excel sheet

STRATEGY 3

	Space left [m2]	Length of water [m]	avg. width of water [m]	width of PZ [m]	Area with PZ [m2]	Space left [m2]	min Diepte [m]	max Diepte [m]	Oppervlakte water [m2]	min Volume water [m3]	max volume water [m3]
Area 5	7800	80	10	28	5280	2520	1	2	800	800	1600
Area 6	49900	300	10	28	19800	30100	1	2	3000	3000	6000
Area 7	17400	230	10	28	15180	2220	1	2	2300	2300	4600
Area 8	39100	300	10	28	19800	19300	1	2	3000	3000	6000
Area 9	9400	0	0	0	0	9400	1	2	0	0	0
Totaal	123600	910			60060	63540			9100		18200

	Space left [m2]	Amount of parks	Area of single park [m2]	Total area [m2]	Area with PZ [m2]	Space left with parks [m2]
Area 5	7800	5	400	2000	22000	5800
Area 6	49900	8	400	3200	54400	46700
Area 7	17400	2	400	800	4000	16600
Area 8	39100	9	400	3600	68400	35500
Area 9	9400	2	400	800	4000	8600

Figure S

Climate adaptive measure matrix calculation Excel sheet

measures	Storage capacity	Evapotranspiration	Heat reduction	Water quality effect	Construction cost	Maintenance cost
	m3	mm/year	C	%	€	€/year
blue roofs	20	0,03	0,05	0	€ 23.557	€ -
gravel layers - maybe remove	20	0	0	0,02	€ 18.628	€ 402
hollow roads	20	0,03	0	0	€ 3.021	€ 227
green facades	2	0	0	0	€ 300.221	€ 30.022
ditches	20	-0,01	0	0,01	€ 15.011	€ 111
water squares	100	-0,01	0,05	0	€ 166.141	€ 183
bioswale with drainage	20	0	0,05	0,02	€ 7.552	€ 76
remove pavement to plant green	10	0,56	0,05	0,02	€ 2.769	€ 101
Rainwater detention pond (wet pond)	20	0	0,05	0,01	€ 4.028	€ 20
Adding trees to the streetscape	10	0,42	0,05	0	€ 1.148	€ 0
urban wetland	20	0,01	0	0,01	€ 6.041	€ 302
Green roofs with drainage delay	10	0,03	0,05	0,02	€ 8.055	€ 483
urban forest	10	0,11	0,05	0	€ 101	€ 5
infiltration boxes	40	0	0	0,02	€ 47.828	€ 536
storage tank or underground water storage	150	-0,01	0	0,01	€ 44.808	€ 717
infiltration fields and strips with surface storage	30	-0,01	0,05	0,02	€ 6.041	€ 50
drainage infiltration transport drains // gravel layer	20	-0,02	0	0,02	€ 17.513	€ 711
rain barrel (one barrel - 1,2 m deep - 10 inflow- 0,3 radius (and 30))	0,34	0	0	0	€ 99	€ -
surface water	100	0,37	0	0,01	€ 22.656	€ 9
supplemental water retention by flexible water level management	30	0,37	0	0,01	€ -	€ -

Figure T

Climate adaptive measure matrix calculation Excel sheet

measures	Storage capacity	Evapotranspiration	Heat reduction	Water quality effect	Construction cost	Maintenance cost		depth	inflow	width	length
	m3	mm/year	C	%	€	€/year		m	x		
blue roofs	2000	2,65	0,05	0,00	€ 2.339.626	€ -		0,2	1		
gravel layers - maybe remove	2000	-0,45	0	1,51	€ 1.850.099	€ 39.962		0,2	10		
hollow roads	2000	2,61	0	0,00	€ 300.016	€ 22.501		0,2	10		
green facades	10	0	0	0,01	€ 1.500.300	€ 150.030		0,02	10	0,5	100m/1000m
ditches	200	-0,11	0	0,07	€ 150.030	€ 1.110		0,2	10	1	100m/1000m
water squares	10000	-0,54	0,05	0,00	€ 16.500.886	€ 18.151		1	10		
bioswale with drainage	2000	-0,43	0,05	1,51	€ 750.040	€ 7.500		0,2	10		
remove pavement to plant green	1000	55,82	0,05	1,51	€ 275.015	€ 10.011		0,1	10		
Rainwater detention pond (wet pond)	2000	-0,39	0,05	0,76	€ 400.021	€ 2.000		0,2	10		
Adding trees to the streetscape	1000	41,48	0,05	0,09	€ 114.006	€ 39		0,1	10		
urban wetland	2000	1,16	0	1,21	€ 600.032	€ 30.002		0,2	10		
Green roofs with drainage delay	1000	2,88	0,05	1,62	€ 800.043	€ 48.003		0,1	1		
urban forest	1000	11,16	0,05	0,09	€ 10.001	€ 500		0,1	2		
infiltration boxes	4000	-0,21	0	1,51	€ 4.750.255	€ 53.203		0,4	10		
storage tank or underground water storage	15000	-0,74	0	1,21	€ 4.450.239	€ 71.204		1,5	30		
infiltration fields and strips with surface storage	3000	-1,11	0,05	1,51	€ 600.032	€ 4.980		0,3	10		
drainage infiltration transport drains // gravel layer	220	-0,15	0	0,15	€ 175.035	€ 7.106		0,2	10	1	100m/1000m
rain barrel (one barrel - 1,2 m deep - 10 inflow- 0,3 radius (and 30))	3393	-0,37	0	0,34	€ 989.602	€ -		1,2	10		
surface water	10000	37,23	0	0,76	€ 2.250.121	€ 900		1	10		
supplemental water retention by flexible water level management	3000	37,08	0	0,76	€ -	€ -		0,3	10		

Figure U