metropool
regioamsterdam

Resilience by Design Metropoolregio Amsterdam

one architecture
new york city amsterdam
SMARTLAND ARCADIS
OVER MORGEN drift Penn
climate adaptation partners

16 October 2020

Dear Reader,

Please find here our report of Resilience by Design for the Amsterdam Metropolitan Region. We have enjoyed working on this project, both because of the challenging and important questions the project raised and because of the fantastic collaborations with all stakeholders, the client team and their experts, and within our team.

The report is organized as a story about the challenges of climate adaptation, our understanding of the situation in the Metropoolregio, and series of high-level considerations and recommendations for climate adaptation in general, and a deeper dive into the four demonstration projects which have helped us hone our recommendations, and which show their local application. In the appendix we have compiled the underlying financial and capacity building analyses of the team, as well as an overview of the process. A summary at the beginning summarizes the lessons learned (a joint production of the ONE team and the Defacto team), and gives a high level overview of the demonstration projects.

In this foreword, I would like to put some attention to what I feel is a key dilemma for climate adaptive urbanization in the region that I distilled from this work, and add some observations about the institutional and cultural environment that we encountered (in part informed by our experience with resilience and climate adaptation projects and processes in 5 continents, which allows us somewhat of an outsider perspective).

There is an urgency for the MRA to construct a lot of new housing and expand supply. This study teaches us that long-term climate adaptation is not fully considered when planning these developments. There is too little consideration for the spatial requirements for cost effective and integrated climate measures beyond 2050, and for the impacts that failure to include these will have on the regional water management system (and public finance).

The need to build (or reserve space for) robust green-blue climate adaptation measures manifests itself in the following dilemma when deciding on the location of future housing. For this, there are two main directions: in existing urban areas or in greenfield locations. Both have pros and cons from a climate adaptation perspective, which are, in our view, not fully considered.

If development takes place in existing neighborhoods and urban areas without factoring in future climate stresses, the infill will reduce available land and with that the capacity to adapt, leading to higher adaptation costs later. If city and regional governments fail to develop longer-term guidance and embed climate-robust principles in the area development strategies, the current trajectory will result in a significant challenge down the road.

The Almere demonstration project in this study underscores that large-scale greenfield developments in greenfield areas have inherent flexibility and provide more opportunities to design in climate-robust principles, at much lower cost. However, greenfield sites are mostly located in places that pose a higher systemic risk.

This dilemma needs to be further studied and inform future urbanization.

Allow me some further observations about the institutional and cultural context of climate adaptation in the Netherlands. First, the magnitude and pace of change of climate impacts in the future are generally underestimated. This prevents the broad mobilization that is vital to make progress and to finance adaptation. The historical strength of the Dutch has been to depend on common sense when solving social challenges; yet, climate adaptation is not a commonsense problem: it is an accelerating crisis. Second, climate adaptation figures less prominently in spatial developments than other transformative concepts, for example the energy transition or circular economy. There is not yet a common understanding of what climate-adaptive means or should be. As a result, there are also few national or regional standards or policies.

Climate adaptation today is practiced by a relatively small group of professionals, often with origins in the domain of water safety. Experts do not always work in a coordinated way. There is a planning mechanism for contemplating and addressing systemic risk, but that functions with total independence from planning for local risks and future stresses in area developments, and it only considers the possibly resulting socio-economic stresses in a limited way. Dutch climate adaptation planning originates from the impressive legacy of expertise in water management, as mentioned, but that also means that adaptation planning runs the risk to become a siloed discipline which does not engage society at large, and which overlooks non-water related stresses.

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Resilience by Design Metropoolregio Amsterdam

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Executive summary

Between April and August 2020, two multidisciplinary teams worked on Resilience by Design Amsterdam Metropolitan Area. The project, spearheaded by MRA Climate-Proof, focuses on the question of how investment decisions in MRA developments can be made climate-adaptive. Through a number of demonstration projects, the teams show that climate-adaptive development is already possible, and that it creates opportunities to link to other sustainability issues, such as the energy transition, circular economy, and improved mobility.

Recognizing that climate change will accelerate in the coming decades, while the preparation time for investments will decrease, Resilience by Design shifts the time horizon for planning from what is typically considered (2050) to what is necessary for the lifetime of today's infrastructure (2100). Design offers a tool to tackle this issue in an integrated manner.

After analysis, design studies, and many conversations with area stakeholders and subject matter experts, the Defacto (rural lead) and One Architecture (urban lead) teams have come up with a number of joint insights for climate adaptation in the region, as well as visual that describe how climate adaptation can create more attractive cities and landscapes and healthier living environments. The demonstration projects thus contribute to a shared awareness of risks, make opportunities visible and help develop stakeholder capacity. They also demonstrate the importance of taking a longer time horizon into account for planning, especially for local developments, and thus form building blocks for better interaction between city and country.

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for more information:

metropoolregioamsterdam.nl/programma/klimaatadaptatie/

Insights

Make the water system more resilient

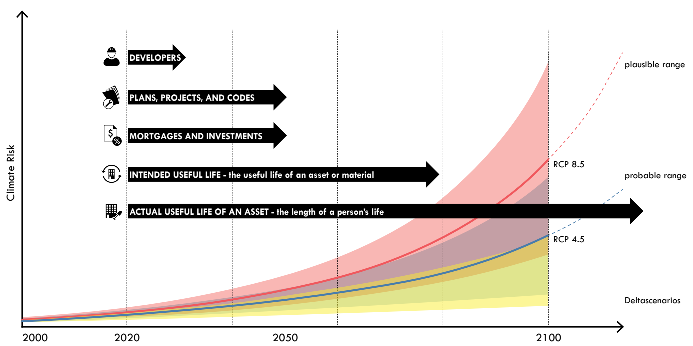
At present, the water system is highly technical and calibrated. While precision is a benefit in the short-term, it requires constant adjustments, and runs the risk of becoming too brittle, with little long-term flexibility (especially as the lead time for adjustments will become shorter with climate change). To build resilience, the system must be able to accommodate change, and incorporate greater tolerances and flexibility. The system must become more decentralized, with areas within the system able to develop and manage water more independently. In order to prevent "lock-ins," it is critical to start this process soon, so that preserving the current system or modifying to create room for adaptation can be a conscious choice, with clearly identified trade-offs, considered for their long-term implications. In analogy to Room for the River, water management requires a paradigm shift from for to Room Adaptation, Change, and Enjoyment.

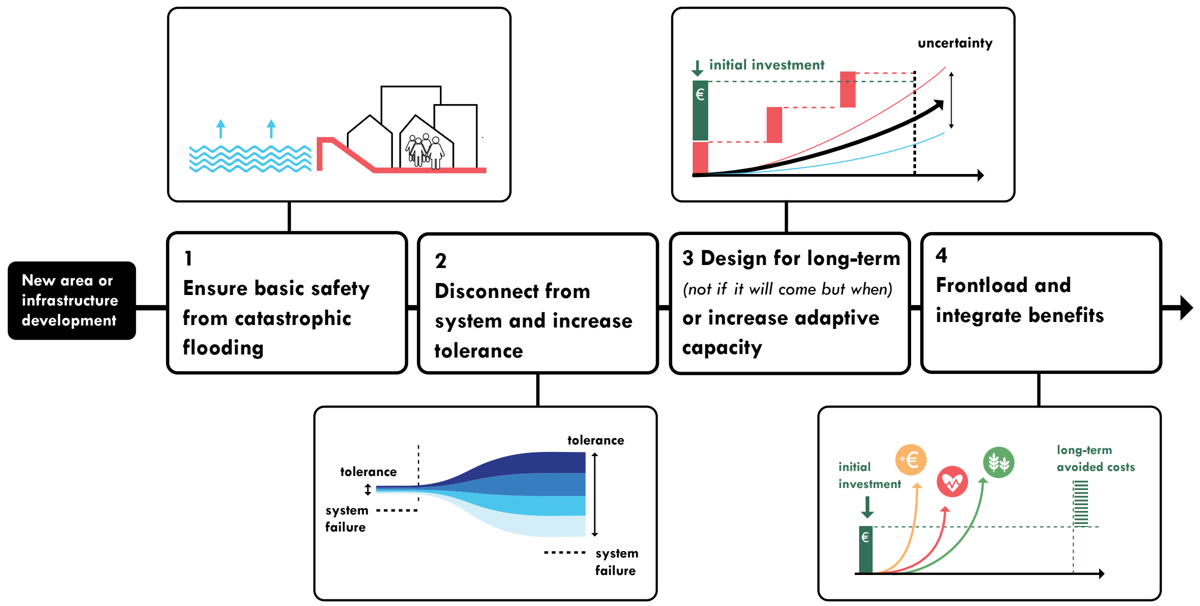
Use less optimistic climate models

The climate models that are currently used for planning in the Netherlands are relatively conservative in their projections. It is necessary to question the assumptions and resulting standards, and to consider that the slow institutional process of reconsidering assumptions and updating climate projections can create future costs. To ensure adaptive measures meet future demands, the range of planning scenarios needs to expand to include more extreme (or plausible) values. And, in addition to water safety and flooding, heat and drought impacts must be more explicitly included as climate adaptation challenges to address.

Link area development to the system level

The time horizon for local area development is now considerably closer from that of the larger water safety system. This can bring risks at a systems level if future local adaptation becomes costly or difficult. Recognizing that decisions made today may have substantial consequences for regional adaptation over the long-term, local planning needs to consider a range of adaptation pathways or scenarios for development. Decisions about climate adaptation and the associated (social) costs must be explored and debated publicly. Regional spatial development strategies must be connected to realistic planning horizons for the lifetime of real estate (looking to 2100 instead of 2050) and link the approach for the water safety system at large.





Do not turn to the future

Planning today with conservative climate projections for a short time horizon (2050) will result in infrastructure and neighborhoods that are not built for the climate realities they will face over their useful lives. This means retrofitting today's buildings tomorrow, with limited space and at great cost. The burden will most likely fall in the public domain. There is an opportunity to avoid a future crisis by designing for higher standards, or by building in flexibility and adaptive capacity in everything constructed today.

Use natural systems for integrated solutions

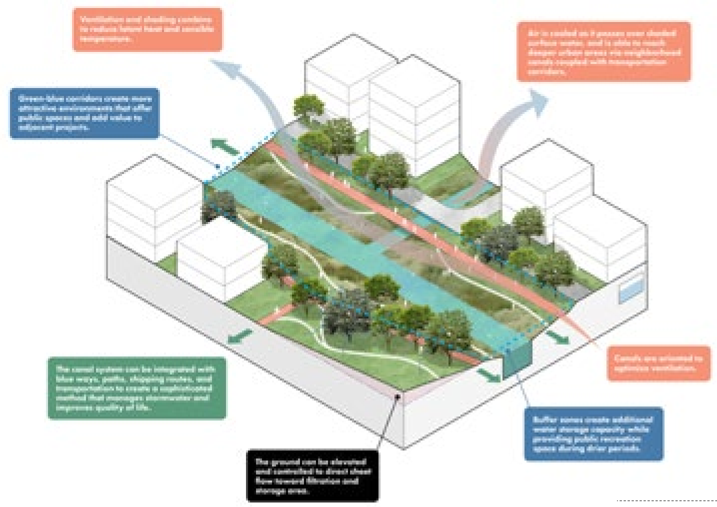
Rely more on natural systems: healthy environments with robust physical and ecological processes are better able to rebound from disturbance, provide multiple ecosystem services and functions, and enable integrated solutions. The blue-green infrastructure of the 21st century cannot replicate that of the past; planners and designers must consider future climates and realize they will have different dimensions, scales, rhythm, and performance to thrive.

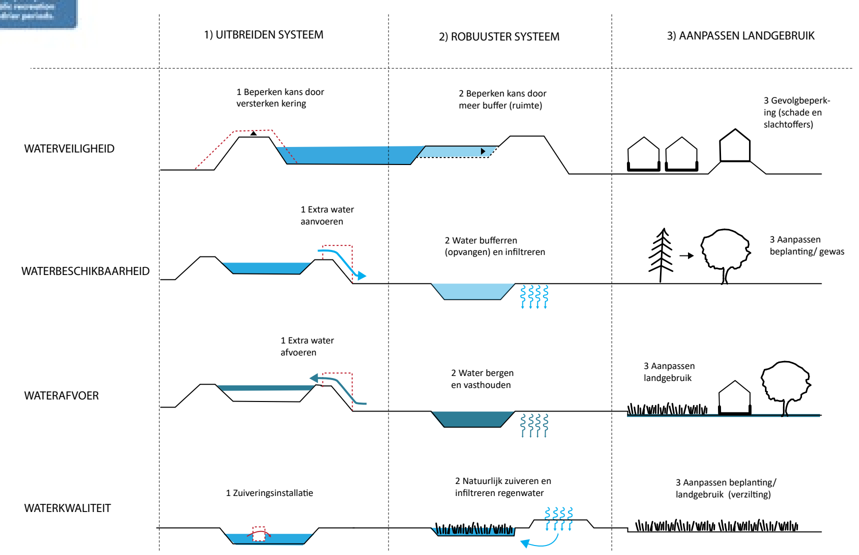
Adjust your financing models

Climate adaptation becomes the compelling business case when financial models account for the true costs of inaction: impacts to long-term investments, social costs borne by local populations, and damage where development fails to consider future climate impacts. It is critical to prioritize climate investments in flexible, natural systems that stay in the public domain and let private parties co-finance from their avoided costs and benefits. Shift private development toward long-term accountability by extending development cycles and innovating with service level agreements to ensure adaptability.

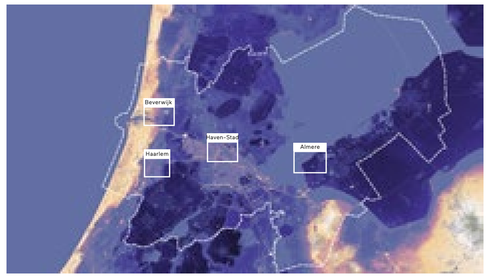
Use design to strengthen capacity

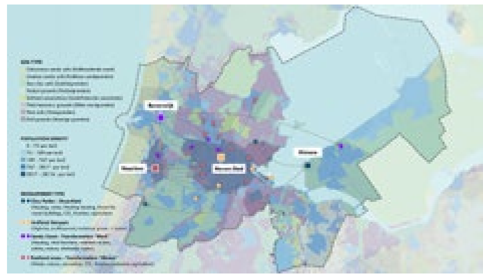
Climate adaptation requires an institutional sea-change. No longer solely the purview of the water sector, adaptation practice must be taken up across all government sectors and levels, working together to create integrated solutions. It must be better integrated in area developments through an inclusive, multi-stakeholder process. Design tools can help facilitate discussions and contemplate alternative scenarios, as well as strategies to build in flexibility and plan adaptively.





One Architecture's four demonstration projects serve less as prototypes than as an incentive to incorporate climate adaptation into ongoing area development processes and to build capacity for cooperation. With this aim, four projects were chosen to represent four different location types, challenges, and corresponding landscapes. Together, the demonstration projects form a map of typical challenges in the region so that the findings can be replicated in similar locations throughout the MRA.





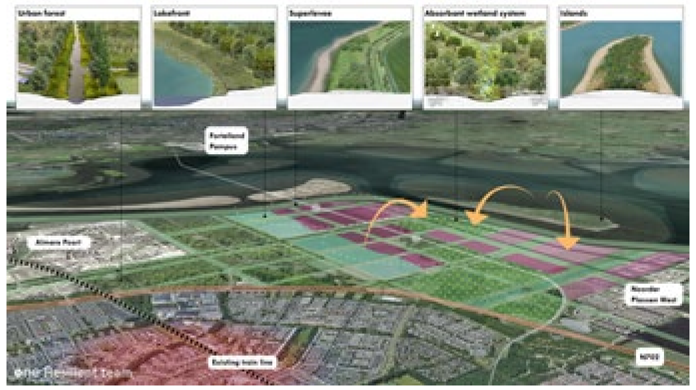
ALMERE-PAMPUS
Nature-based pre-development

Assignment
'Greenfield' development in deep polder.

Concept
Before more than 25,000 homes are built on Almere Pampus, the subsoil and vegetation can be developed in such a way as to create a robust basis for a climate-adaptive neighborhood. The project links the earthmoving to the dynamic development of nature and coastal protection in the Markermeer.

Benefits
By the time construction is done, the ecology and water management are already in order, and the benefits can be enjoyed immediately.

Implementation
The cost of this approach is lower than traditional approaches, especially if the period between initial investment and housing development is relatively brief. If we take into account reducing the risk of further subsidence and the provision of ecological benefits, and strategically establish goals in the meantime, the case becomes even stronger.



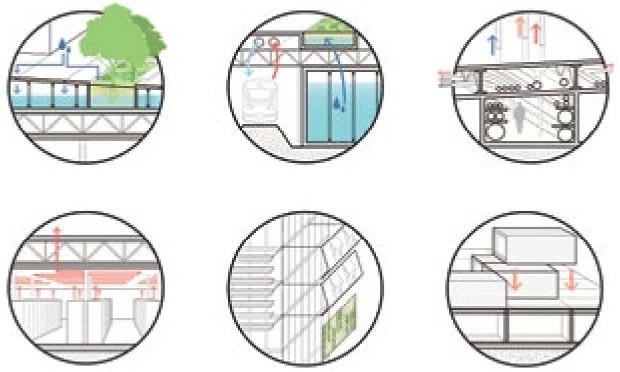
AMSTERDAM HAVEN-STAD
Build in adaptive capacity

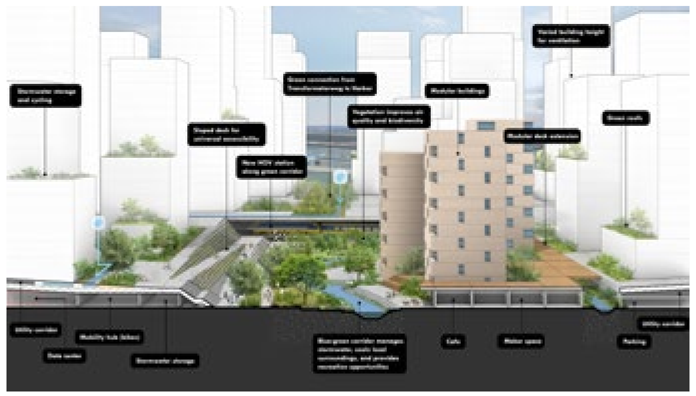
Assignment
High density new construction in 'urban hotspot.'

Concept
This new district for 70,000 inhabitants includes a new city center planned on a deck above the infrastructure of the Hemknoop. The proposal makes intelligent use of a combination of technical and Nature-based Solutions. This saves water management costs for the deck and creates opportunities to link climate functions. It also creates a central open space amenity, which can be modified. This builds in flexibility and adaptive capacity.

Benefits
This approach prevents possible overinvestment in climate adaptation and provides scope for incorporating incremental insight in subsequent phases of development.

Implementation
New approach for development agreements between private and public parties, for example through long-term service level agreements.





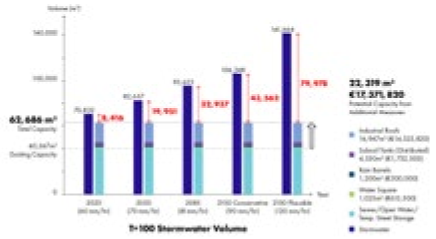
BEVERWIJK BUSINESS DOCKS
Collaboration by entrepreneurs

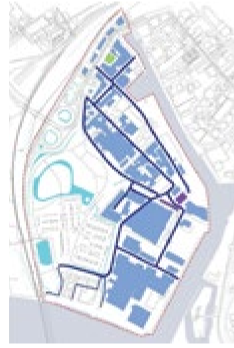
Assignment
Transformation of the work area along the inner dune edge.

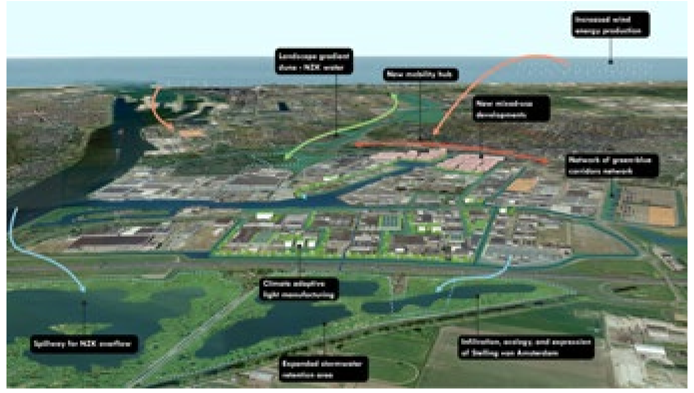
Concept
Climate stress will rapidly increase on the crowded industrial zone. Entrepreneurs and owners can take advantage of the dynamics in the area and, through cooperation with each other and with the municipality, address the climate challenge while increasing the attractiveness of the area for more diverse functions.

Benefits
Efficient use of resources through the coupling of tasks (climate adaptation and energy transition, reducing flooding and heat stress with area upgrade, private and public resources).

Implementation
Next step is a pilot together with the business organization GreenBiz IJmond and the municipality.







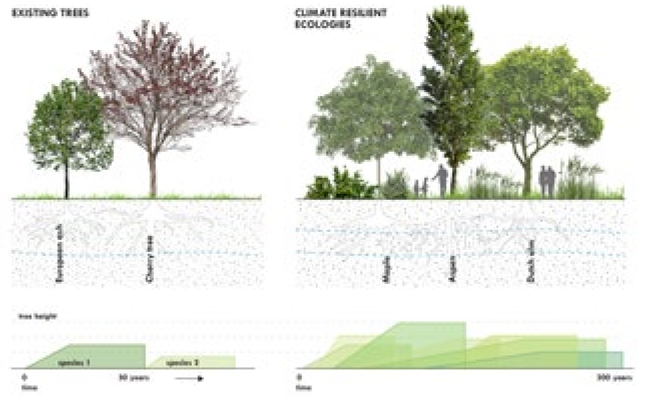
HAARLEM SCHALKWIJK
Trees as a link

Assignment
Transformation of post-war residential area within polder.

Concept
This project links water and heat strategies and proposes to use the necessary rejuvenation of the district's tree stock, together with proposed small shifts in public space, to increase climate resilience. This strategy will be applied at the future public transport hub, Haarlem Nieuw Zuid.

Benefits
A sustainable tree strategy delivers a multitude of 'ecosystem services'. The costs of redevelopment in the area are considerably lower than alternative measures.

Implementation
The project provides an opportunity to intentionally build capacity among the various departments of the municipality, investors, and the local population.



How to ensure that climate adaptation will become a “normal” part of integrated investment decisions within the MRA, now and in the future?

The challenge asked the question: how to ensure that climate adaptation will become a “normal” part of integrated investment decisions in the Amsterdam Metropolitan region now and in the future? The question has several interesting implications. The first is the focus on climate adaptation along with the use of the word “normal.” At this moment, climate adaptation is often considered an add-on or extra element, interesting to consider in a similar way to the energy transition or the circular economy. There are policies around it, but it is not yet a normal part of development. Integrated relates to the current context in the Netherlands, where climate adaptation falls under the domain of water safety. To a certain extent, a focus on ecology has become integrated into area development or infrastructure development, but not climate considerations. Investment relates to the question of how to make this work bankable, but also how to ensure that climate adaptation becomes part of investment planning at a high level? It also points to the fact that adaptation is currently mostly paid for by public sector, especially the water boards. The reference to the MRA reinforces the regional nature of the challenge. In the Netherlands, climate adaptation depends on national programs like the Delta Programme as well as regional programs led by the provinces and local programs either run by each of the water boards or by local municipalities. The last piece refers to now and in the future. On the one hand, the challenge aims to create a sense of urgency, leading to pilots and demonstration projects. At the same time, RBD invites longer-term thinking. Therein lies one of the major paradoxes of such a project, one that is evident in its outcomes.

The beauty of climate inclusive development

The genesis of the RBD project occurred at a 2018 conference called We Make the City in Amsterdam. ONE presented work from the United States as examples of designing climate-adaptive places with multiple benefits. These projects not only demonstrated the value of integrating financial and economic perspectives into planning but also the importance and impact of working with a multitude of stakeholders to develop robust solutions.

Public spaces can be built into resilient coastlines

Considering and planning climate-adaptive infrastructure in an integrated way can benefit cities and especially coastal environments. It is a tool to improve the cities of the present. Furthermore, there is a power in images and visualizing these integrated solutions that can help create urgency and follow up.

Streets can transform to manage stormwater

Inland environments have an urgent need to deal with issues such as heat and stormwater. These challenges require different types of solutions, which combine traditional or hard engineering with Nature-based Solutions. Heat and stormwater impacts not only residential areas, but also industrial areas.

Rivers and streams can manage increasing rainfall and improve public health

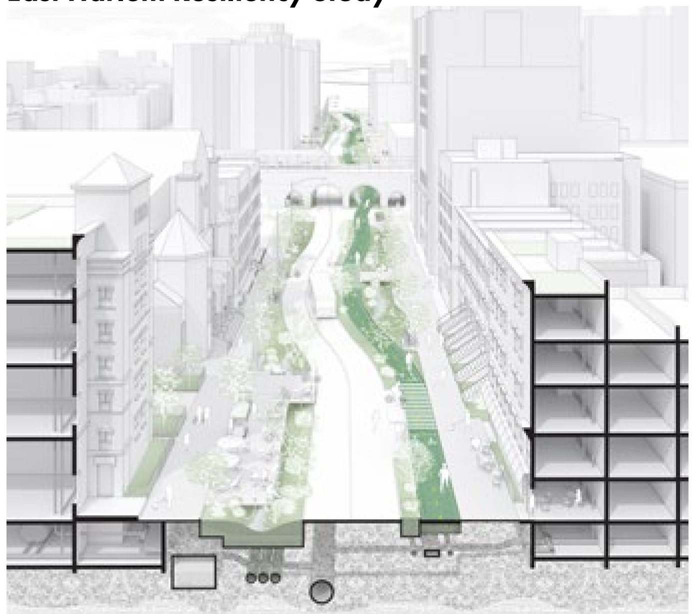
The benefits of restored river corridors extend far beyond their immediate footprints. There is a significant body of pioneering work that demonstrates the potential for waterways to buffer stormwater and enhance livability in urban areas.

Rebuild by Design - The BIG U

Resilient by Design - Islais Hyper-Creek

Water as Leverage Semarang

East Harlem Resiliency Study



Living with Heat Chelsea

East Harlem Resiliency Study

Bishan-Ang Mo Kio Park, Singapore

Ramboll Studio Dreiseitl

India Basin, San Francisco, CA

SOM

Mill River Park, Stamford, CT

Sasaki

Project context

HOW DO WE MAKE DECISIONS UNDER UNCERTAINTY TO SUCCESSFULLY PREPARE FOR A RESILIENT FUTURE?

Climate change is real, is irreversible, and is accelerating

- **KNMI (2014):** **45 - 85 cm SLR by 2085 (95% probability, RCP 8.5)**
- **Deltaprogramma:** **1 m SLR by 2100 ('plausible range,' 66% probability)**
  Updates to be expected in 2023 - 2026
- **Rapid ice melt scenario:** **+ 2 m by 2100 (from 'plausible range' to 'possible,' RCP 8.5)**
- **Long-term sea level rise:** **25 - 50 m (over multiple centuries)**

The RBD project begins with larger considerations: how to think about decision-making in the context of climate change, and the meaning of resilience in broader terms.

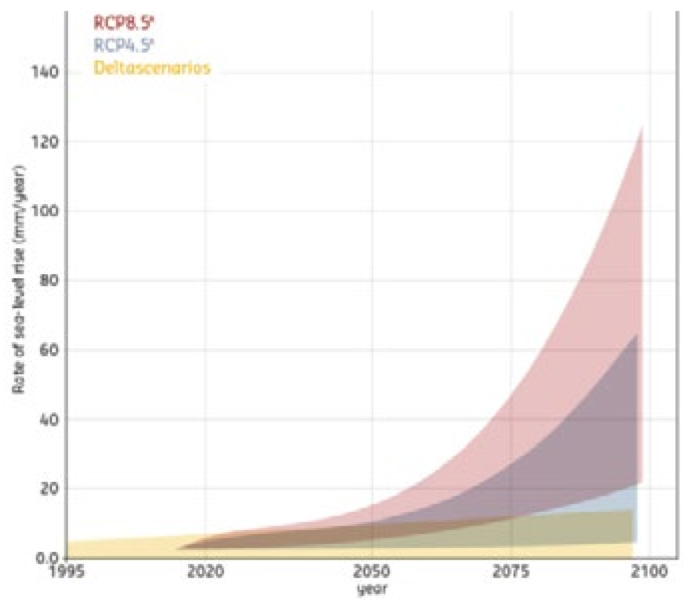
It is critical to establish from the start that climate change is real; it is irreversible, and it is accelerating. Intergovernmental bodies have mapped out a range of carbon emissions scenarios (Representative Concentration Pathways) for the future, from "business as usual" to aggressive carbon emissions reduction. While historical emissions trends continue to track along the RCP 8.5 pathway, the current Deltaprogrammma scenarios that are used in the Netherlands as the basis for planning use more moderate projections for emissions.[1,2] This effectively means planning for the low end of the range when considering sea level rise projections. The 2014 KNMI scenarios represent a range of probabilities; they too might not be aggressive enough. Generally speaking, both the KNMI and the Delta program scenarios can be considered highly optimistic about sea level rise and about the impacts of climate change. There is general awareness that they need to be updated, but since these scenarios are already fundamental to a national process of inclusive conversations with all the institutions and stakeholders in this space, there is not a process in place to update them in the near term. Climate projection updates are anticipated to arrive in 2023, or perhaps even 2026. At the same time, there are Antarctic melt scenarios that, while highly improbable, could add two or more meters to sea level by the end of the century. And sea level will continue to rise beyond this century: in a few centuries sea level will be 25 and 50 meters higher than it is now, at which point the Netherlands will be almost entirely submerged.

The present moment represents an inflection point. It marks the end of a period of sea level stability – relatively brief in the course of human history – and the beginning of a period of accelerated change. The change itself is unpredictable, but human behavior has set in motion this drastic sea level rise over time. Living in a time period with both a high level of unpredictability and a high level of change has implications for planning.

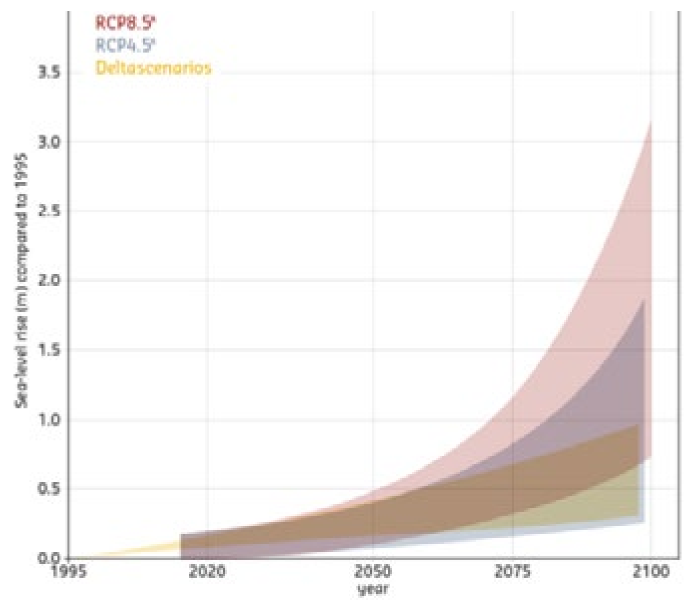
1. Schwalm, Christopher R., Spencer Glendon, and Philip B. Duffy. RCP8.5 tracks cumulative CO2 emissions. PNAS (Aug 2020): 117 (33) 19656-19657; DOI: 10.1073/pnas.2007117117;

2. Deltaprogramma 2020 (2019). Doorwerken aan de delta: nuchter, alert en voorbereid. Ministerie van Infrastructuur en Waterstaat. deltaprogramma2020.deltacommissaris.nl

Rate of sea level rise

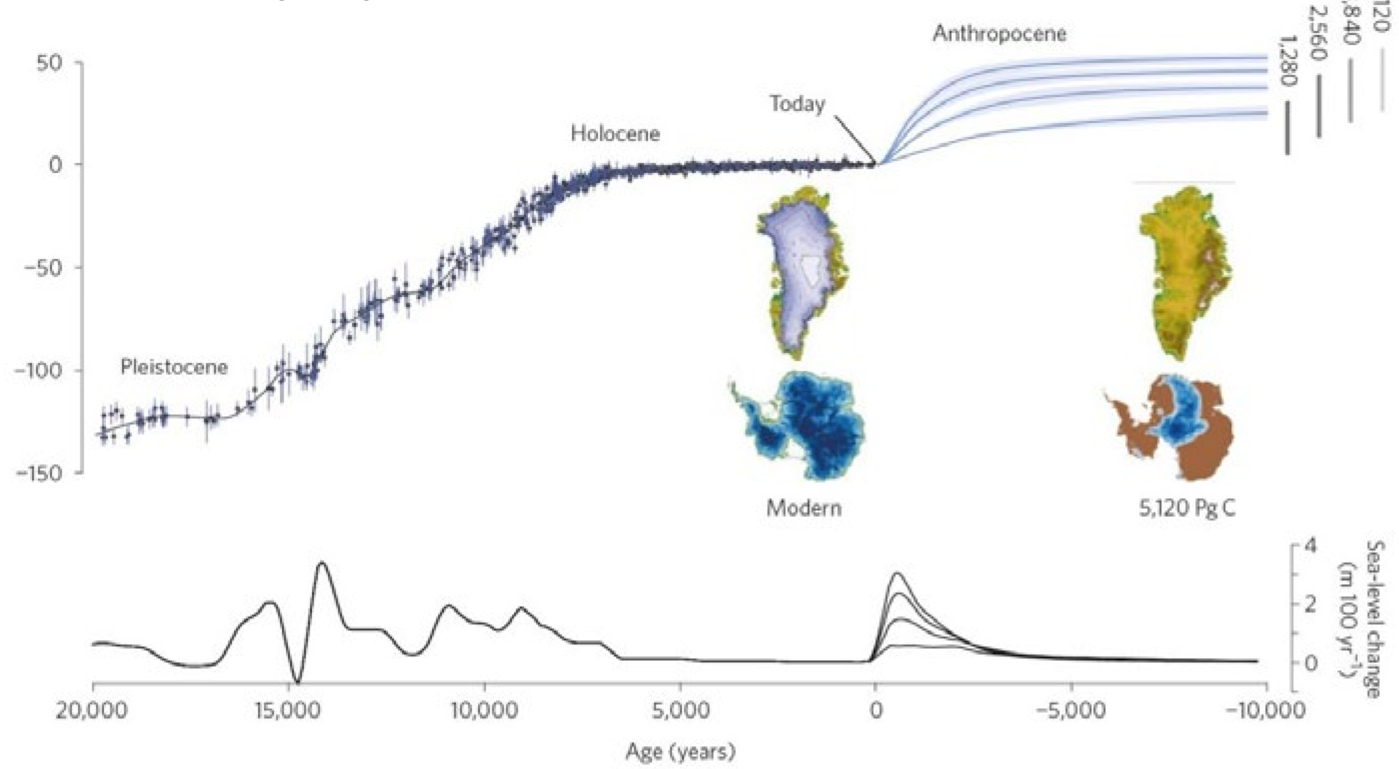


Magnitude of sea level rise



Source: Haasnoot, M. et al. (2020). Adaptation to uncertain sea-level rise; how uncertainty in Antarctic mass-loss impacts the coastal adaptation strategy of the Netherlands. Environmental Research Letters, 15(3). doi.org/10.1088/1748-9326/ab666c

Past and future changes in global mean sea level



Source: Clark, P. et al. Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. Nature Clim Change 6, 360–369 (2016). doi.org/10.1038/nclimate2923

The climate crisis will bring many chronic risks

In the Netherlands, there is a tendency to focus on sea level rise because flood risk is the greatest threat, if not the most immediate. The system of dikes, dunes, and pumps is not yet at the end of its useful life, and at this moment, remains relatively secure.

Yet, climate change comes with numerous other impacts. For example, a changing climate will bring more intense rainstorms, longer periods of droughts, warmer average temperatures, more heat waves, and most significantly, many more hot nights. The future of the MRA will not only have additional flood risk but a host of other challenges including nuisance flooding and heat stress.

There is mounting evidence that planning needs to move away from the overly optimistic climate scenarios and the Netherlands needs to grapple with its longer-term adaptation trajectory. To that end, the research institute of Deltares organized a hackathon, later memorialized through a report, in which they developed a range of scenarios for long-term adaptation.

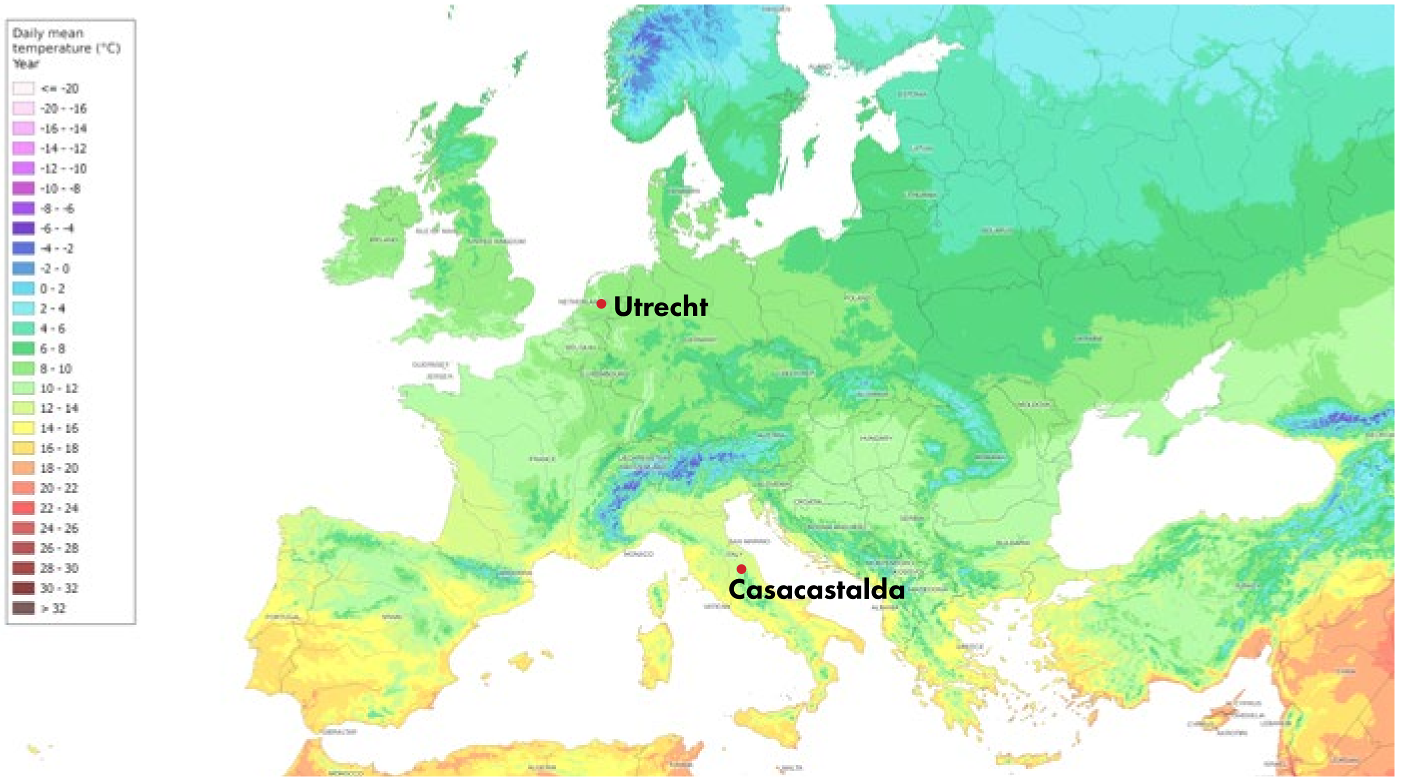
The different scenarios show the importance of developing longer-term plans, but still operate at a high level of abstraction. The models foresee an continuation of the Dutch system as it now largely exists and assume change is a long way out.

On the one hand, there is an ongoing emphasis on pumping. With sea level rise, when the rivers cannot flow into the sea anymore, the system will require pumping all that water out or having immense dikes around the river, with pumping in the lower-lying areas. Another option includes pursuing land formation in front of the coastal zone to create a buffer for our water, moving into the sea. And a final option focuses on partially retreating from lower-lying areas and only protecting the areas of great value.

In early sessions of the RBD project, officials were quick to dismiss some of these scenarios as far-fetched and in some way unfeasible. The scale of spatial adaptation would be immense, and the common perception is there isn't really the space. Another critique is that people do not believe the transition is possible. Disrupting the water system will create a host of problems. At the core, the challenge is that even if one of these scenarios had to be enacted, there is a lack of understanding how to make the transition

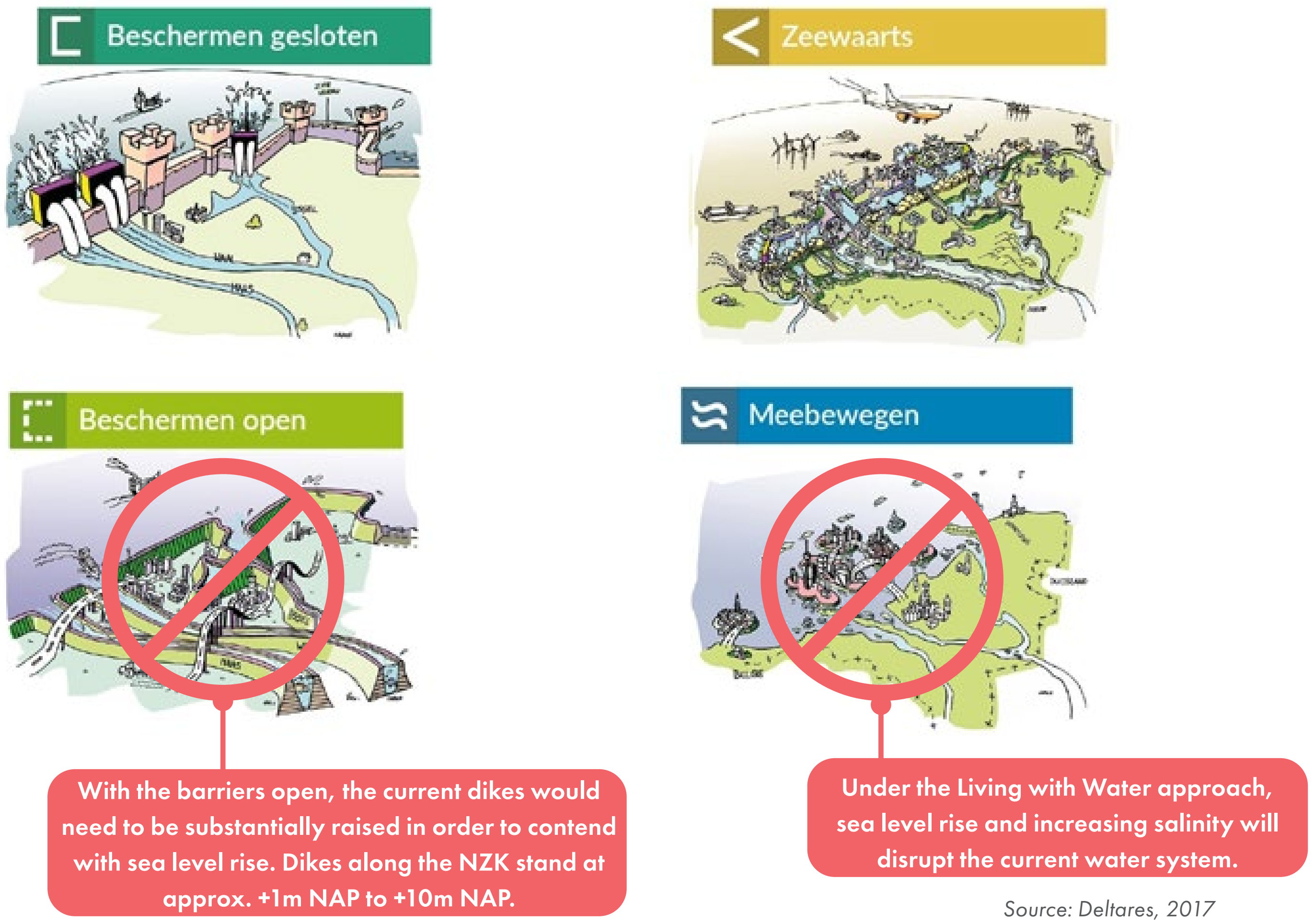
Fundamentally, the landscape in the MRA is a technological machine.

By 2070, the climate in Utrecht (near Amsterdam) will resemble that of Umbria today: more intense rainstorms, longer periods of drought, and hotter, with more hot nights



Source: National Geographic, "See how your city's climate might change by 2070," (April 14, 2020); www.nationalgeographic.com/magazine/2020/04/see-how-your-citys-climate-might-change-by-2070-feature/

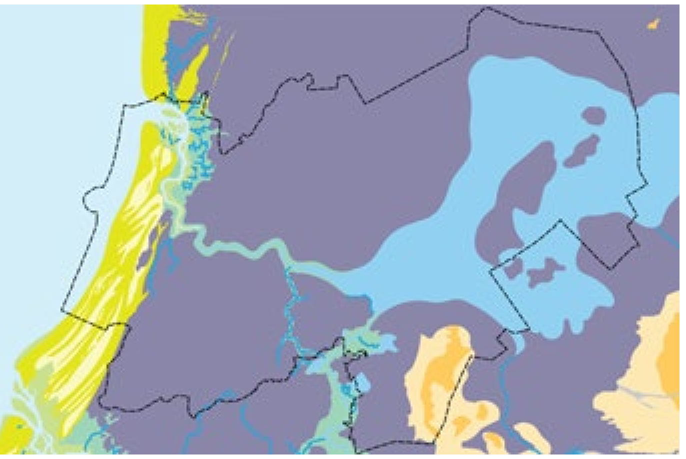
The main threat for catastrophic and systemic risk is sea level rise. Research such as the Deltares "Hackathon" demonstrates that risk is still a long way out



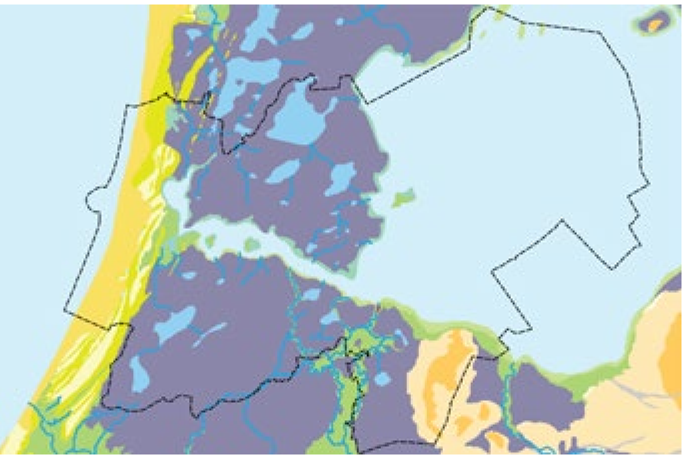
Source: Deltares, 2017

MRA LANDSCAPE AS TECHNOLOGICAL MACHINE

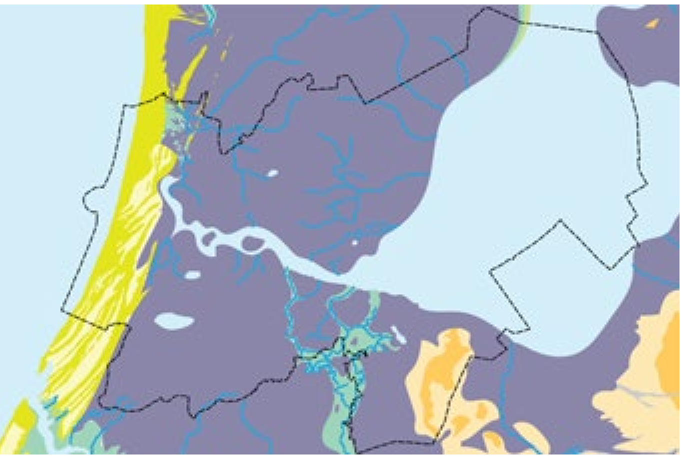
Pre-Medieval



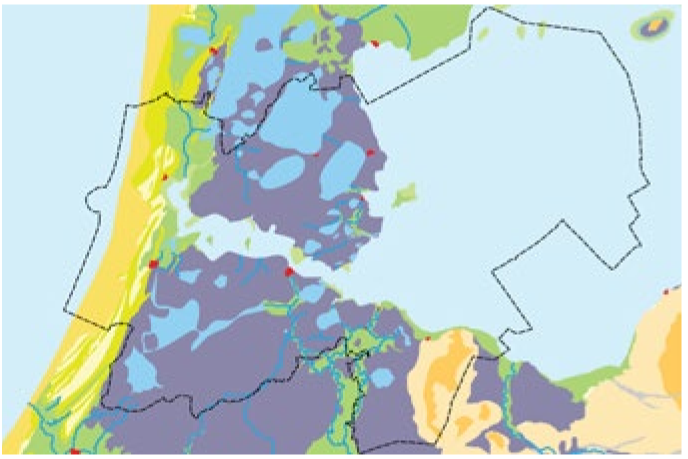
16th Century



Pre-16th Century



17th Century



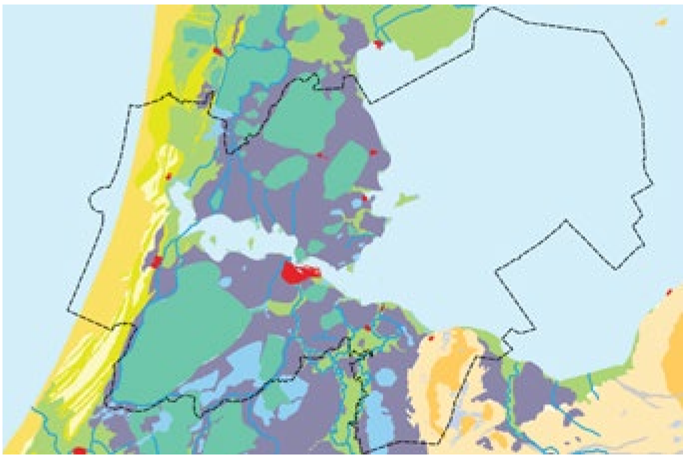
Legend

- Open water and inland water (Buitenwater en binnenwater)
- Watercourses (Waterlopen)
- Salt marshes and river plains (Kwelders en riviervlakten)
- Mudflats and swallows (Wadden en slikken)
- Peat area (Veengebied)
- Pleistocene sandy areas, above 0m. NAP (Pleistocene zandgebieden, boven 0m. NAP)
- Pleistocene sandy areas, below 16 and 0m. -NA (Pleistocene zandgebieden, beneden 16 en 0m.
- Stuwwallen, gestuwde keileem en door stromenc landijs gemodelleerde ruggen en dalen
- Loess area (Lössgebied)
- Dyed salt marshes and river plains (Bedijkte kwelders en riviervlaktn)
- River dunes (Rivierduinen)
- Areas with Tertiary and older deposits (Gebieden met Tertiaire en oudere afzettingen)
- Areas with salt marshes and ridges (Gebieden met kwelderwallen en ruggen)
- Drying (Droogmakerij)
- Beach walls and low dunes (Strandwallen en lage duinen)
- Beach plains and dune valleys (Strandvlakten en duinvalleien)
- Blowing sand (Stuifzand)
- River plains and stream valleys (Riviervlakten en beekdalen)
- Steden (City)

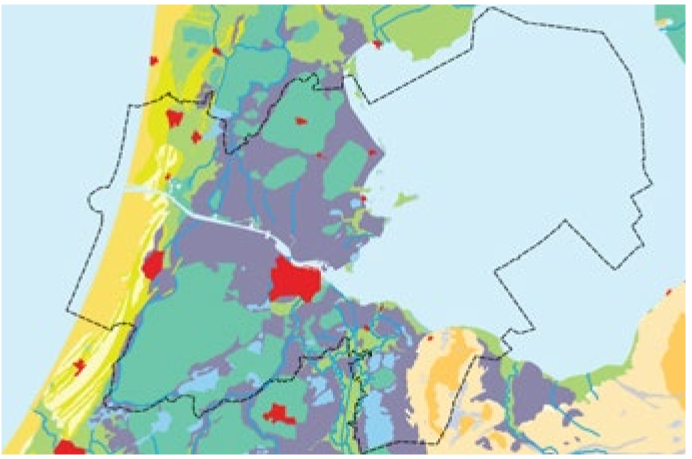
Design of the landscape over time

The MRA developed and changed substantially over time. In pre-medieval times, it was a very wet delta with rivers flowing from the German hinterlands through to the North Sea. Over time, the coastal dune system closed itself, creating an immense swamp. In that swamp, different polders have been excavated or have been reclaimed over time, depending on the available technology.

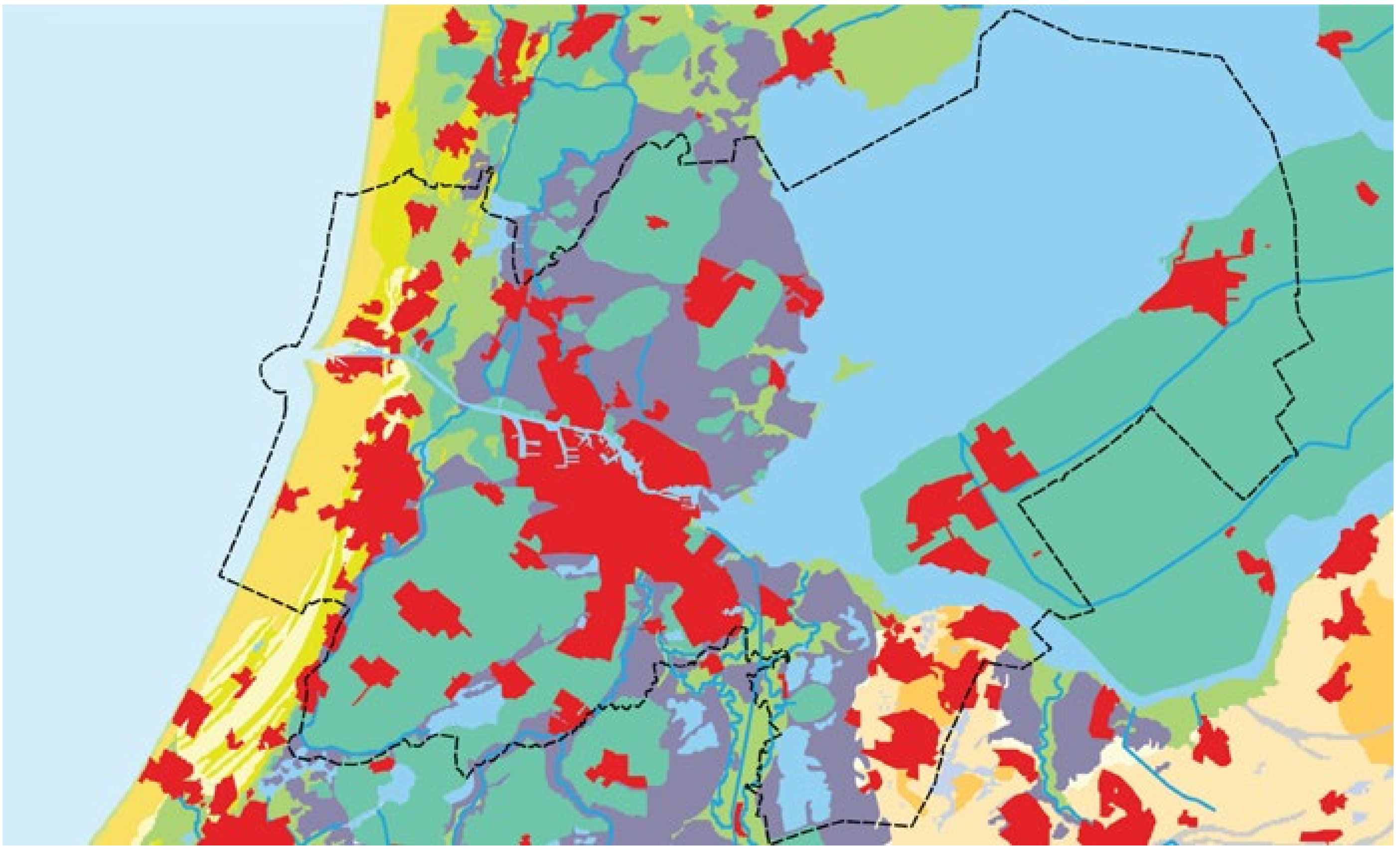
19th Century



20th Century



21st Century



Catastrophic risk is managed through an increasingly sophisticated water management system, which also serves myriad other agendas

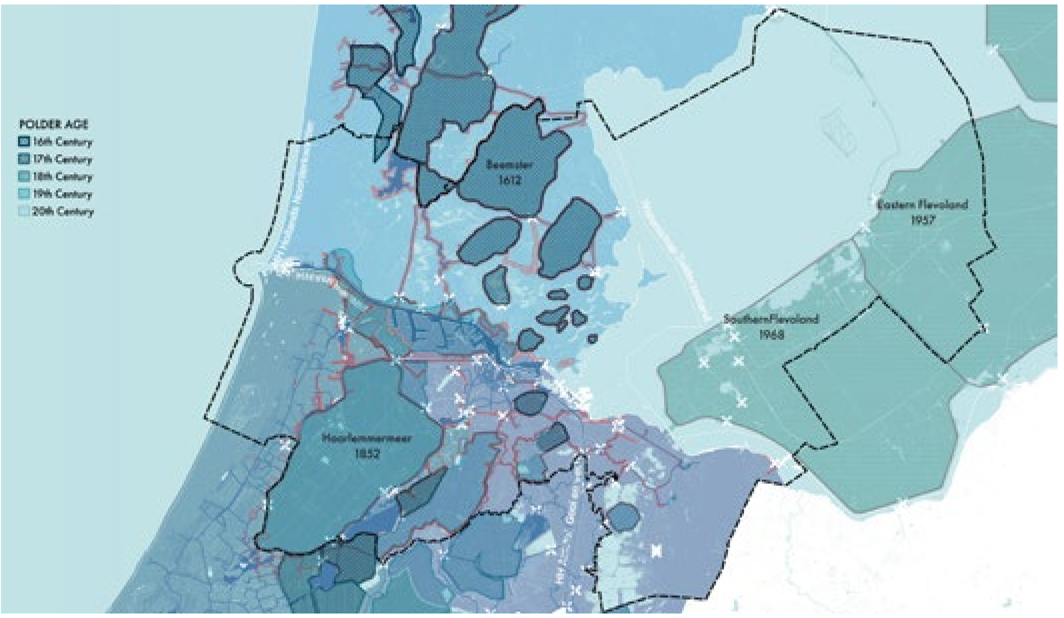
The system of water management with polders is highly sophisticated. It is controlled by many measures, including dikes, pumps, and sluices. The system has been built out sequentially since the 12th century, encompassing the entire nation. Thus it has become integral to the political system, with water boards as independent political entities able to raise their own taxes. This water system has been nearly perfected in the background of all the other developments over this time. Changes in agriculture, changes in urbanization, trying to accommodate and balance the range of interests: these have been an important asset for the Dutch but also relatively fragile because of the demands on the system. At present, the political and institutional frameworks to manage the system exist, but as stresses increase, it becomes more difficult to maintain, with costs rising over time.

Sources (from top left): IBM, ibm.com/blogs/internet-of-things/ibm-maximo-amsterdam/; n/a; Waterschap Amstel, Gooi en Vecht, agv.nl/nieuws/2017/oktober/nieuw-peilbesluit-voor-ijsselmeergebied/; De Nieuwe Meerbode, meerbode.nl/verkiezingen-twee-keer-stemlokaal-in/, Waternet; Waterschap Amstel, Gooi en Vecht, "Dikes," waternet.nl/ons-water/dijken/; Facility Apps, "Follow Dike Strength With FA," March 25, 2019, facilityapps.com/en/follow-dike-strength-with-fa/; Ibid; Waterschap Amstel, Gooi en Vecht, agv.nl/onze-taken/bescherming-tegen-water/veilige-dijken-in-heel-nederland/

THE MRA WATER SYSTEM

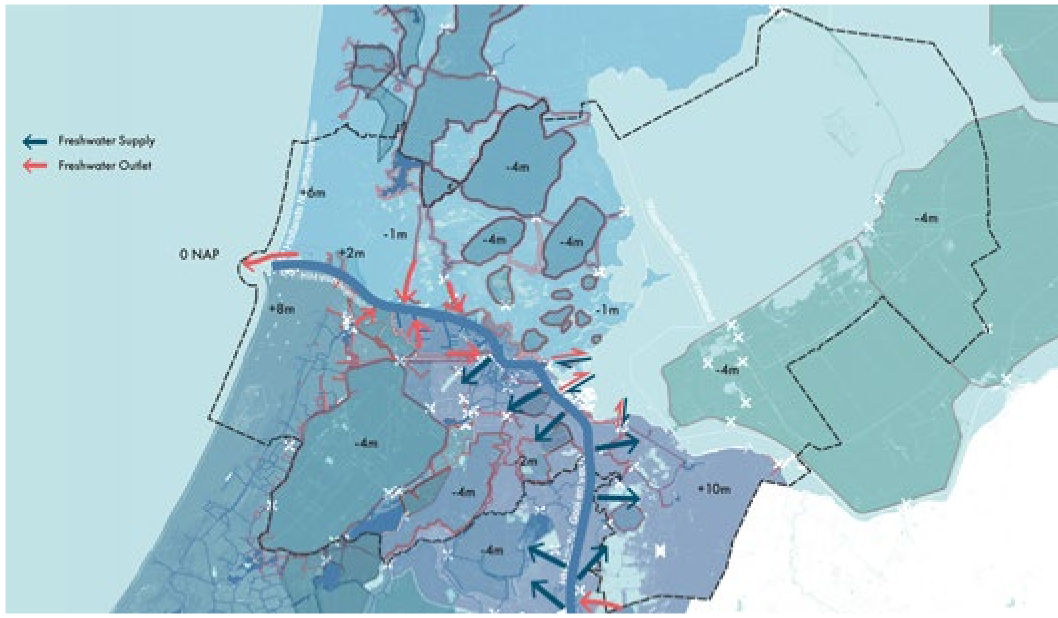
The Dutch water system is linked through its historical development, in which polders, surrounded by dikes, were reclaimed in sequence, and in which each polder manages its own water levels.

Amsterdam metropolitan area polders encompass the old city of Amsterdam, behind the coastal dune system. A canal connects Amsterdam to the North Sea. This area represents a sea transformed into a lake. Two of the largest polders were built in the 1950s and 1960s.



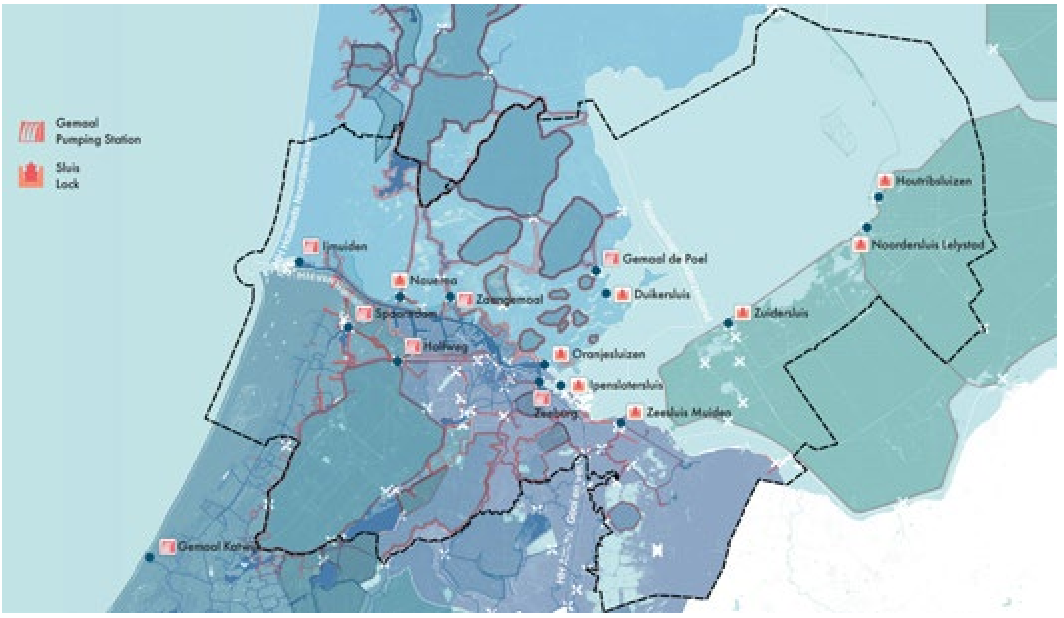
This complex system drains on the ARK-NZK.

The entire system drains through two canals that connect the Rhine River in the south to the North Sea, the Amsterdam Rhine Canal and the North Sea Canal from Amsterdam. The two canals not only provides drainage, but also supply the necessary fresh groundwater to adjacent areas to mitigate saltwater intrusion or support agricultural functions.



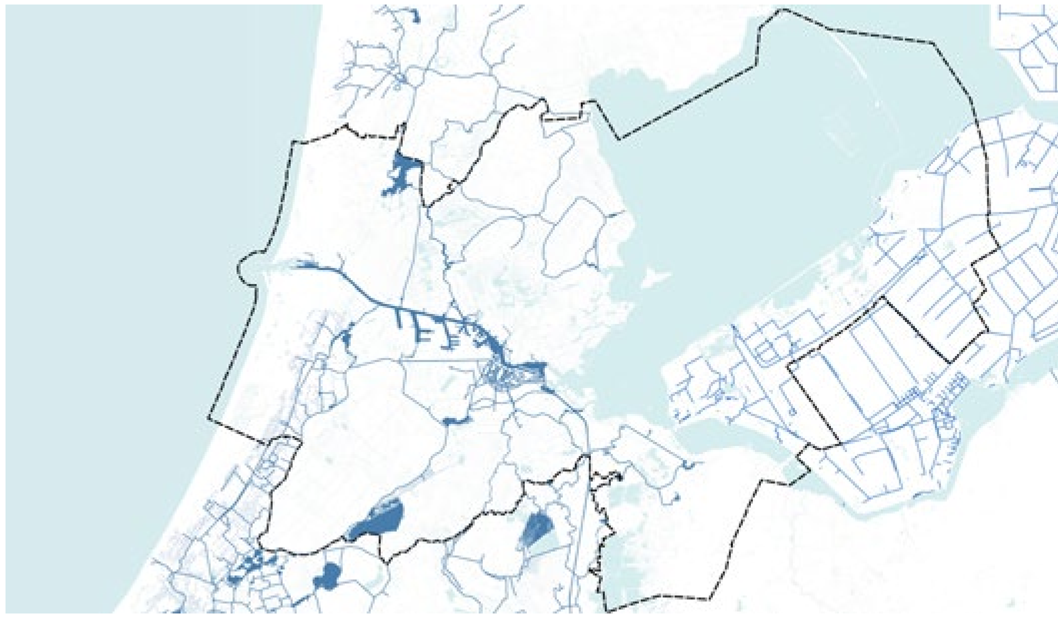
These polders are connected by a system of canals and pumps. Within these units, water levels can vary through weirs and internal drainage, to suit the needs of farmers or to avoid salinity.

The large, six-meter deep polders take enormous pumping capacity. They are connected by a sophisticated system of canals and pumps, and for each of these individual landscape elements and areas, a system of weirs, sluices, and other infrastructure controls the water level as appropriate for the polder's land use. For example, certain agricultural uses require drier conditions, while wetter conditions can counteract saltwater intrusion.



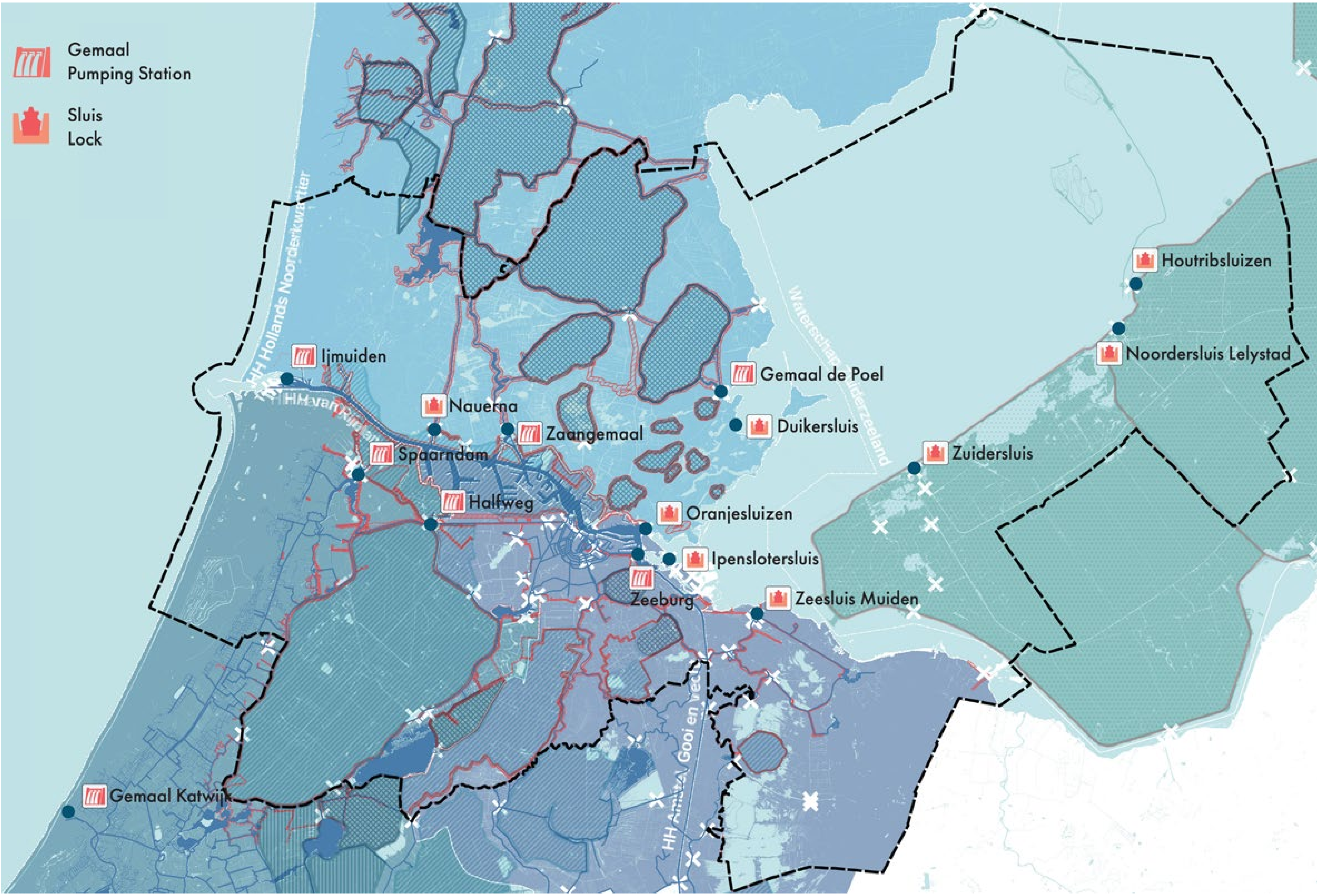
The polder water of an "inland" polder must travel a great distance to reach the open water, as in the example of the peat polder Kockengen.

Each polder is able to drain step-by-step onto the greater system, until it is finally pumped out in the North Sea.

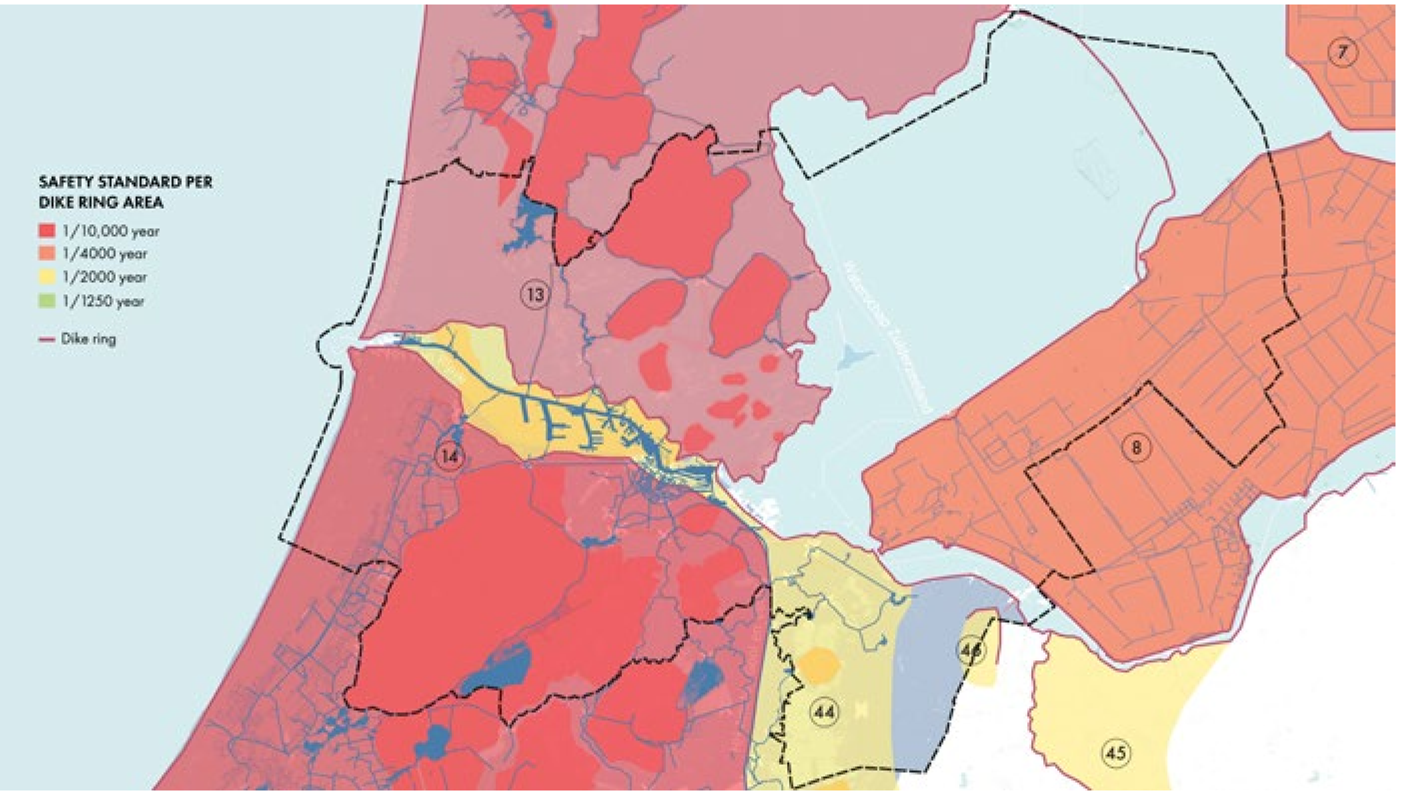


The system has a technological river as its spine: the ARK/NZK

Today, the Dutch polder system fundamentally depends on the technological river of canals as its spine. One adaptation pathway to rethink this technological river to deal with a changing climate, arguably, is to assess that river and create a bit more room for the river. This strategy is analogous with the Room for the River program in the south. Here, perhaps it is not literal room but expand flexibility in the system, and room for starting to consider different long term scenarios.



Groups of polders are aggregated in dike rings, which protect against catastrophic flooding. But the system is becoming fragile.



In aggregate, the polders not only maintain water on a very local level but also are designed to address catastrophic flooding or flood risk. Yet, much of the technological river lies outside of these dike rings. Some of these polders are aggregated in dike rings that function as units with an equal protective level. The twentieth-century polder forms its own dike ring to protect against catastrophic flooding. This means that even when one dike ring collapses, only that compartment will flood and not the entire country. There is the unlikely possibility of a domino effect, but overall, the polders comprise a safe system, with different safety standards for each dike ring.

The system is becoming fragile as the frequency of intense precipitation events increases with climate change. The total rainfall projections do not change significantly, but storm events will be more intense over a twenty four- or forty eight-hour period. These changes will bring stresses to the system. In addition, the main pumping station at IJmuiden, one of the biggest pumping stations in the world, will need to be used much more regularly, because in the future gravity drainage at low tides will become rare. With operations comes wear and tear, as well as the increased risk of mechanical failure, thereby increasing the flood risk. Failure is a serious concern. Building additional pump stations is one strategy, and another is to start using the inner lake, the Markermeer, as a buffer.

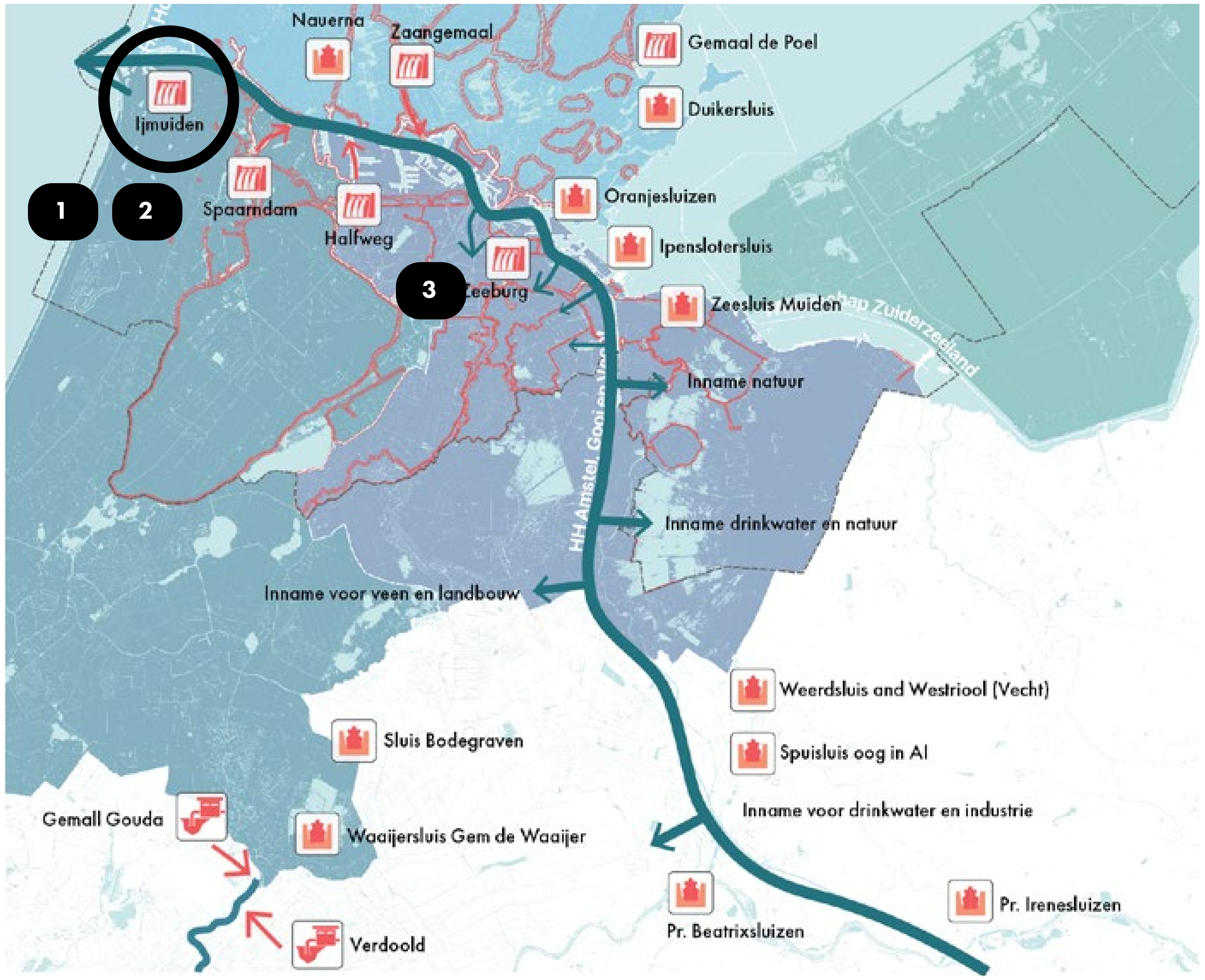
Highly sophisticated systems in which everything is interconnected makes adaptation challenging, creating a certain lock-in to the status quo. It can be explained using the metaphor of driving through the desert. Taking this journey with a contemporary car is impossible because the car is too complicated to fix. It is better to take a De Cheveaux Sahara, an aptly-named car, because with some duct tape and some rubber, it can be easily adapted and repaired. In some way the old car is more resilient, even if it performs less well than the contemporary car, which could be called brittle. If something goes wrong, it is complex to fix it.

1.
Failure at the IJmuiden pumping station with a recovery time of 12 hours or longer currently occurs every 1.5 years on average, with a system failure probability of 1/72 years. If the pumping system at IJmuiden were to never fail, the probability of the ARK/NZK system failure would be reduced to 1/2000, suggesting that the system is highly vulnerable to local failures and recovery times.

2.
Within the next 50 years, the probability of system failure is expected to increase to once every 10 to 20 years due to climate change. These projections are based on KNMI scenarios accounting for sea level rise and extreme rainfall, but they do not take subsidence, land use changes, or infrastructure changes into account.

3.
Within the AGV boezem system, the current probability of failure varies. In Amsterdam Oost, the probability of exceeding NAP +0.00m is 1/115 years.

Source: Faalkansanalyse Noordzeekanaal/Amsterdam-Rijnkanaal

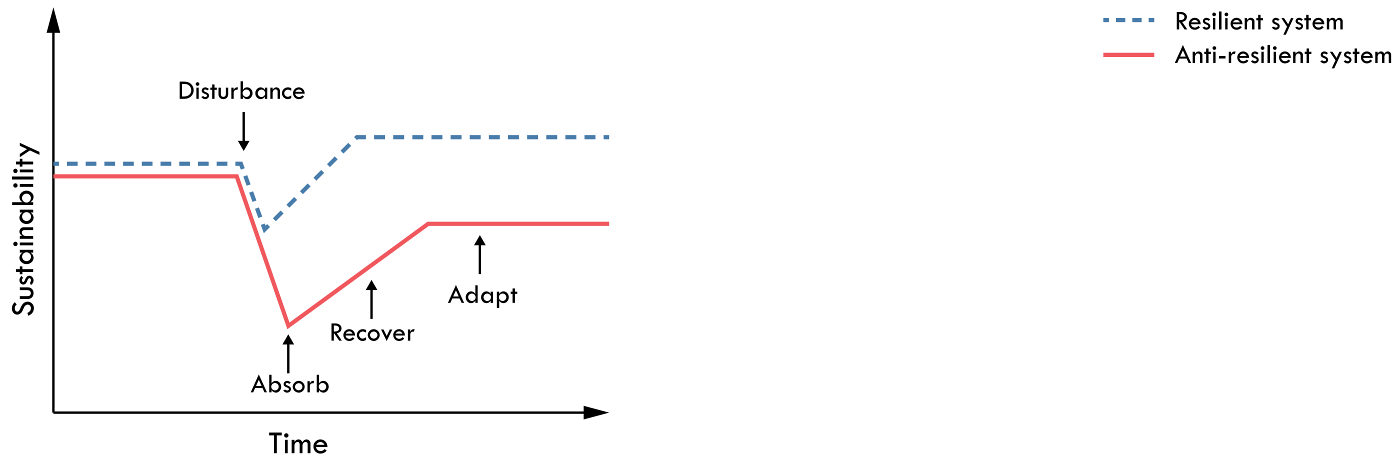


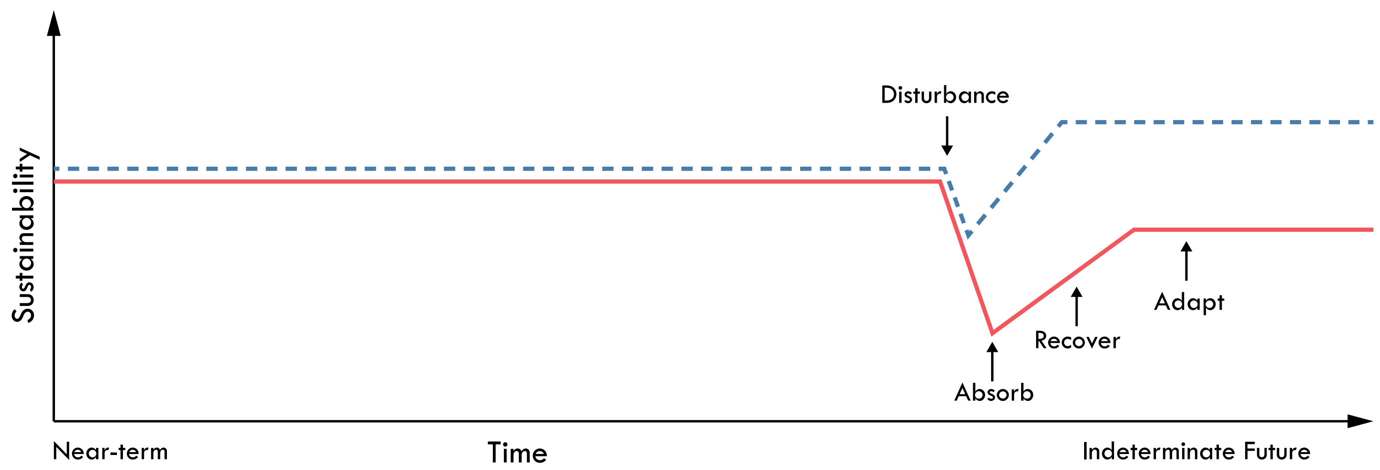
Examining the system through a resilience lens, we recognize it lacks adaptive capacity. This is why it is critical to build resilient systems.

Through a resilience lens, it is clear that the technological system serves multiple functions and is connected not only to physical but also social and political systems. It does not have the adaptive capacity that it should. This capacity is necessary to respond to the uncertainties that come with climate change: how much rainfall, heat, and sea level rise to plan for, and what is the long term solution for the Netherlands. To create resilience by design, it is important to consider it from a theoretical perspective. In a non-resilient or anti-resilient system, a shock cannot be absorbed, leading to a decrease in system performance. Even after recovery and adaptation the performance falls short. In a resilient system, the impact of a shock is smaller, while recovery and adaptive capacity is greater. This enables a better and more transformative recovery.

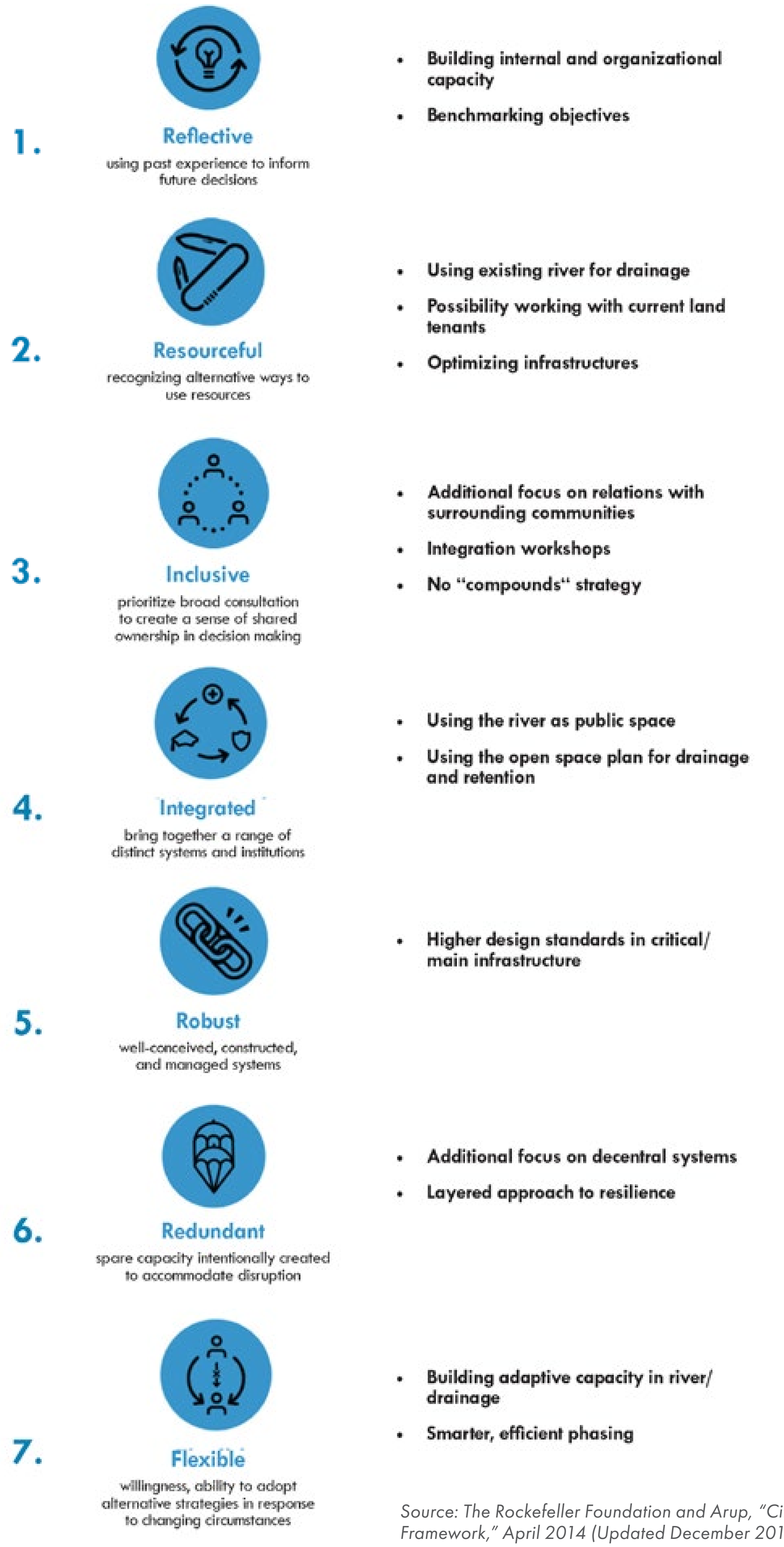
The principles of resilience underpin the types of systems with the capacity to bounce back in a transformative way. They include organizational capacity and the ability to learn; being resourceful and using resources that in a smart way. To be inclusive, to understand that it is not only one particular shock, but there is a high level of unpredictability and a relationship between shocks and stresses. There is a possibility to start thinking about integrated solutions, and in that acknowledge different perspectives, mobilize different actors and funding or resources to build resilient systems. It is crucial to create systems that are more robust, with redundancy and flexibility, so that when something fails, there is not an entire system collapse.

While risks are increasing, there is a general sense in the Netherlands that the risk of systemic failure remains low in the short- to medium-term.





Principles of Resilience — 100 Resilient Cities

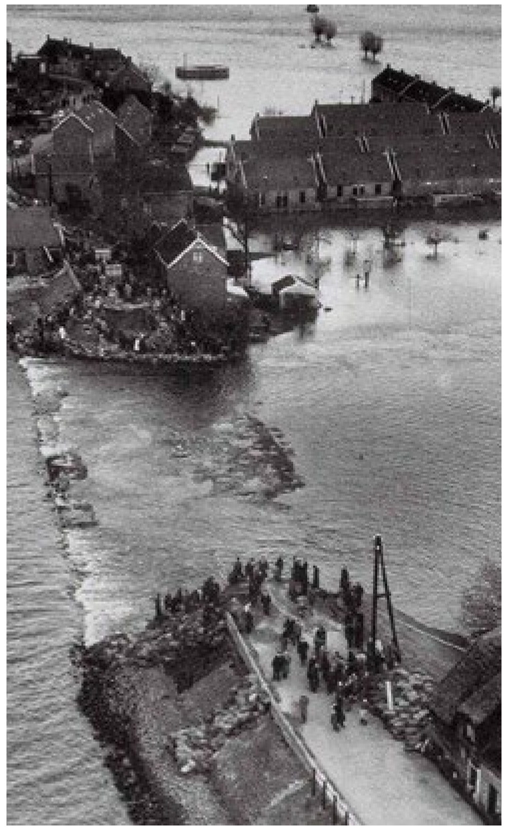


Source: The Rockefeller Foundation and Arup, "City Resilience Framework," April 2014 (Updated December 2015).

The system is not yet resilient. With accelerated climate change, the time of constant precise adjustments will soon be over. It creates lock-ins; it cannot deal with the heightened fluctuations that will come; it is too brittle and lacks adaptive capacity.

At the same time, since anything built now will most likely remain in place for the future, it is important to start thinking now about how to make the Dutch technological machine more resilient.

Dike breach during the North Sea flood of 1953

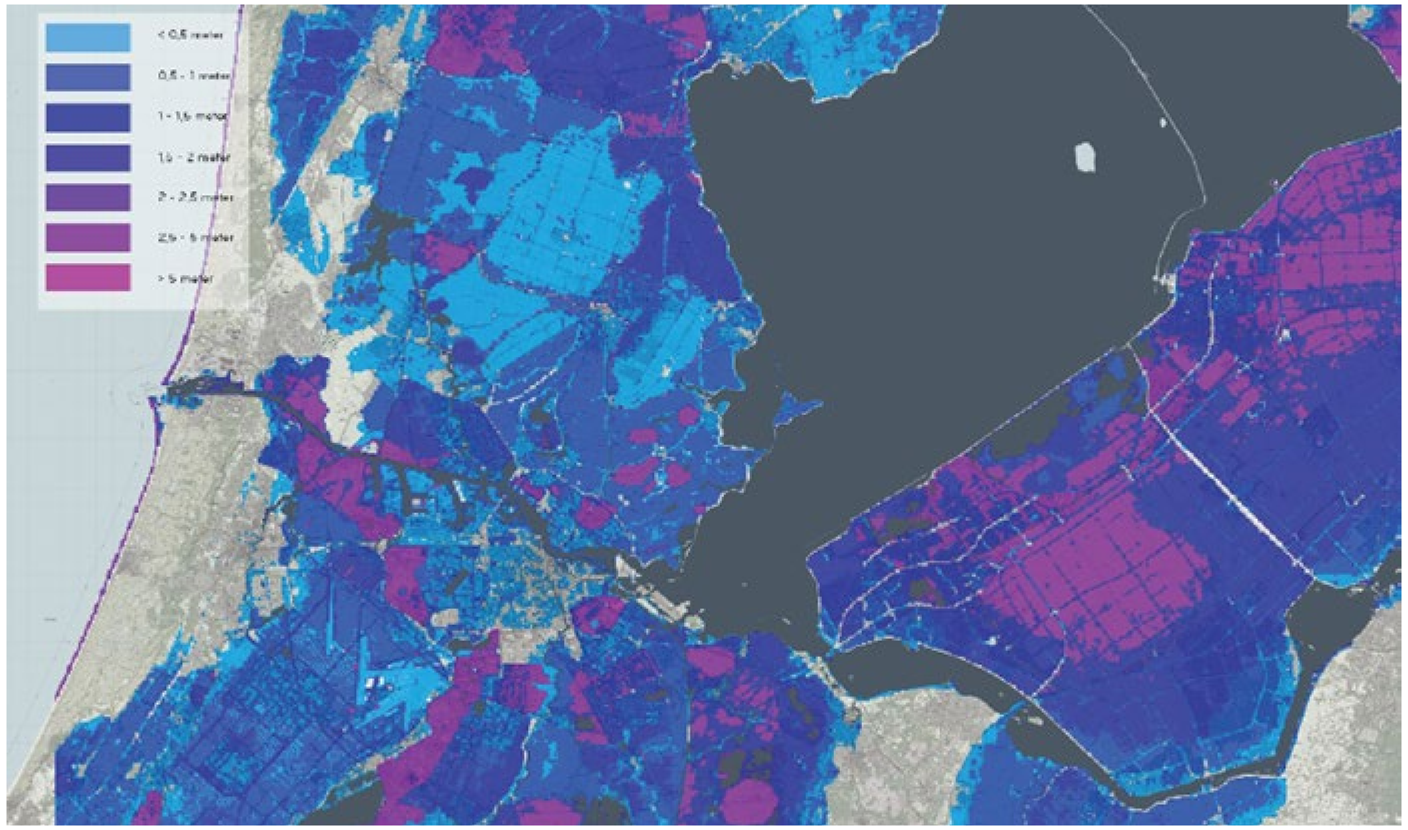


Source: Wikipedia

Flood depth projections indicate the potential for local catastrophic risks.

It is also important to acknowledge local risks. Here indicated in terms of flood depth.

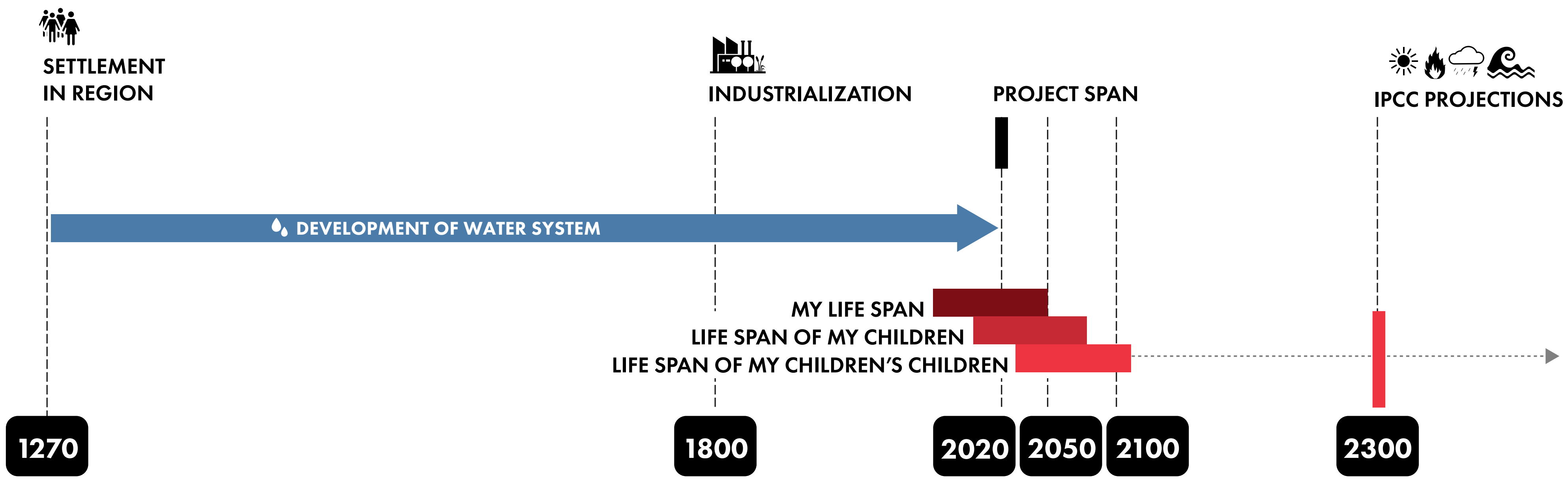
Flood depth mapping



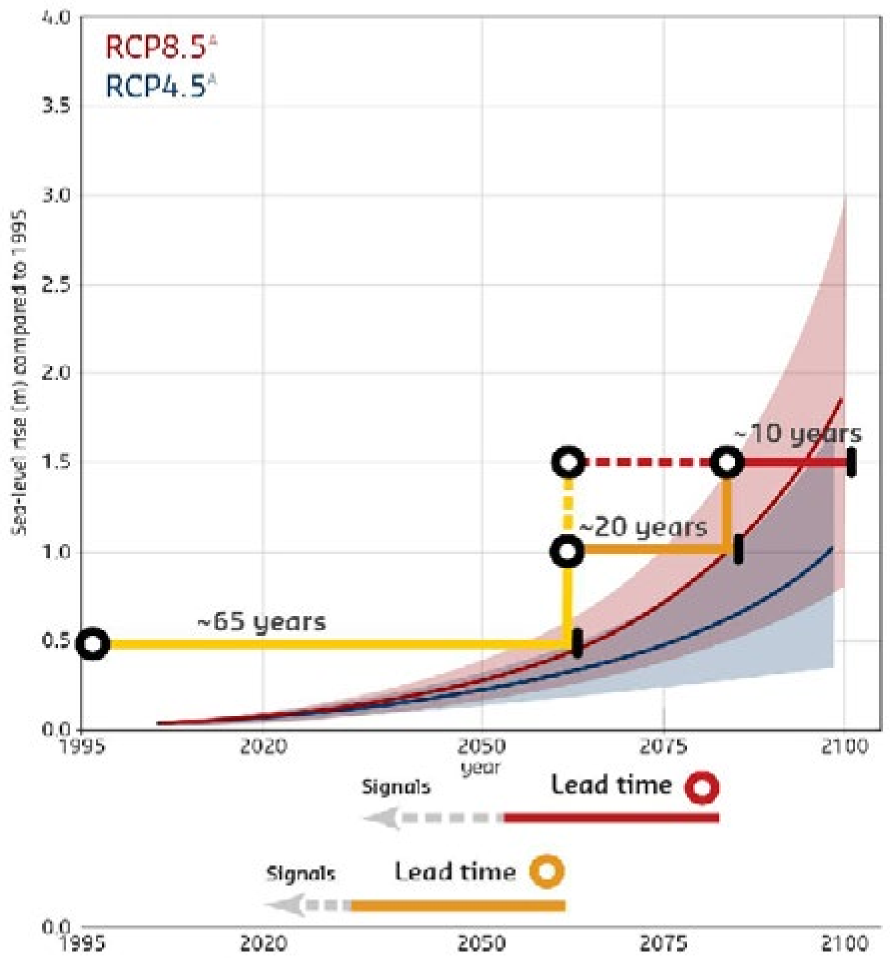
Source: Deltaprogramma 2020.

To manage catastrophic risk, planning needs to consider the lifespan of infrastructure and the time it takes to prepare. In some scenarios, we are now deciding on the infrastructure that will still be in place in future world with an entirely different magnitude of risk.

Time horizons in planning



Shorter decision-making process



Source: Marjolijn Haasnoot et al. 2020. Environ. Res. Lett. 15. doi.org/10.1088/1748-9326/ab666c

Judging risk in terms of dike rings with 1 in 2500-year recurrence makes it challenging to sell this argument more broadly. Instead, the argument should be that thinking about the future starts today with planning the functional lifespan of contemporary infrastructure projects. This lifespan brings them into an entirely different climate condition. Moreover, many projects that enable climate adaptation have a long lead time. If a climate change accelerates, the available lead time becomes shorter, because the signal that change is needed is not apparent soon enough to act.

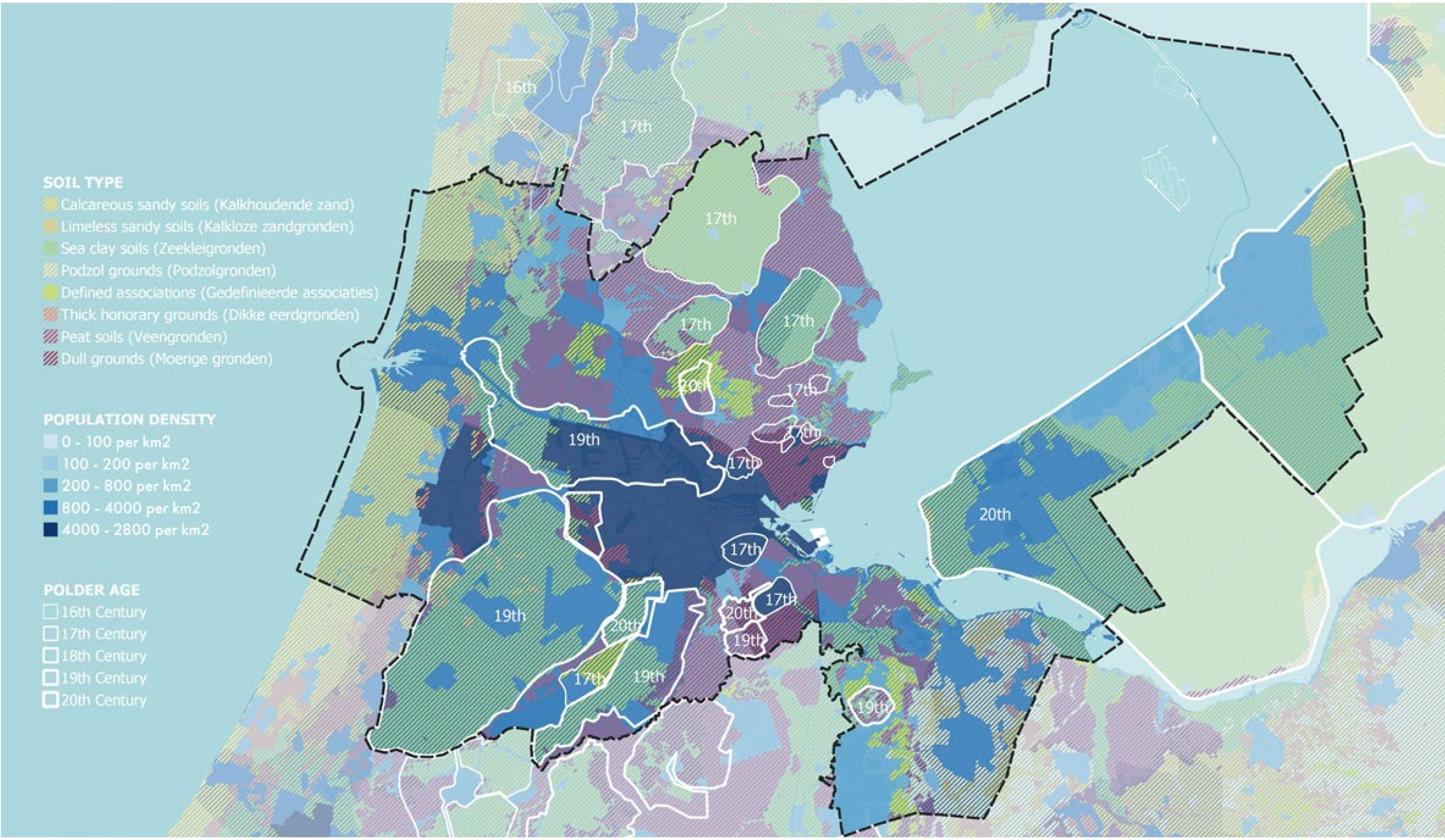
The very concept of long-term planning is evolving. The duration of a project is often only thirty years. Its lifespan may be a century. After a period of stable climate, the pace of change is increasing. IPCC climate projections describe a period of more than two centuries, but it is common for people not to care about impacts over this timeframe because they exceed a typical human lifespan. Still, they will occur in the lifespan of our children or grandchildren.

TO MAKE THE SYSTEM MORE RESILIENT, WE MUST TAILOR MEASURES AND APPROPRIATE DEVELOPMENT TO LANDSCAPE TYPES

Making this actionable on a systems level begins with understanding Operative Landscape Units in the MRA.

Whereas interventions on a systemic level are important, it is also critical to start thinking for the range of landscape types how to make new development more resilient, and which would create resilience within these individual landscape units to reduce the complexity of the overall system.

Similar to the way the Bay Area Adaptation Atlas created operative landscape units, the MRA could begin to define these functional landscape areas.



Reference:
The San Francisco Estuary Institute, "San Francisco Bay Shoreline Adaptation Atlas," sfei.org/adaptationatlas

A more resilient system requires a move away from the paradigm of 'water safety.' The new system has a different set of principles at its core.

Increase flow and buffering capacity
creating overflow polders and retention areas

Increase tolerance
adapting the building stock or allowing salt water intrusion

Improve optionality
ensuring new developments are not locked into high maintenance water management

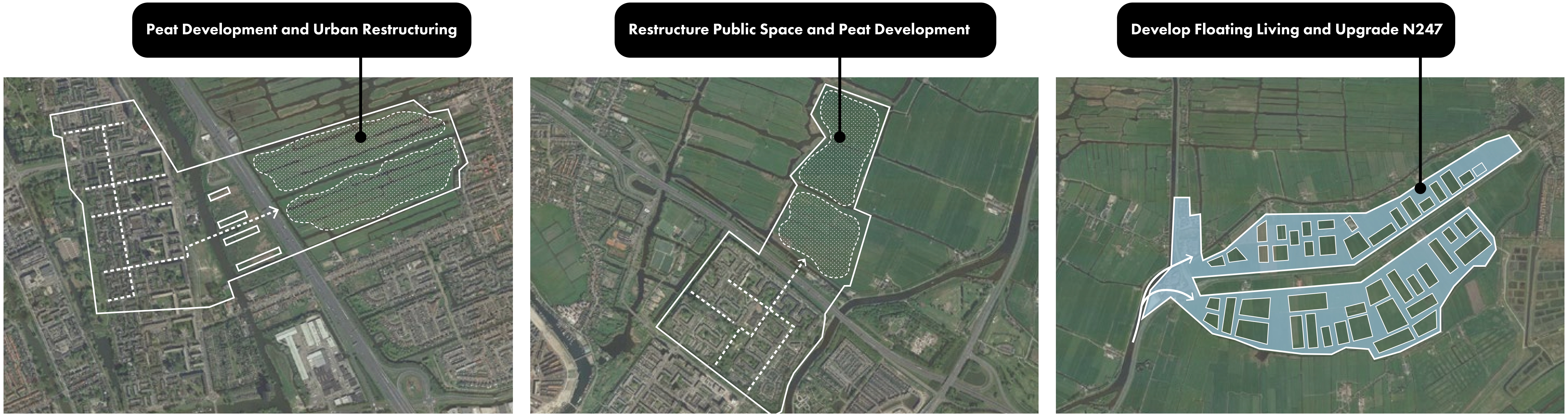
Increase feedback within and between systems
investing in pilot projects and experimentation

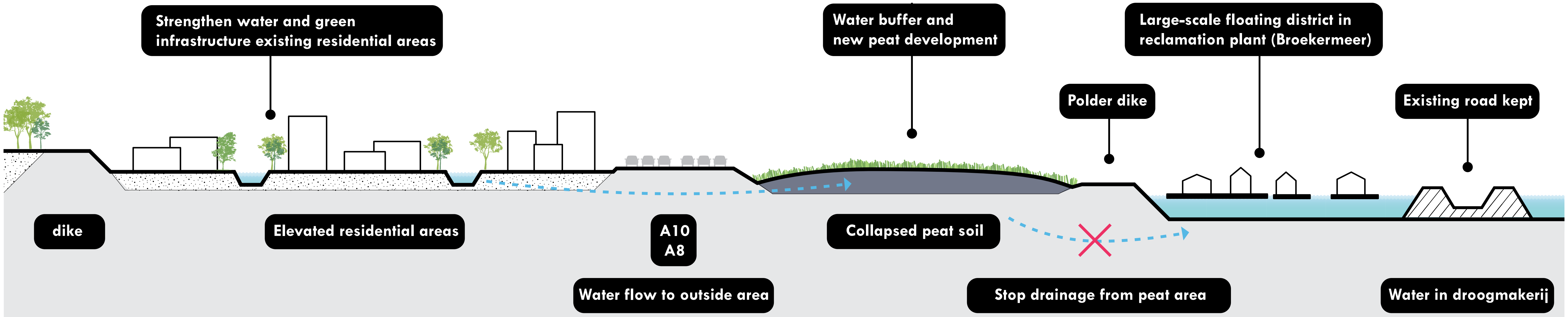
Reduce complexity of the system
no longer treating each individual area as a component of the larger system

Reduce risk of system failure across components
creating local redundancy and capacity for water management

Veenpolders: Typified Operative Landscape Units

There are a range of approaches and ways of thinking about working with Operative Landscape Units, which these sketches explore. Each of these landscape units relates to appropriate types of developments and development that is not beneficial. For example, approaches for developing the low-lying peat areas close to the urban systems. This area requires further development.





Key climate challenges

IF WE NEED OPERATIVE LANDSCAPE UNITS TO FUNCTION INDEPENDENTLY FROM THE SYSTEM, WE NEED TO MANAGE WATER LOCALLY.

PLANNING NOW AVOIDS SIGNIFICANT COSTS IN THE LONG TERM.

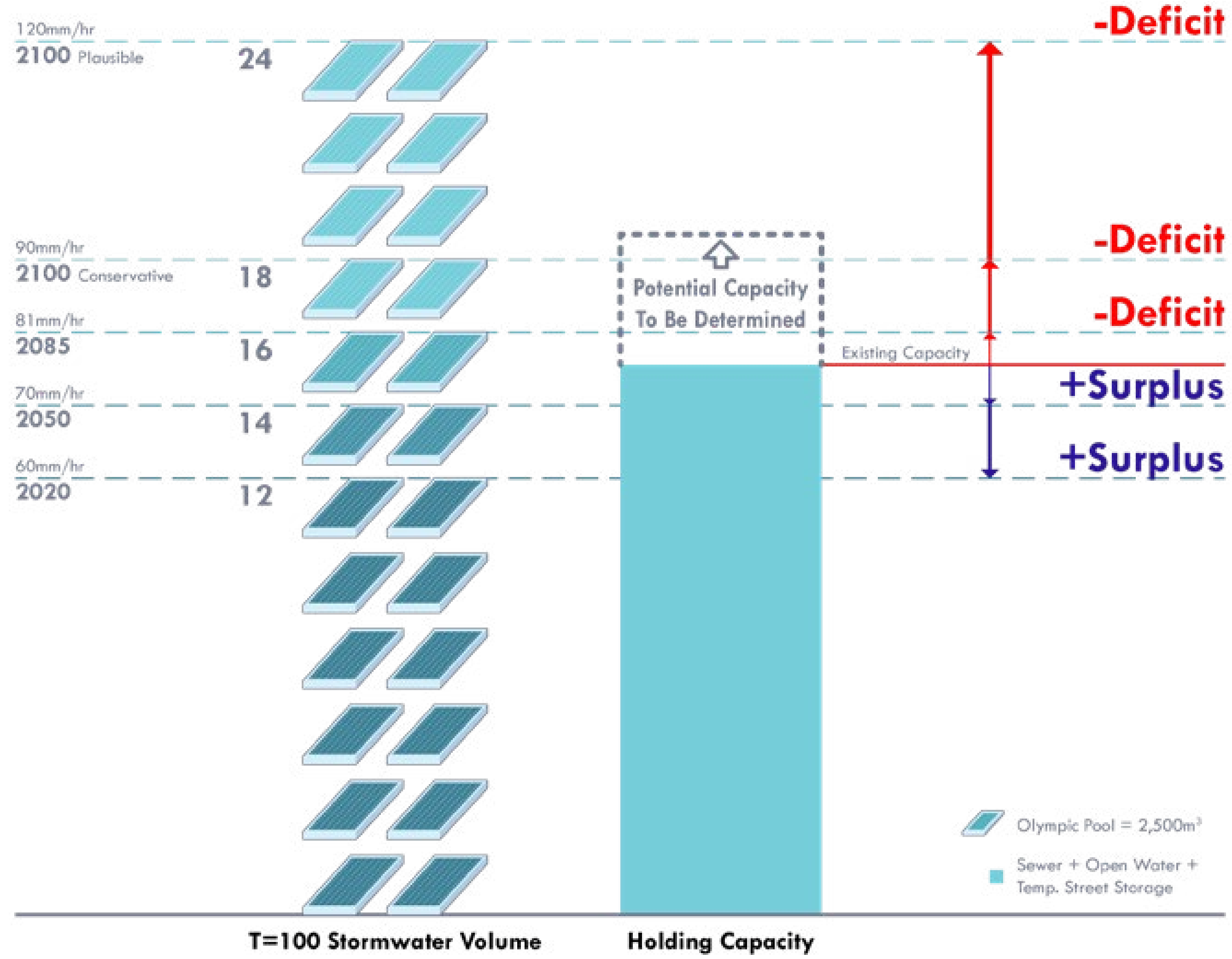
A vulnerability analysis conducted across the MRA revealed representative areas susceptible to the impacts of climate change based on multiple climate risk factors, demographic indicators, and development profiles. Referencing the Klimaateffectatlas, KNMI climate scenarios, local geospatial data, and scientific reports, this study compared the relative risk due to subsidence, drought, extreme heat, heavy rainfall, and the potential for flooding due to system failure, among other factors. The climate risk analysis considers short-term impacts as well as the compounding effects climate change is projected to have toward the end of the century. By cross-referencing the critical risks in each location with RIVM health characteristics and considering ongoing and planned developments within the MRA, several locations emerged as ideal opportunities for implementing a long-term approach to climate resilience.

A shift toward a system where the individual landscape units function more independently is imperative. This means starting to change water management locally. It comes not only from an analysis of resilience, but also from legislation, for instance, what in the Netherlands is called "Omgevingsvisie." Beginning from this new understanding of the relationship between local and systemic, analysis shows that planning now avoids significant long-term costs.

For a given site, any new development must account for current stormwater volumes in its planning. Yet, stormwater volumes will increase in the future. Factoring in a fifty percent increase estimate as a starting point, which by some estimates is considered relatively conservative, the capacity of the current system can be tested. The analysis asks: what increase in volume can the site accommodate in the future, at what point do deficits appear, and then how do you address these deficits?

- **How much holding capacity can we add?**
- **What are the measures we can use?**
- **How much would it cost?**

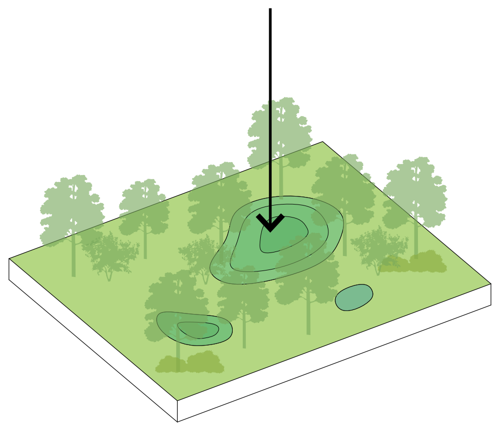
THRESHOLD ANALYSIS
Flood Mitigation Measures



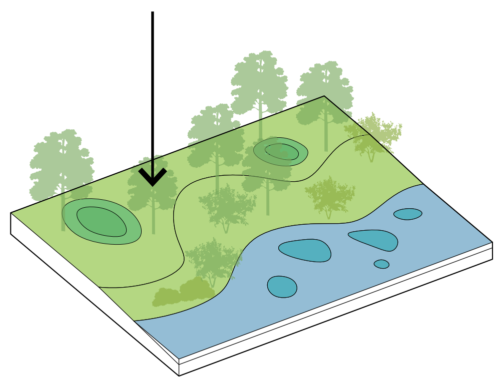
THRESHOLD ANALYSIS
Toolkit of Flood Mitigation Measures

Each adaptation measure comes at a different cost. Blue-green solutions are less costly than highly-constructed gray solutions, but blue-green solutions, in general, require more space.

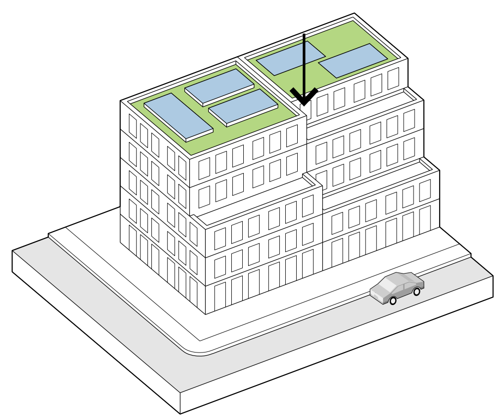
Rain gardens temporarily hold rainfall runoff and allow infiltration.



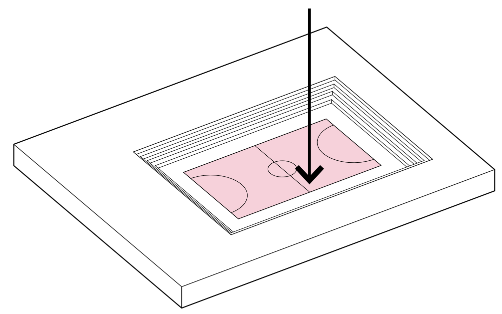
Natural shorelines and wetlands buffer against fluctuating water levels and support ecological health.



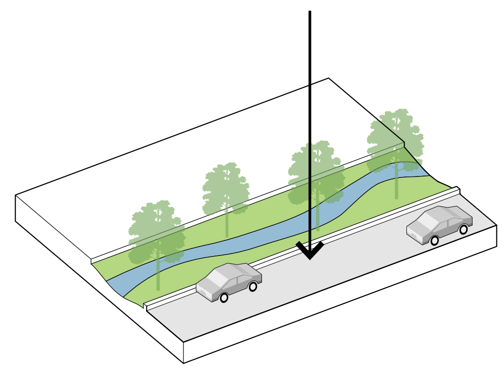
Blue and green roofs increase the volume of water stored and control the amount of water released.



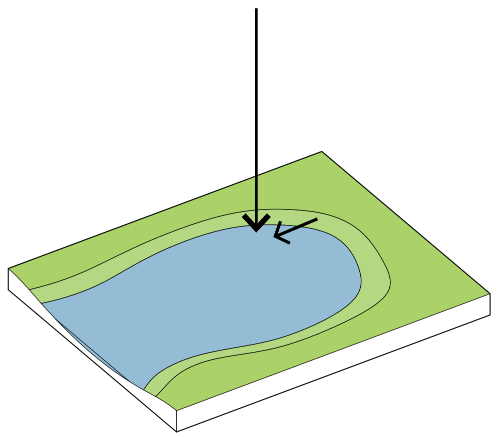
Water squares can function as public space while dry and store runoff during heavy rainfall events.



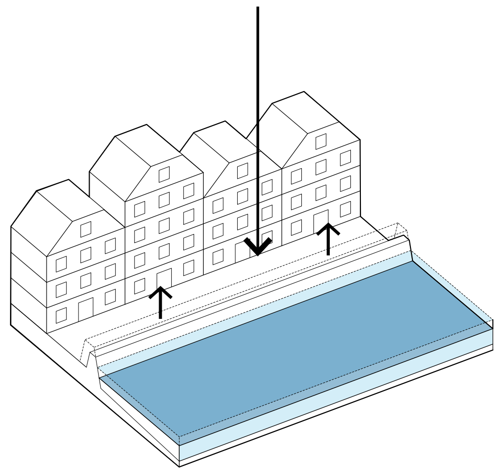
Bioswales can reduce stormwater runoff and filter rainwater naturally.



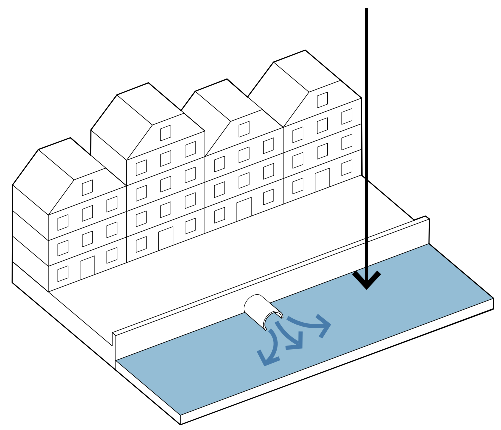
Detention ponds store stormwater to prevent localized flooding.



Raising dikes allows for increased holding capacity



Increasing pump capacity keeps dry areas from flooding as water levels rise.



Measure	**Application**	**Investment Cost (€/m3)**	**Potential Holding Capacity (m3/m2 of measure)**
Removing Pavement For Green	General	0	0
Temporary Storage On Streets	Roads	0	0.1
Additional Open Water	General	67	0.3
Ponds	Parks	133	0.3
Water Gardens / Wadi	General	167	0.3
Rain barrel	Properties	417	0.24
Subsoil Storage Crates	General	660	0.75
Water Square	Squares	1125	0.563
Blue & Green Roofs	Buildings	2430	0.075
Green Façade	Buildings	2000	0.09

THRESHOLD ANALYSIS

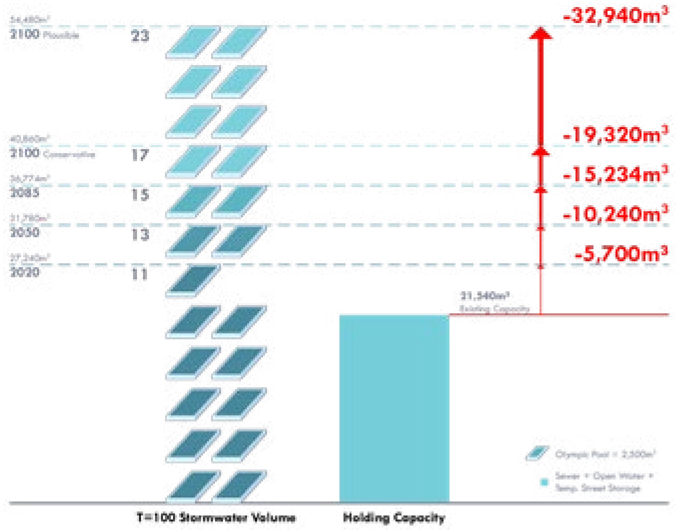
Holland Park (Bergwijkpark Master plan)

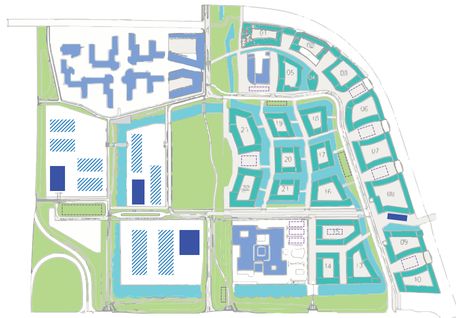
The new development of Holland Park to the southeast of Amsterdam is now under construction. The threshold analysis uses existing capacity as a baseline and maps out a scenario for adding stormwater management capacity. In the near-term, it is possible to add capacity, but at a significant cost. Adding expensive measures such as blue roofs would cost even more, but still leave a deficit, which indicates a continuing risk of nuisance flooding in those areas. Moreover, local flooding puts stress on the water system at large, contributing to its fragility and thus increasing not only nuisance flooding risks but also widespread flood risk.

Most significantly, if adaptation measures are not built into the initial development in the right way, the costs later will be even greater. To build with that additional deficit, it may be necessary to demolish buildings or implement more drastic stormwater management measures, which is challenging in highly urbanized and dense areas such as the Netherlands.

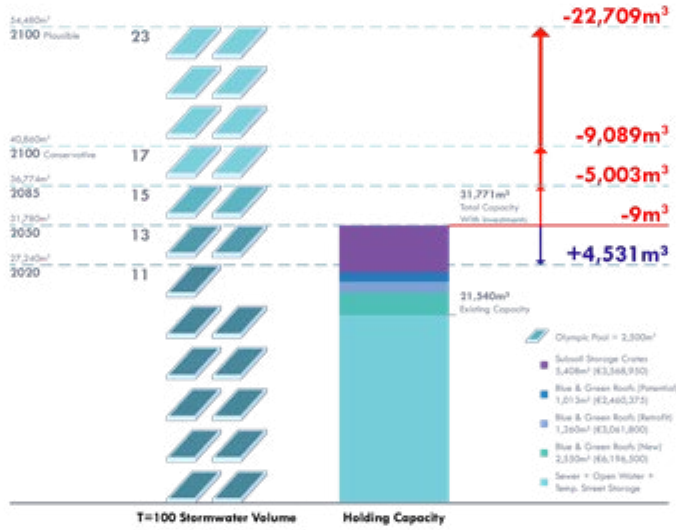
Holland Park

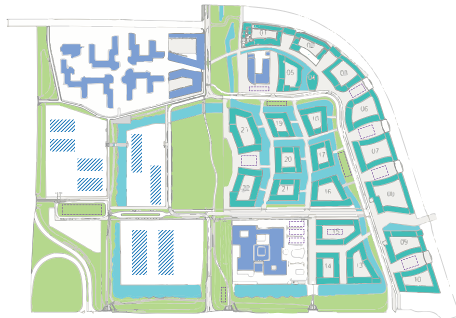
- **At the current holding capacity, a 100-year storm could cause significant local flooding**
- **The deficit will increase over time**



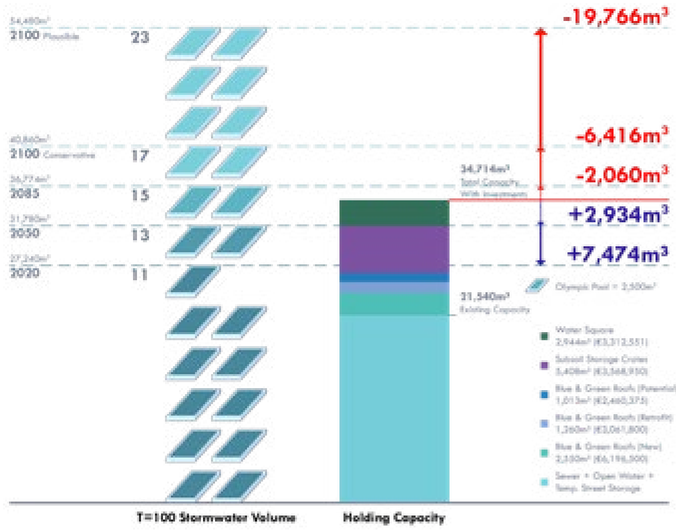


- **"Easy" measures (blue roofs and storage crates) only work until 2050, at great cost**
- **Total Cost = €15,287,625**
  Assumed Floor Area = 500,000 m²
- **Average Cost Per Floor Area = €30.57/m²**





- **Adding built measures such as water squares does not add significant capacity**
- **The future calls for a rethinking of open space and retention in a more holistic approach**
- **Total Cost = €18,600,176**
  Assumed Floor Area = 500,000 m²
- **Average Cost Per Floor Area = €37.20/m²**



As catastrophic risks increase, so too will systemic stresses. Urban heat is an underestimated stress.

While water has management been front and center a long time, from a resilience perspective, more holistic thinking about stressors is urgently needed. In the United States, urban heat is increasingly recognized as a problem. In the coming fifty years, heat impacts likely pose a greater public health risk than flooding for New York City. In the Netherlands, heat stress is underestimated. The RBD project expands upon recent mapping efforts to track the cascade of impacts that relate to extreme heat.

In this time of pandemic, there is great interest in the relationship between heat and public health. The summer of 2020 has brought both drought and heatwaves in the Netherlands, which adds to a sense of urgency. While some data is beginning to emerge, in general, it is limited; heat is much less well-understood than the water system. Even with a limited understanding, it is already evident that heat and water are often linked and adaptation to both can be addressed in an integrated way.

Extreme heat metrics

EXTREME HEAT

HEALTH

Behavioral Health
Mental health ↑
Violence ↑
Social Unrest ↑
Sleeping Problems ↑
Mortality ↑
Hospital Admissions ↑
Home Care Provider demands ↑

Insurance (health)
Claims ↑
Premiums ↑
Insurability ↓

Emergency responders
Volume ↑
Costs ↑
Capacities ↓
Health systems ↑
Healthcare workers ↑

Respite Demands
Cooling centers ↑
A/C demands ↑
Parks, open spaces ↑
Cooling Spritcers ↑

Physical Health
Cardiovascular ↑
Respiratory ↑
Vector borne ↑
Morbidity, co-morbidities ↑
Increases in negative health outcomes for those who are/have: Diabetes, Homeless, Athletes, Event Participants, Outside Workers (police, gardeners, construction, etc.) ↑

REAL ESTATE

School
Childrens' Discomfort ↑
Fatigue ↑
Concentration decreases
Shortness of breath ↑
Overheating ↑
Dehydration ↑
Headaches ↑
Playground heat ↑
School schedules/activities adjust

Habitability
Comfort ↓
Desireablity ↓
Value ↓

Insurance
Claims ↑
Premiums ↑

SPECIES

Flora
Species shifts, natural systems ↑
Cooling capacities, trees, plants ↓
Vegetation Damages ↑
Tree Falls ↑
Algae Blooms ↑
Water-based species ↓
Veterinary demands ↑
Maintenance ↑

Fauna
Species shifts, migrations ↑
Cascading impacts (fisheries, agriculture) ↓

OUTDOOR RECREATION SPACE

Management requirements ↑
Maintenance ↑
Water quality ↓
Social nuisance (demands as well as noise in parks, terraces, barbeques) ↑
Waste ↑
Social cohesion ↑
Bathing/swimming facility demand ↑

INFRASTRUCTURE

Tech Disruptions
Data centers ↑
Transfers ↑

Rails
Damage ↑
Cost ↑
Rails expand or track splatter or buckle
Rail schedules slow down
Switches fail
Bridges do not close
Communications systems fail

Shipping
Routes ↓
Cost ↑
Locks and barriers close

Air
Capacities ↓
Cost ↑

Bridge Category
Bridge function ↓
Roads connected by bridges use ↓
Distribution routes must reroute and costs ↑

Energy
Grid capacities ↓
blackouts ↑
Distribution ↓
Cost ↑
Energy demand ↑
Transmission efficiency ↓
Transmision lines

Trucking
Road stability ↓
Cost ↑
Pavement softens, load capacity
Pavement buckles, damaging infrastructure
Concrete slabs expand and fragment

Cooling Water
Cooling water discharges ↓
Cooling water availability ↓
Power plant production ↓
Manufacturing production ↓
District cooling systems capacity ↓

WATER

Quality
Hypoxia ↑
Cooling Capacity ↓
Tourism ↓
Fisheries ↓
Bacteria ↑
Odor ↑
Management costs ↑
Maintenance costs ↑
Customer complaints ↑

Availability
Dinking water ↓
Tourism ↓

PUBLIC REALM

Consumers in public environments ↓
Chilled environments ↑
Energy demands and costs ↑
Demand for products related to cooling (swim gear, ice cream, drinks, AC/fans) ↑
Public Transit riders ↓
Private Car use ↑

PRODUCTIVITY

Agricultural
Crop yields ↓
Crop damage ↑
Crop failure ↑
Cost of water ↑
Drought insurance ↑
Hail damage ↑
Crop quality ↓
Production site damage (outdoors, greenhouses)
Farm animal water demand ↑
Irrigation demand ↑

Outdoor Work
Parks ↓
Farms ↓
Construction ↓
Tourism ↓
Accidents ↑

DROUGHT

Insurance
Fire risks ↑
Water Availability ↓
Water costs ↑
Shipping access, load limits ↓
Shipping costs ↑

Events
Exposure to heat increases with participation in outdoor events ↑
Festival organizers preparation requirements increase ↑

Informed by Mindmap hitte in de stad
Jeroen Kluck and Lisette Klok, Hogeschool van Amsterdam

Heat stress can have significant health impacts

Behavioral Health
Mental health ↑
Violence ↑
Social Unrest ↑
Sleeping Problems ↑
Mortality ↑
Hospital Admissions ↑
Home Care Provider demands ↑

Insurance (health)
Claims ↑
Premiums ↑
Insurability ↓

Emergency responders
Volume ↑
Costs ↑
Capacities ↓
Health systems ↑
Healthcare workers ↑

Respite Demands
Cooling centers ↑
A/C demands ↑
Parks, open spaces ↑
Cooling Spritcers ↑

Physical Health
Cardiovascular ↑
Respiratory ↑
Vector borne ↑
Morbidity, co-morbidities ↑
Increases in negative health outcomes for those who are/have: Diabetes, Homeless, Athletes, Event Participants, Outside Workers (police, gardeners, construction, etc.) ↑

HEALTH

For every temperature increase of 1˚C there is a:

- **2.2% Increase mortality, including 12% respiratory illnesses, especially relevant in the era of Covid**
- **21% Increase in ER admissions**

For temperatures above the optimum, mortality increased for malignant neoplasms, cardiovascular disease, respiratory diseases, and total mortality.

An estimated 1400 to 2200 people died during a severe heatwave in the Netherlands in 2003. While the primary impact was to the elderly in nursing homes, extreme heat is a threat to people of all ages, especially poor, chronically ill, and socially isolated populations. Still, the impacts are felt by many: the very young, outdoor workers, and people playing sports.

The most commonly reported heat-related symptoms among the elderly in a Dutch study were sleep disturbance (62%), fatigue (61%), and breathing discomfort (29%).

Sources:
van Loenhout et al. Heat and emergency room admissions in the Netherlands. BMC Public Health 18, 108 (2018). doi.org/10.1186/s12889-017-5021-1

Sampson, N. R., et al. (2013). Staying cool in a changing climate: Reaching vulnerable populations during heat events. Global environmental change : human and policy dimensions, 23(2), 475–484. doi.org/10.1016/j.gloenvcha.2012.12.011

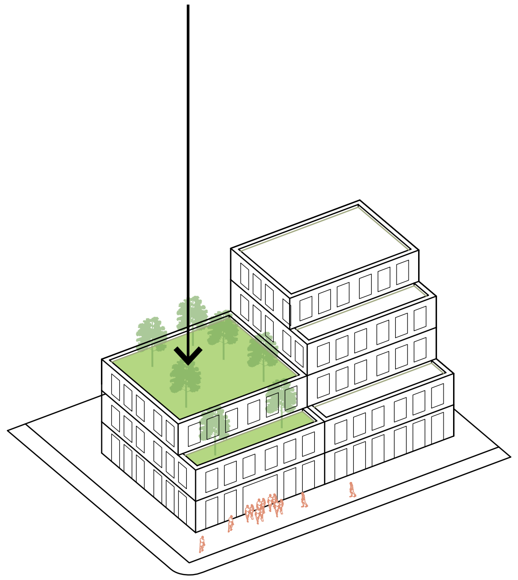
Kafeety, A., Henderson, S.B., Lubik, A. et al. Social connection as a public health adaptation to extreme heat events. Can J Public Health (2020). doi.org/10.17269/s41997-020-00309-2

THRESHOLD ANALYSIS
Toolkit of Heat Mitigation Measures

The relationship between water and heat is evident in this toolbox, which describes heat mitigation measures and explores their potential impact.

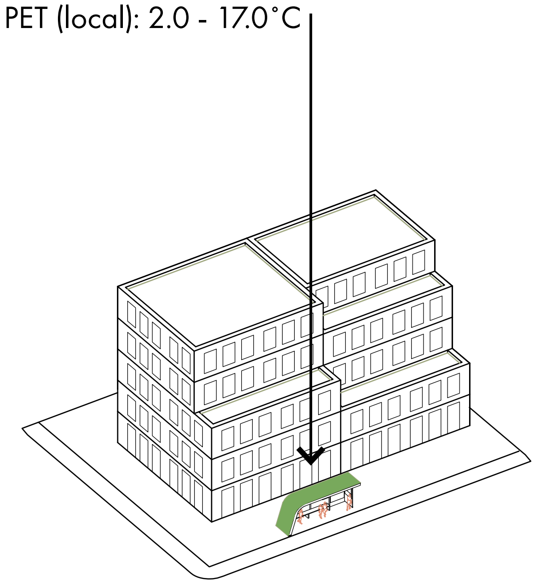
Access to Community Centers, which serve as cooling centers during times of extreme heat.

Health measure with no cooling effect



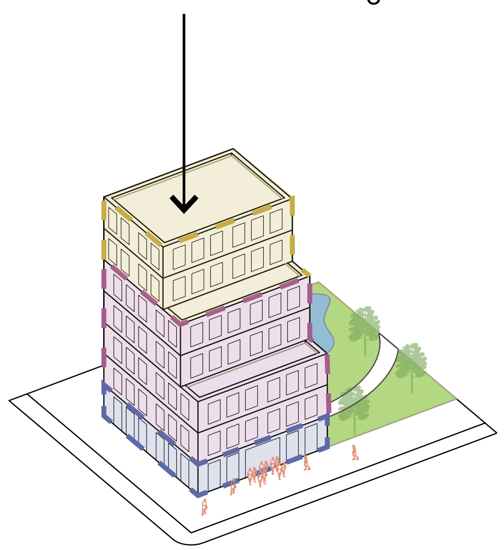
Shade structures are designed to provide relief from the heat and may also serve as bus or water bottle stations.

Air temperature (local): 0 - 1.0˚C
PET (local): 2.0 - 17.0˚C



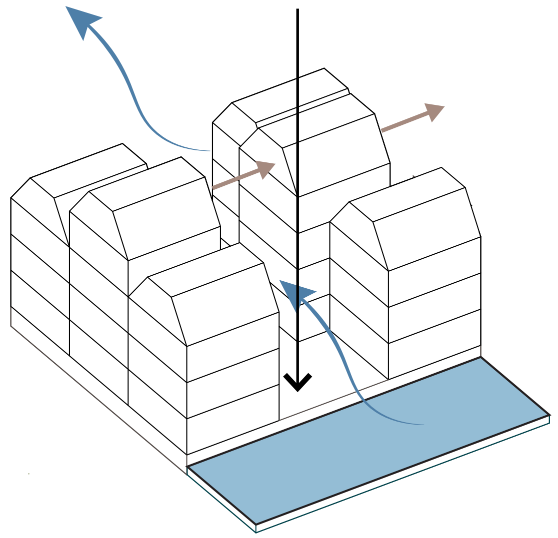
Zoning changes - In exchange for additional building height and a mixed-use zoning designation, more space would be available at ground level for cooling community centers.

Health measure with no cooling effect



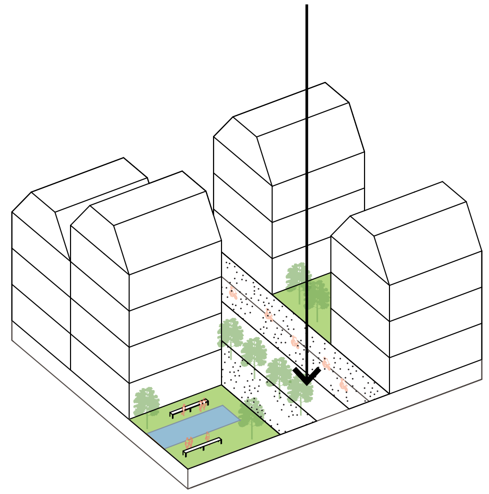
Leverage water as natural cooling resource by keeping existing corridors clear of buildings that block breezes from the waterfront.

Air temperature (city): 0.5 - 1.3˚C
Air temperature (local): 0.1 - 0.8˚C
PET (local): 0.2 - 2.0˚C



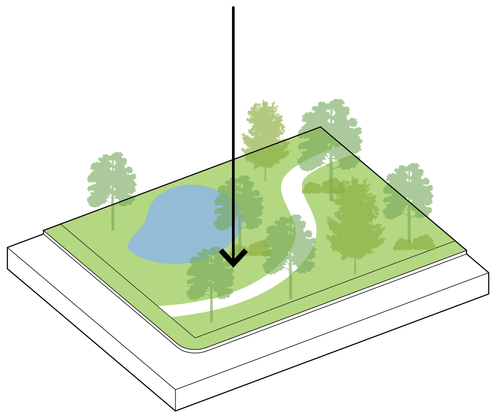
Heat-mitigating pedestrian connections improve connectivity and cool urban areas.

Air temperature (city): 0.1 - 1.1˚C
Air temperature (local): 0.9 - 1.2˚C
PET (local): 0.4 - 4.9˚C



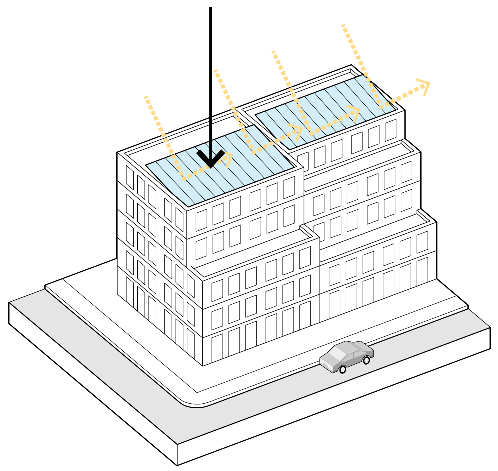
Parks and green, open spaces create lower temperature for neighboring areas.

Air temperature (city): 0.2 - 2.7˚C
Air temperature (local): 1.1 - 2.0˚C
PET (local): 1.9 - 4.2˚C



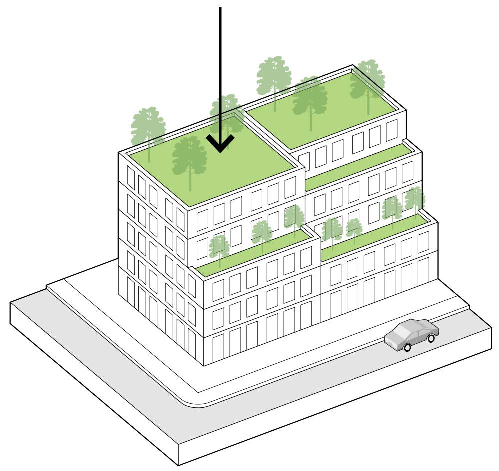
Reflective roofs increase albedo, decreasing radiant heat.

Air temperature (city): 0.9˚C maximum



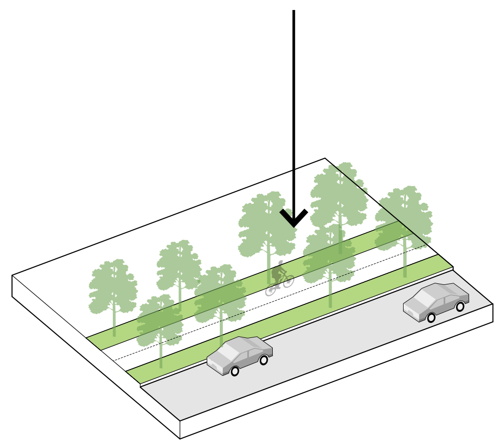
Green roofs reduce solar heat gain.

Air temperature (city): 0 - 1.7˚C
Air temperature (local): 1.0 - 1.6˚C



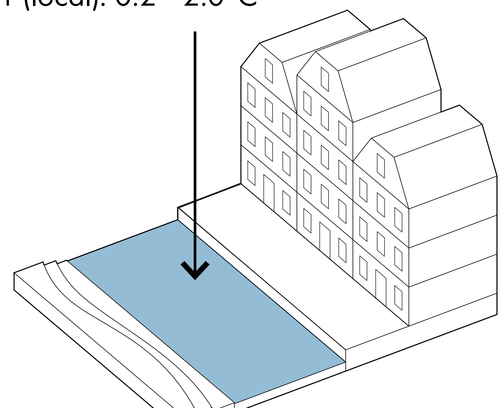
Pervious pavement and planted surfaces can store precipitation and surface runoff.

Air temperature (city): unknown
Air temperature (local): unknown



Canals and surface water naturally reduce urban heat gain.

Air temperature (city): 0.5 - 1.3˚C
Air temperature (local): 0.1 - 0.8˚C
PET (local): 0.2 - 2.0˚C



CURRENT NORMS ARE NOT SUFFICIENT AND WILL LEAD TO SIGNIFICANT COSTS LATER. CLIMATE STRESSES ARE NOT YET CONSIDERED HOLISTICALLY.

The threshold analyses show that current developments will need to be adapted by mid-century at great cost. The cost will likely fall on the public.

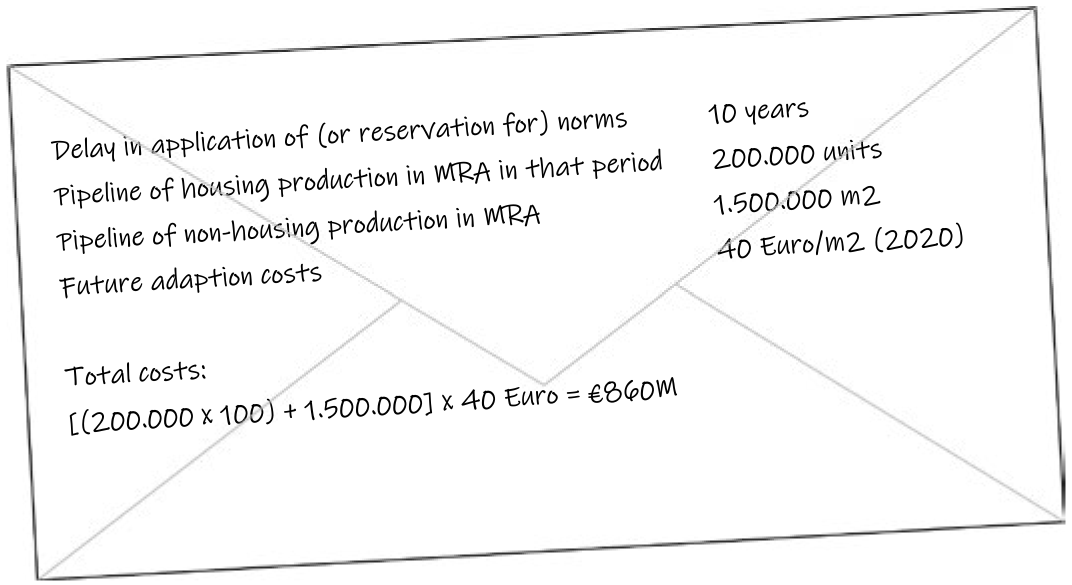
The threshold analysis shows that climate stresses are not yet considered holistically and current planning norms are not sufficient, leading to significant cost later.

Climate projections and impacts are often perceived as abstract, leading to inaction. Visualizing them in terms of tangible, actionable timeframes helps to reframe the urgency of action today. Starting in 2020, the outlook for developers might be only a decade. Plans, projects, and current codes, as well as mortgages and investments have a timescale of approximately thirty years, or 2050. But thinking in terms of building and infrastructure lifecycles and human lifespans points to the need to change definitions and standards; these will become part of an entirely different climate reality over their lives.

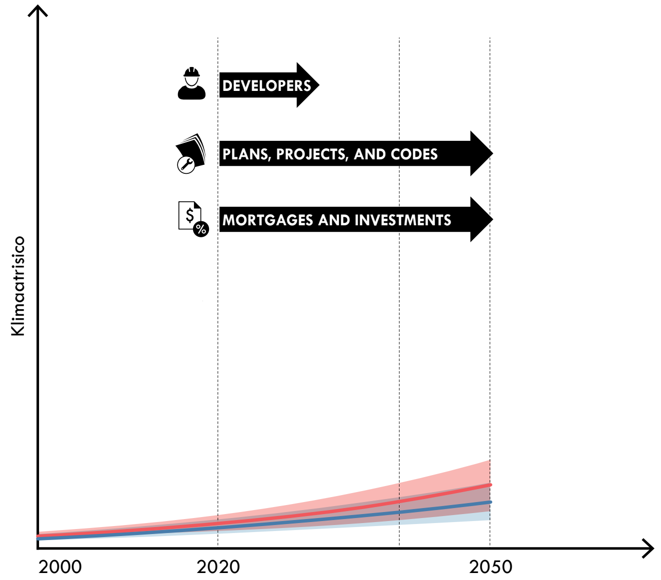
Today's climate change impacts are only the beginning. A failure to plan and invest thoughtfully, to begin changing our norms now means the cost of adaptation will fall by default in the public domain.

Institutional inertia will cost us billions

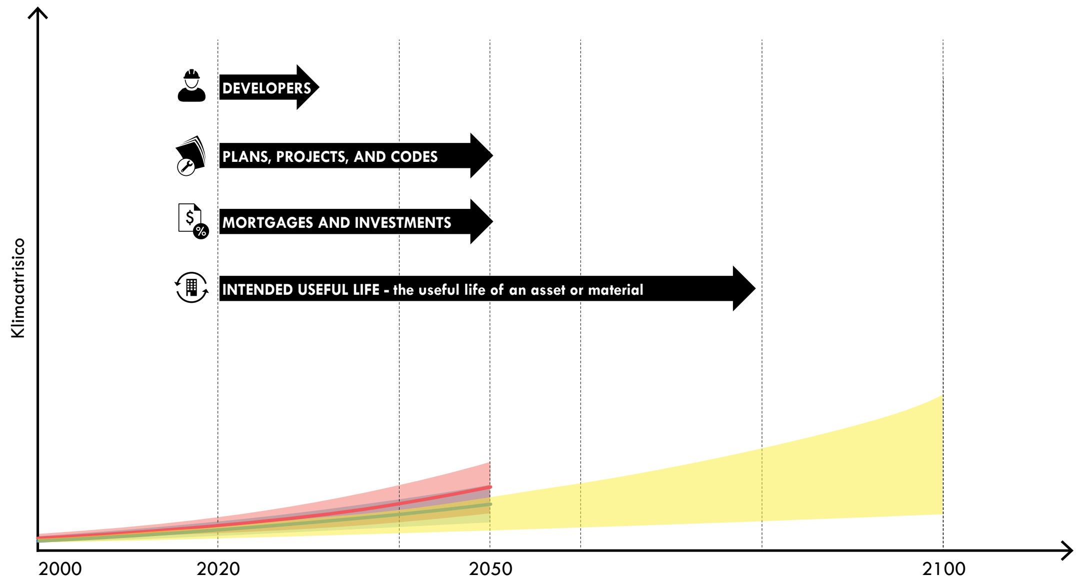
A back of the envelope calculation shows the cost of this institutional inertia. Even with these rough estimates, and without trying to make an exhaustive calculation, the great cost burden is clearly evident.



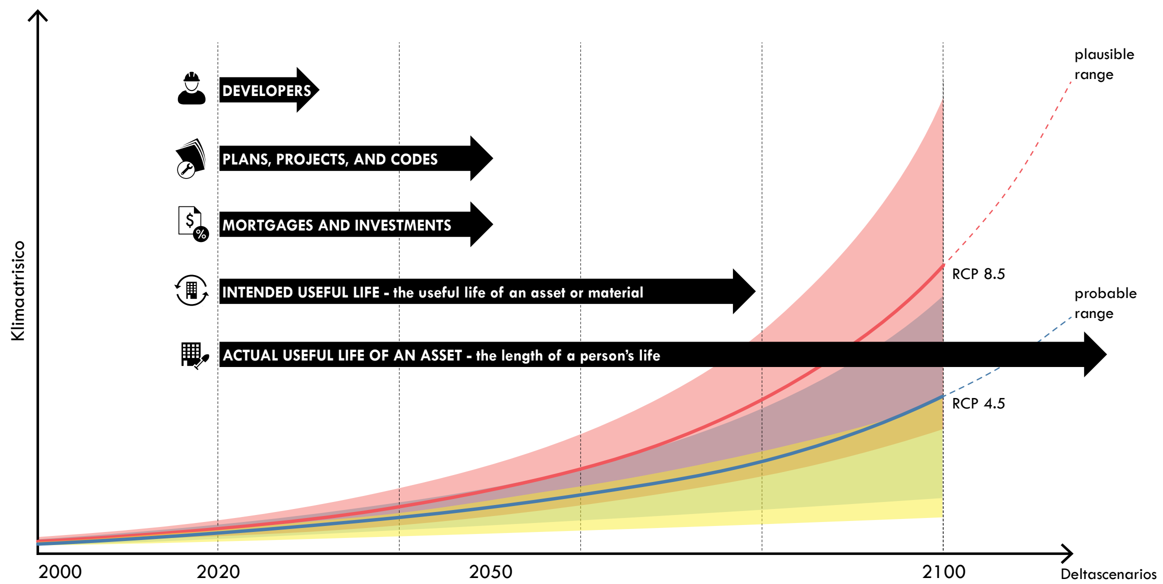
Underestimates local risks



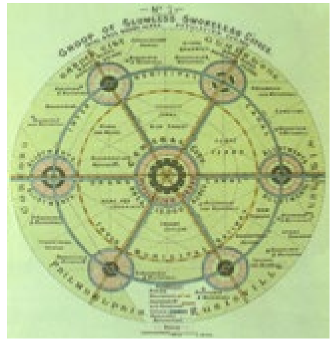
Underestimates systemic risks



The combination creates a greater failure



IN THE 21ST CENTURY, OUR GREEN-BLUE INFRASTRUCTURE MUST BE RE-CONCEIVED FOR A CHANGING CLIMATE



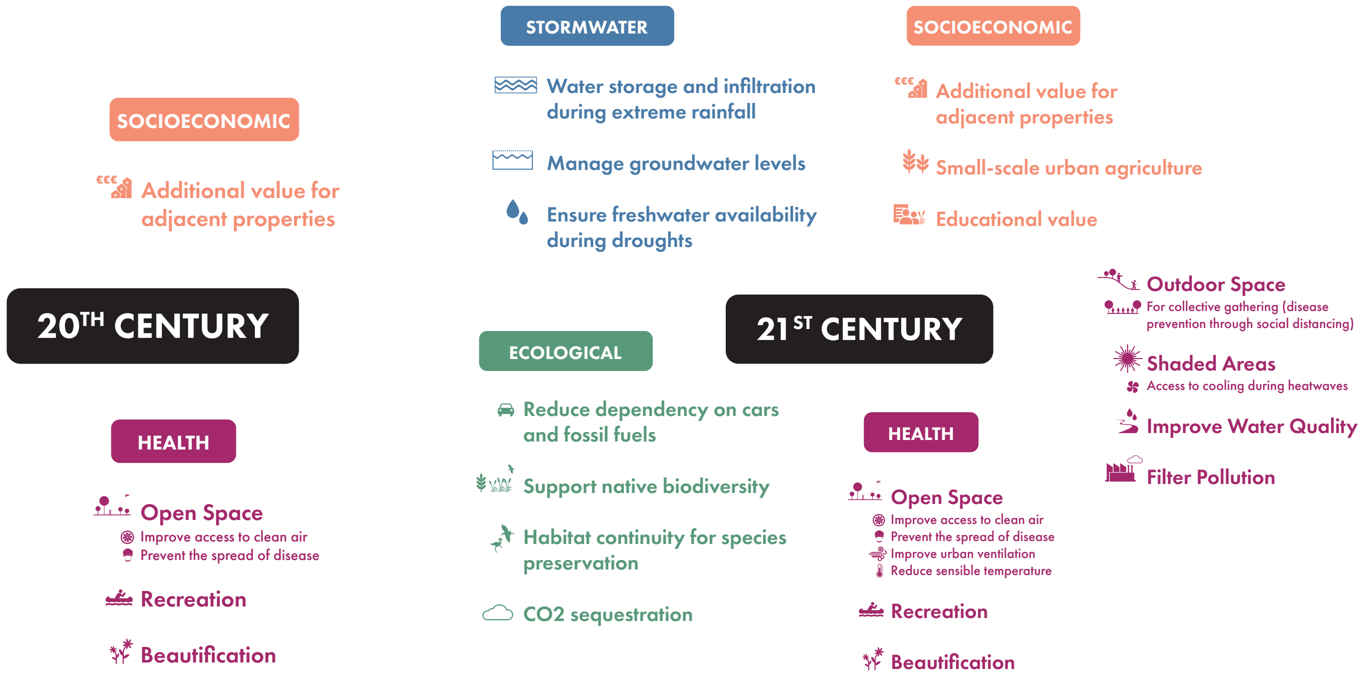
The Garden City ideal promoted small cities surrounded by vast green areas for agriculture and recreation. It informed the dominant approach to urban green spaces in the 20th century

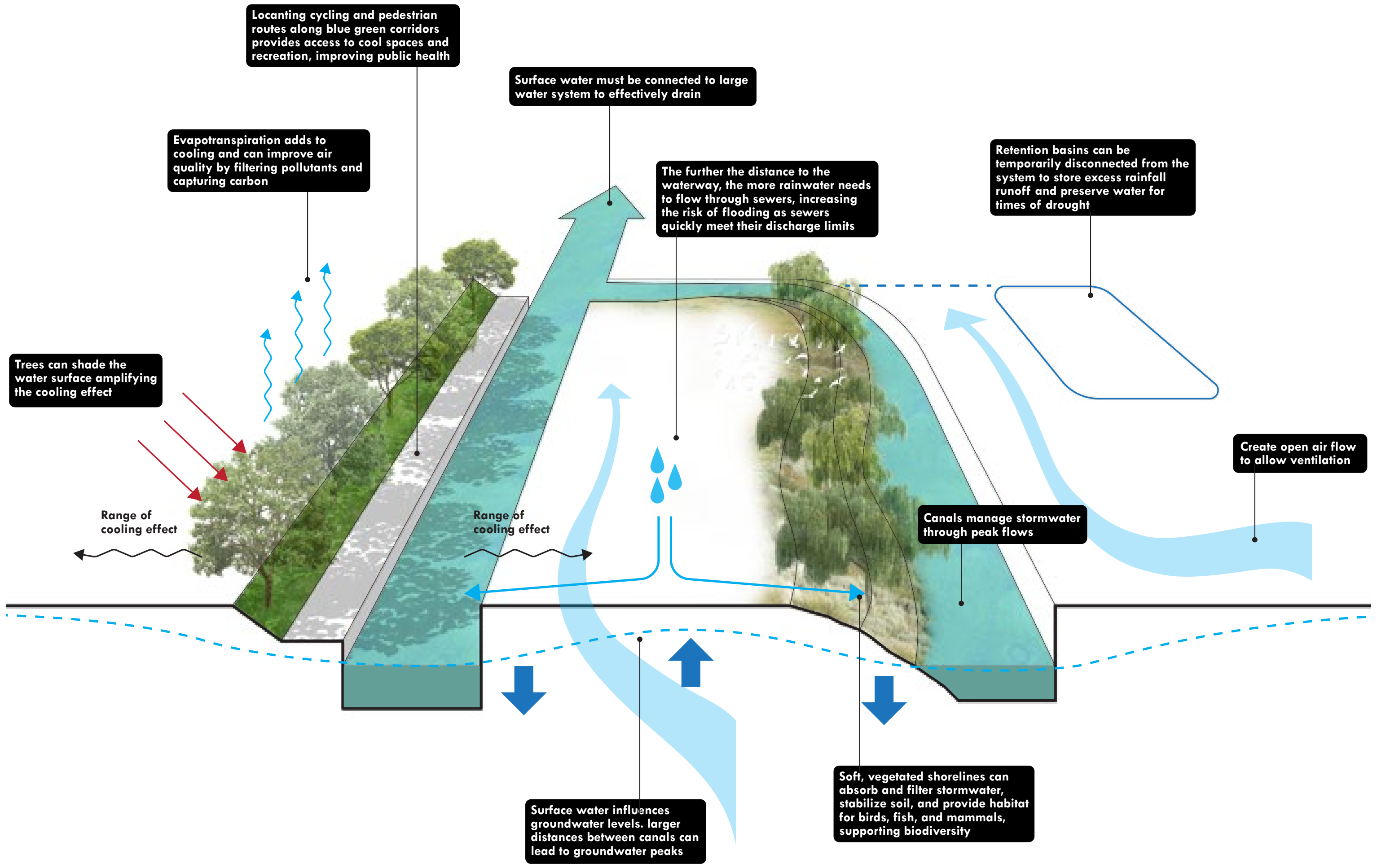
21st-century blue-green networks must perform myriad ecosystem services

The challenge that lies ahead is clear, but what are the solutions? One is to make infrastructure systems more resilient and adapt their system characteristics to be able to deal with potential shocks and stresses. Green and blue infrastructure is the primary tool to address many of these elements.

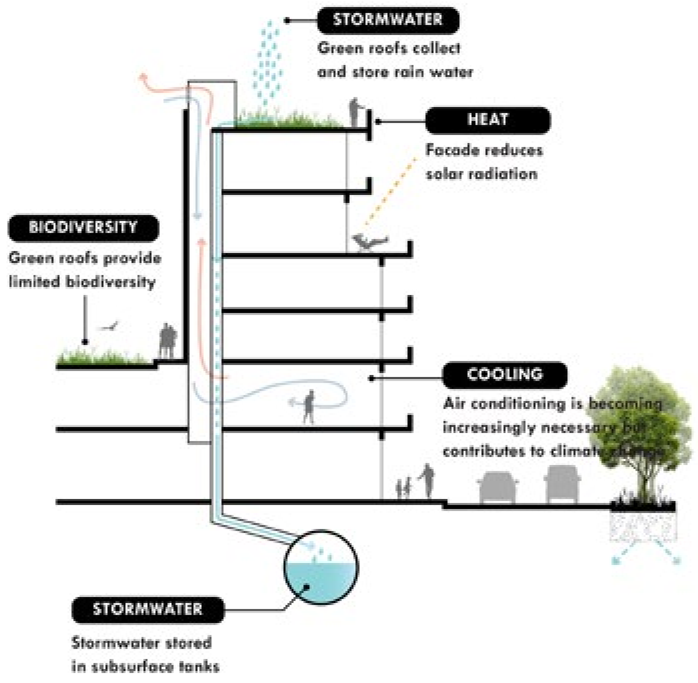
The green and green-blue spaces of the 21st century need to address a multitude of issues: temper heat stress, manage water levels, protect freshwater availability, support ecological services, and sustain biodiversity.

Green-blue spaces and networks have the potential to perform numerous ecosystem services. For optimal function, their siting in urban areas must be reconsidered. In the Netherlands, historically there was a tendency to place open space at higher elevations. To manage stormwater, however, green-blue space must be at a low elevation. They need to be more proximate in the rhythm of the urban fabric to address local water issues and provide cooling effects. In their placement, rhythm, size, and performance, these are very different from the parks of the past.

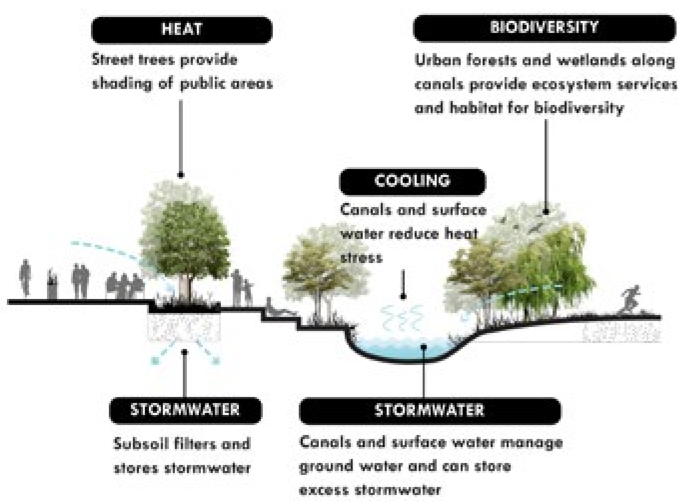




Climate adaptation measures must touch every aspect of the private and public realms to achieve climate robust development



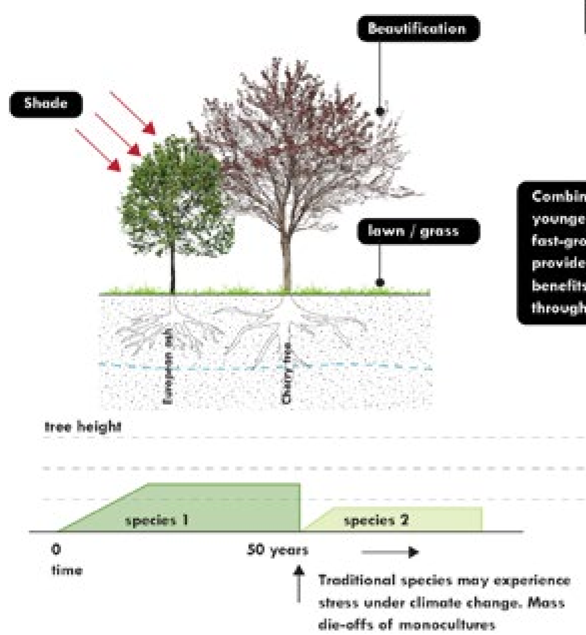
Buildings



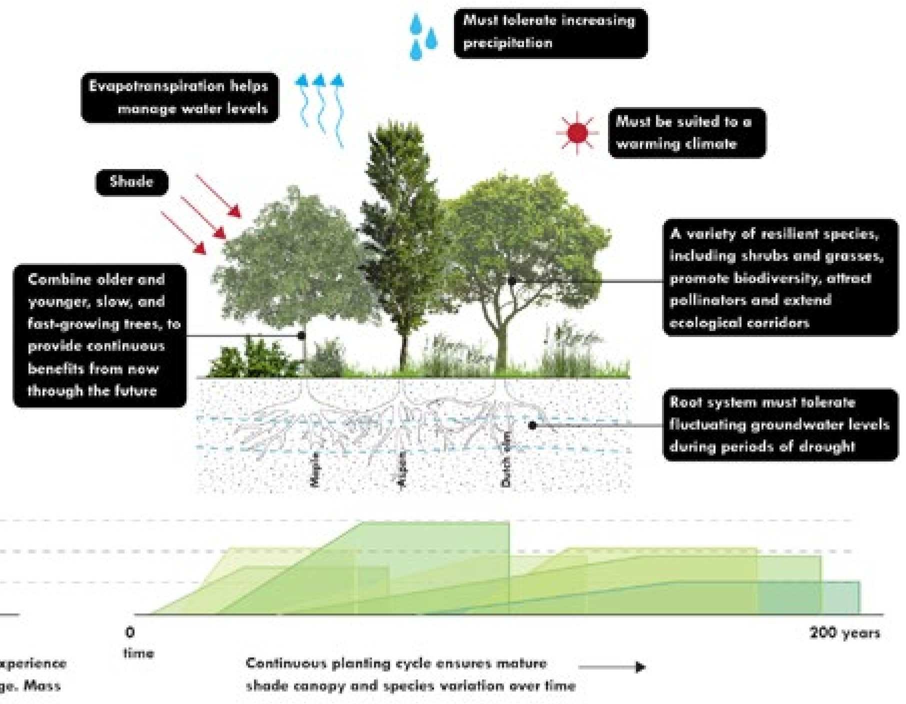
Open spaces

At the same time, rethinking building design will make our neighborhoods better and more livable. Their functions can be addressed, reducing costs and providing greater benefits to open space.

The planting of trees is another aspect of green-blue infrastructure that also invites rethinking along with parks: the timing of planting and the selection of species that will tolerate the changing climate. The technical approach that informs the Dutch water system, also extends to the practice of urbanism. As a consequence, particular neighborhoods experience large-scale die-offs in a short period because they have all been planted at the same time.



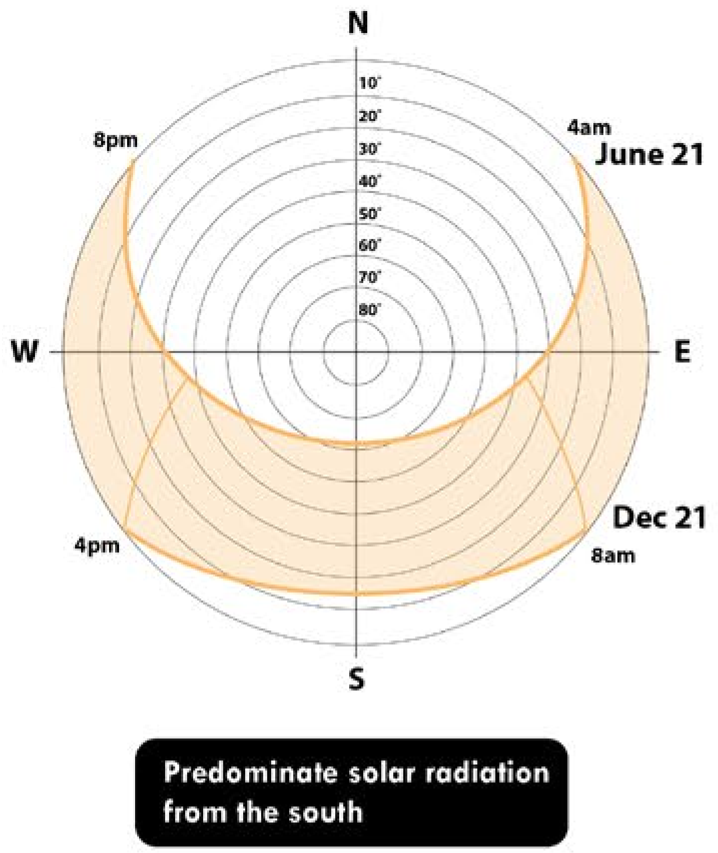
Trees

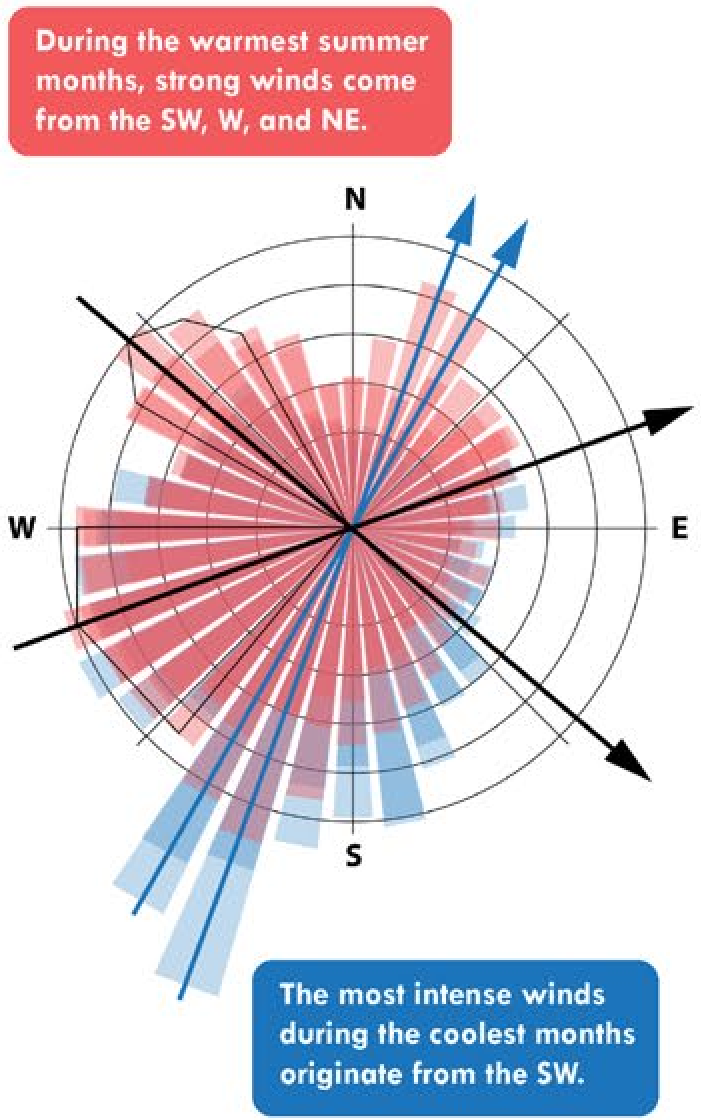


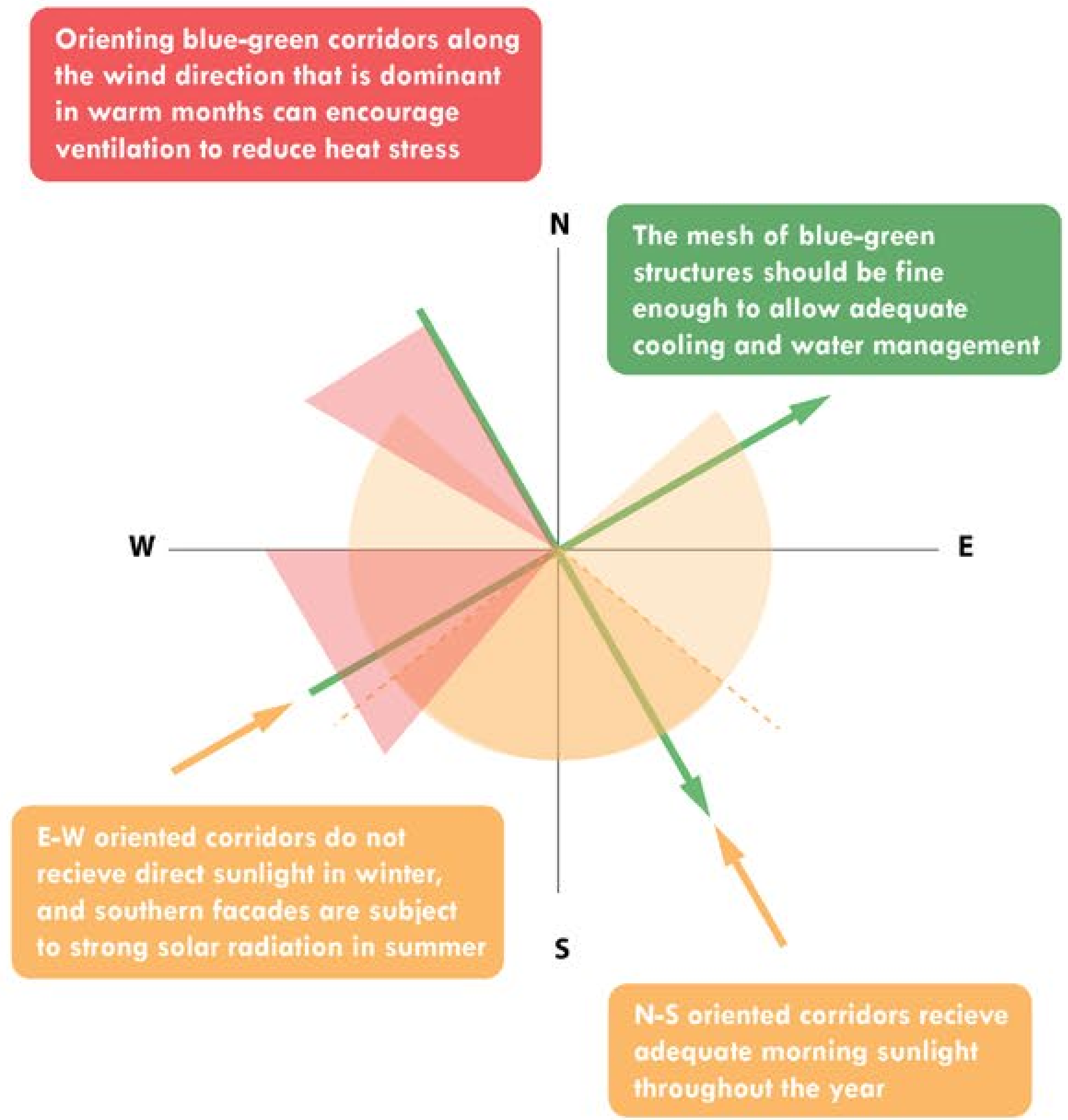
Landscapes

Blue-green corridors can be designed to maximize ventilation and shading, reducing heat stress

Design for shading and prevailing winds are additional environmental considerations that can be integrated into area developments. The orientation of particular measures might have benefits, but the topic demands further study, given the potential drawbacks in winter weather and the limited wind effects on hot days.

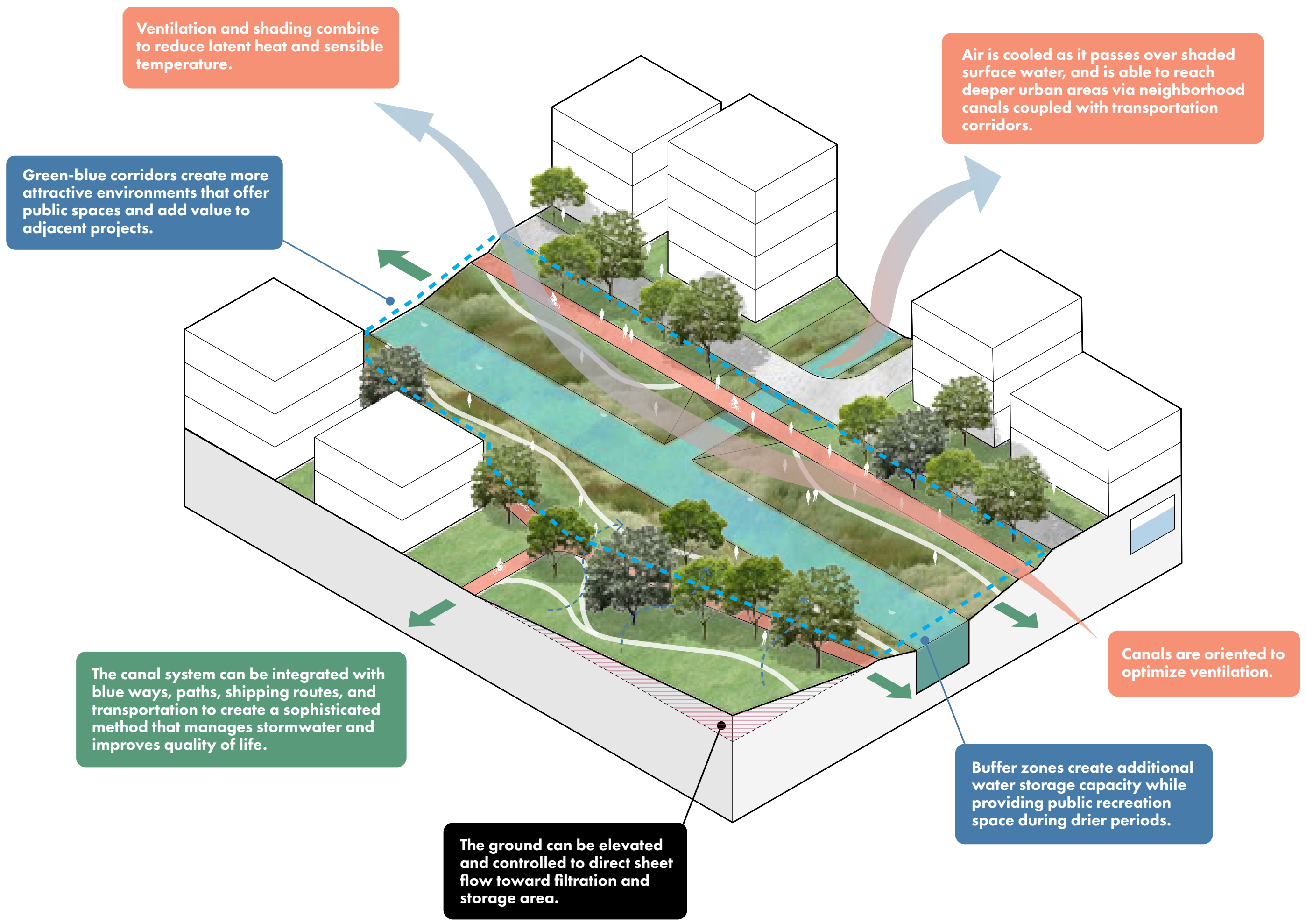


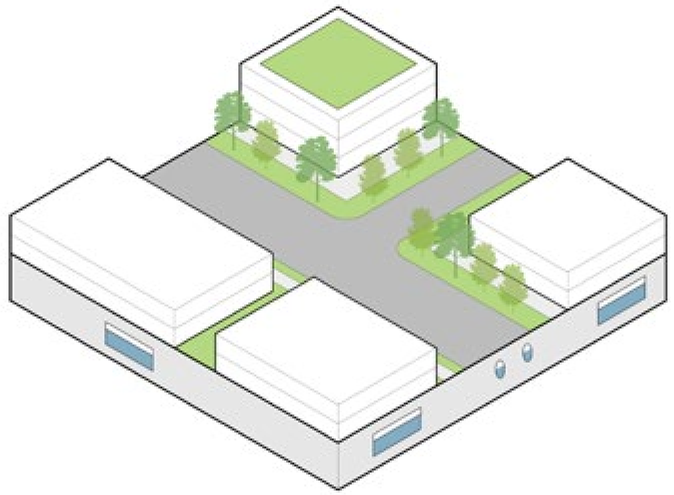




The result: a new appreciation for the public realm and a realignment of relationships between the public and the private

Rethinking the use of open space and the performance of the public realm has implications for what would otherwise be addressed in the private realm, which in turn suggests reconsidering the institutional, financial, and zoning decisions that cities make. Creating more space in the public domain may support all these functions. It alters the calculation for land that a government could dispose or lease. In the case that private investors contribute to capital and maintenance costs, it could reduce maintenance costs, a topic for further study.

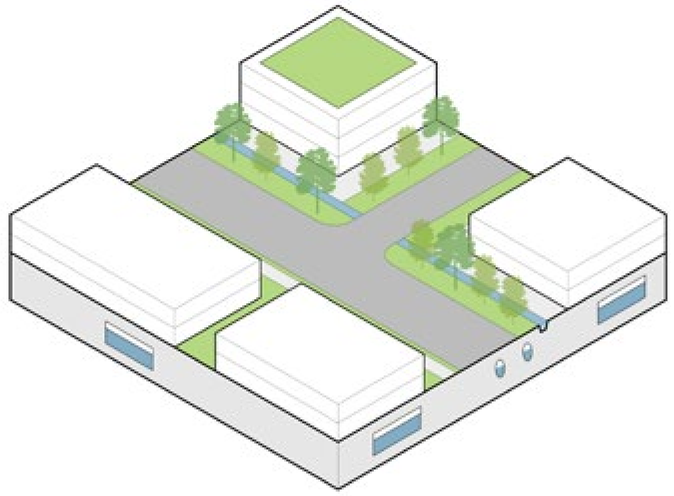




Traditional Drainage
Water and heat stress are addressed within private lots, resulting in high initial costs and no capacity to address future flooding.

Green open space ratio = 1.0 (baseline)

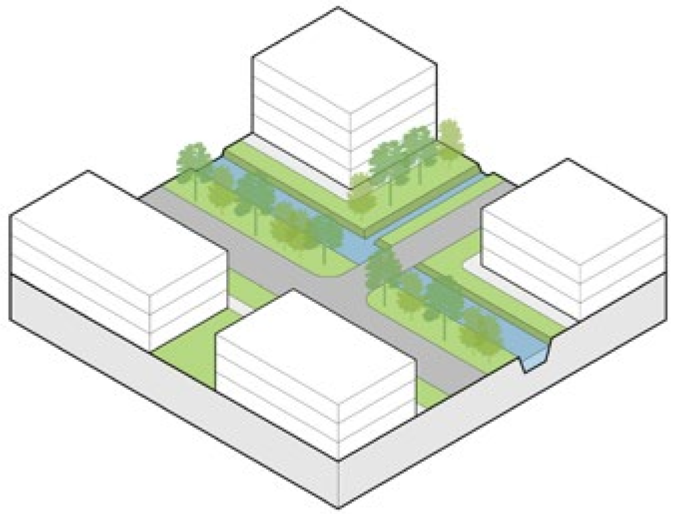
Area:
45% built
35% paved
20% green



Minimum Resilience
Water and heat stress are addressed within private lots, with future flood capacity built into the open space. Low initial costs and moderate benefits.

Green open space ratio = 1.1x traditional

Area:
43% built
35% paved
22% green



Maximum Resilience
Water and heat stress are addressed within both private lots and public space, accommodating future climate risks and resulting in the highest public benefits.

Green open space ratio = 2.0x traditional

Area:
35% built
25% paved
40% green

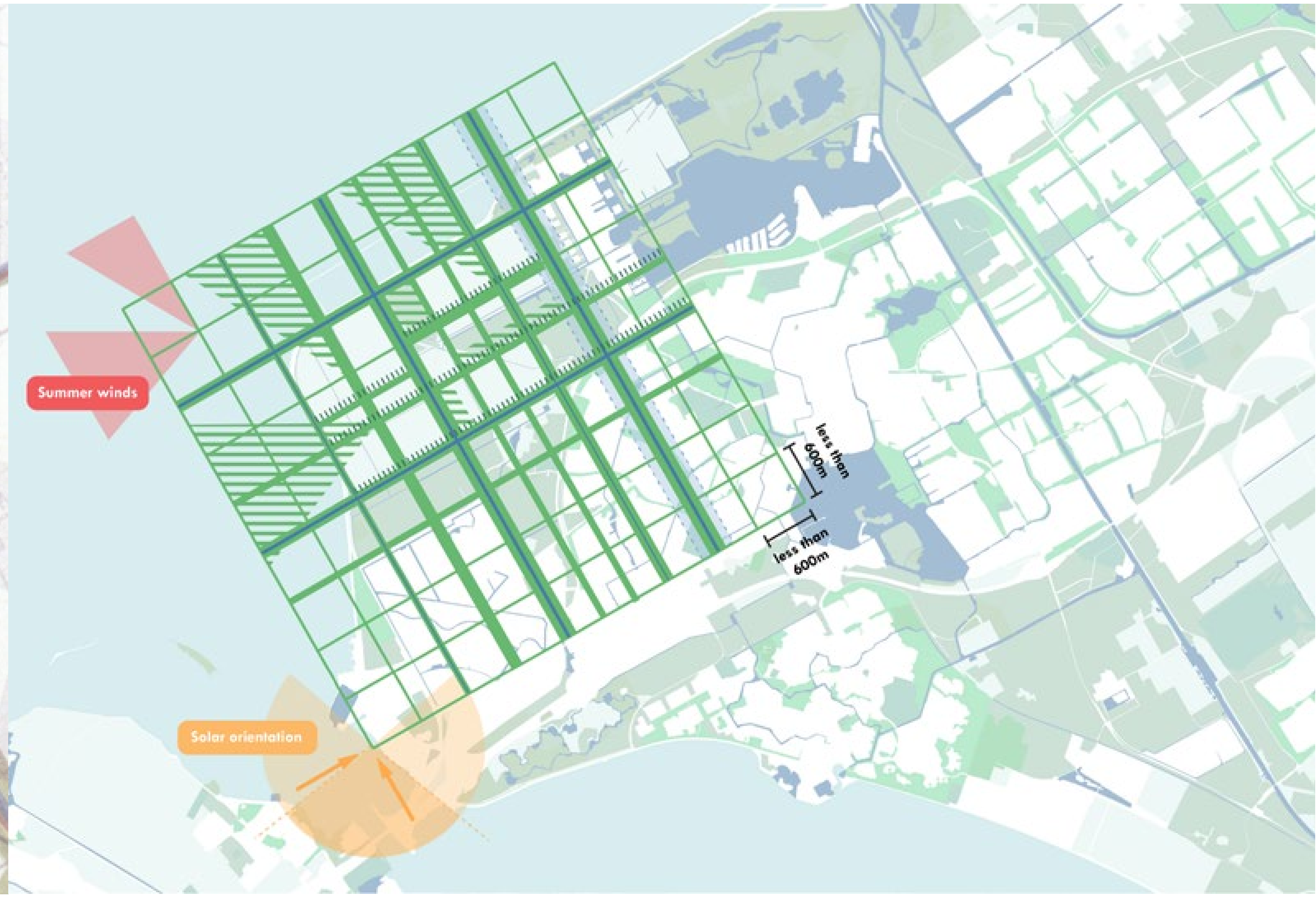
An example could be re-thinking the original Almere plan to create a 21st century green-blue framework

The 1970s plan of Almere, to the east of Amsterdam, clearly articulates the importance of the green structure in planning the new town. Today, revisiting the plan from the perspective of con-temporary urban demands, the green structure needs to integrate with finer-grain measures and undergo other subtle changes to perform.

The larger question for area development is understand how to align interventions with the location of greatest impact and benefit. The existing conditions analysis suggests focusing on the potential of open space performance may deliver the greatest benefits.

Original network of blue-green corridors

Finer blue-green network mesh



These actions are urgent to begin today. Climate stresses will increase on a local level, reducing the quality of life and limiting the willingness to invest.

The threshold analysis illustrates the urgency of action not only from a catastrophic risk perspective, but also from that of nuisance risk and stress perspective. Even if the design of local development is not asked to address catastrophic risk, managing risks holds many other implications for neighborhoods. Increasing climate stress will start to reduce quality of life and potentially limit willingness to invest. Repeated flooding of basements or overflowing sewers cannot be-come the status quo – it doesn't work. A failure to adapt to variable quantities of water, flooding and droughts, will lead to ecosystem degradation and infrastructure impacts. The Netherlands already experiences flood events and urban heat stress.

Basement flooding

Infrastructure impacts

Frequent flooding

Smelly sewers

Drought and ecosystem degradation

Heatwaves

WE LEARNED

Climate related stresses, including nuisance flooding and heat, are much more immediate than potential catastrophic shocks.

The MRA can better address issues of social equity through the approach to climate related stresses.

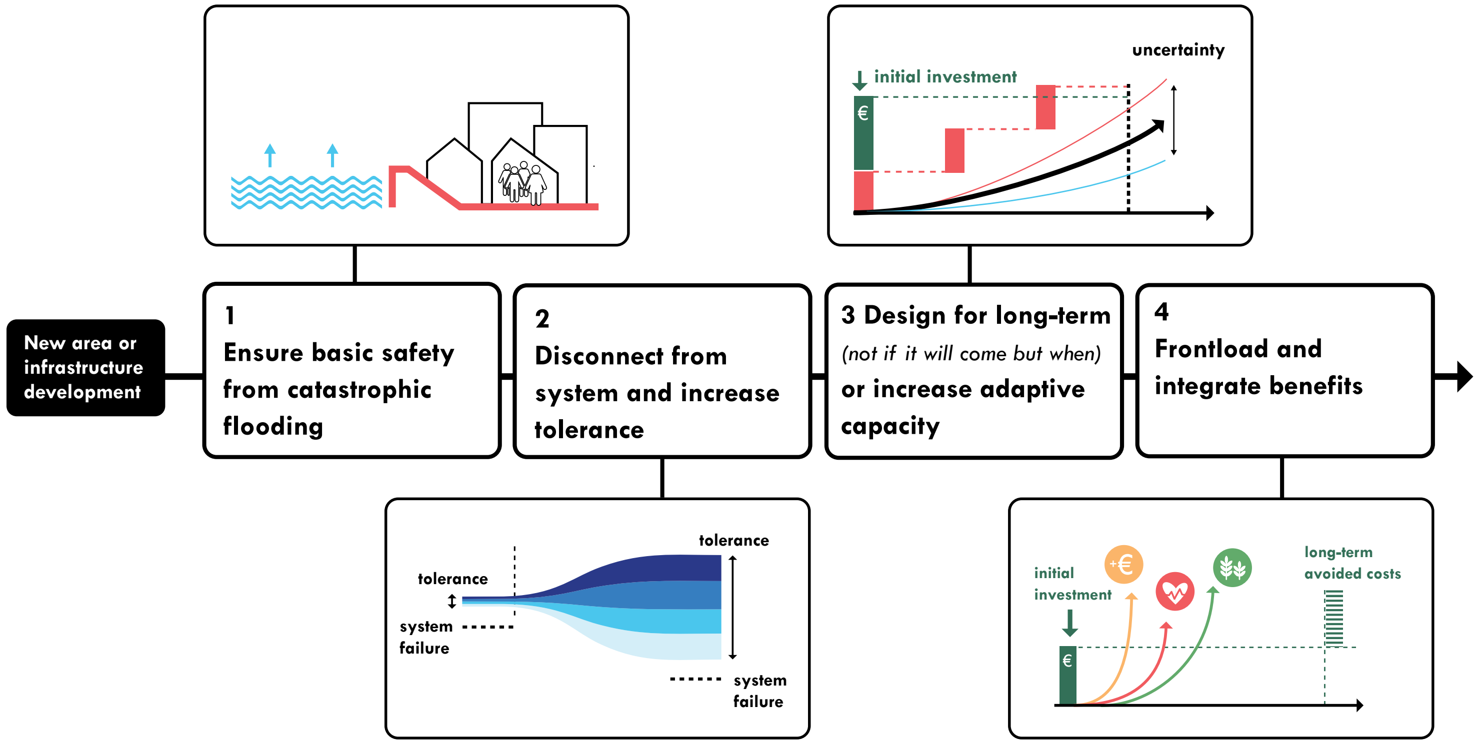
Stresses can be leveraged to generate more near-term funding, as they impact broader money flows and the willingness to invest.

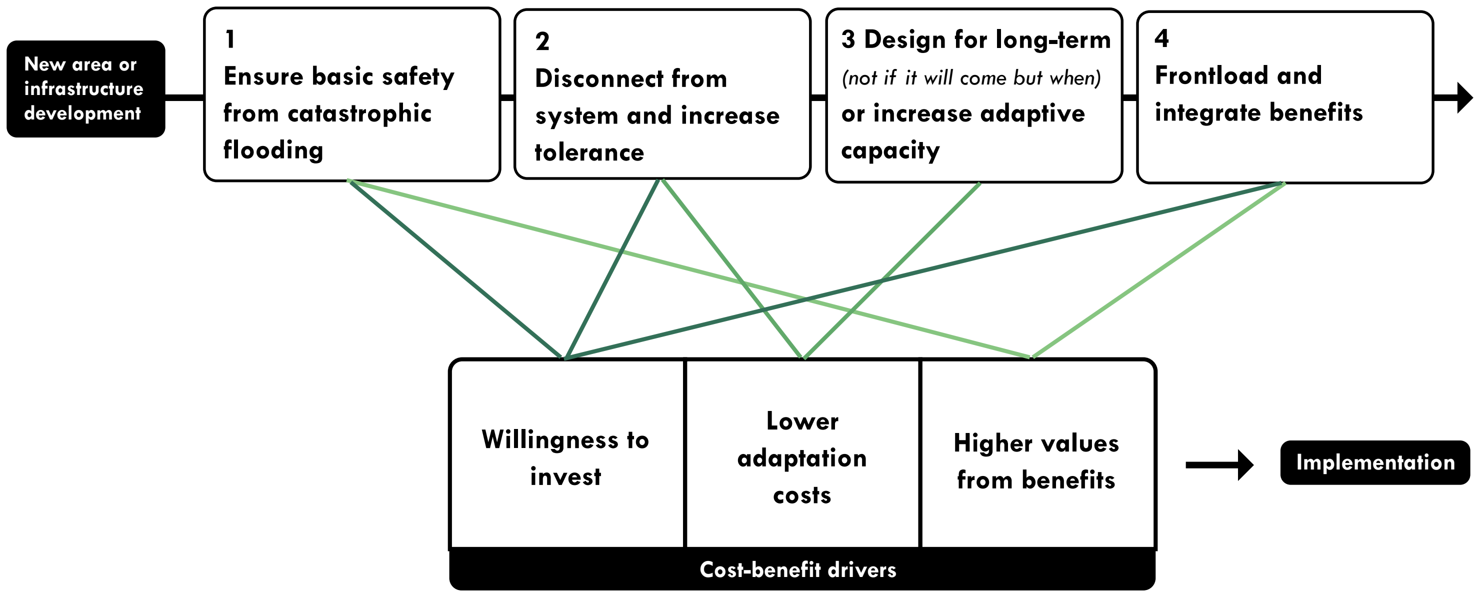
Multi-tiered strategy for any area or infrastructure development

The initial research points to a few key findings for the MRA. First, climate-related stresses of nuisance flooding and urban heat are much more immediate in their impacts than potential catastrophic shocks. Second, there must be a greater effort to understand and address their implications for social equity. Last, linking stresses to green-blue solutions suggests a way to start leveraging or generating more near term funding for change. Finding ways to capture the money flows that come with green-blue strategies increases willingness to invest and makes these tools more attractive.

Area developments require a multi-tiered strategy. They must do more than ensure basic stormwater capacity to provide safety from catastrophic flooding. Resilient development needs to disconnect from the system and increase its onsite tolerance. Strengthening the adaptive capacity of development means designing for the long term. In that context, the benefits need to be front-loaded and integrated, as they are linked to important cost-benefit drivers.

The willingness to invest is closely linked to the overall risk profile of each area. In a development context increasingly shaped by international flows of capital, an important consideration in any adaptation cost is who will pay and how the frontloading of cost impacts project value. There are multiple aspects of the adaptation proposition that can be monetized or capitalized, and value is created through the integration of multiple benefits.





DEMONSTRATION PROJECTS

Take place in dynamic environments with ongoing planning processes

Focus on nudging climate adaptation toward inclusion in existing processes rather than proposing alternative plans

Acknowledge the centrality of various actors in each area

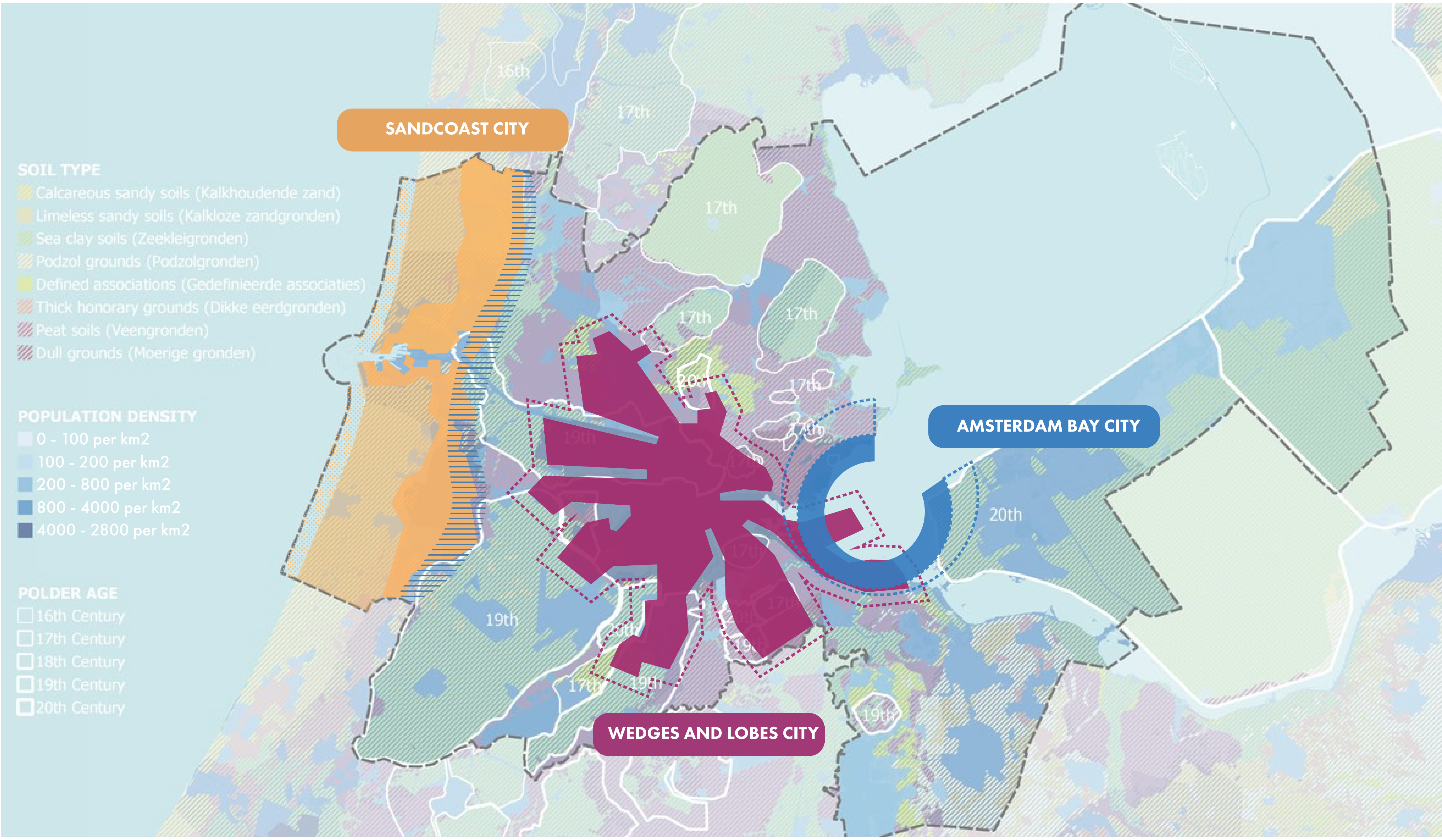
Combine spatial perspectives with development and finance tools

Consider replicability throughout the MRA

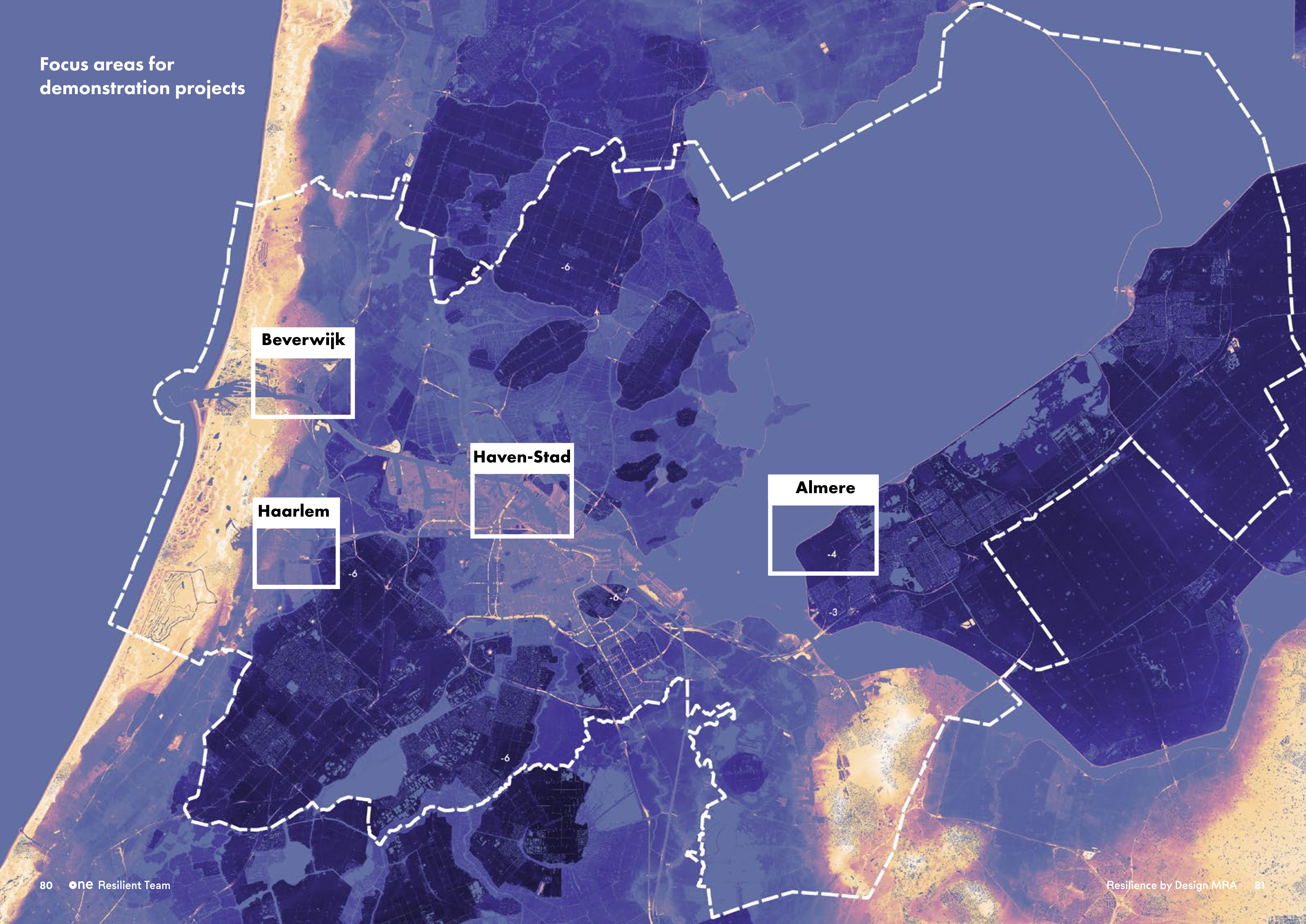
Demonstration projects

The four demonstration projects offer a view toward the future. They could function as pilots and describe how development could become more climate-adaptive by taking a different approach. The project sites all represent dynamic environments with ongoing planning processes and active investments, which is very common throughout the MRA. These characteristics make them suitable locations to consider project bankability. Rather than suggesting alternative plans or proposing iconic projects, the focus for the demonstration projects is to nudge climate adaptation into the processes that are already underway. The projects require great consideration for the different actors and stakeholder in these spaces and connecting new insights with development and finance tools. Not least, the projects must be evaluated for their replicability throughout the MRA.

The demonstration projects explore different urban or sub-urban systems that are at play in the MRA, which would each warrant a different type of project. There are three primary areas of consideration. First is the western coast, along the Atlantic. Next is the center city of Amsterdam, its fingers and polders. There is a strong relationship between the city and its immediate environs. Last, there is a new city forming to the east and connecting to the new town of Almere and what is called the Amsterdam Bay Area or Amsterdam Bay City.



Focus areas for demonstration projects



Demonstration projects

The four demonstration projects describe different types of transformation, from an established neighborhoods to a new development hotspot to a greenfield development. Given their planning characteristics, the actors in these areas also differ. Each concept highlights a distinct set of tools, with larger applicability.

TYPE	GREENFIELD	HOTSPOT	TRANSFORMATION "WORK"	TRANSFORMATION "LIVE"
SITE	Almere Pampus, Amsterdam Bay Area	Haven-Stad Amsterdam	Beverwijk De Pijp	Haarlem Nieuw Zuid
LANDSCAPE	Deep clay polder	Artificial raised landscape	Dune-peatlands transition zone	Former rural peat land
ACTORS	Municipality, province, country	Municipality, developers	Municipality, contractors, individuals	Municipality, corporations, residents
CONCEPT	Prepare the Pampus site (and the future Amsterdam Bay Area) to be climate proof when construction starts through a Building with Nature process	Use service life agreements to re-think the relationship between public and private expenditures in climate for the long term, such that we front load the benefits	Help multiple property/parcel owners to understand how they can, through collaboration amongst themselves and with the municipality, adapt to climate in a more efficient way	Integrating extreme heat into urban development by linking to public health
TOOL	Advanced subsurface development, ecology	Long-term service life agreements (SLAs) and adaptive planning for high-density	Collective adaptation reduces individual costs	Tree canopy development, mobility, capacity building

Almere-Pampus

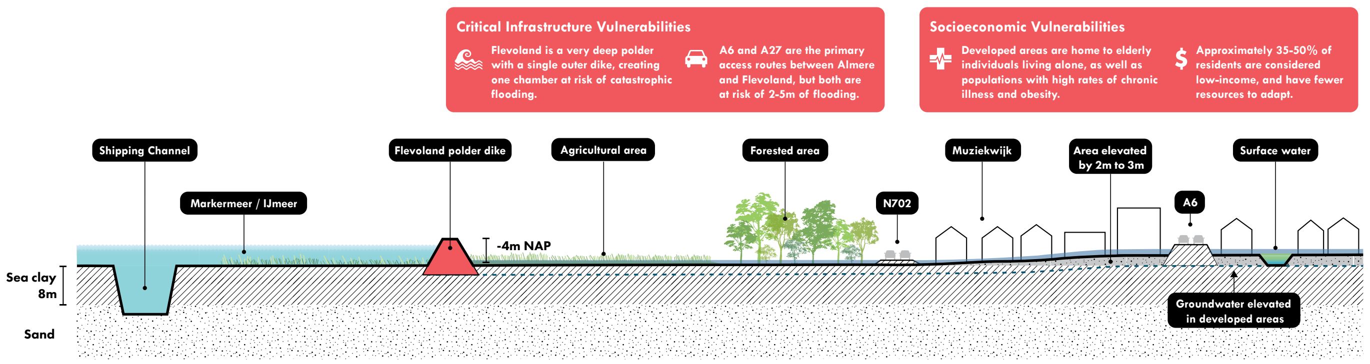
Nature-based pre-development

ALMERE
Vulnerability analysis

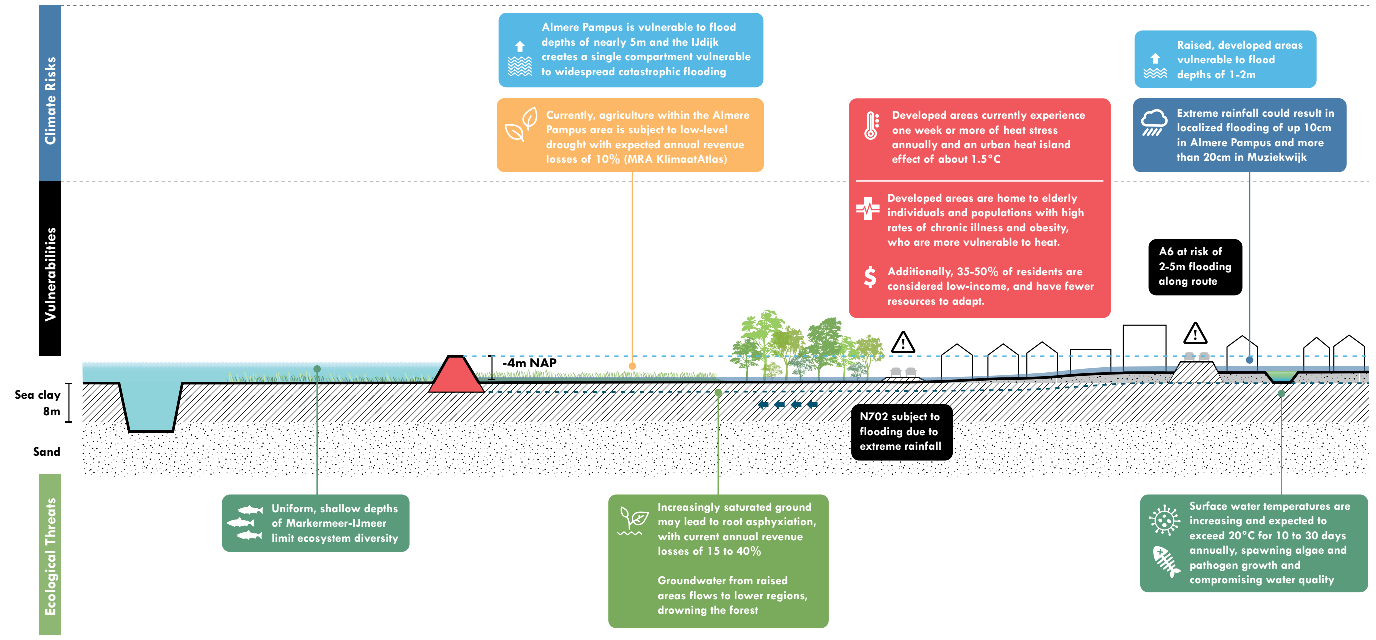
A series of transect studies unpack how the urban system works and its physical, as well as socio-economic vulnerabilities. Almere is a deep polder, about four meters below sea level as well as below the level of the Markermeer. The lake bottom is very silty, requiring periodic dredging more generally and to maintain the shipping channel Much of the new town is already built out. The Pampus site is partly agriculture, partly forest.

The vulnerability analysis found that subsidence and rising groundwater levels threaten agricultural productivity in the near term and could cause nuisance flooding for future development. This could also impact forested areas in subsequent decades, as saturated soil threatens the root systems of trees. Extreme rainfall is projected to cause localized flooding in developed and planned areas, and will intensify over time, leading to increased flooding. Neighboring developed areas experience heat stress that is currently somewhat mitigated by the adjacent forest. As the Pampus area is developed, the urban heat island effect could exacerbate heat stress that is already increasing due to climate change, making green areas even more critical. Toward the second half of the century, rising sea levels area projected to increase pressure on the water management system, including maintaining levels in the Markermeer. This could put the Flevoland polder, which is three to five meters deep in Almere-Pampus, at risk of flooding.

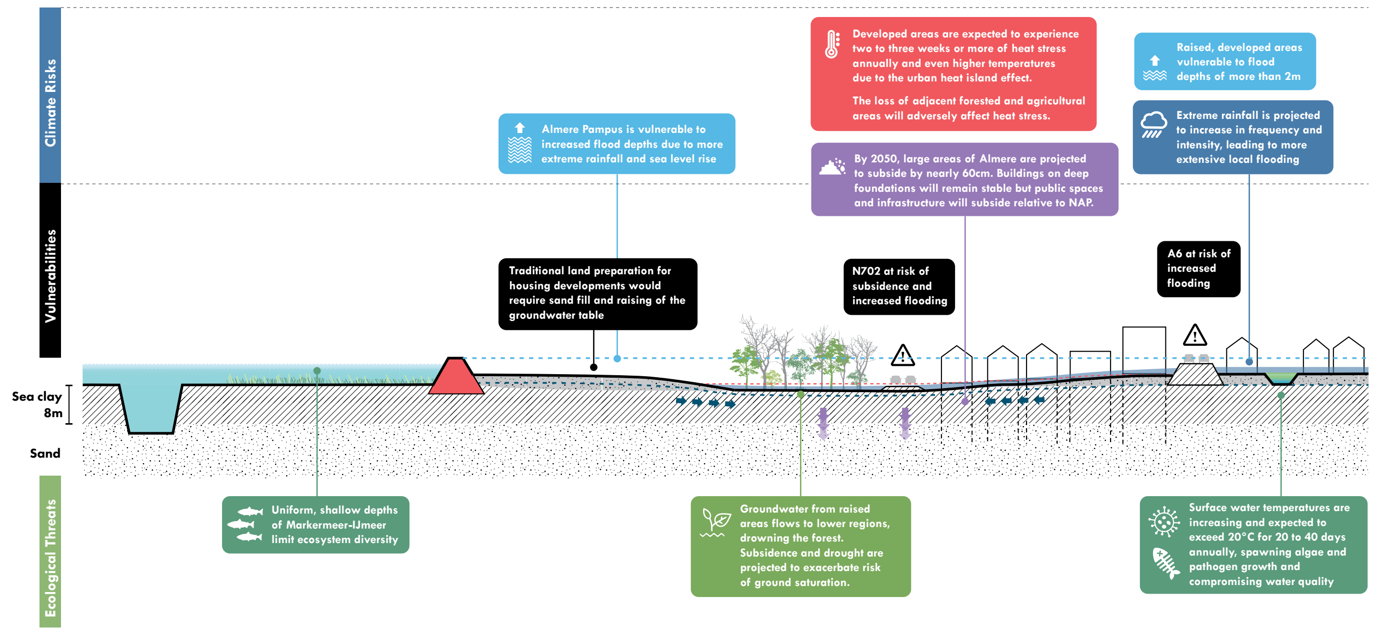
Existing



Climate risk 2020



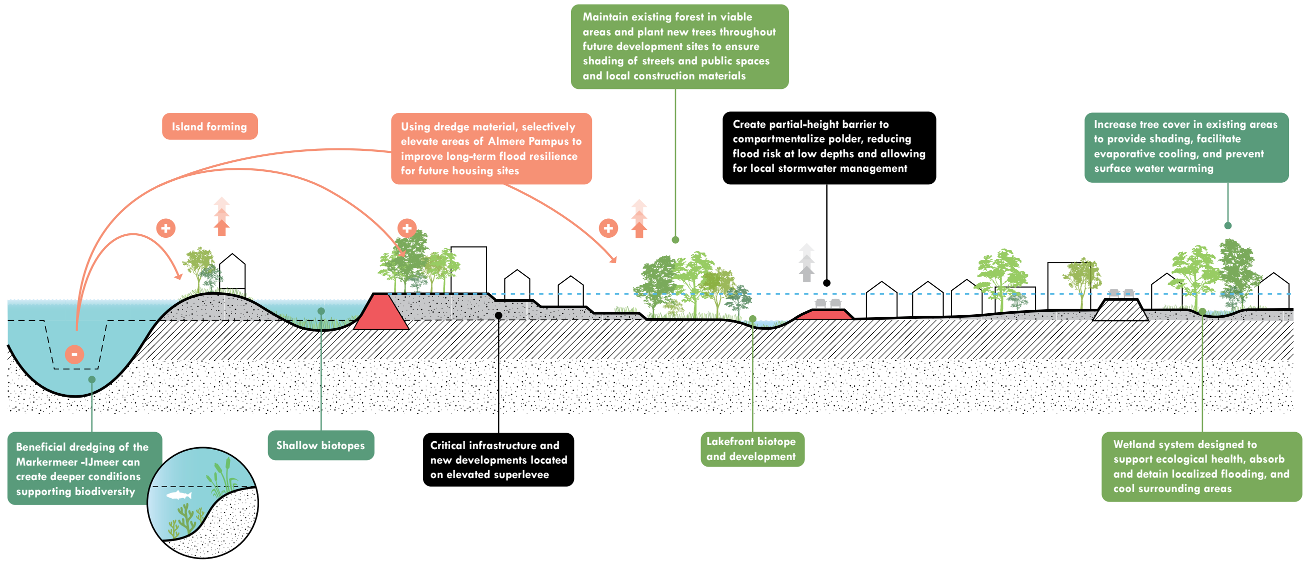
Climate risk 2050

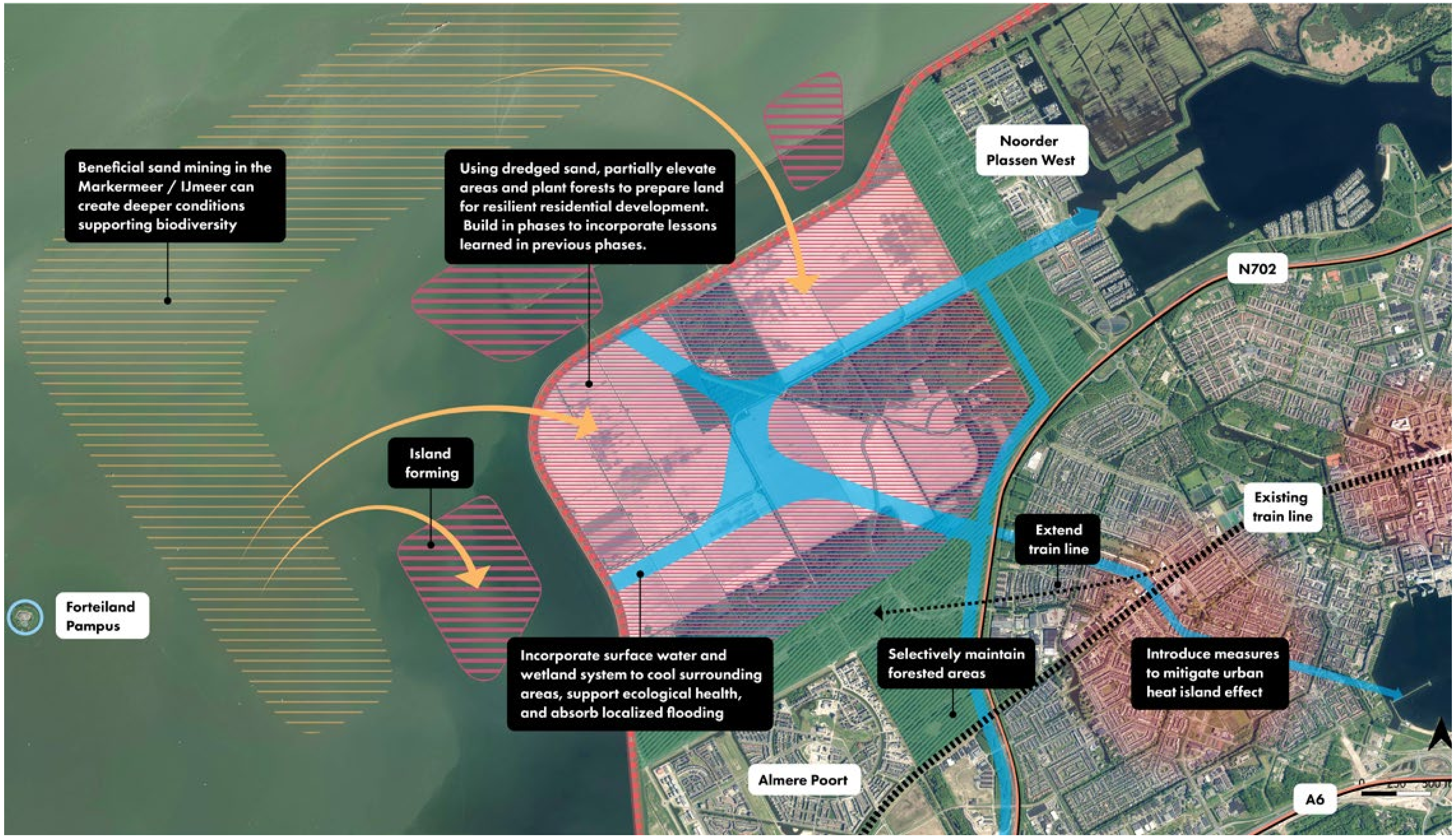


ALMERE
Opportunities

The proposal for a climate robust future begins with elevating certain areas to allow for vertical evacuation to reduce flood risk in this low polder. This also strengthens the visual connection be-tween the area and the lake.

Next, there is an opportunity improve lake ecosystem quality by increasing its diversity. Using a mining operation to remove the top layer of clay provides access to a lower layer of sand, which then can be used to elevate the areas within the polder. The result will be a natural lower area for the water to drain toward. If done intelligently, the new blue systems can enhance the climate robustness of the area at large and also perform some of the stormwater management function specifically.





Map of opportunities: linking interventions to ongoing planning

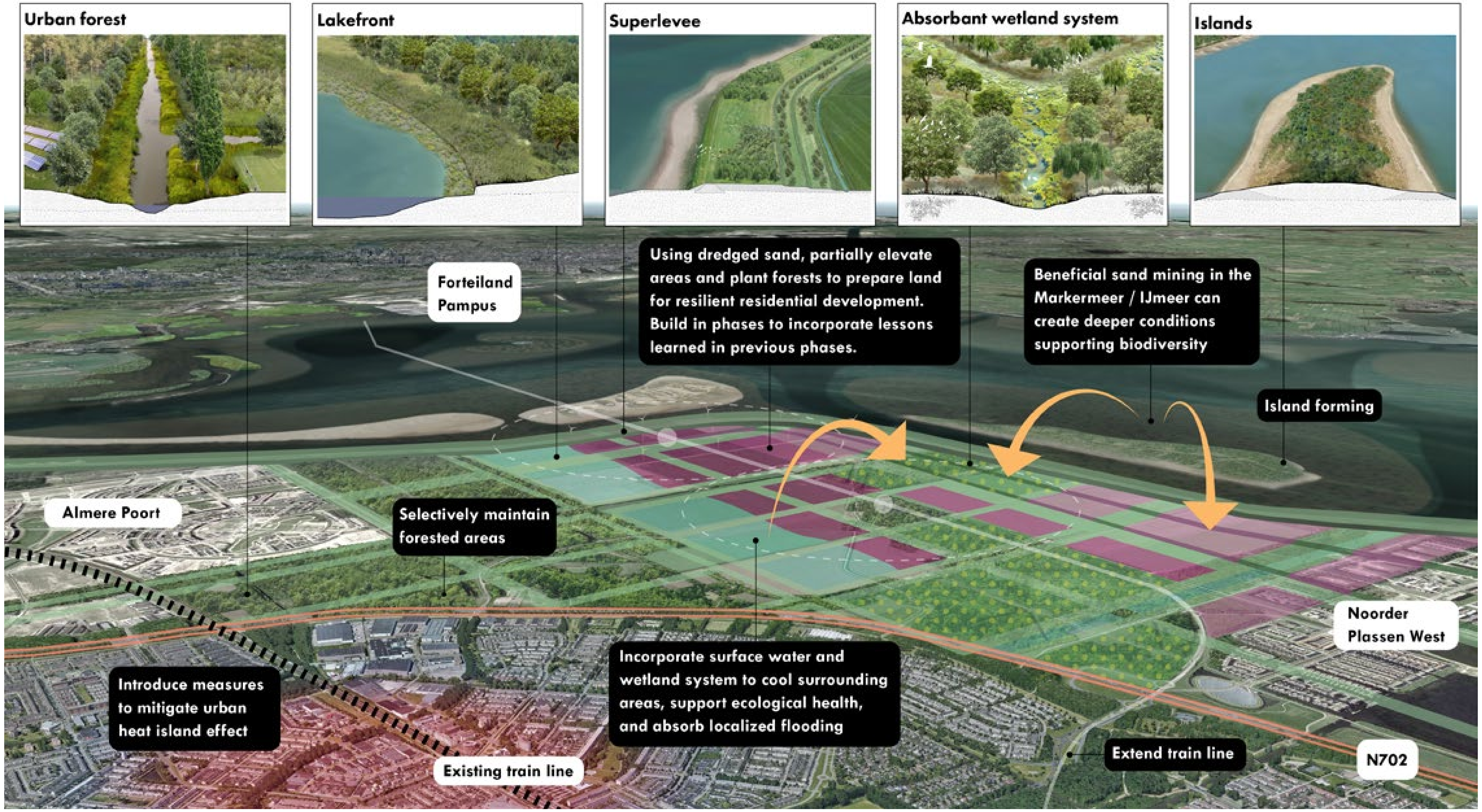
ALMERE
Land preparation in Almere Pampus

- How do we engage the ongoing MIRT processes for long-term housing development?
- Can we prepare the area to be 'deeply' climate adaptive using nature-based solutions, such that heat mitigation measures and the water/subsurface system are in place before development starts?
- Can we demonstrate that such solutions are cheaper than traditional solutions?
- Can we make a business case for early preparation?

A range of climate adaptation interventions through landscape can complement the ongoing planning processes and create new, beneficial environments. The wetland system would be sited at a lower elevation as the backbone of the area's green infrastructure. Tree planting efforts focus on long-term survivability, and could become the framework for future streets, to ensure shading and cooling. The wetlands not only help to manage stormwater and contribute to biodiversity, but also create the structure and delineate areas for housing development. Land preparation also works alongside temporary uses, such as solar farms or tree plantations. CLT is increasingly an interesting and appealing building material. These temporary natures can support timber growth and development for future construction.

Beyond the polder, there are opportunities for island formation. These new islands could support housing as well as many different types of nature purposes. The islands could become a new kind of national park. There is already a strong precedent for the creation of new nature areas. The nearby Oostvaardersplassen preserve, which was built in the late 1960s, is now one of the top ten nature reserves in Europe. While it is a recent and artificial construction, it has already demonstrated its vital importance to the migration patterns of many birds species.

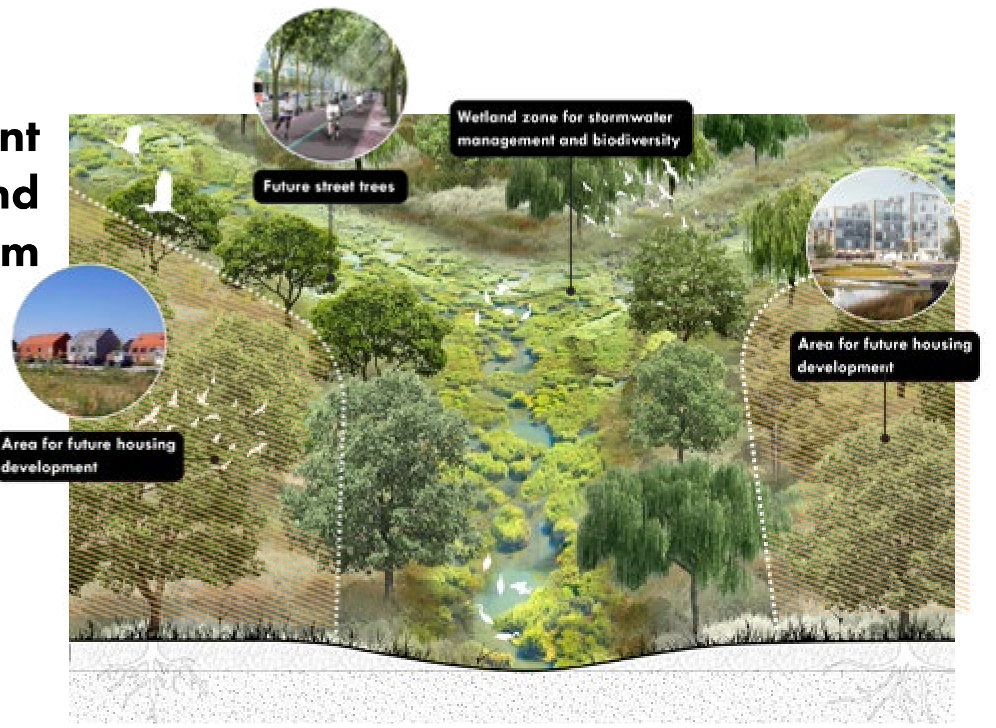
The northern and western edges of Pampus can take the form of a super-levee, extended into the lake to create space for neighborhood developments, as well as critical functions and infrastructure at a higher elevation.



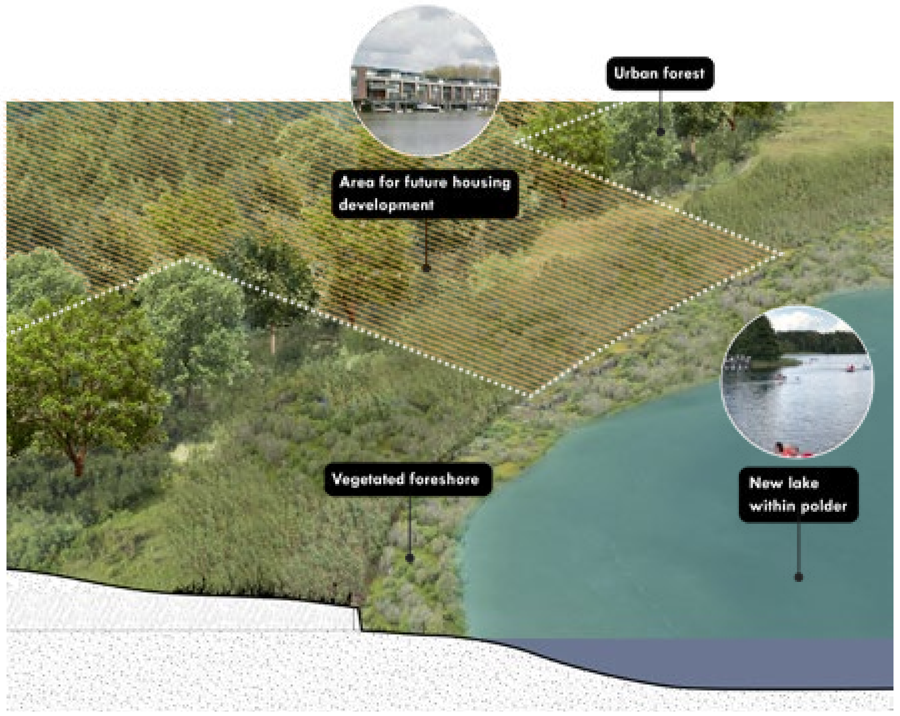
ALMERE
Landscape proposals

Together, these operations form an integrated strategy
that sets the stage for climate-robust development.

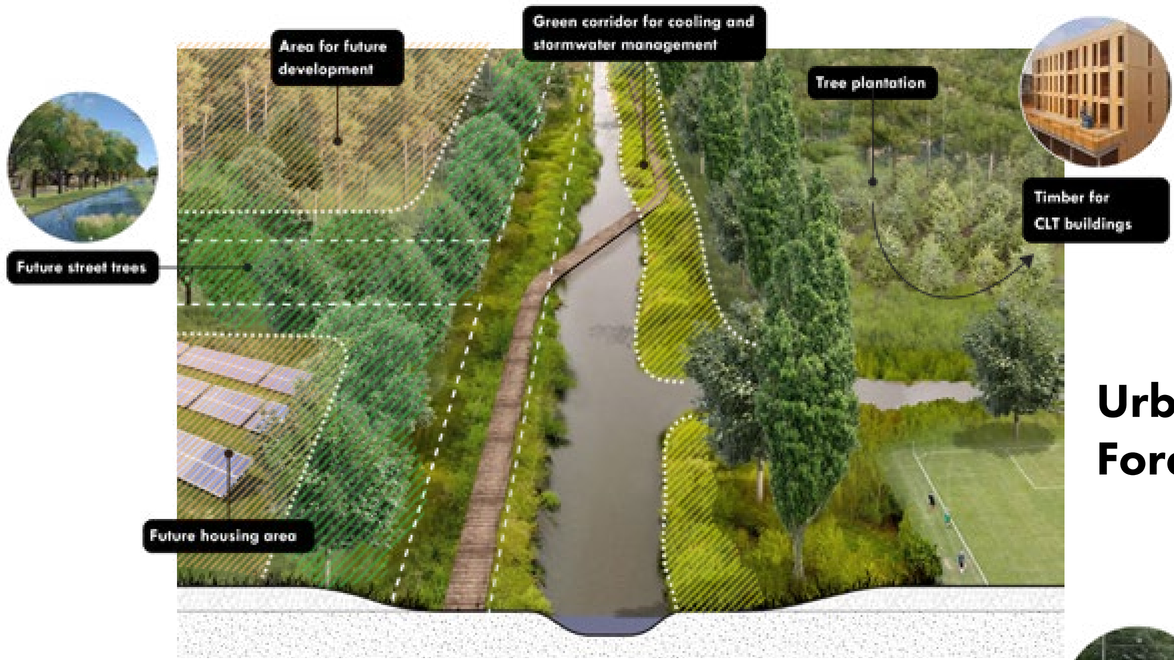
Absorbent Wetland System



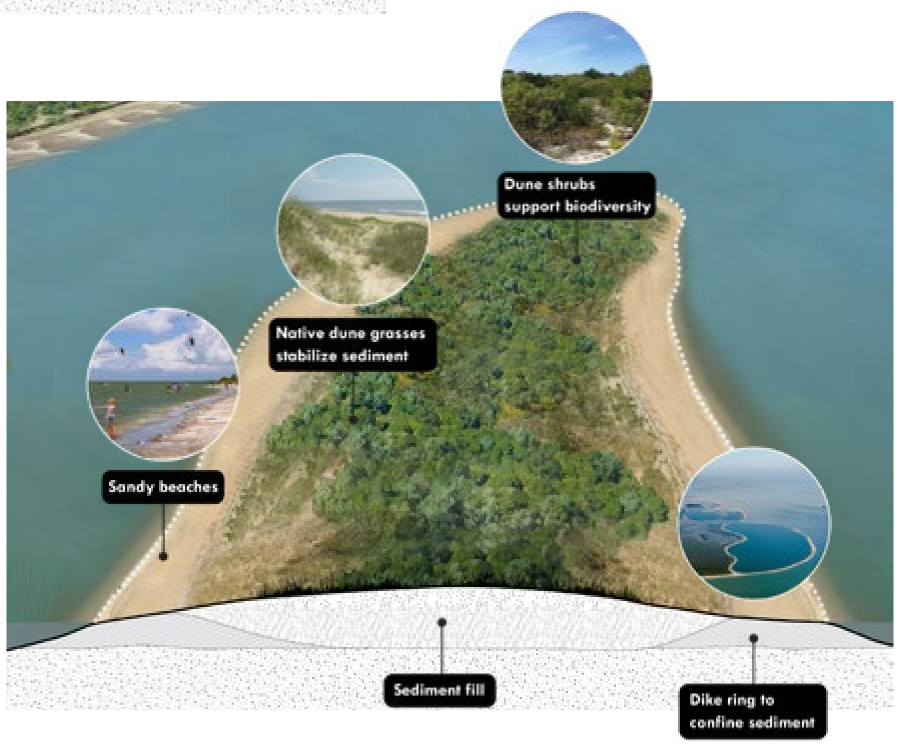
Lakefront



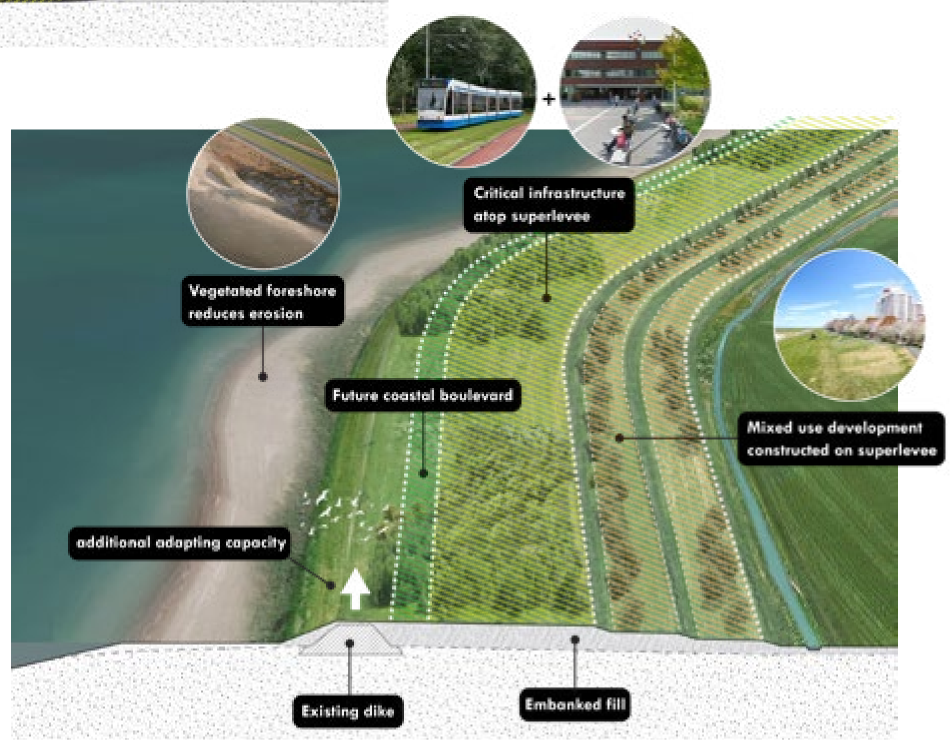
Urban Forest



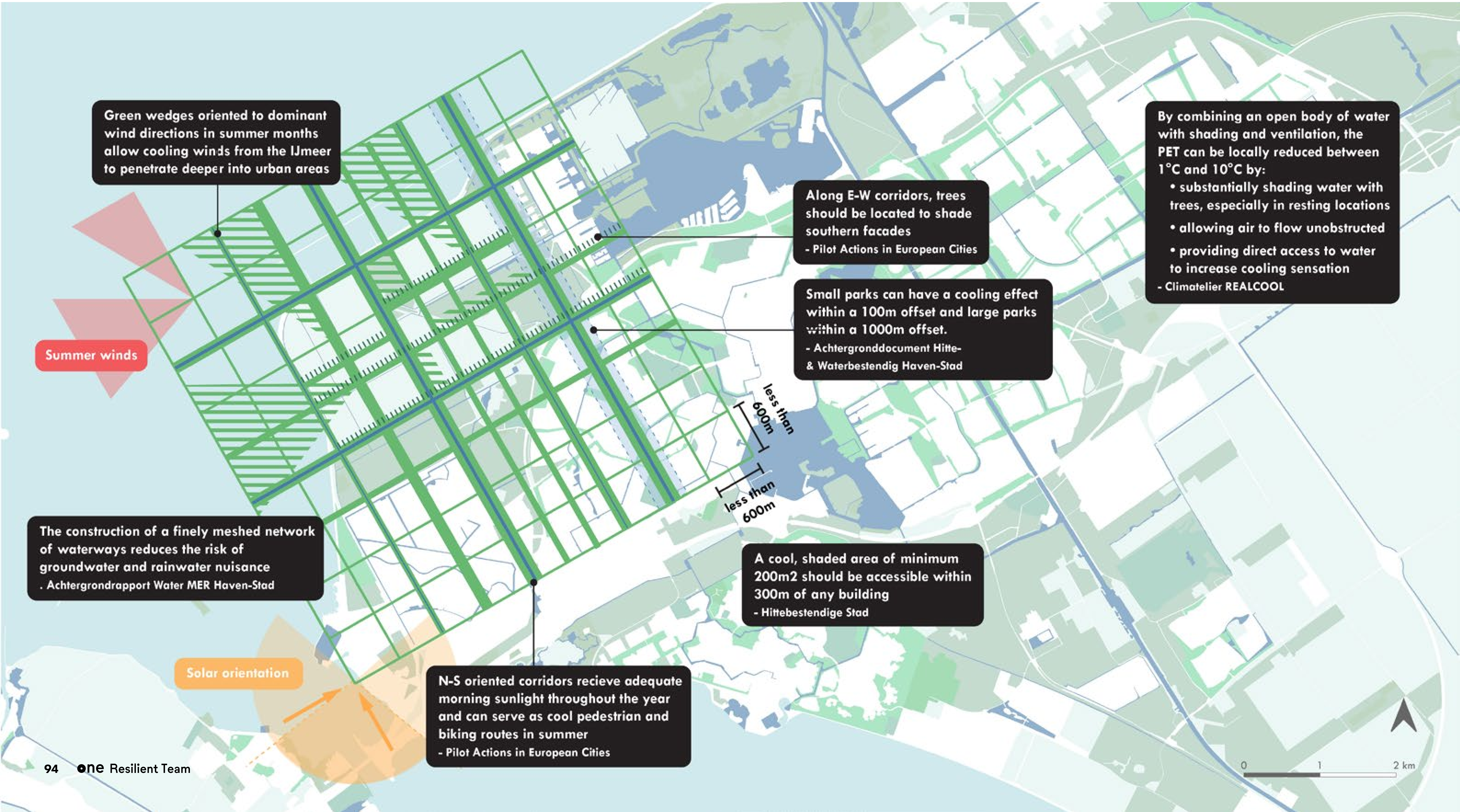
Islands



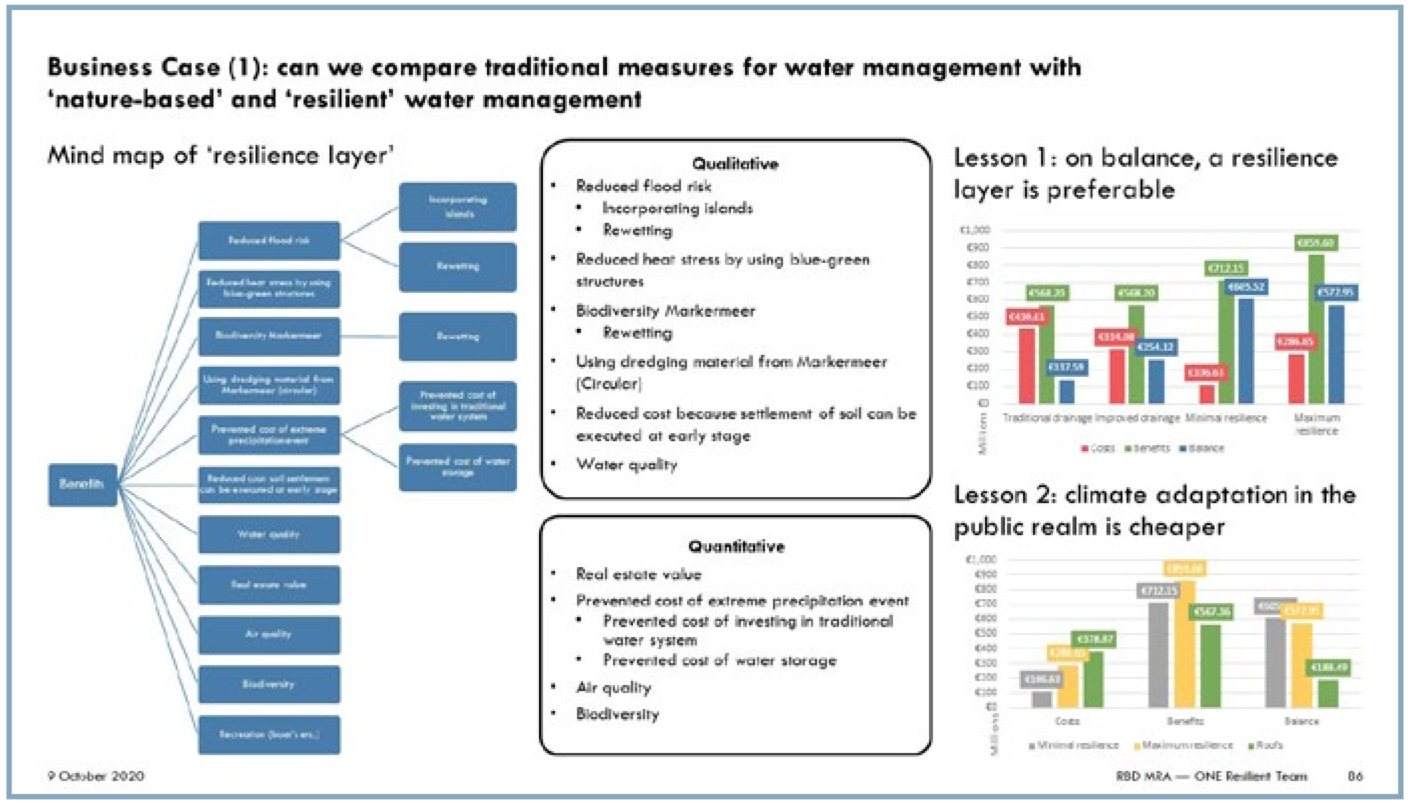
Super-levee

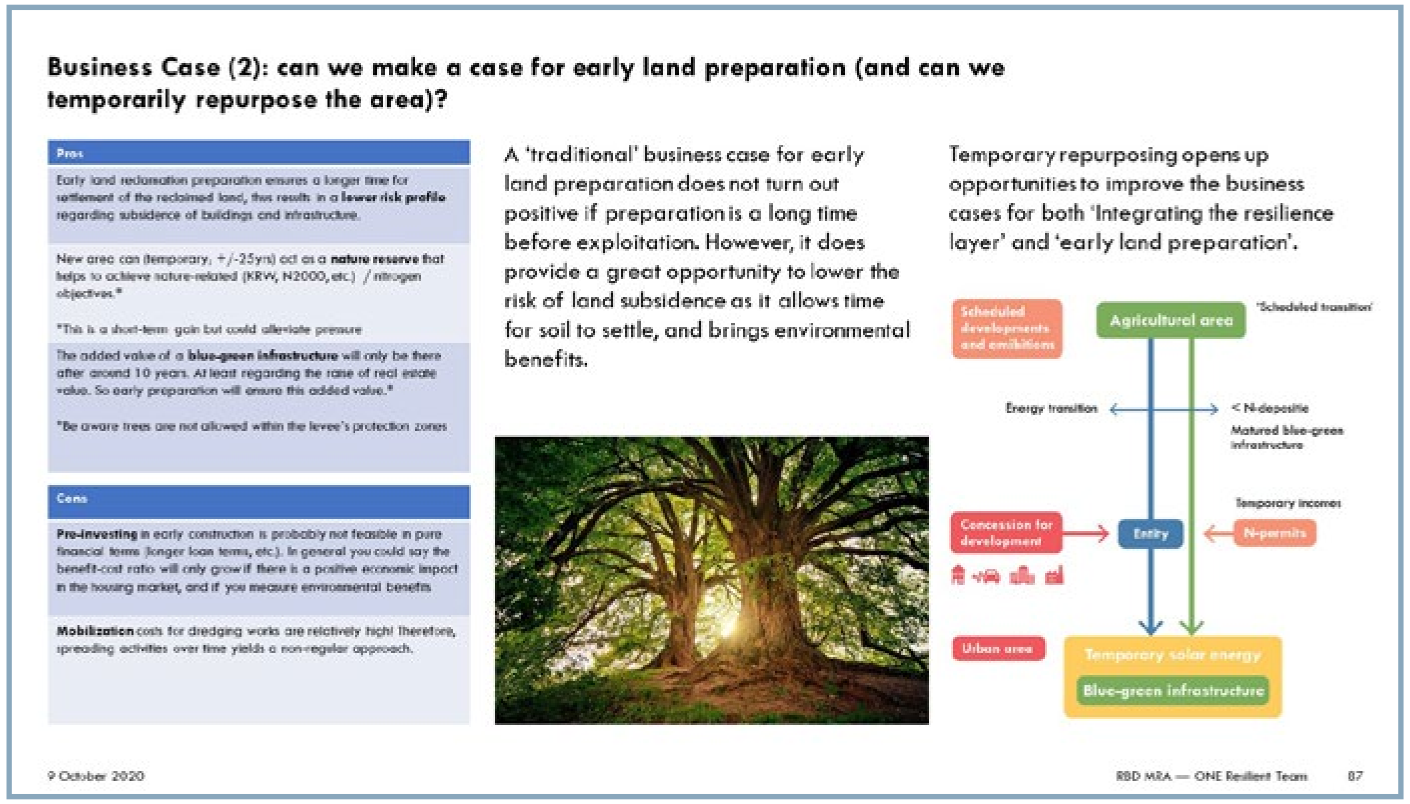


ALMERE
Resilient blue-green corridor grid



ALMERE
Business Case





The business case analysis also yields interesting findings that support the pre-development approach. On balance, using these measures is much more cost-effective than traditional drainage systems. Furthermore, climate adaptation in the public realm is much cheaper than trying to achieve the same performance through private development.

However, there is not a strong financial case for early land preparation in the traditional sense. With a long duration between the preparation and the development, the business case is not there. Yet, if the development follows not long after the preparation, there are quantifiable benefits such as reduced risk of land subsidence, environmental benefits, and even temporary uses, and these together can support bankability.

Source: Arcadis bankability analysis for RBD MRA. Refer to Appendix for further analysis.

Amsterdam Haven-Stad

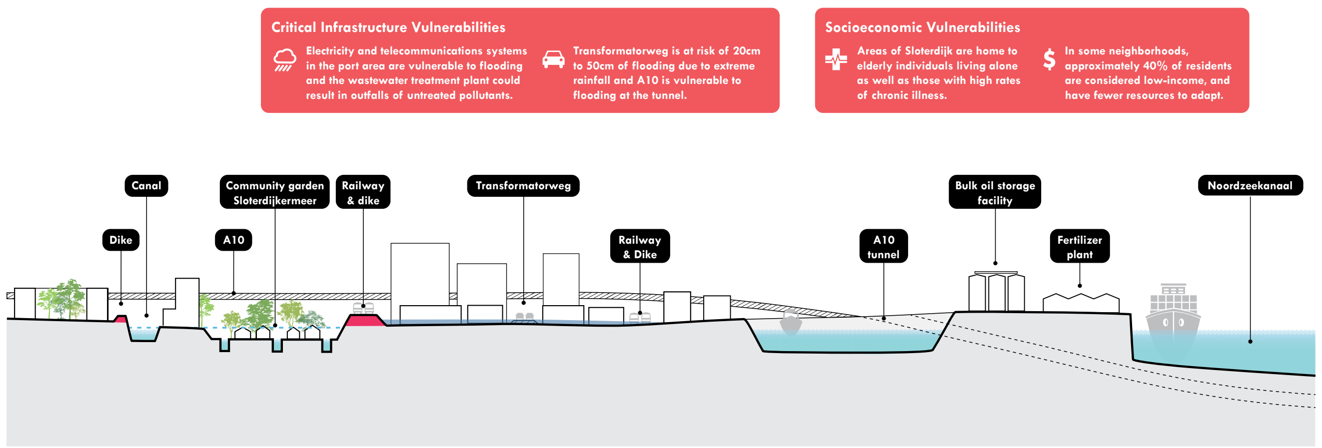
Build in adaptive capacity

HAVEN-STAD
Vulnerability analysis

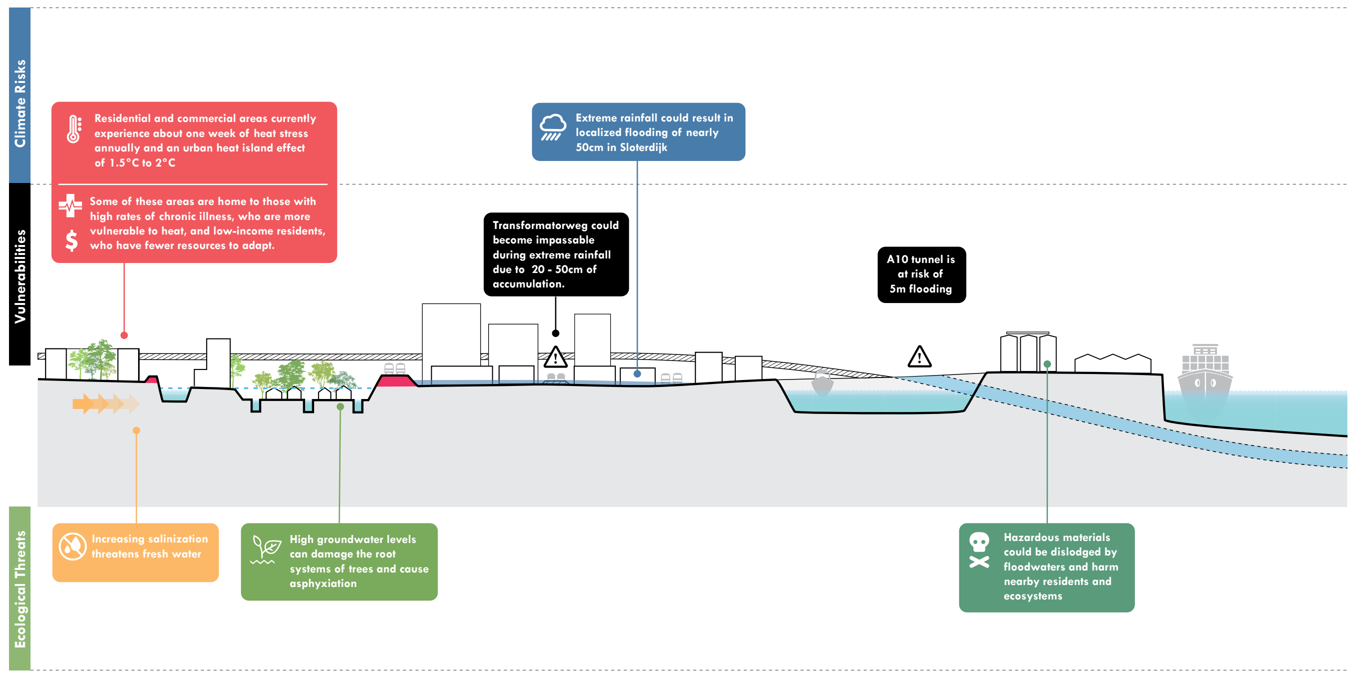
Haven-Stad lies outside of the dike rings; it connects to the North Sea Canal and to Amsterdam. At present, the area contains industrial land uses, while area plans project residential development for the future.

Large areas of the zone slated for Haven-Stad are at risk of significant flooding due to rainfall, including at depths of more than 30cm along primary roadways and in populated areas. The in-tensity and duration of extreme rainfall events will increase with climate change. Much of the area planned for Haven-Stad is relatively low-lying compared to the Noordzeekanaal. In addition to being highly susceptible to flooding due to extreme rainfall, these areas- particularly those out-side the dikes- are vulnerable to flooding due to fluctuating levels in the NZK. In the long-term, sea level rise is projected to strain the pump system, while increasing rainfall upland may lead to higher levels of discharge from the Rijn into the canal system. By 2050, the Haven-Stad area is expected to experience three weeks of heat stress annually, in addition to a high urban heat island effect. Without climate-resilient updates, high-density developments planned for Haven-Stad would exacerbate localized heat stress and strain stormwater systems beyond capacity.

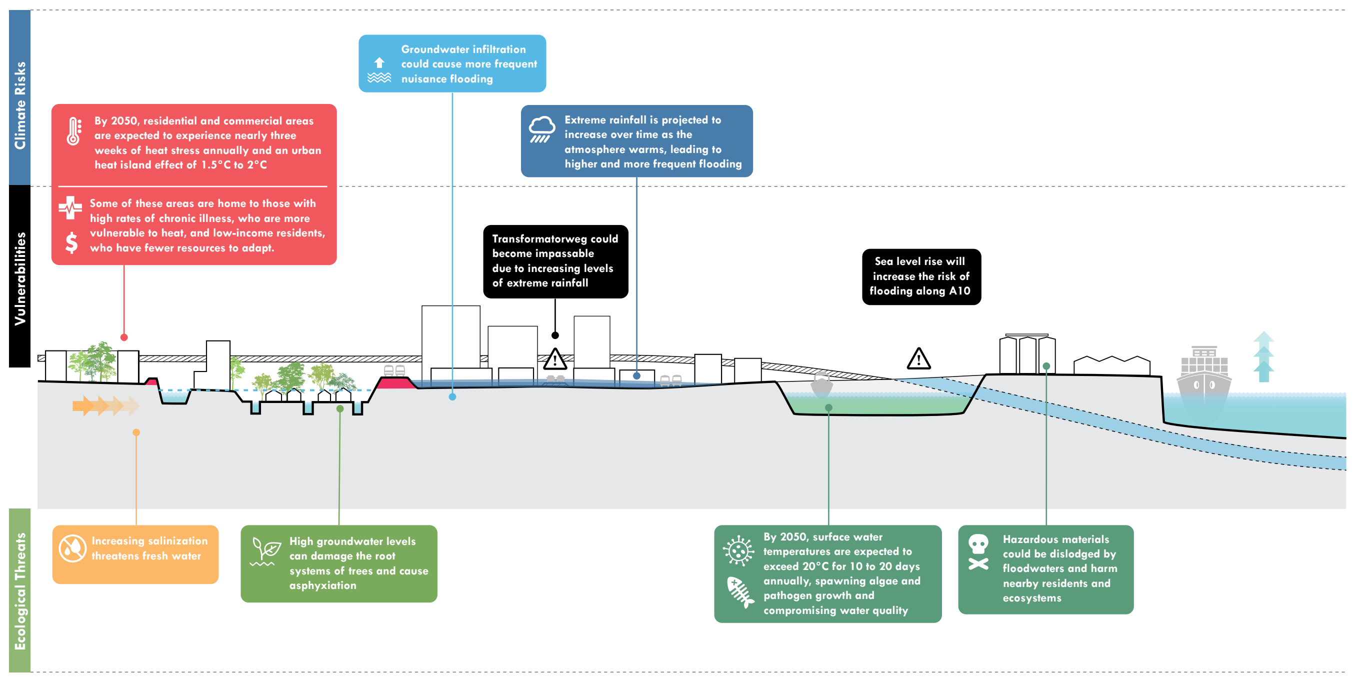
Existing



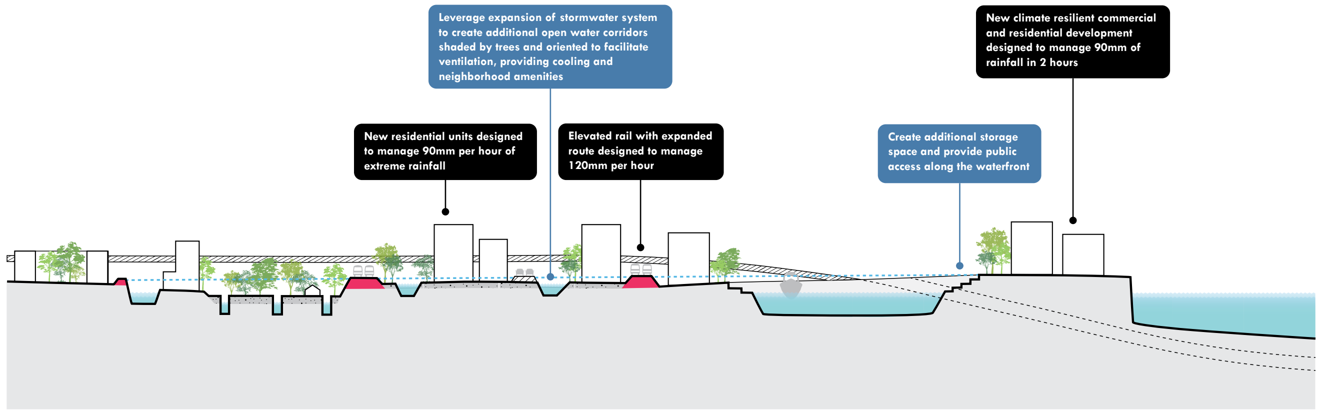
Climate risk 2020



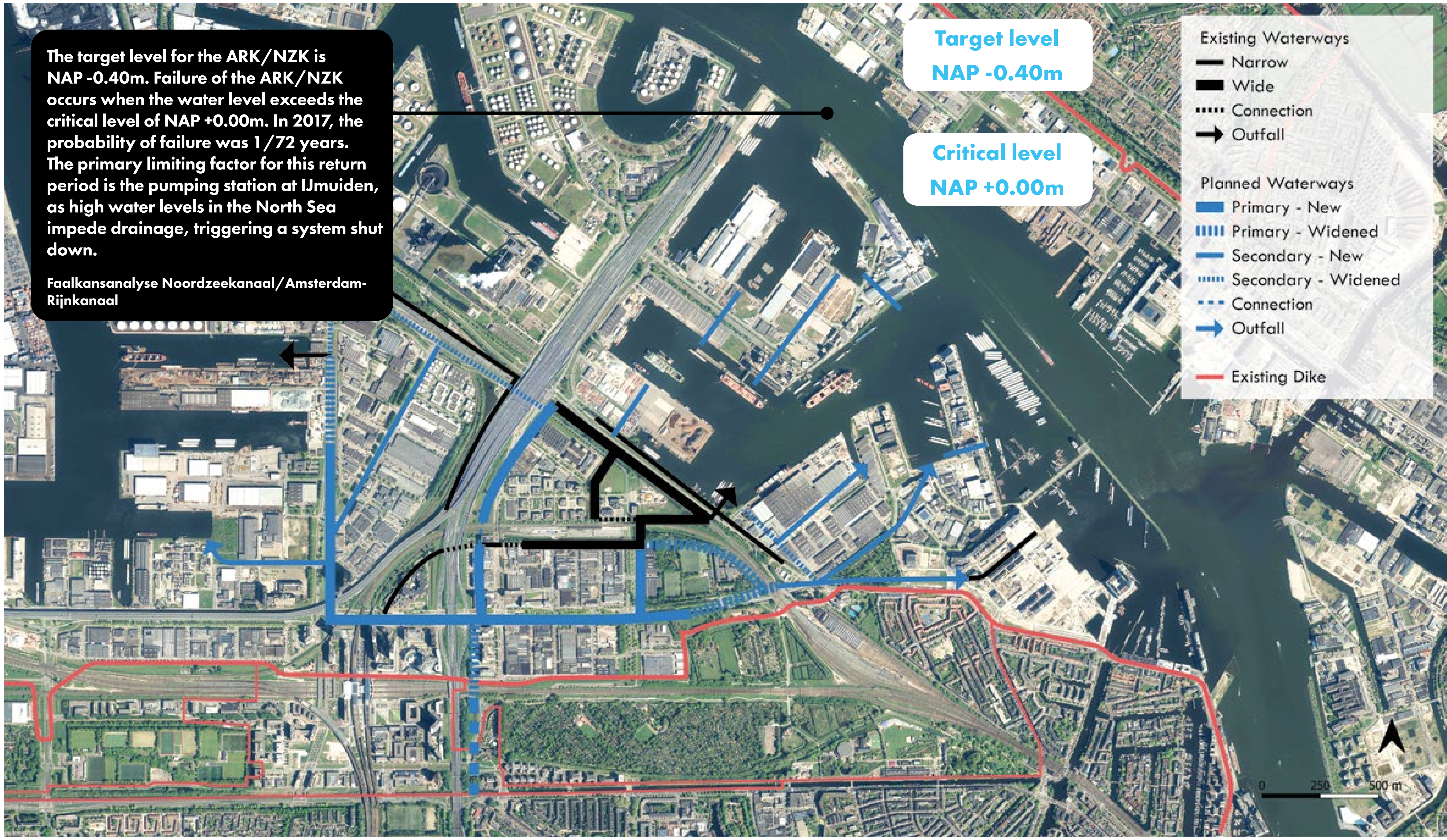
Climate risk 2050



HAVEN-STAD
Opportunities



The opportunities for Haven-Stad lie in increasing its stormwater capacity, with heat mitigation as a secondary aim. In addition, the ongoing development represents a pathway to elevate the area's critical functions and infrastructure. In the future, the canal must accommodate greater variability in water levels than it does now.



HAVEN-STAD

Case Study: Nieuw Zuid Development

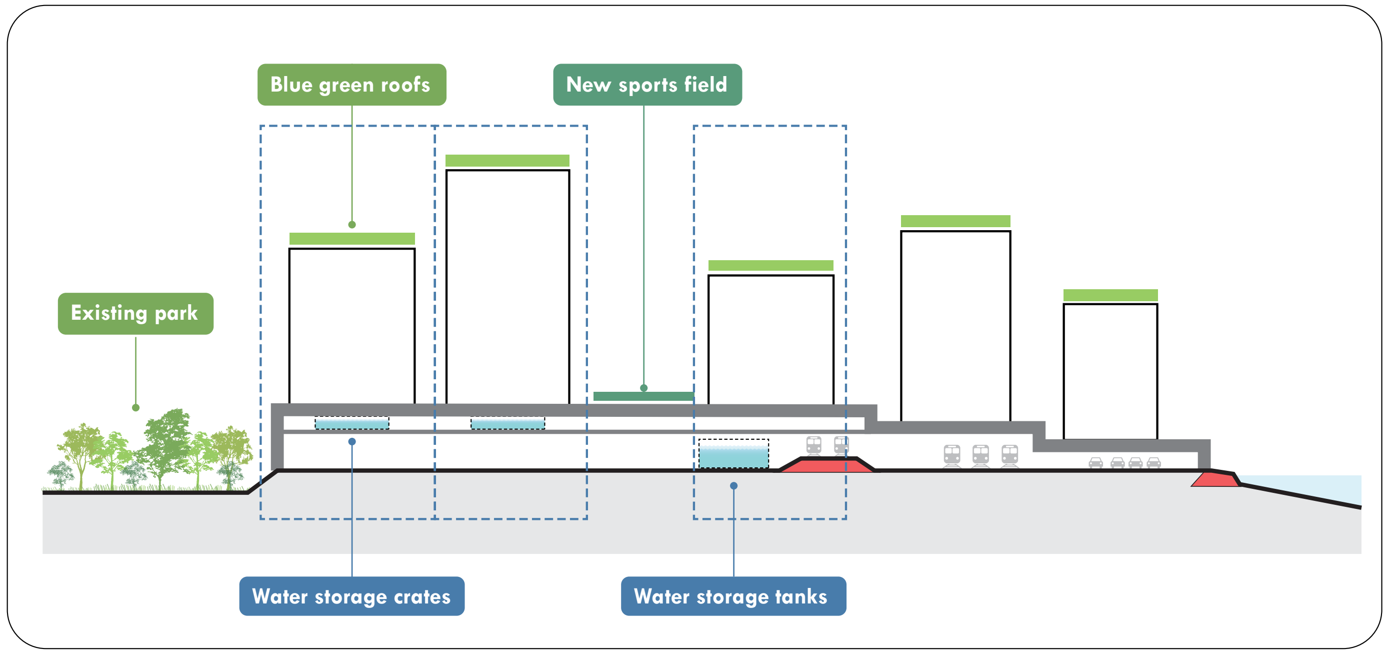
- **Can we re-calibrate a highly technical deck to support high-density development, along with the intended water system?**
- **Can we reduce the cost of climate adaptation measures, and increase the adaptive capacity and flexibility?**
- **Can we maximize the 'koppelkansen'?**
- **Can we make a business-case for 'adaptive capacity'?**
- **Can we propose longer-term development contracts, perhaps focused through 'service level agreements'?**

The high-density environment points to a set of further questions. The proposal begins with placing all the development on a deck to accommodate the vast infrastructure that passes through the area. This prompted the question: what further benefits can come from the highly-technical deck? Can it be modeled after Hudson Yards in New York, or can create a new paradigm for integrating the water system? Can this integrated model allow for reduced climate adaptation costs while increasing the adaptive capacity and the flexibility of the development? Can the development maximize what in Dutch is called "koppelkansen," or the ability to link different systems together, and to create efficiencies through making work with work. And finally, does the development make a compelling business case for adaptive capacity, and what implications does this hold for the future of development contracts?

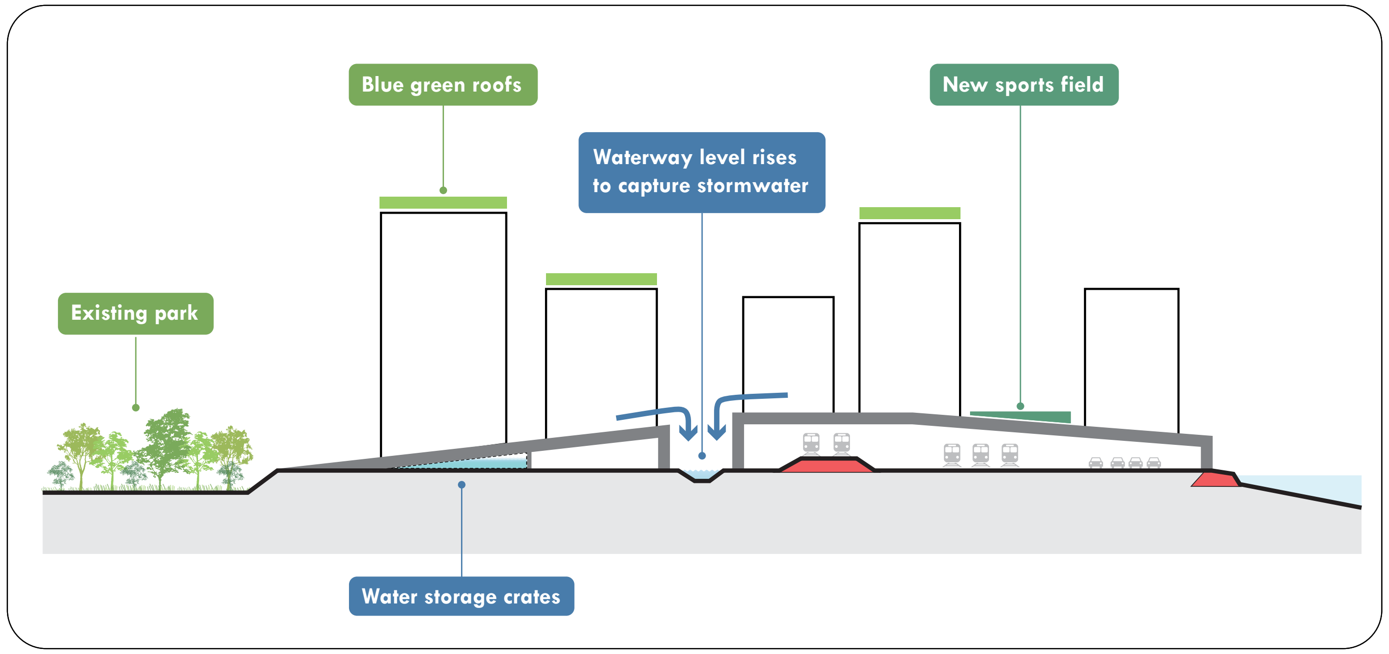
HAVEN-STAD

Increasing rainfall and heat stress can be managed in several ways

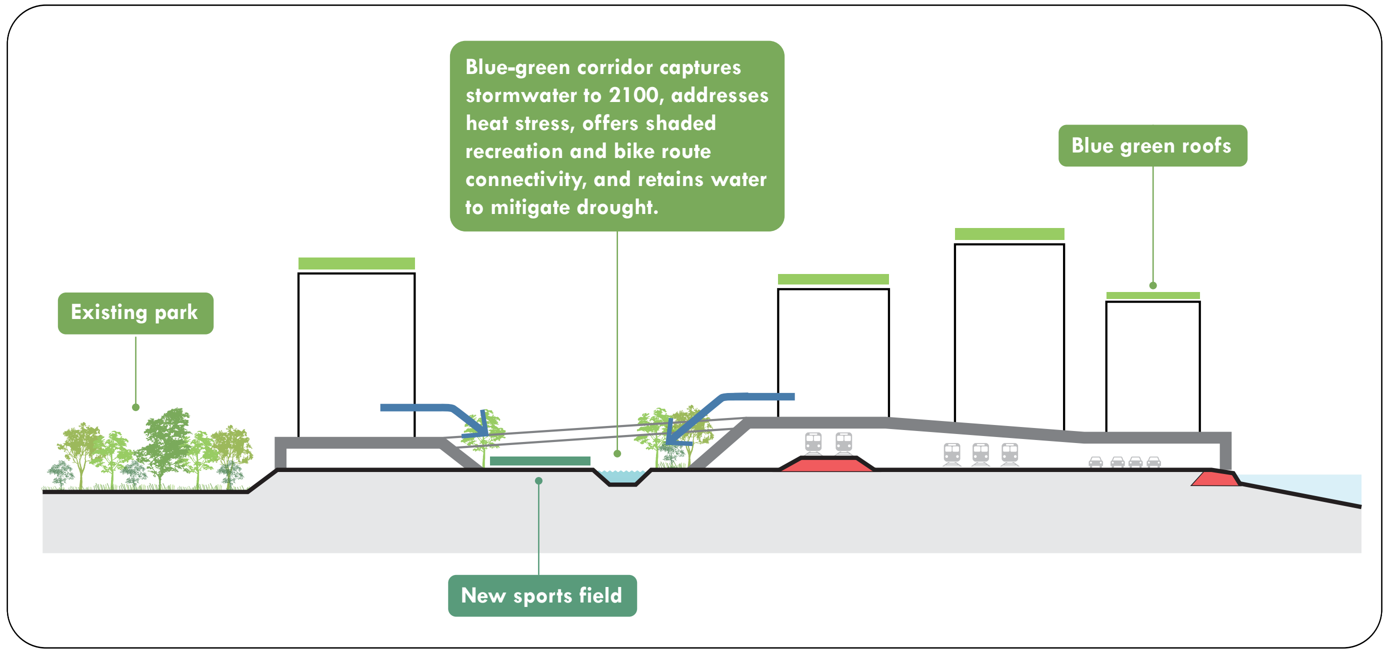
1. Each individual development solves stormwater on site



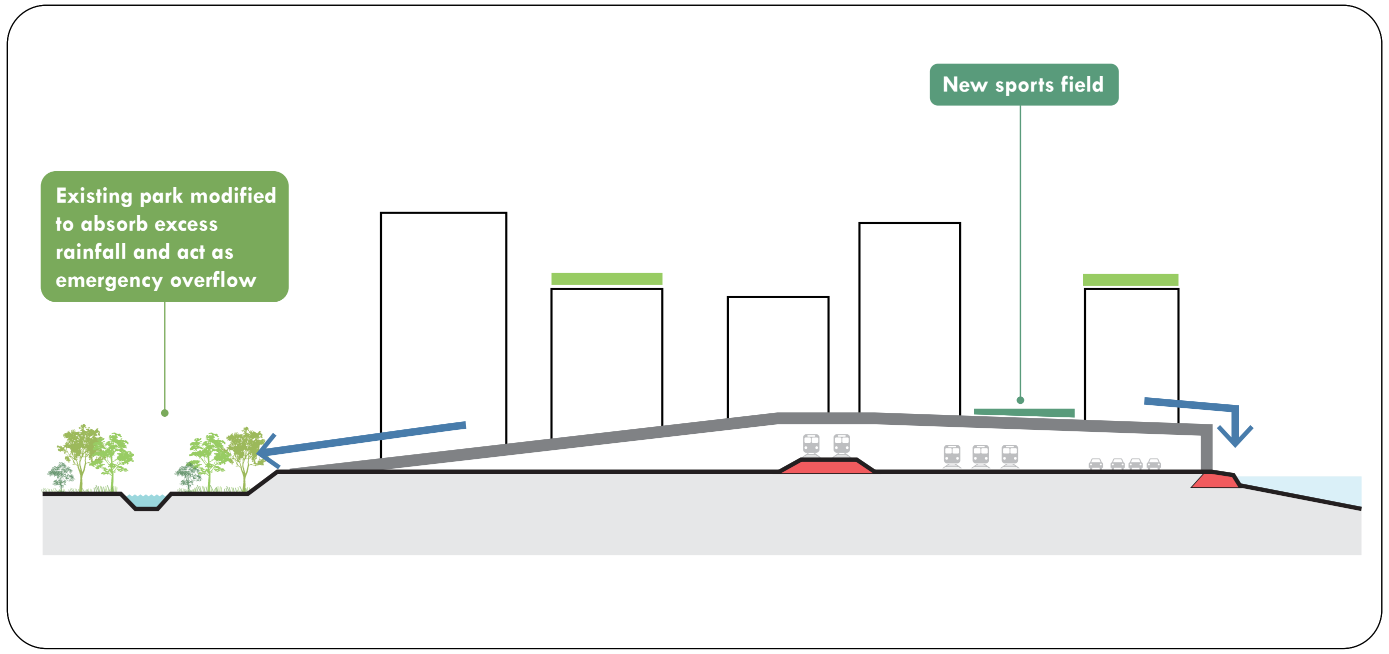
2. Small waterway serves as temporary water storage



3. Blue-green corridor to address long-term climate risk



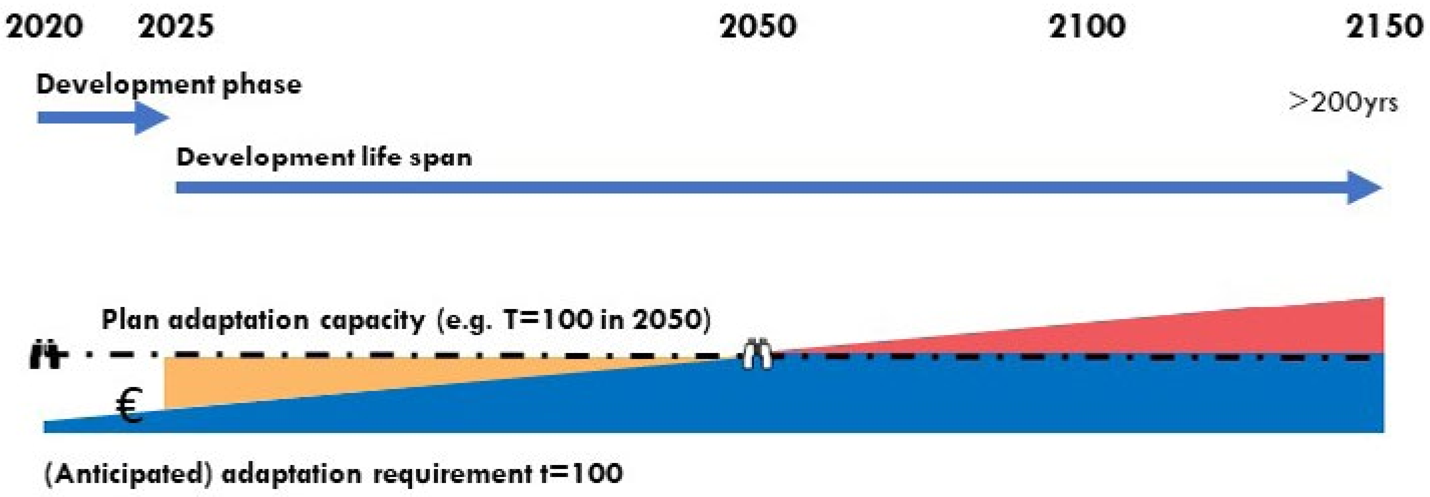
4. Stormwater managed off-site



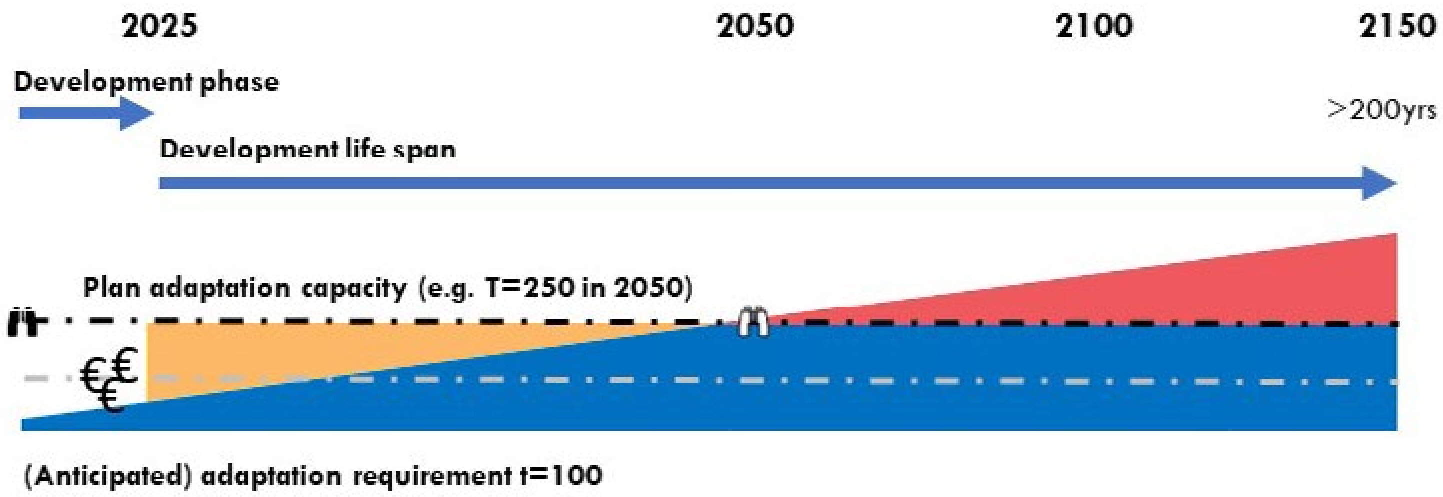
HAVEN-STAD
The value of adaptive capacity and flexibility

These studies raise the question of how to capture the value of adaptive capacity and flexibility. If climate change were predictable, it would be possible to balance pre-investment. Since this is not the case, climate adaptive measures run the risk of creating over-investment in the initial phase of a project leading to underinvestment later. Using higher standards than are commonly accepted is one response to reduce risk since the impacts of climate change remain uncertain. Or alternatively, there is a risk of underinvestment if climate change accelerates. The future could lead to a scenario where it could be impossible to recoup over-investment and interest counter-counts, or equally find space to construct a new layer of measures if the upfront measures fall short.

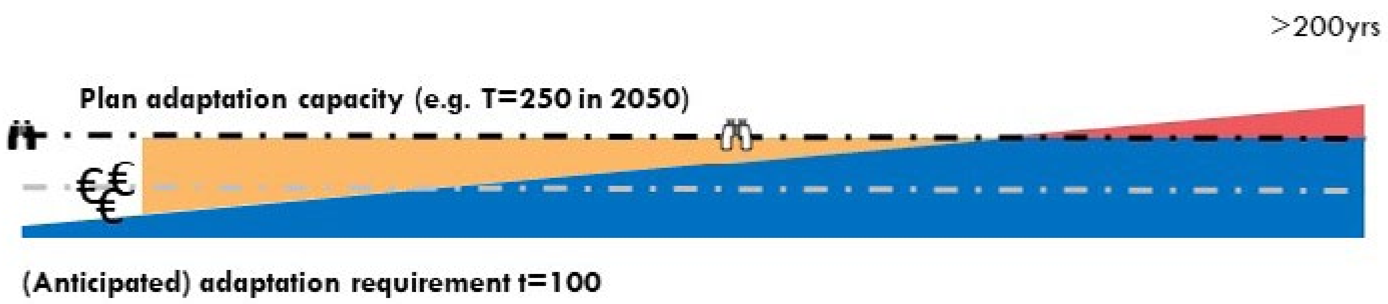
Current rigid development and adaptation norms



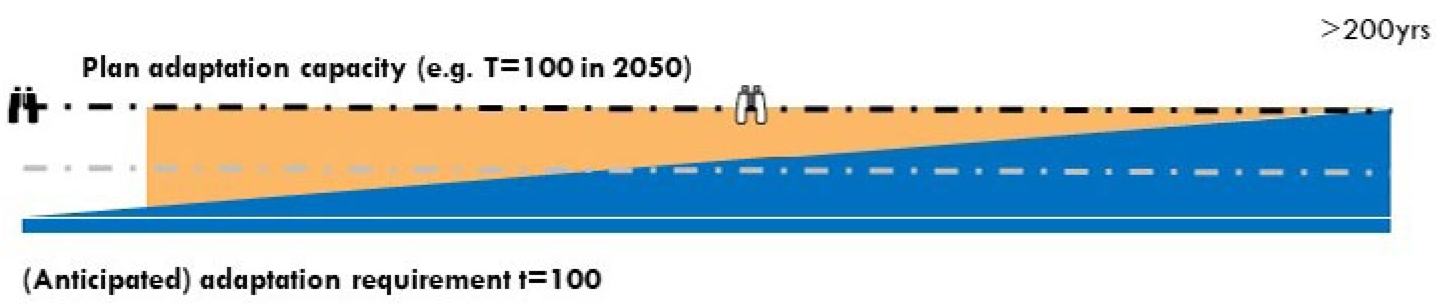
Climate change accelerates



Higher norms in Haven-Stad



Climate change slows



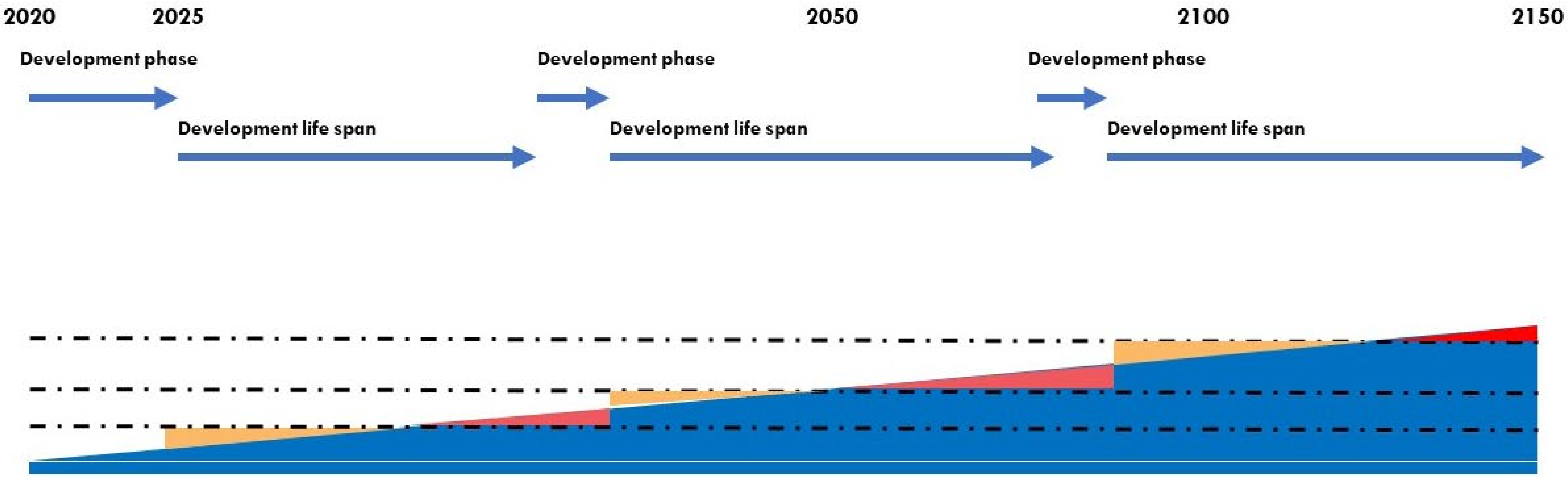
Source: Arcadis bankability analysis for RBD MRA.
Refer to Appendix for further analysis.

Overinvestment
Underinvestment

HAVEN-STAD

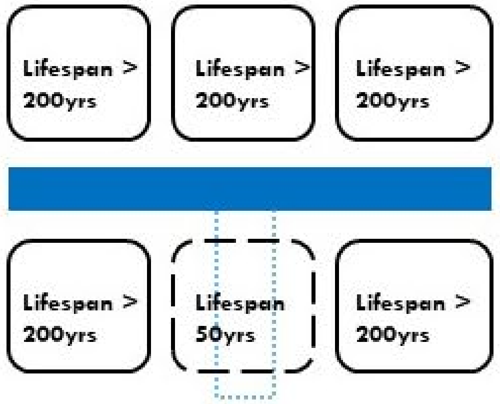
How to achieve adaptive capacity and flexibility

As a result, the way forward relies on creating much more flexibility in the planning process and determine that certain aspects will plan for longer lifespans while other much shorter than average. These measures embed flexibility in the system. These combined measures offer an approach to area-wide adaptation.



(Anticipated) adaptation requirement t=100

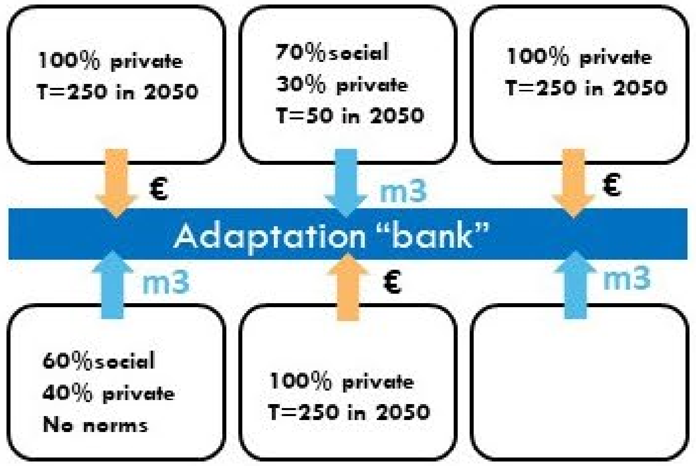
Flexibility and temporality in design



Diversification in norms

Link program and climate adaptation norms

Green blue infrastructure as an "adaptation bank" to transfer m3 and the required € between plots and area's



Source: Arcadis bankability analysis for RBD MRA. Refer to Appendix for further analysis.

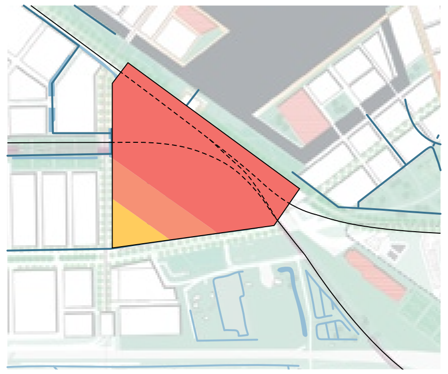
HAVEN-STAD

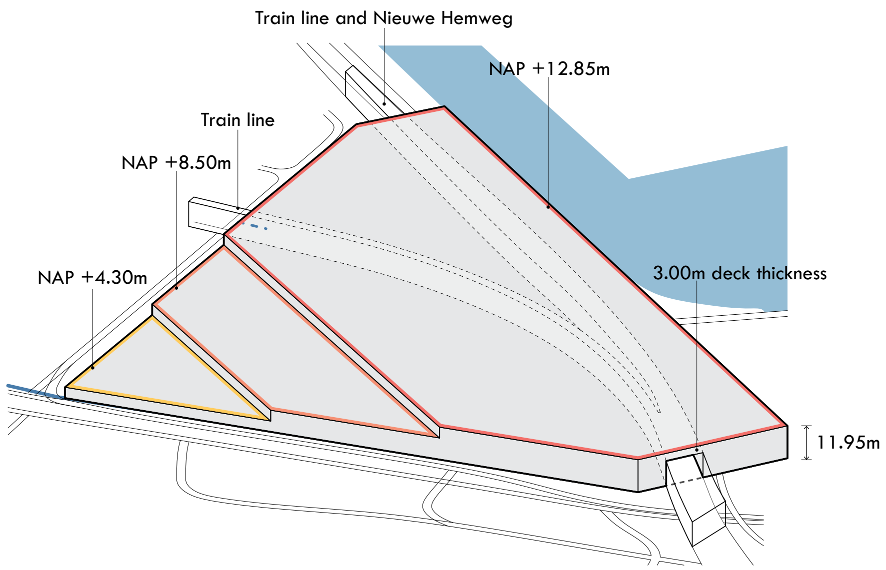
How to achieve adaptive capacity and flexibility

The spatial proposal interrogates the design of the proposed deck for Haven-Stad, which had not taken the existing canals into account. What is currently above ground will become the future underground, and the infrastructure within will remain at the current height because the high groundwater table in the Netherlands makes any excavation prohibitively costly and challenging.

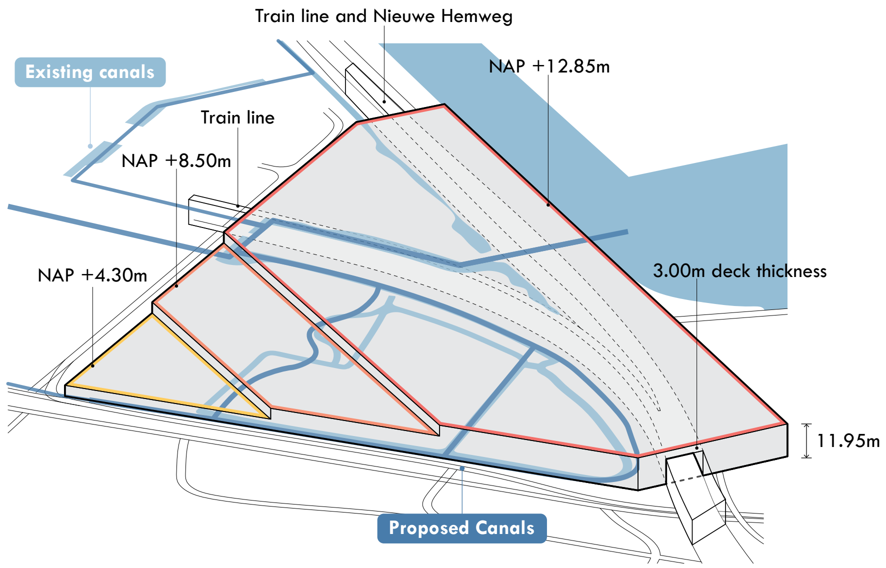
After evaluating the alternatives, the preferred concept keeps some of the existing canals in place and creates a substantial green buffer zone. The buffer zone can support active recreation – soccer fields – as well as detain stormwater. Still, for some of the areas adjacent to the deck, there may need to be other water management solutions. Over time, as the success or failure of our climate mitigation plays out and climate projections become more definitive, there is the potential to replace the soccer fields or extend the deck to create new space for development.

The flexibility creates a more intelligent and cost effective way to address water management and mitigate heat, but it delivers multiple benefits if it can connect the different green structures in the surrounding areas in a better way.

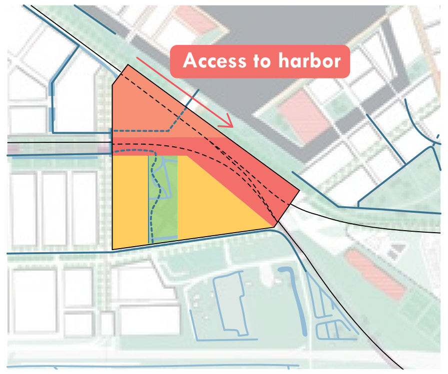


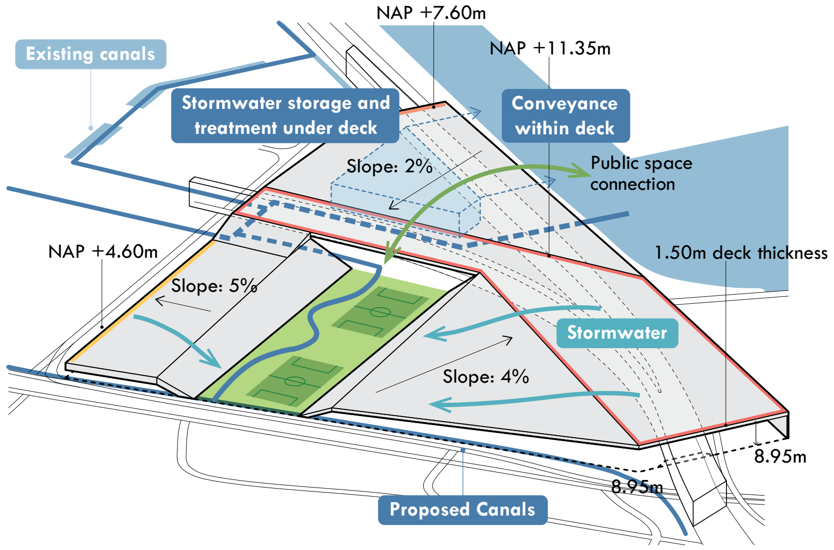


Simple tiers

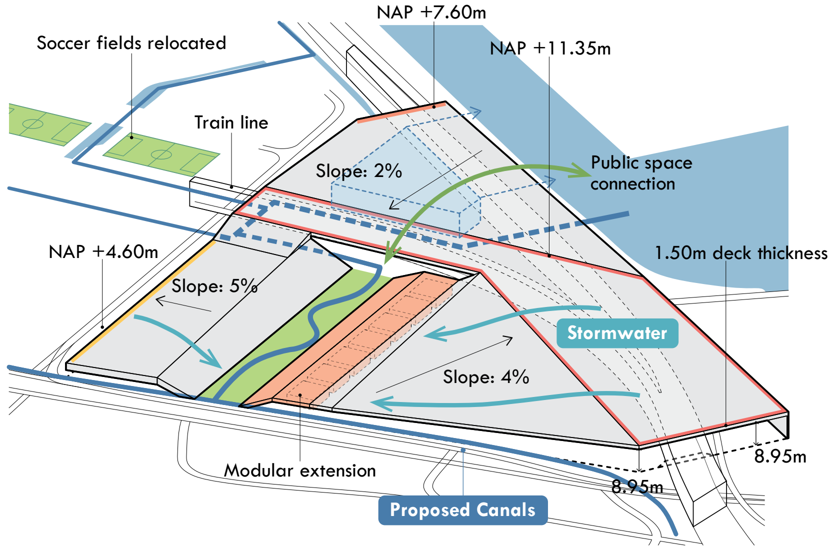


Canal system

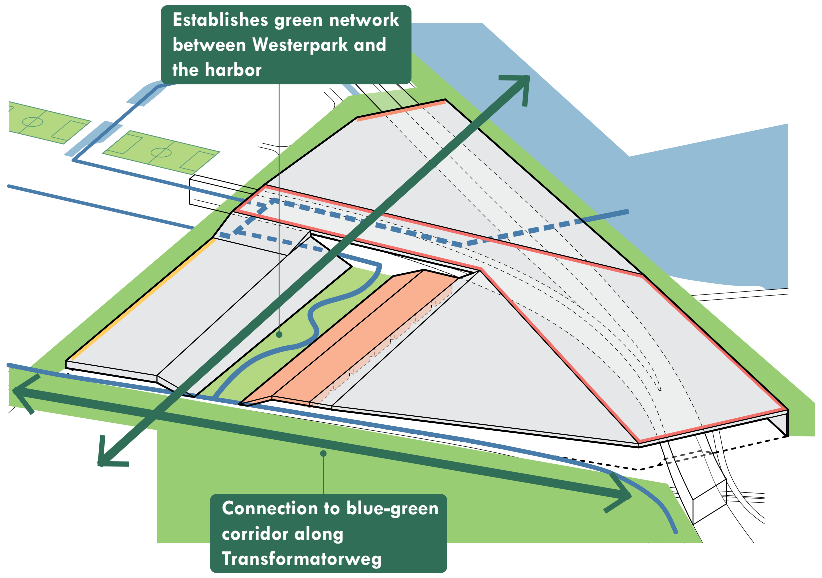




Phase 1



Phase 2



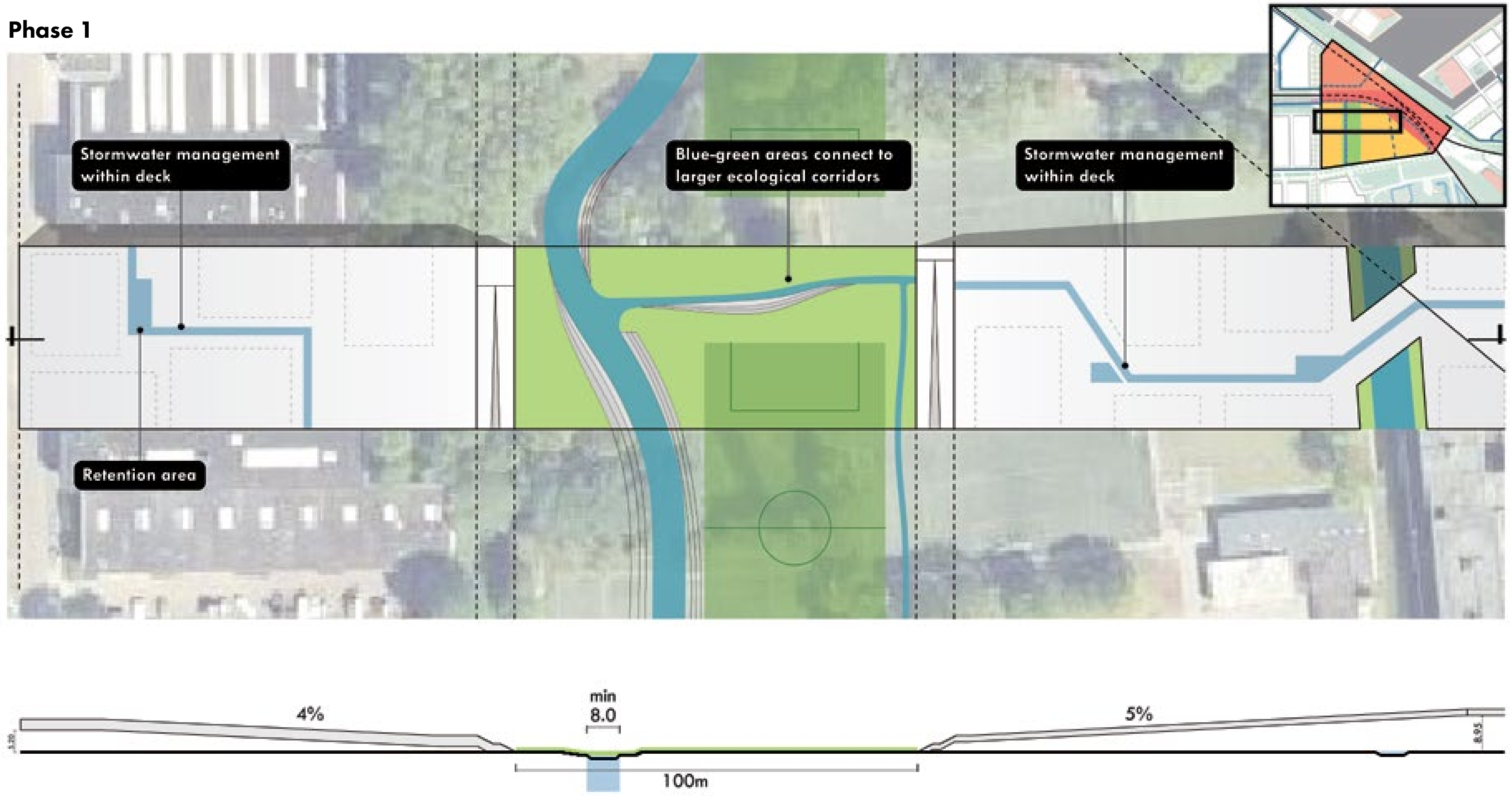
Phase 2

HAVEN-STAD

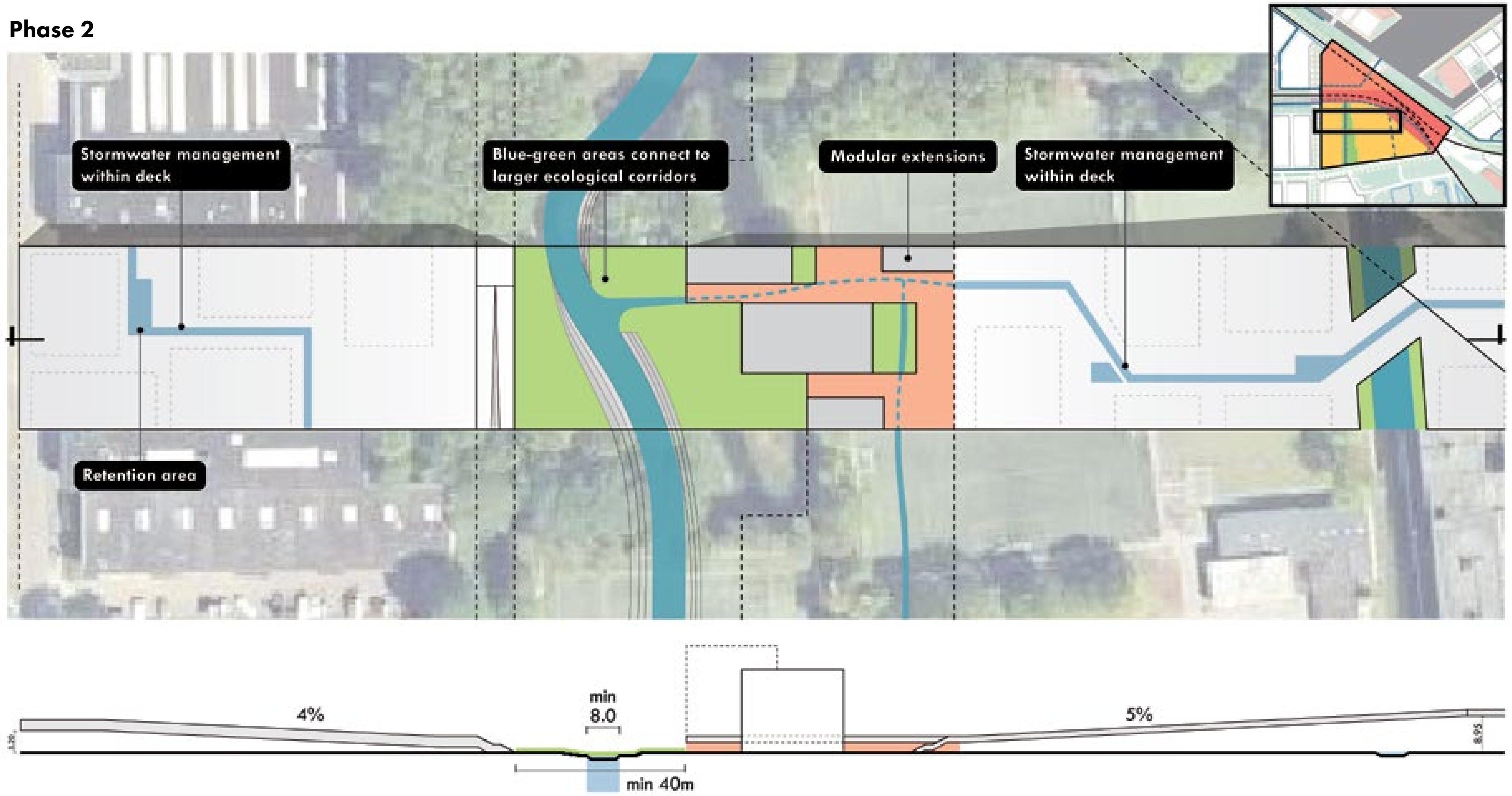
How to achieve adaptive capacity and flexibility

Plan studies and precedents for long-term transformation of the flexible investment approach

Phase 1



Phase 2

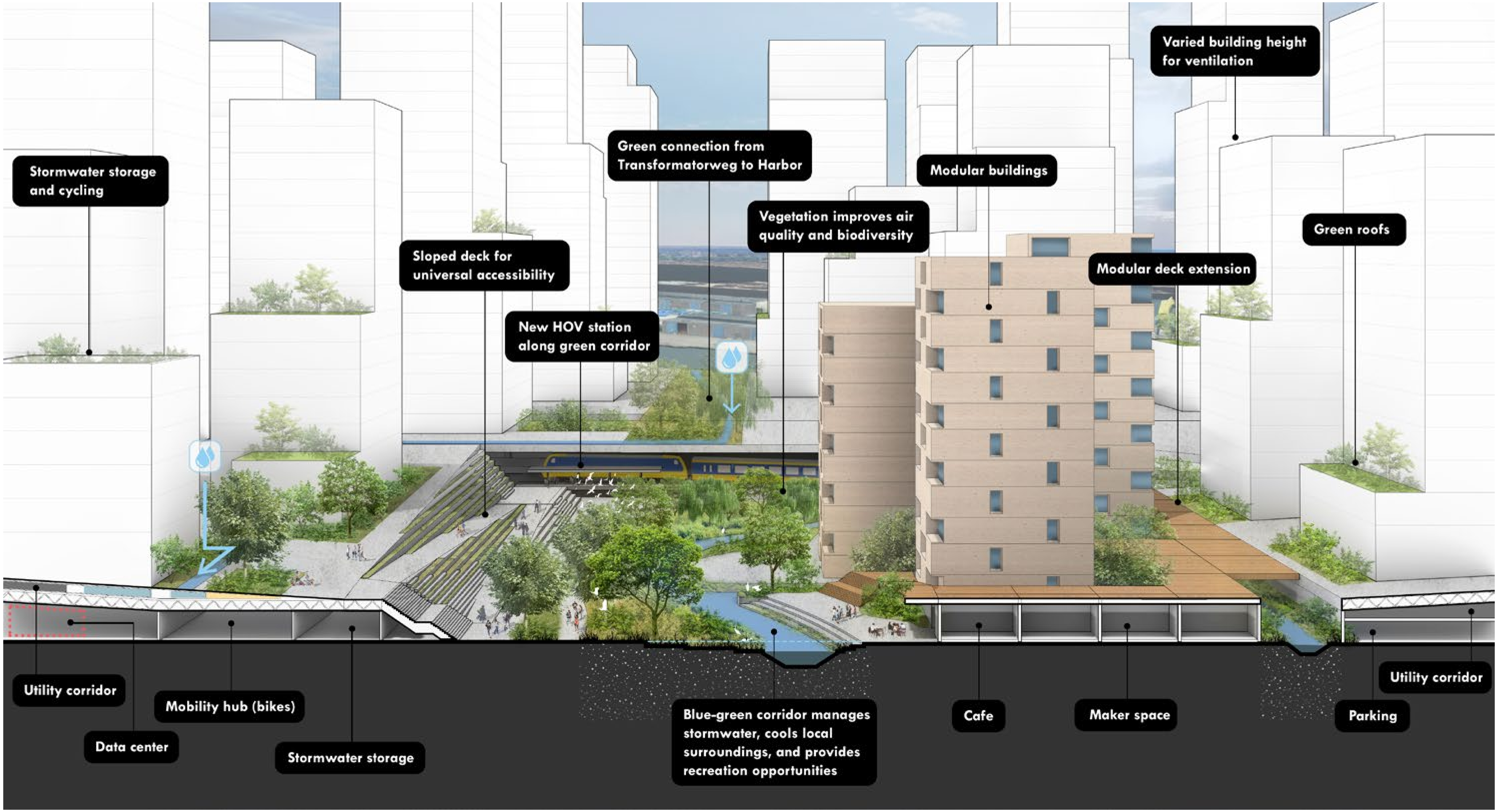


HAVEN-STAD

Opportunities within deck and open space to address climate

The development proposal creates a new urban space that is fully linked with its water strategy. With the station underneath, the deck becomes an important and central green space comprised of modular parts.

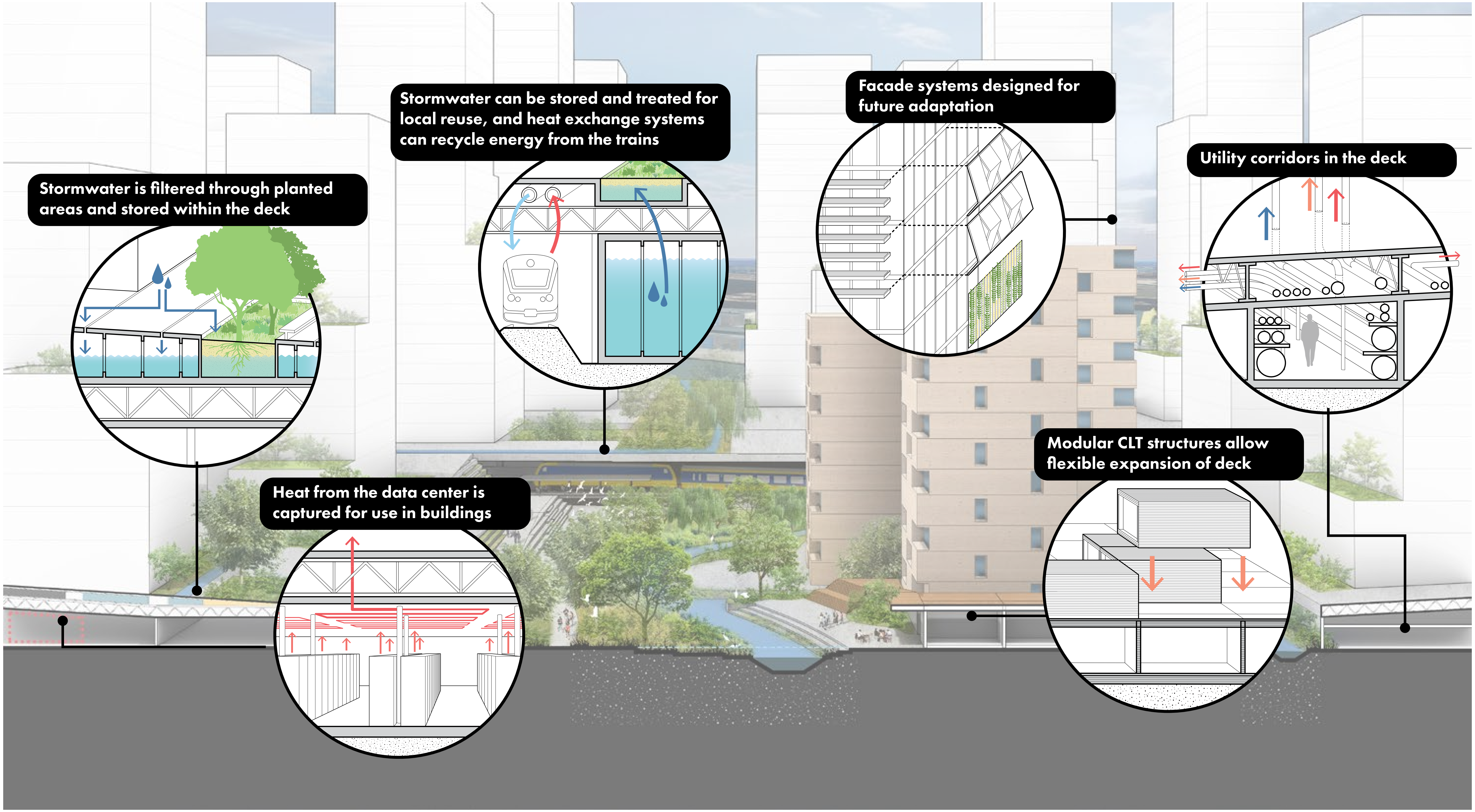
Section perspective of Haven-Stad fully built out



HAVEN-STAD

Opportunities within deck and open space to address climate

The proposal finally explores the technical detail of the deck and its potentials, as there is not yet a complete understanding of how it would perform.



Beverwijk Business Docks

Collaboration by entrepreneurs

BEVERWIJK

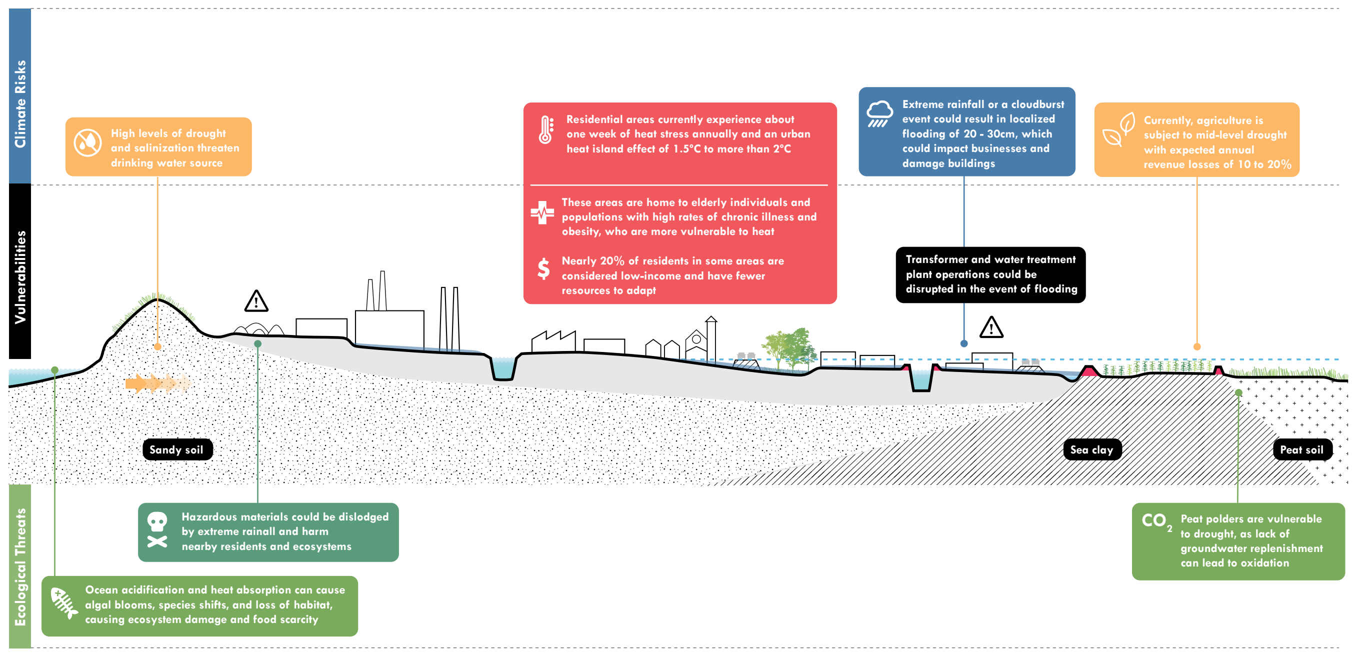
Vulnerability analysis

The Beverwijk area displays a wide range of site conditions, from the dune system to the west, at the coast, to an area where development sits atop sea clay where the Rhine River used to flow through, to an inland area of peat lands with existing industrial land uses.

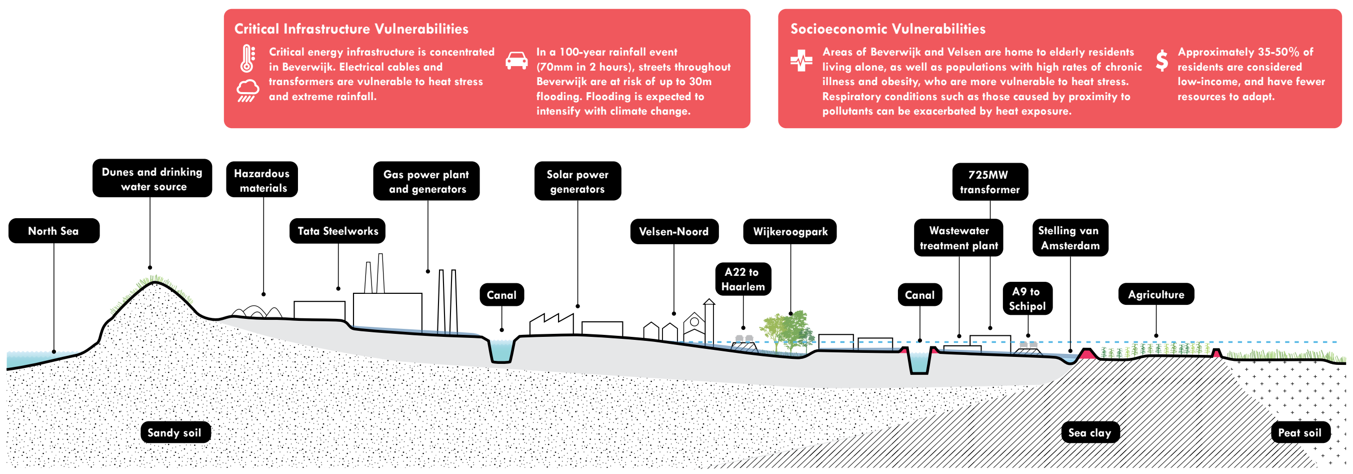
Beverwijk is currently vulnerable to extreme rainfall in both residential and industrial areas. This trend is projected to increase with climate change, causing nuisance flooding that could compro-mise road networks and building stock within the next few decades. Critical energy infrastruc-ture is concentrated in Beverwijk and transformer and water treatment plant operations could be disrupted in the event of flooding.

Adjacent peatlands and agricultural areas are subject to drought. Lack of groundwater replenishment could lead to peat oxidation. Along the dunes, drought threatens freshwater supply. By 2050, areas of Beverwijk are expected to experience three to four weeks of heat stress annually and an urban heat island effect in exceedance 2°C due to large areas of paved surfaces and a lack of trees. Heat stress, including sensible heat (PET), is expected to pose a significant hazard by mid-century and beyond.

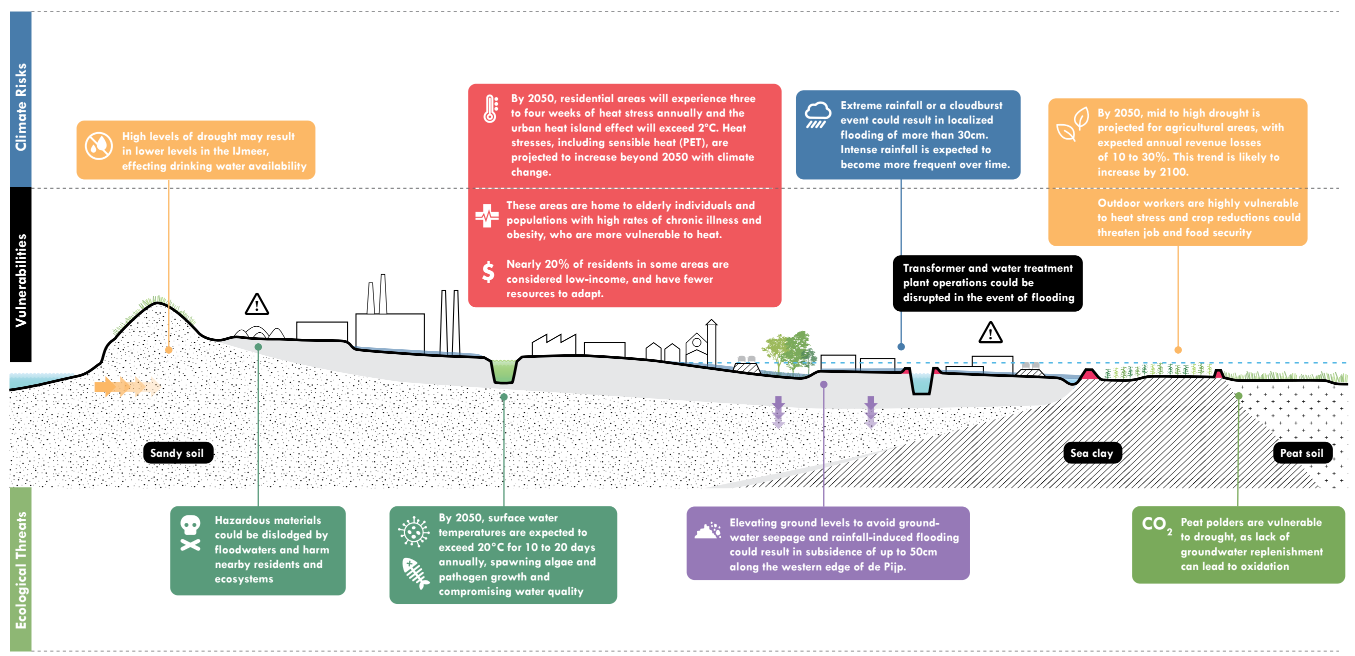
Climate risk 2020



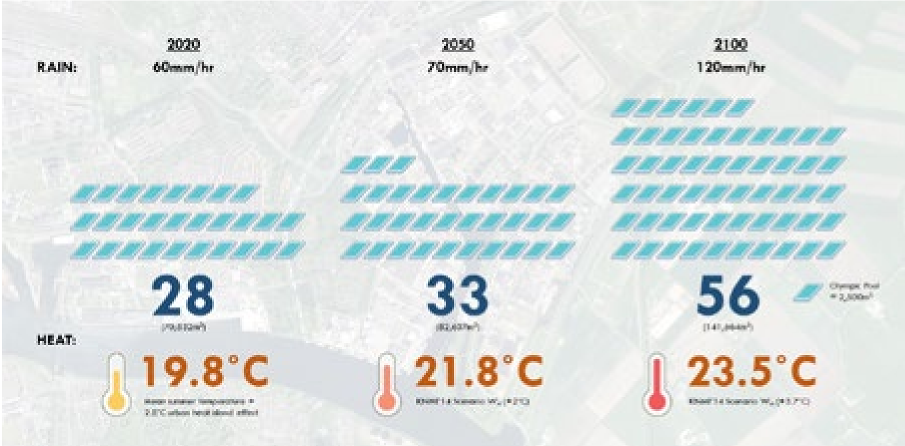
Existing



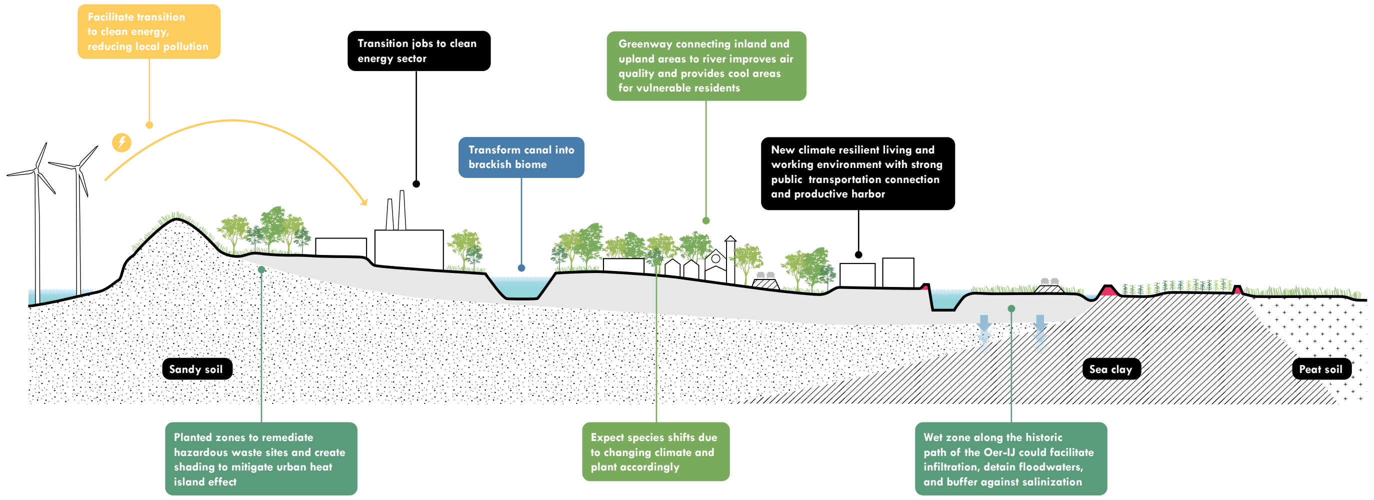
Climate risk 2050



BEVERWIJK
Opportunities

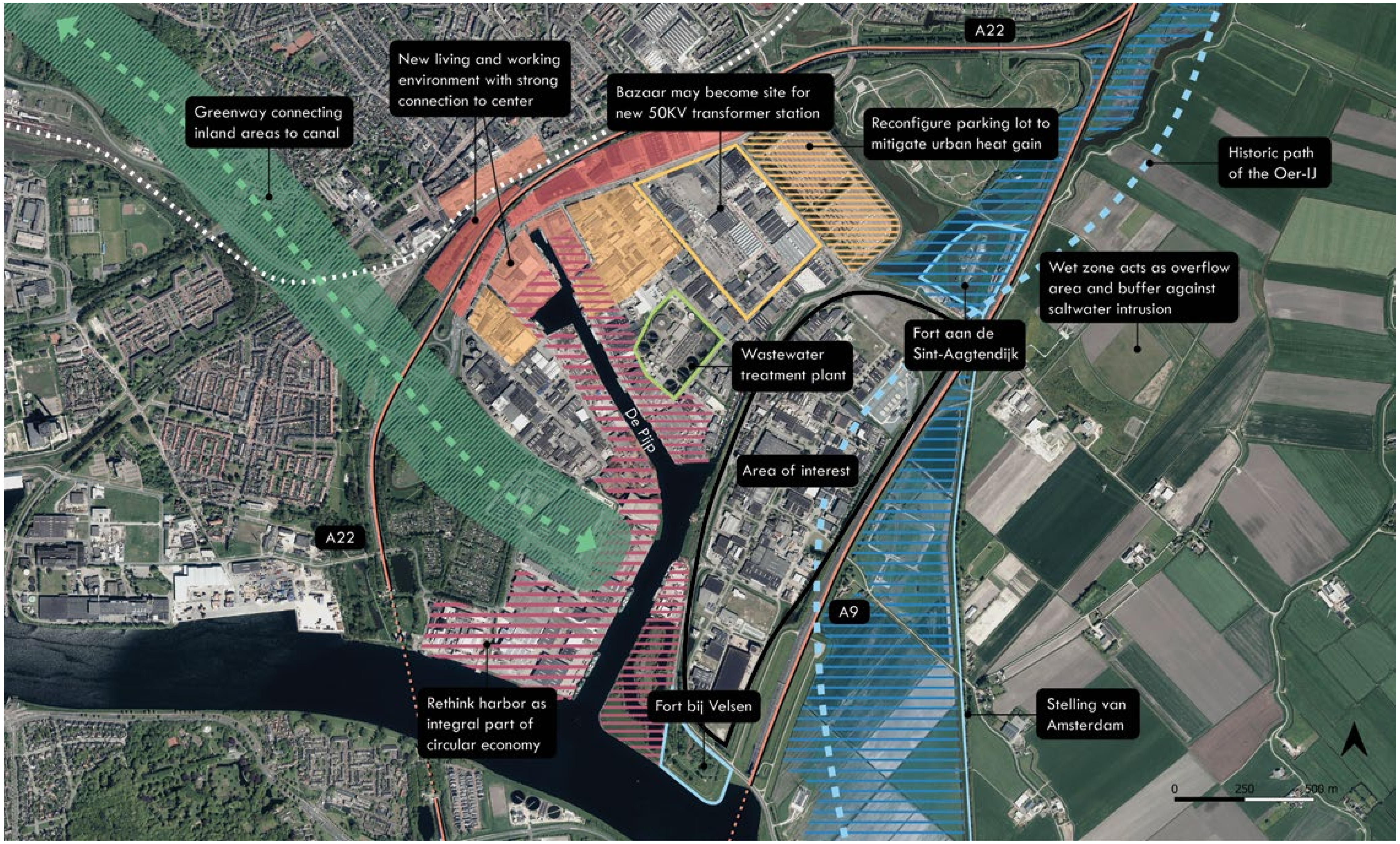


Note: T=100 storm in 2100 (120 mm/hr) follows current practice for stress tests, AGV Waterboard



There are a range of opportunities to start to improve this highly industrial area. The existing built fabric primarily consists of low density industrial properties with some larger infrastructure interspersed.

Visualizing the climate-driven demands on existing land uses shows how significant the demand is today and by the end of the century to accommodate increases in stormwater and mitigate rising average temperatures as well as extreme heat.



BEVERWIJK
Threshold analysis

The Beverwijk case prompts two principal questions: is there a way to reduce the adaptation costs that individual property owners and businesses will bear by helping them collaborate and by linking climate adaptation to the energy transition? And, how can individual align and aggregate to generate area-wide improvements?

Threshold analysis

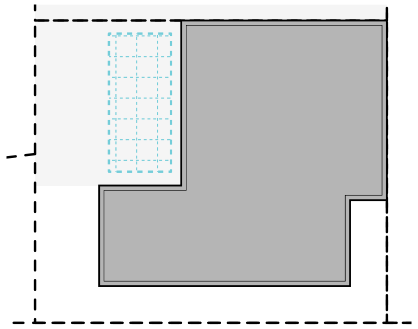
Typical property

2,234 m² Site Area

56% Built Area

44% Parking / Operations

T=100 (2020) Adaptation 60 mm/hr

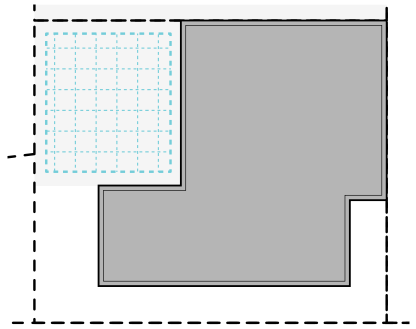


135 m³ Stormwater

180 m² Subsoil Crates*

Total = €89,100

T=100 (2100) Adaptation 120 mm/hr



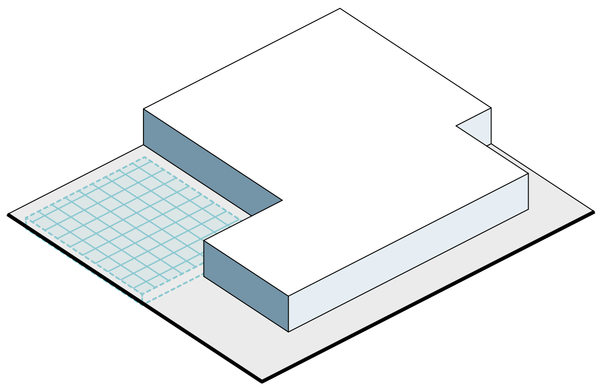
270 m³ Stormwater

360 m² Subsoil Crates*

Total = €178,200

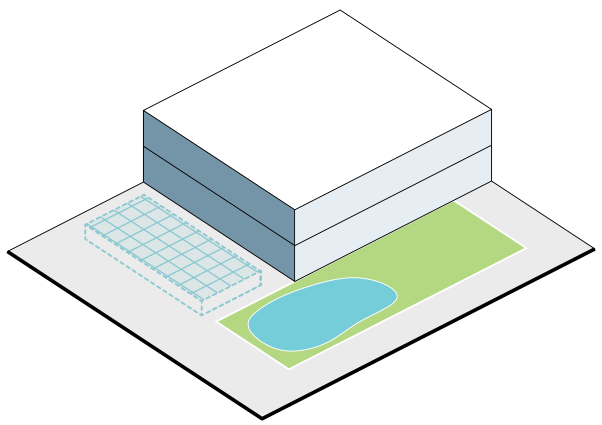
Cost reduction strategy: densify

Densifying creates space for cheaper water storage strategies that require a larger footprint



360 m² Subsoil Crates = €178,200

Total Private Cost = €178,200



180 m² Subsoil Crates = €89,100

300 m² Water Garden = €15,000

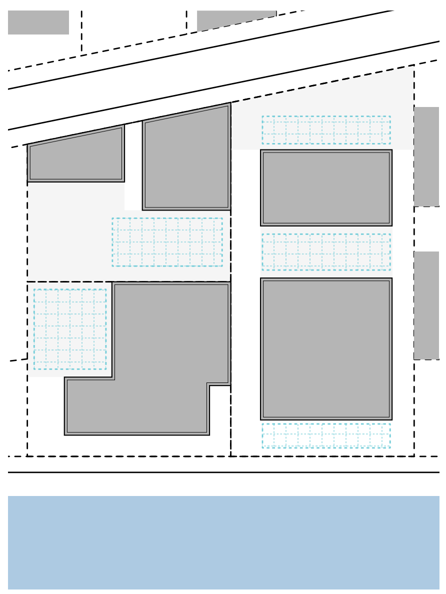
150 m² Open Water = €3,000

Total Private Cost = €107,100

- **Can we reduce the adaptation costs that will fall on individual property owners/businesses by helping them collaborate and by linking climate adaptation to the energy transition?**
- **Can we align individual improvements such that area-wide improvements can be generated?**

Cost reduction strategy: collaborate

Every parcel by itself



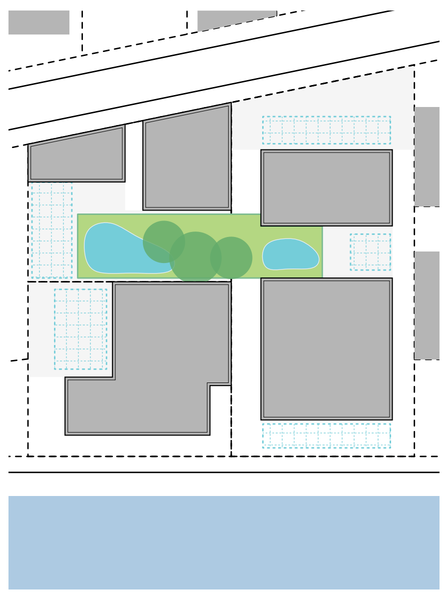
46% Built Area

54% Parking & Operation

1,390 m² Subsoil Crates = €688,100

Total Private Cost =
€688,100

Collectively (20% parking & operation)



46% Built Area

43% Parking & Operation

11% Water Retention

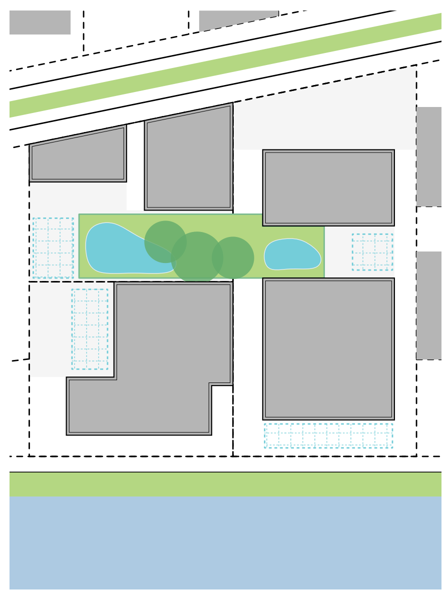
1,000 m² Subsoil Crates = €495,000

632 m² Water Garden = €31,700

300 m² Open Water = €6,000

Total Private Cost =
€532,700

Use Public Right-of-Way



46% Built Area

43% Parking & Operation

11% Water Retention

610 m² Subsoil Crates = €302,200

632 m² Green / Storage = €31,700

300 m² Open Water = €6,000

Total Private Cost =
€339,700

+ 978 m² R.O.W. Storage = €49,000

Private + Public Cost =
€388,700

Note:
T=100 refers to a storm where rainfall totals that have a one percent probability of occurring at that location in that year.

** Assumption for stormwater storage, infiltration after storms may require additional aid.*

BEVERWIJK
Cost reduction and benefits

Examining a prototypical parcel helps to identify the likely cost of adaptation and think through different ways to seed more efficient land use practices for collective benefit. It points to the value of using the right of way and sharing uses across property boundaries to share functions.

As a model for collective action, the case study shows the benefit of planning adaptation in a much more integrated way, creating and locating green spaces where they provide the greatest benefit by improving and cooling the microclimate at a reduced cost.

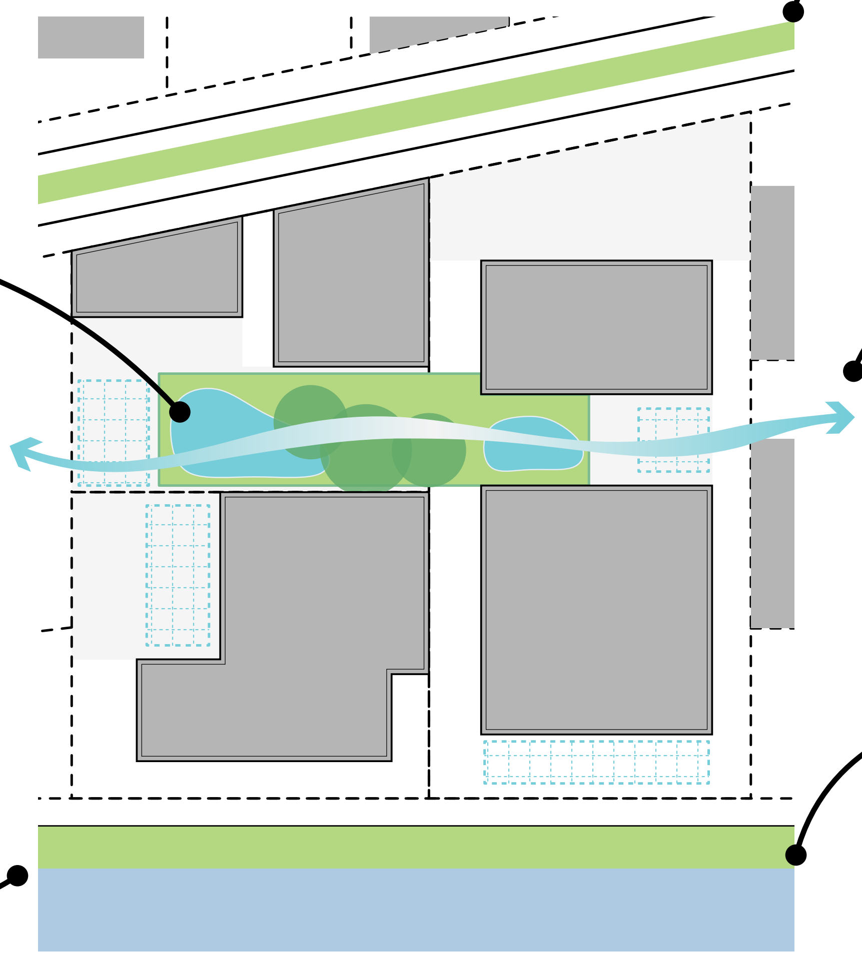
Still, the model of collective action raises new questions about the necessary organizational and management entity to facilitate maintenance and coordination over the life of the project.

A collective, district-wide system is better prepared to connect with future developments

Green areas, trees, and surface water features are great opportunities for placemaking and friendly communal spaces

Cambridge UK

Connection to the canal (with valves) potentially facilitates water management in both direction



Bioswale in public R.O.W. filters surface runoff and adds stormwater storage capacity

30th Ave SW, Seattle USA

Central, connected green space improve the quality of the site and mitigate heat stress by facilitating ventilation and night cooling

Greenway along the waterfront helps avoid solar heat gain on the facades and manage sheet flow

BEVERWIJK
Pooling resources

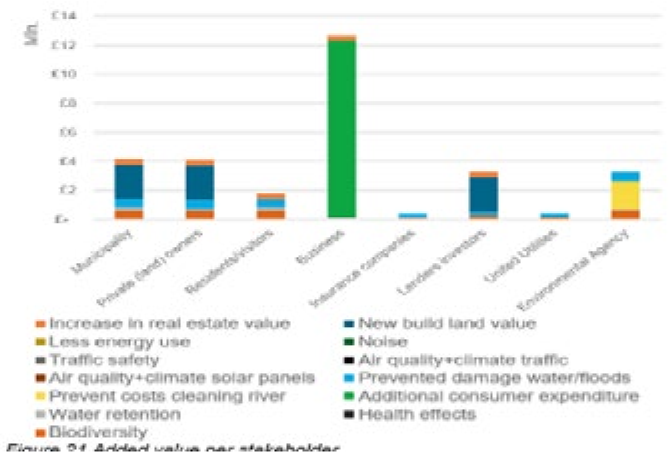
Proposal: activate the business community (Greenbiz)

Initial spatial-financial analysis demonstrates that there are many possibilities for optimizing adaptation costs and benefits through collaboration between property owners, and between property owners and the municipality, especially when these collaborations are linked to the ongoing transformations in the area.

Local business organizations embraced these results, and added that it would be interesting to link deeper to the energy transition, where local entrepreneurs are already making headway.

A next step would be to organize a 'tailor-made' 'resilience-by-design 'optioneering' session, focused on Beverwijk Business Docks.

- Further develop tools and images that show multiple optimization possibilities and benefits.
- Focus upon results that show costs and benefits of such solutions, show the financial arrangement and allocate both costs and benefits to stakeholders
- Discuss insights gained with all stakeholders (small enterprises, city council, industry local business representatives, waterboard, health-sector/ insurers)
- Identify the roadmap towards implementation; the financial instruments that need to be applied to capture all benefits identified, identify opportunities and willingness to co-finance the transition

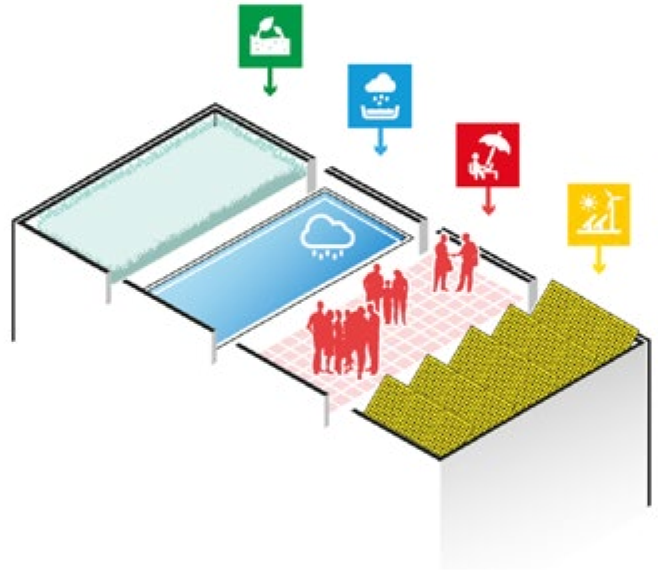


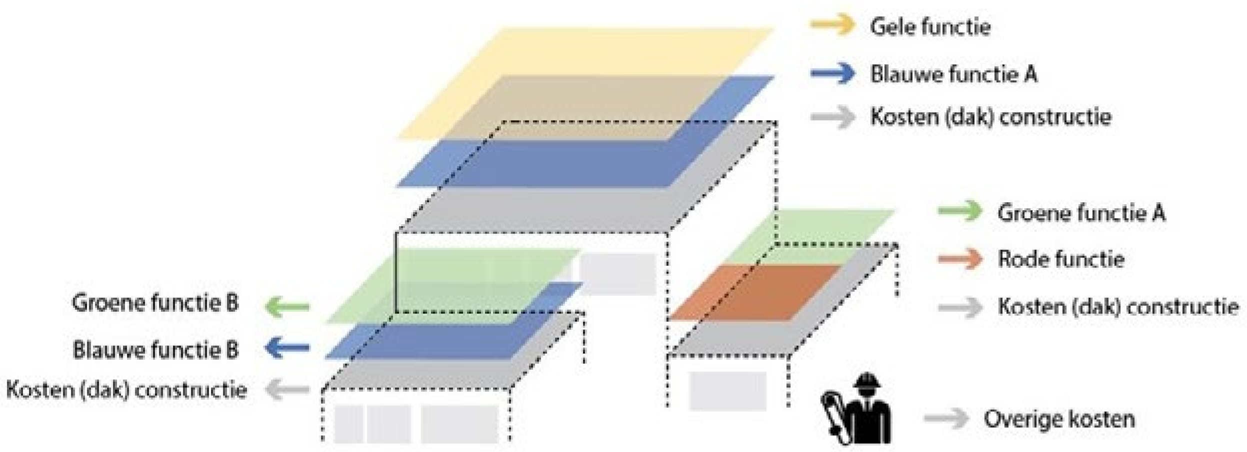
Source: Arcadis bankability analysis for RBD MRA. Refer to Appendix for further analysis.

Working with stakeholders from GreenBiz, the local business association, the next steps are to activate the business community as partners in the development of the project and start to think about this transformation in a much more integrated and collaborative way, by developing a toolkit and process. In Beverwijk, the project relies less on a financial outcome or a design than a process to inform a different set of practices around adaptation and collaboration.

Case study: linking climate adaptation and the energy transition through green/blue/yellow roofs

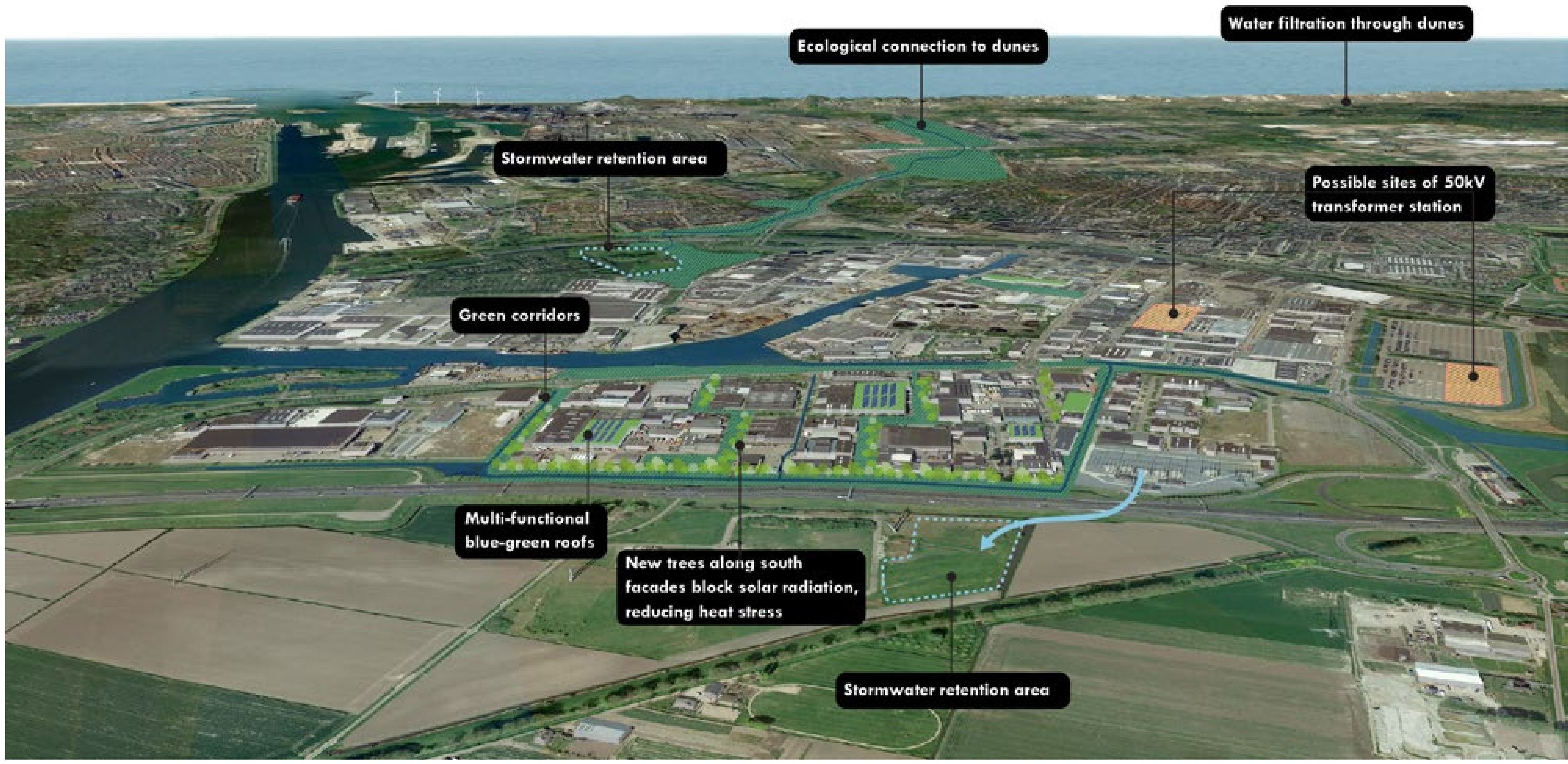
- On existing roofs the current construction limits additional values of multi-functional roofs. In areas and circumstances like Beverwijk-Bazaar this is not the way to go
- However, if existing buildings need to be completely renovated or new buildings are planned, the application of multi-functional roofs are feasible. The business case appears to be very positive, climate risks will be limited, additional values are clear. The results show an initial financial arrangement to discuss
- Our advice is to focus on the implementation, by both regulation and co-financing / funding of multi-functional roofs. This in order to ensure that climate adaptation will become a 'normal' part of integrated investment decisions, when renovations or new buildings are planned

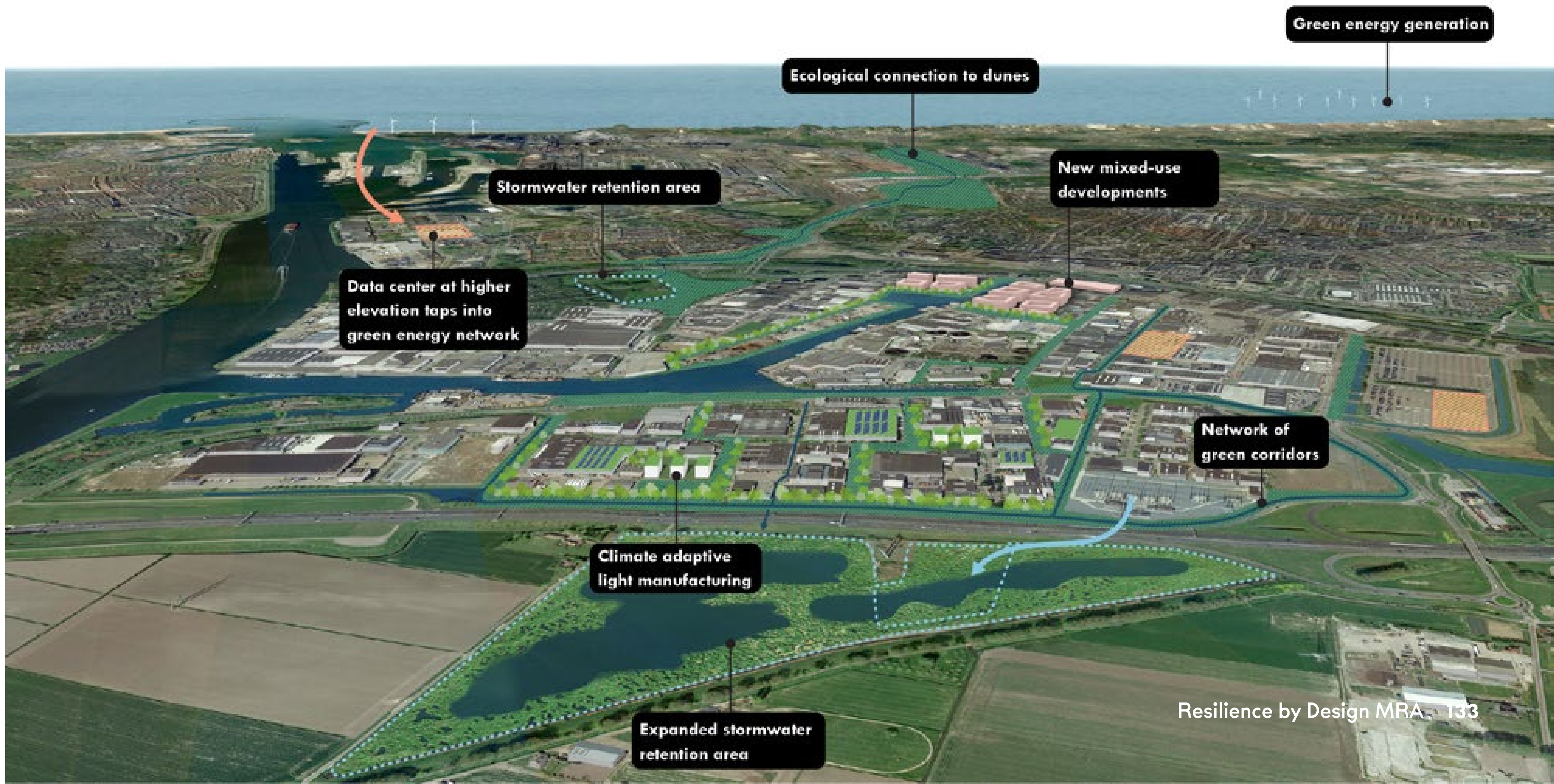




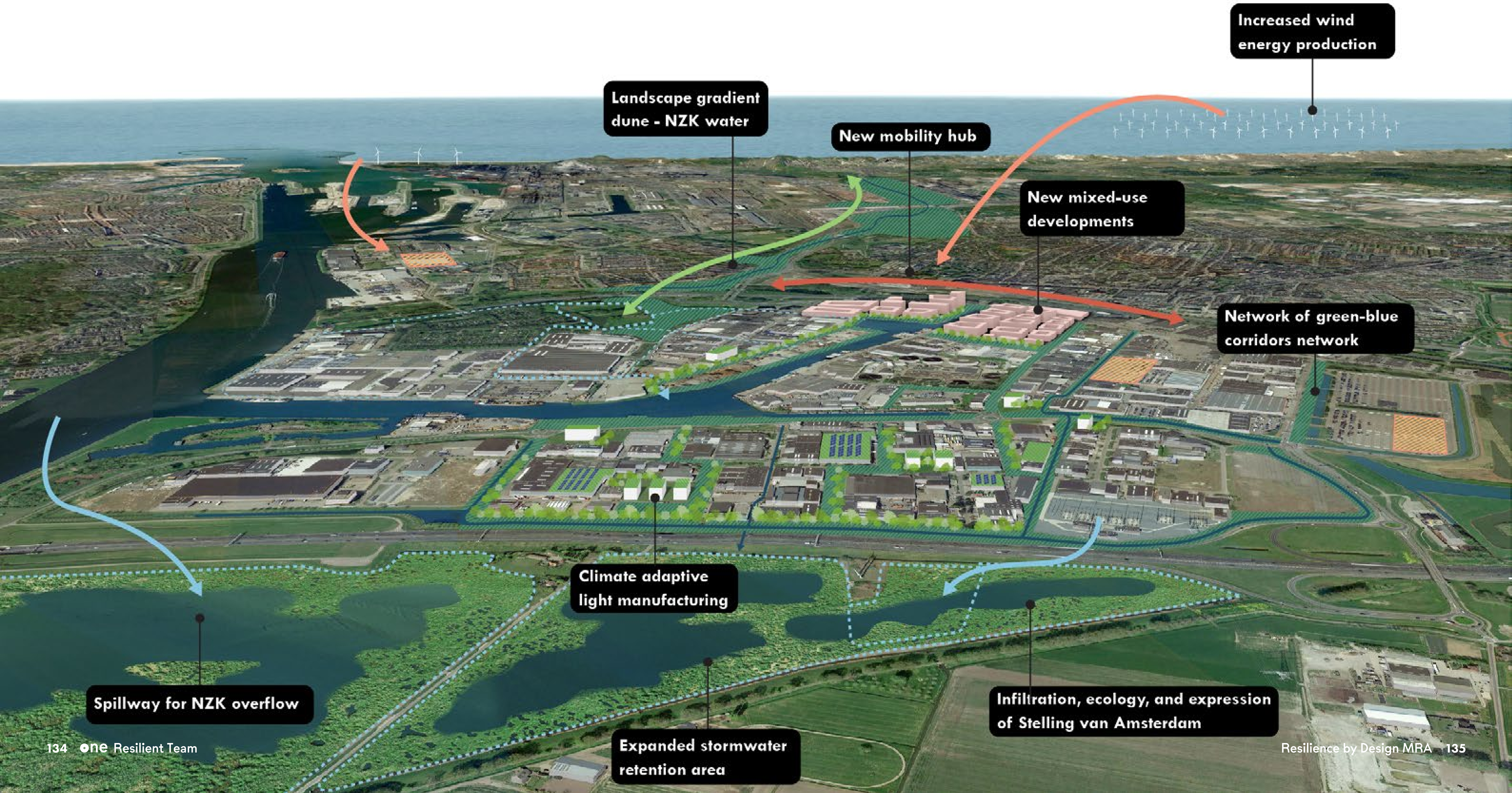
BEVERWIJK
Collaborative vision

Over time, a new network of collaboration can lead to a stronger and healthier public realm, transforming the area with improved open space assets and reducing the impact of a changing climate to local industrial businesses.





BEVERWIJK
Collaborative vision



Haarlem Schalkwijk

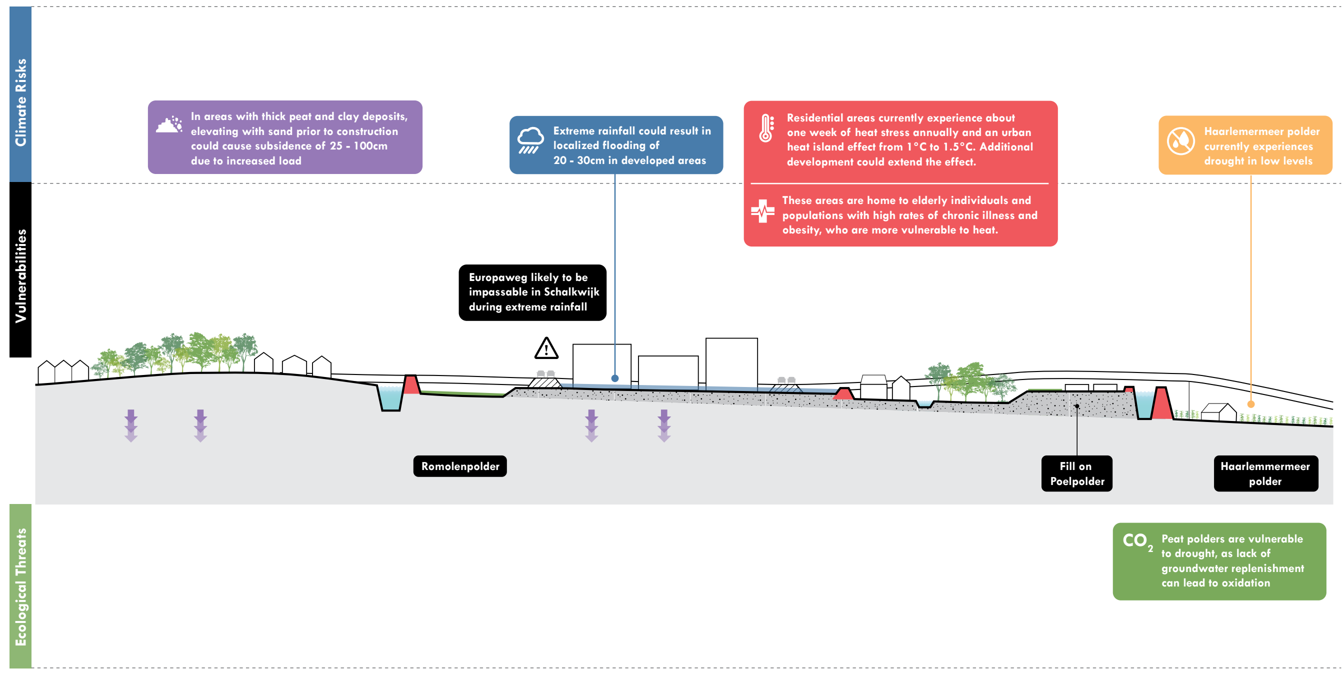
Trees as a link

HAARLEM
Vulnerability analysis

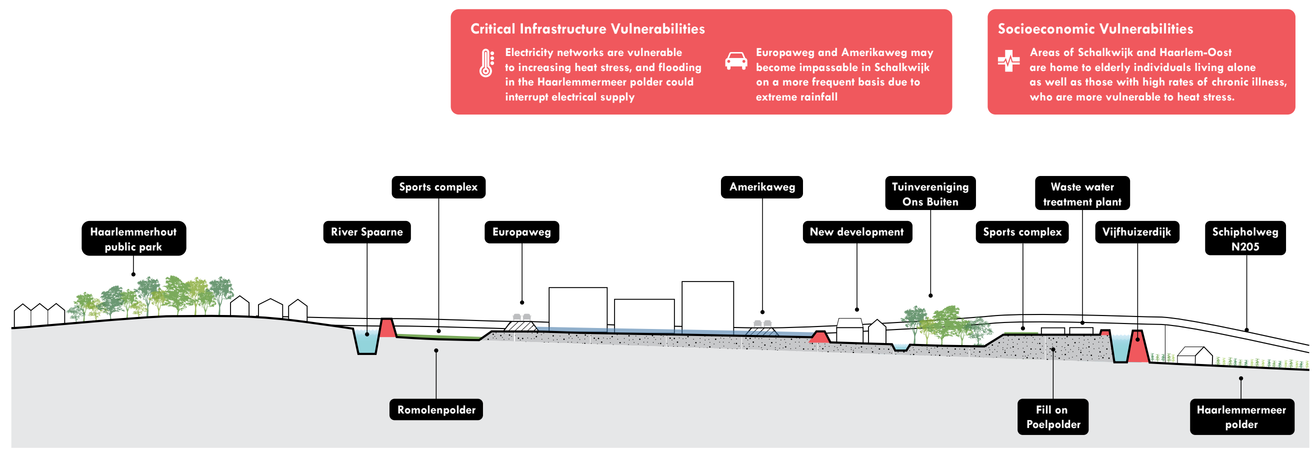
The final demonstration project concerns a site on the eastern side of Haarlem. It has elements of a dune- related system, but primarily is composed of polder that contains a 1950s-1960s neighborhood surrounded by an interesting green buffer zone as was characteristic of the post-war era.

Extreme rainfall currently results in localized flooding in highly trafficked, developed areas. Europaweg and Amerikaweg are projected to become impassable on a more frequent basis due to increasing rainfall caused by climate change. Electricity networks serving Schalkwijk are vulnerable to increasing heat stress, and flooding in the Haarlemmermeer polder could interrupt electrical supply to surrounding areas. Agricultural districts adjacent to Schalkwijk are at risk of 60cm subsidence by 2050. Increasing drought and lower groundwater levels due to climate change could exacerbate the issue, leading to peat oxidation and vegetation stress. By 2050, developed areas are expected to experience two to three weeks of heat stress annually and an increased urban heat island effect. If current trends continue, heat stress will increase significantly through the end of the century. Many of the street trees in the area are reaching the end of their lifespan and the species diversity is relatively low. This could lead to continued mass die-offs resulting in periods of low canopy cover and little shade. The current condition of the tree stock may provide an opening for an integrated approach that simultaneously addresses water, heat, and ecological challenges.

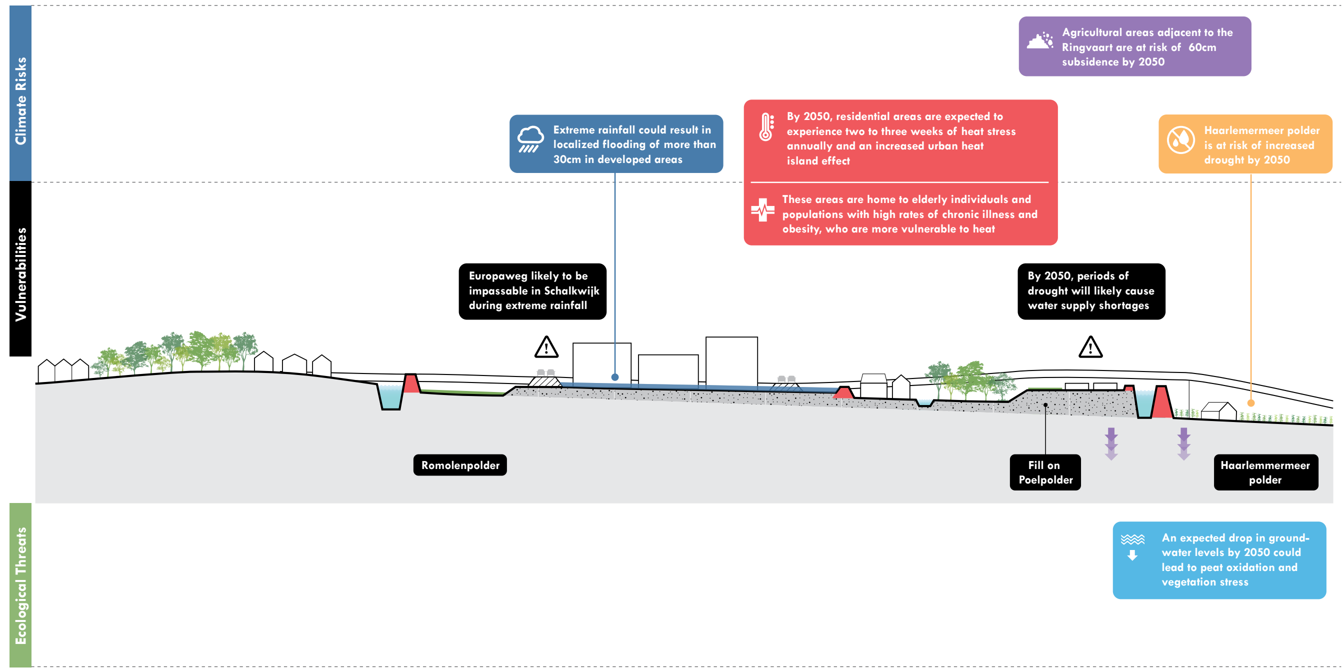
Climate risk 2020



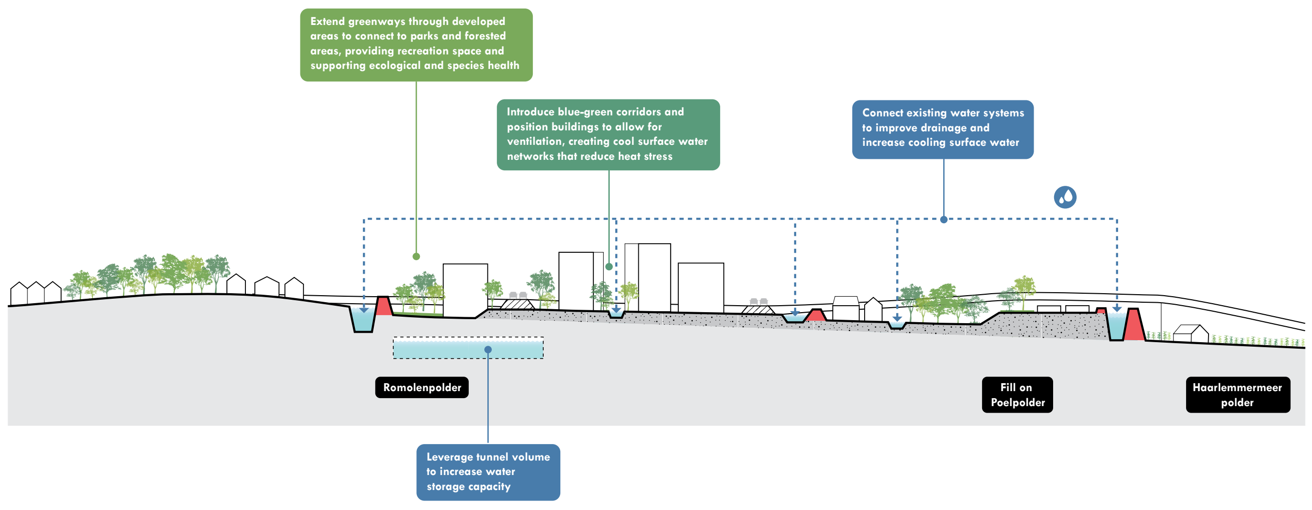
Existing



Climate risk 2050

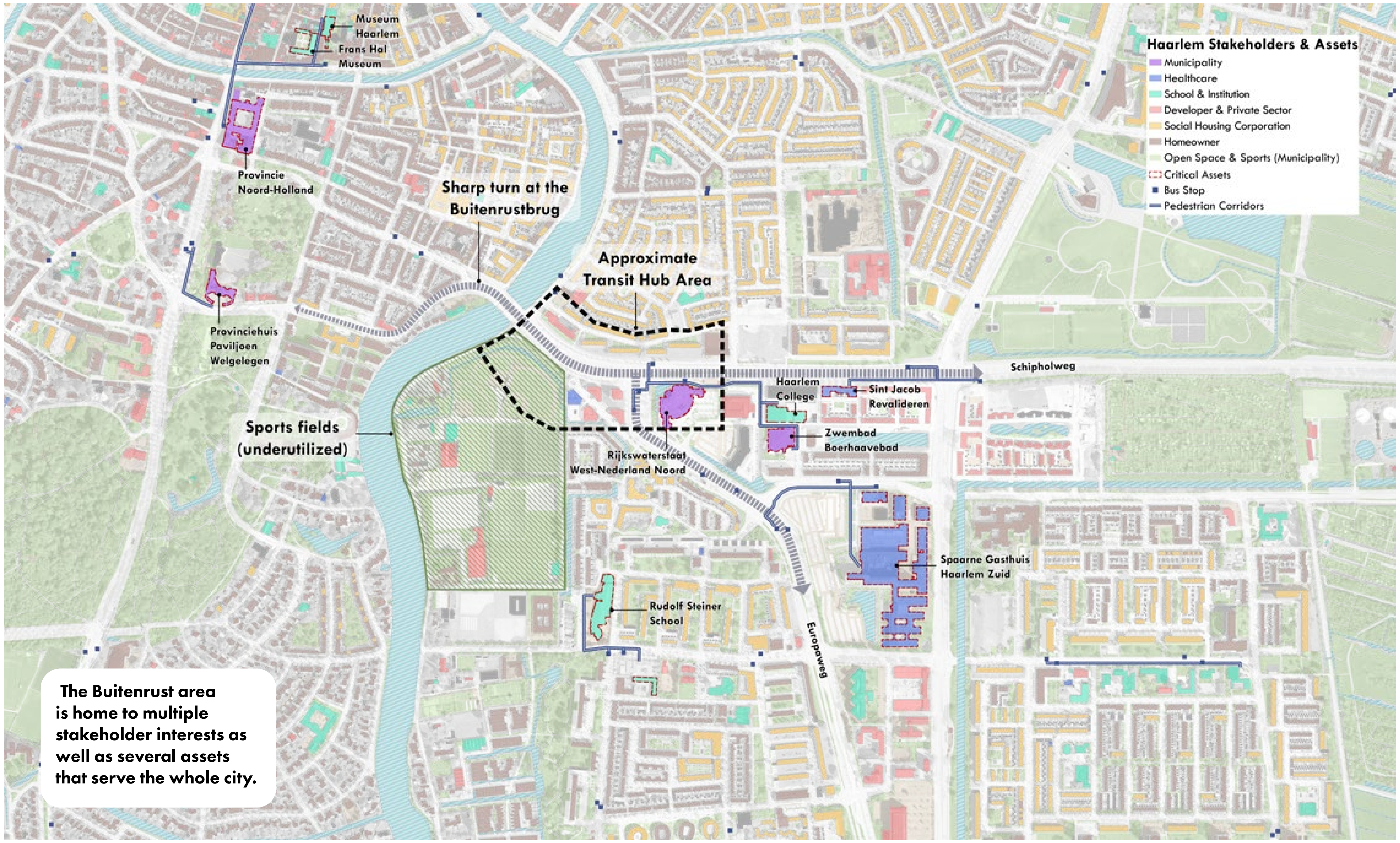


HAARLEM
Opportunities



The Haarlem site exemplifies how the transformation process can be used to link climate systems in a novel way.

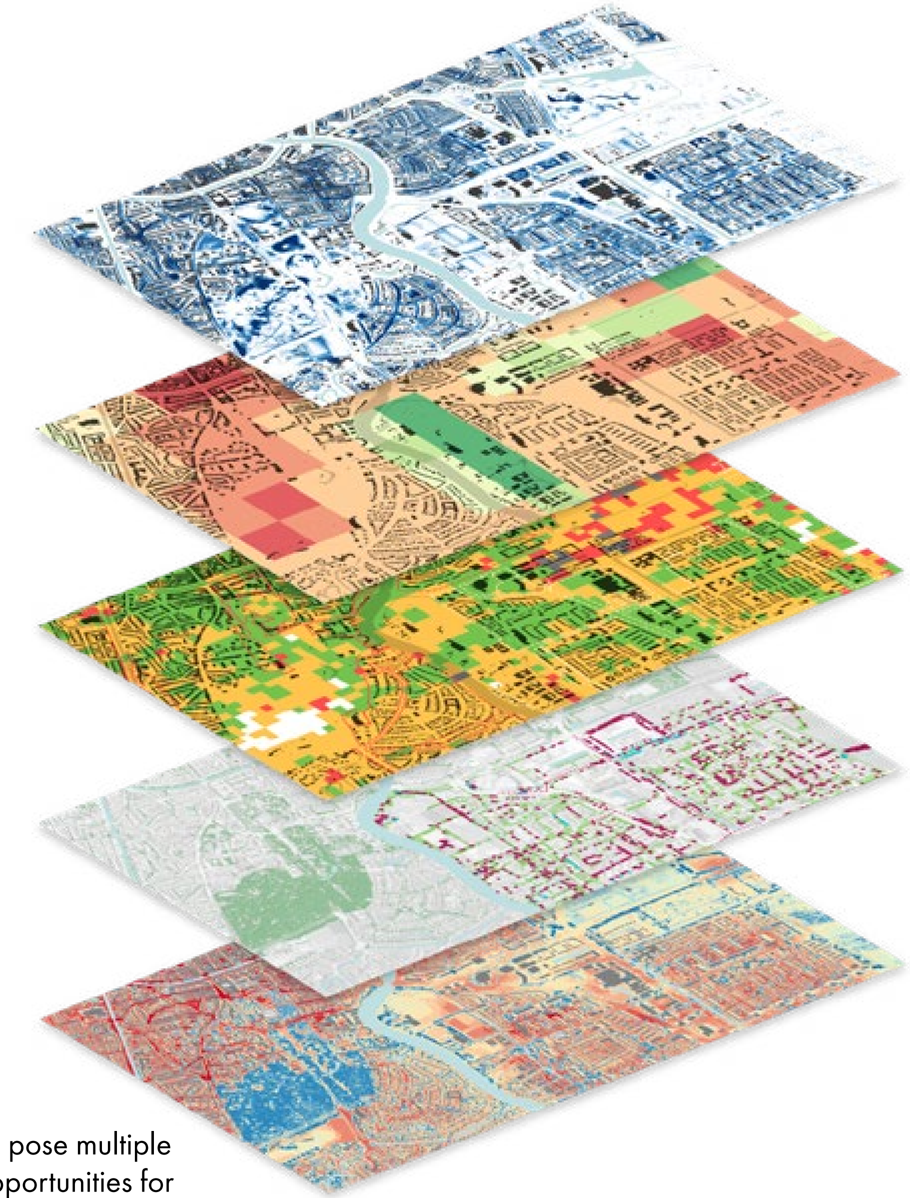
The pattern of post-war development is evident, not exactly towers in the park, but drawing upon CIAM and other work that period as a reference. The area centers on a transit hub that is slated for future development because it provides a major link to central Amsterdam and to the airport. There are some sports fields that are underutilized. The area is remarkably diverse with many local stakeholders.



HAARLEM
Climate stresses

Here, again, the questions for climate adaptation revolve around a shared approach to heat and stormwater: is there a way to use trees to highlight the links between urban heat mitigation and water management? For the identified focus area, is there a way to increase density along with enhancing the tree canopy and local the green-blue infrastructure? Last, is there a way to leverage a conversation about trees to build capacity within the neighborhood and create new connections between actors?

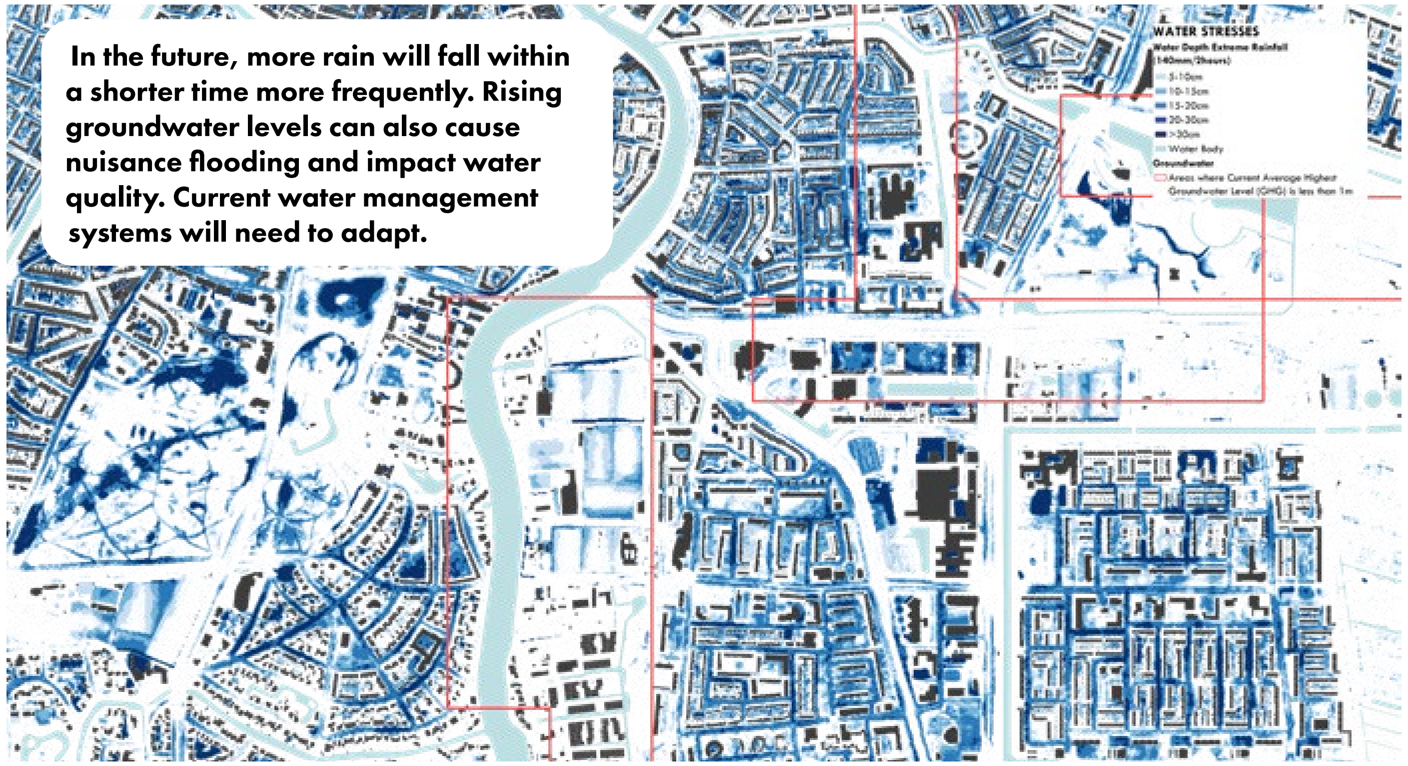
Through a fine-grained mapping exercise it is possible to link and layer the different climate stresses to understand how they relate and overlay their impacts on the neighborhood. These analyses focus on the water stresses related to extreme rainfall, as well as on the heat and drought stresses that already exist today. Heat and drought manifest as significant risks to the area. In addition, research points to an emerging challenge with the existing tree canopy, where many trees are nearing the end of their lives.



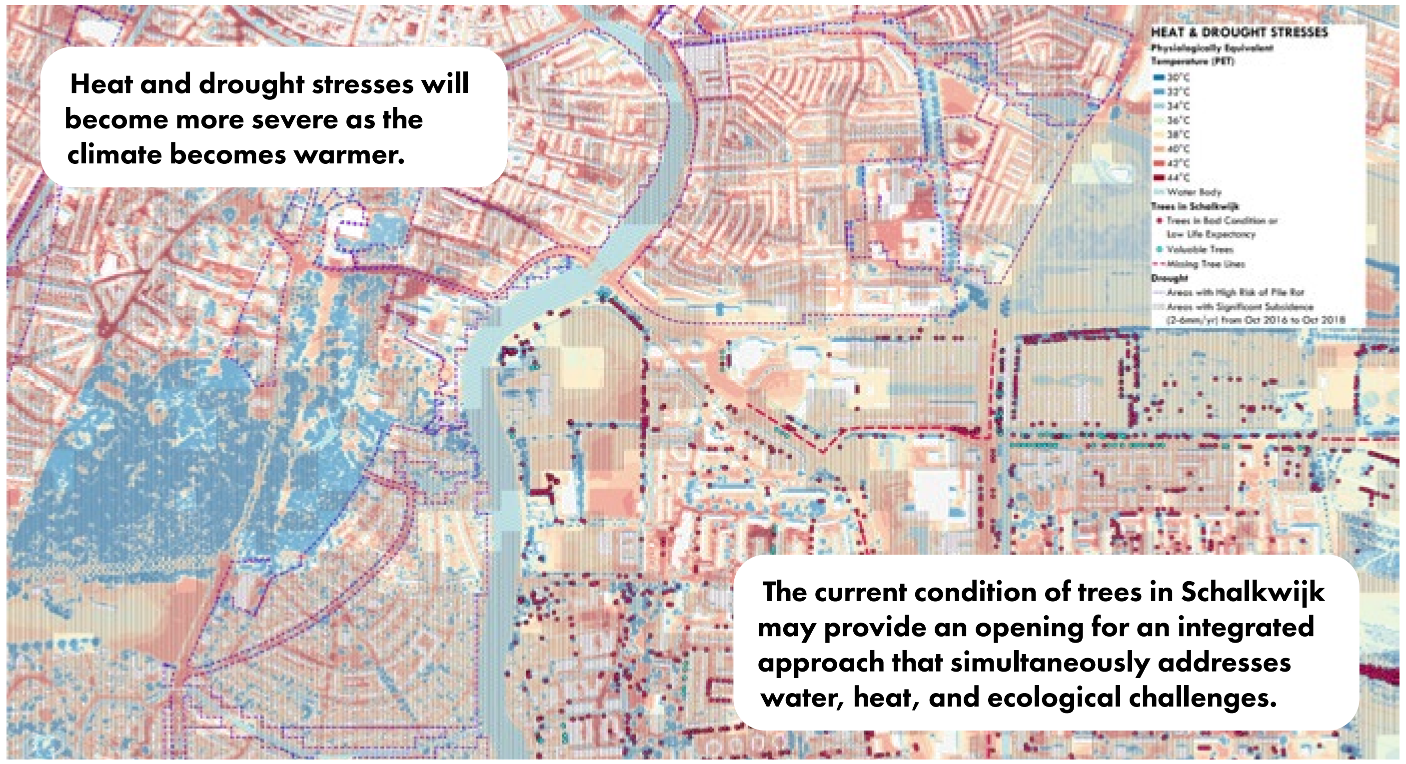
A combination of climate stresses could pose multiple challenges, but they could also offer opportunities for integrated designs.

- **Can we use trees to highlight links between urban heat mitigation and water management?**
- **Can the area be densified while increasing the tree cover/green-blue infrastructure?**
- **Can we use a conversation about trees to build capacity within, and connect between, actors?**

Water stresses



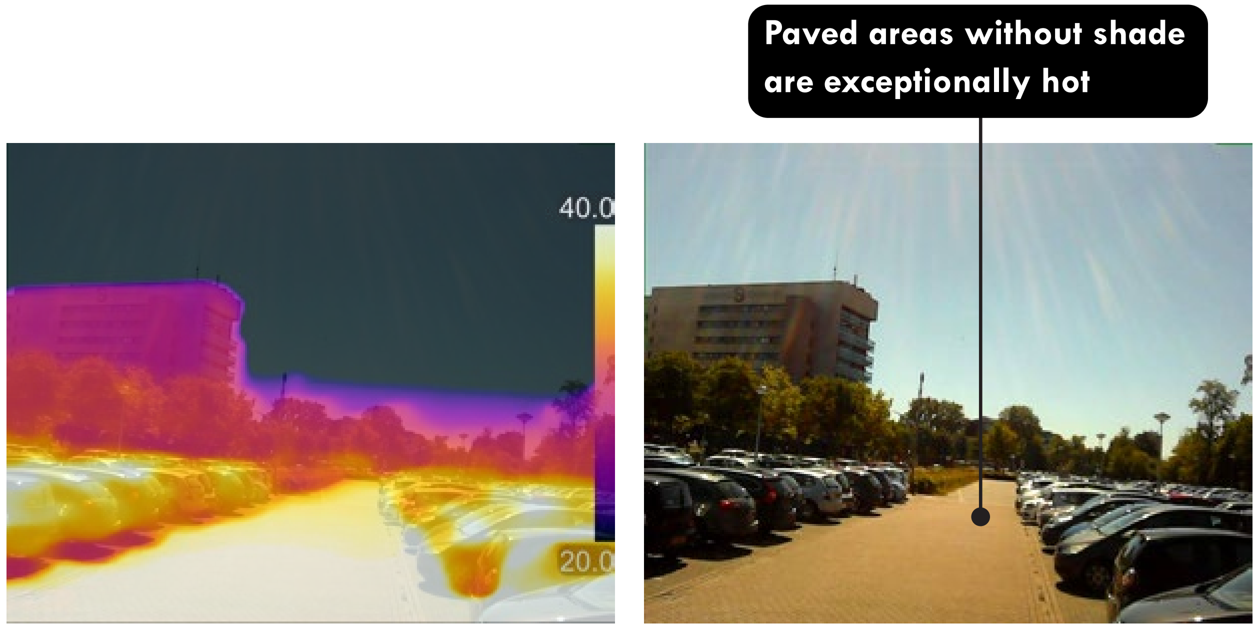
Heat and drought stresses

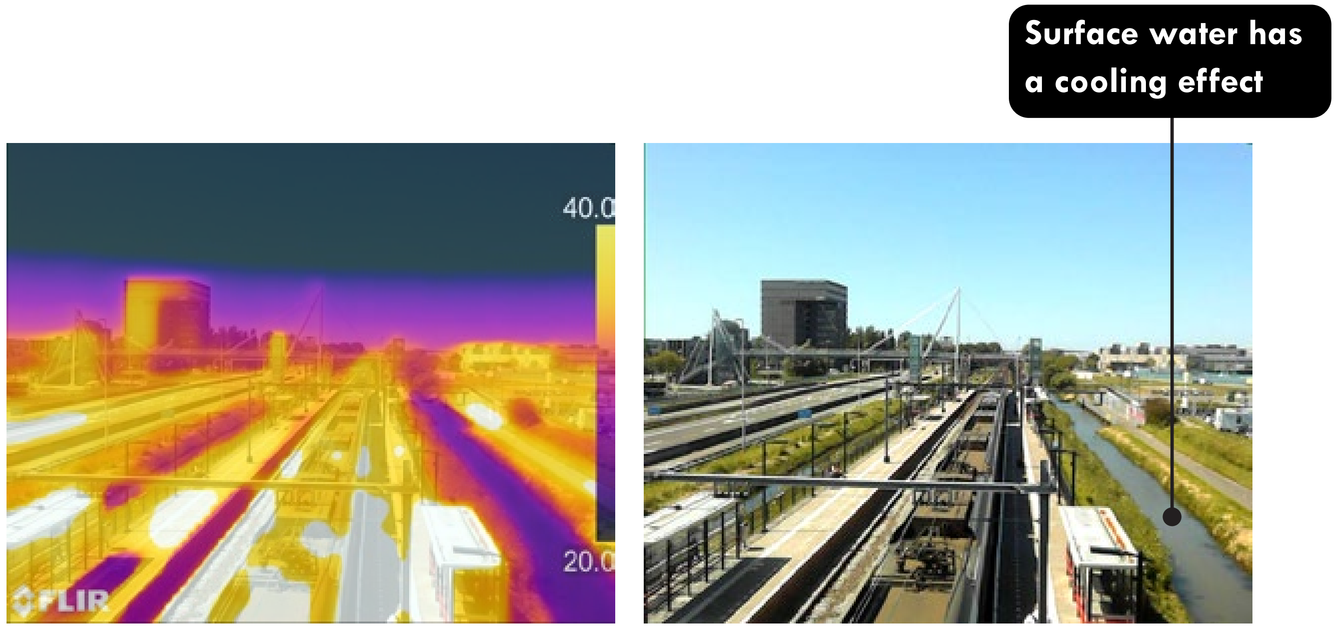


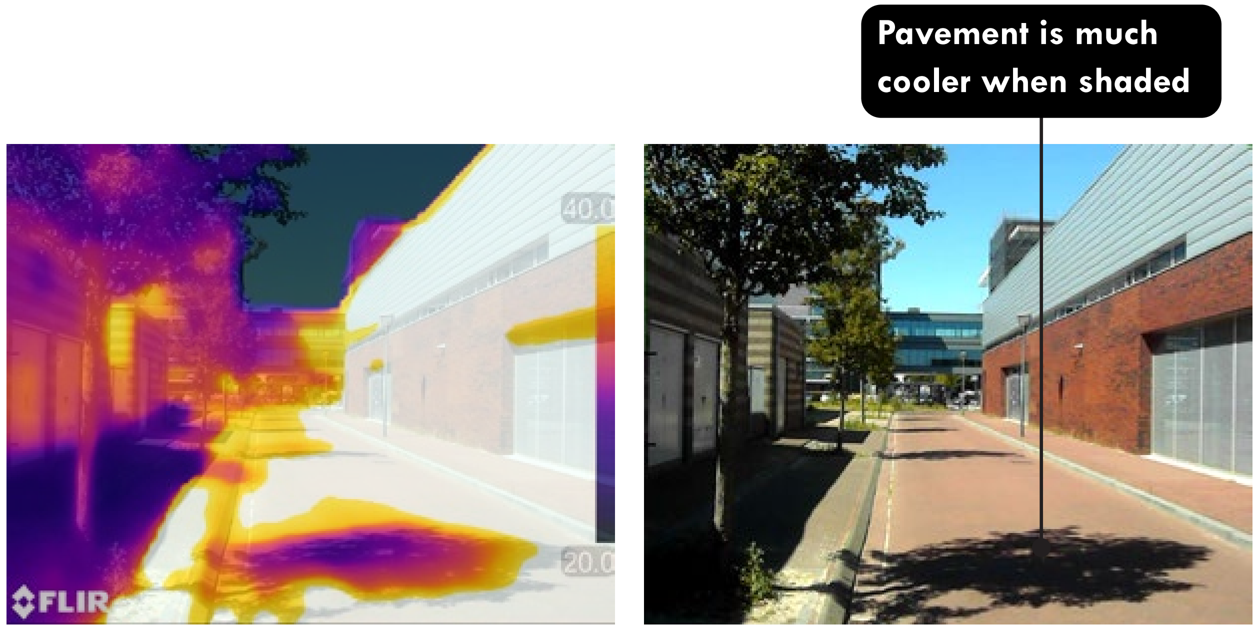
HAARLEM

FLIR imagery captures heat mitigation measures

Using photography that captures surface temperature, the differences between shaded areas or areas under trees and impervious areas without many trees come into stark relief. Also visible are the cooling effects that come with water bodies.





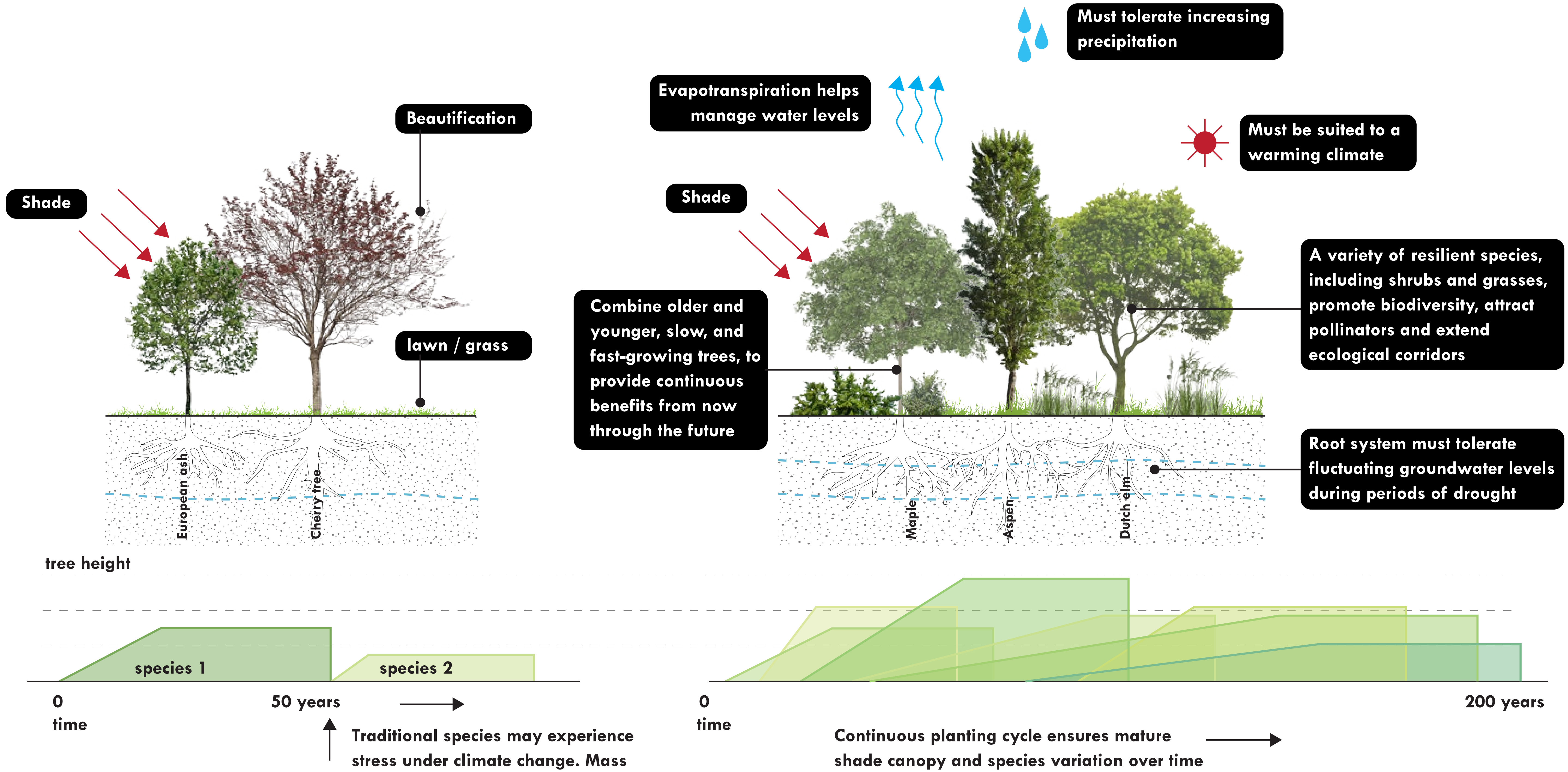


HAARLEM

Ecological challenges: adaptive tree plan

Trees

Landscapes

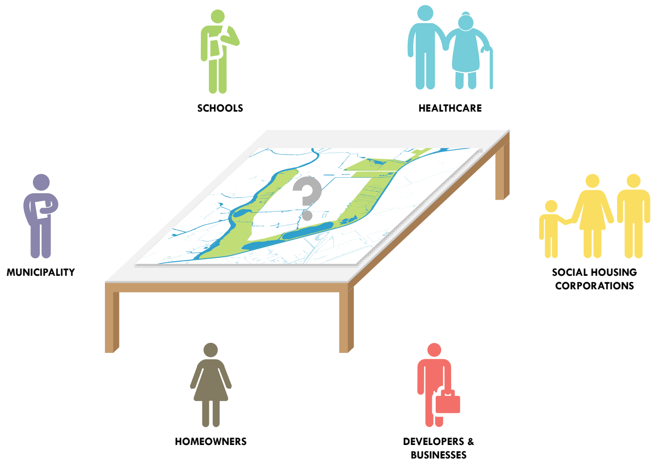


HAARLEM

Engagement process and actors

The challenge is twofold: first, to identify all the actors, and then to engage them and build capacity around the transformation of the neighborhood and public realm.

In envisioning a new type of public space, it is critical to bring together multiple local actors and start a conversation.



Capacity building within actors





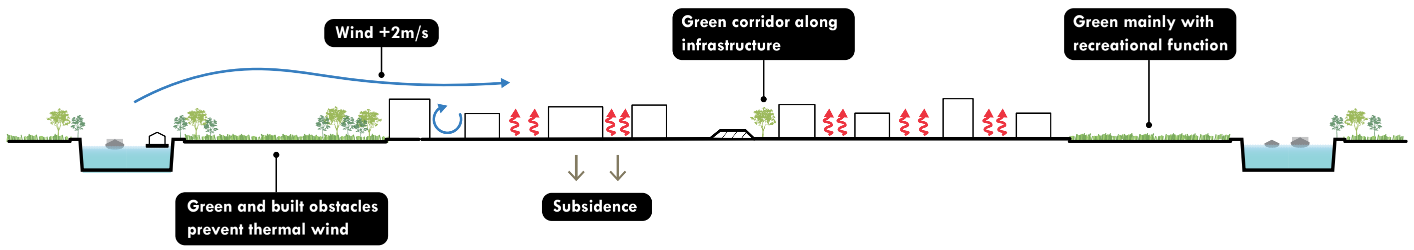
In this city, there is clear potential to activate folks and bring them into the conversations, and through this start to re-conceptualize the green space network and its character. Some local ecosystems or flows start to appear with benefits can contribute to local quality of life.

A new approach to green spaces is needed under climate change

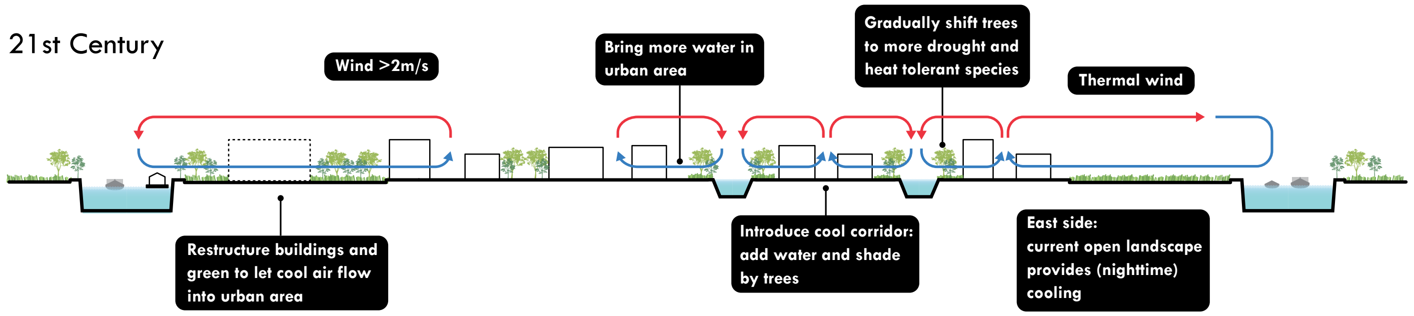
20th Century

21st Century

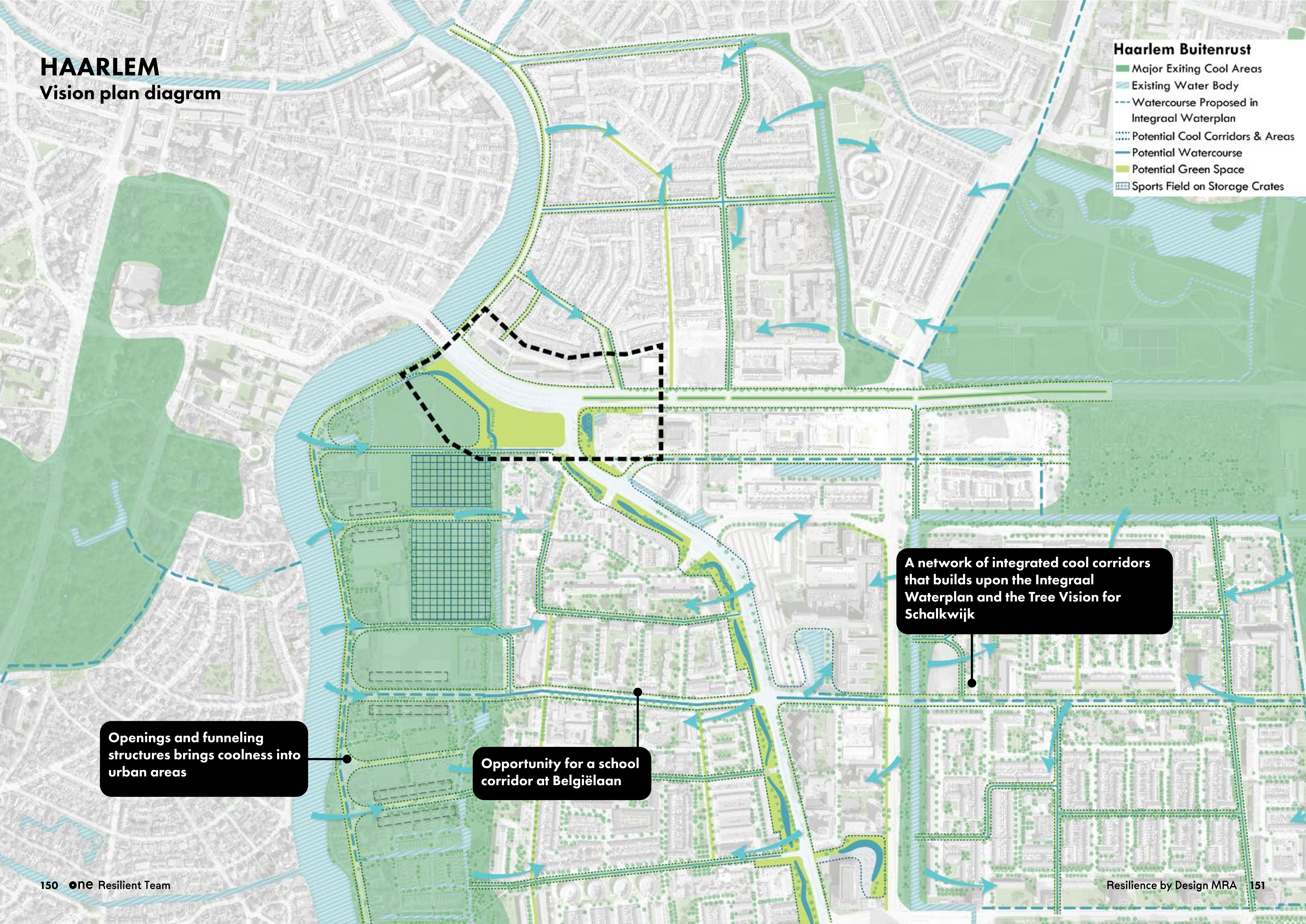
20th Century



21st Century



HAARLEM
Vision plan diagram

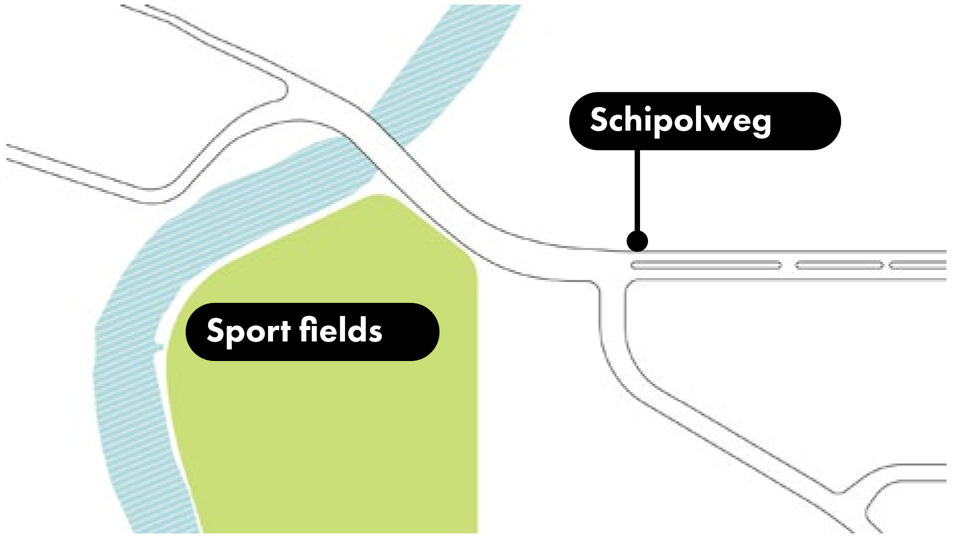


HAARLEM

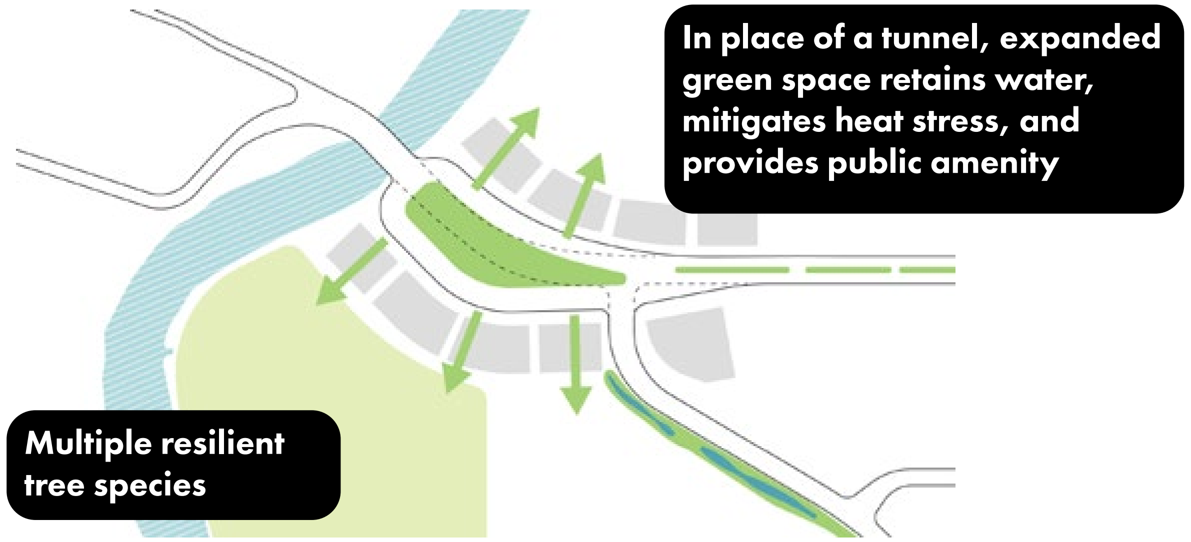
New development provides an opportunity to address climate issues within the public space

The area around Haarlem Nieuw Zuid remains relatively constrained. There is a plan to develop a transit hub, which also necessitates a tunnel, and in addition a desire to create new recreation, leisure, or commerce nearby. These components suggest that the future transit hub will have the ingredients to becomes an attractive place to spend time, not just to pass through. While the tunnel concept responds to certain site and ownership constraints, a alternate direction for climate-proof development would entail giving the new transit hub additional space. Not only does this avoid tunneling to decrease construction costs, it opens up the possibility to create an arboretum within this transit hub that could bring cooling benefits.

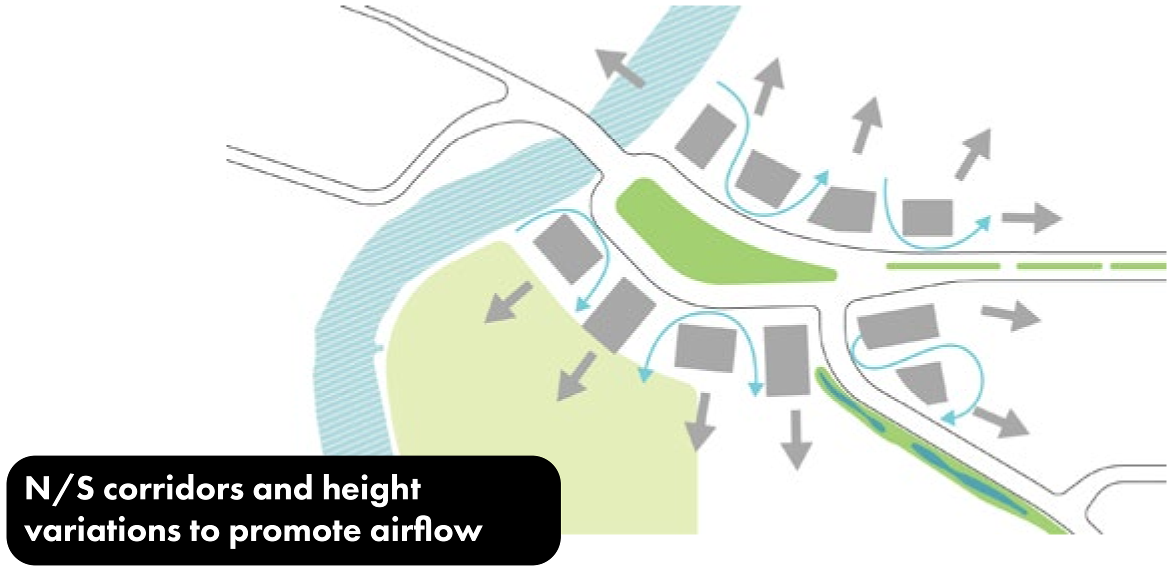
1. Existing



2. Reconfigure roadway to accommodate traffic and transit while creating a central public space



3. Break up building massing to allow public connectivity and encourage ventilation



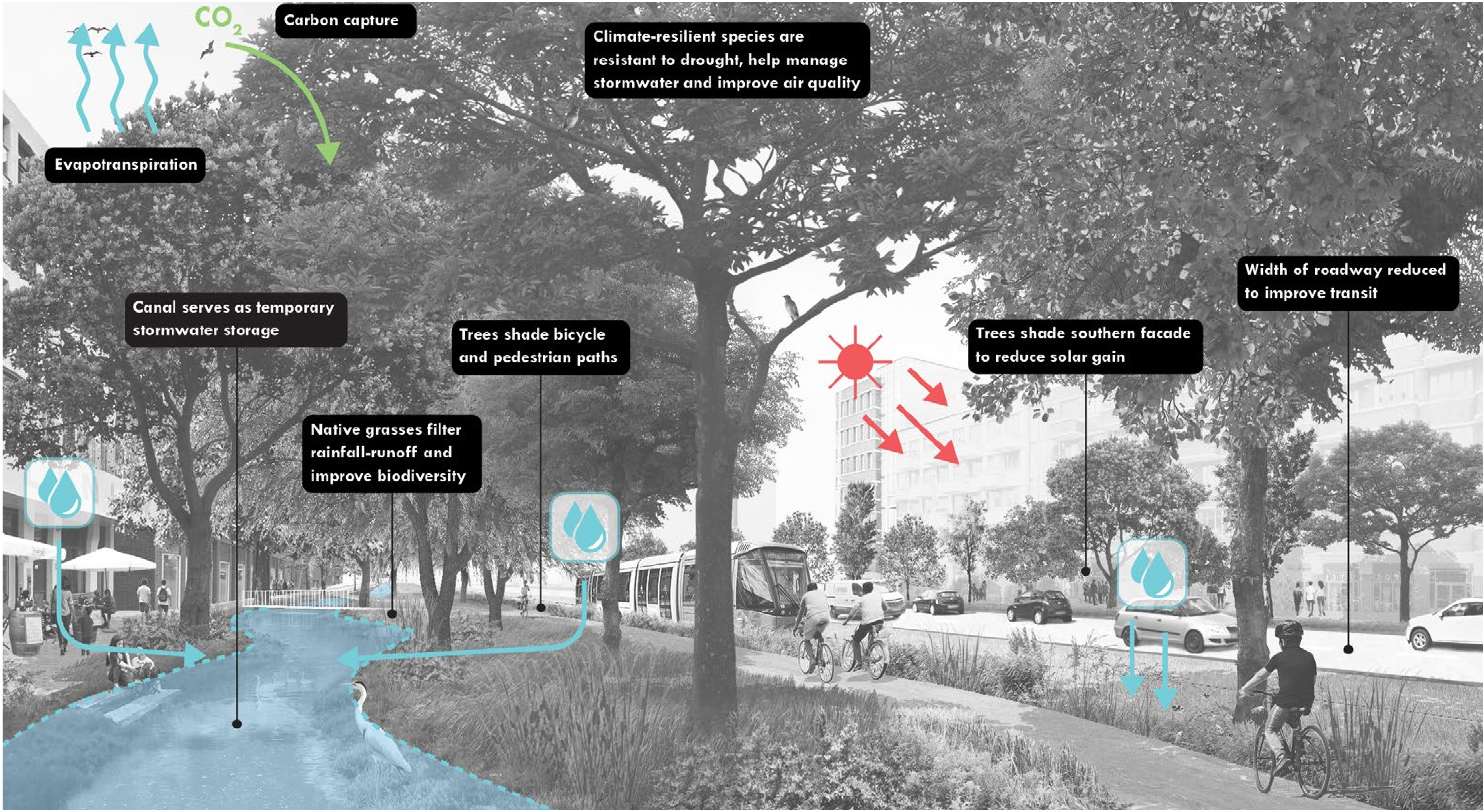
4. Public "arboretum" improves mobility and manages urban heat and water issues

HAARLEM

Transit hub concept with cooling and stormwater management functions

HAARLEM

Transit hub concept with cooling and stormwater management functions



HAARLEM

Business case: strengthen local capacity

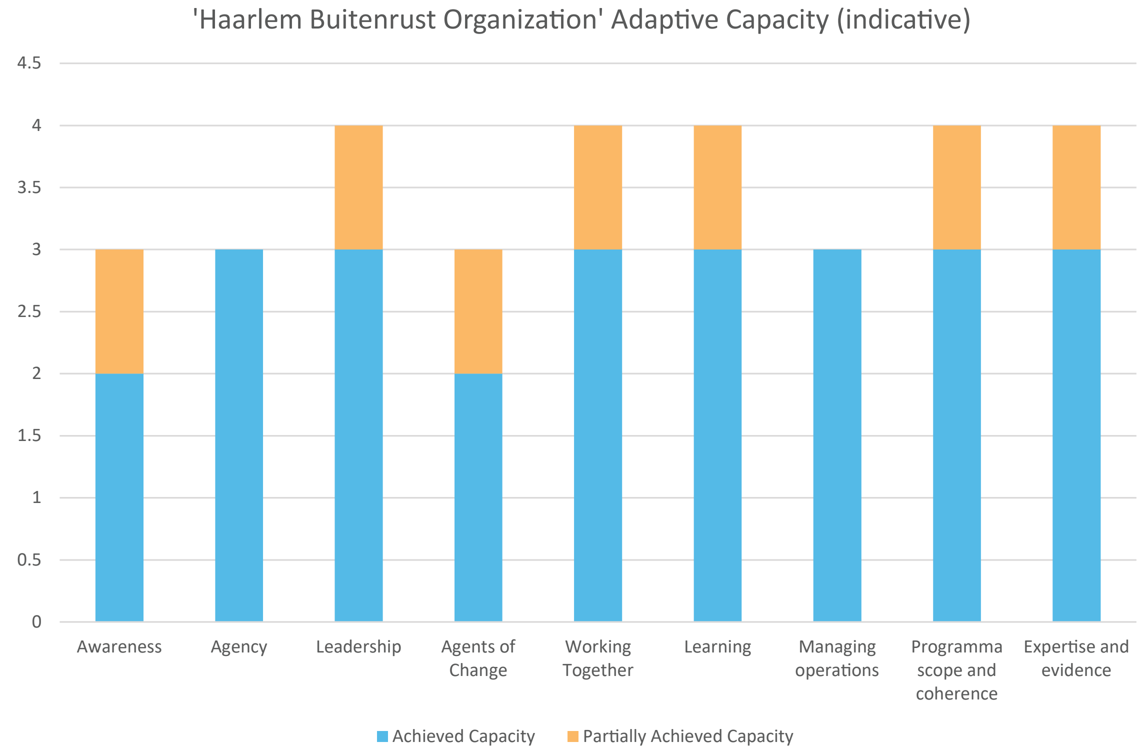
Source: Arcadis bankability analysis for RBD MRA. Refer to Appendix for further analysis.

In a series of interviews (small sample size), the project explored the local capacity for climate adaptation:

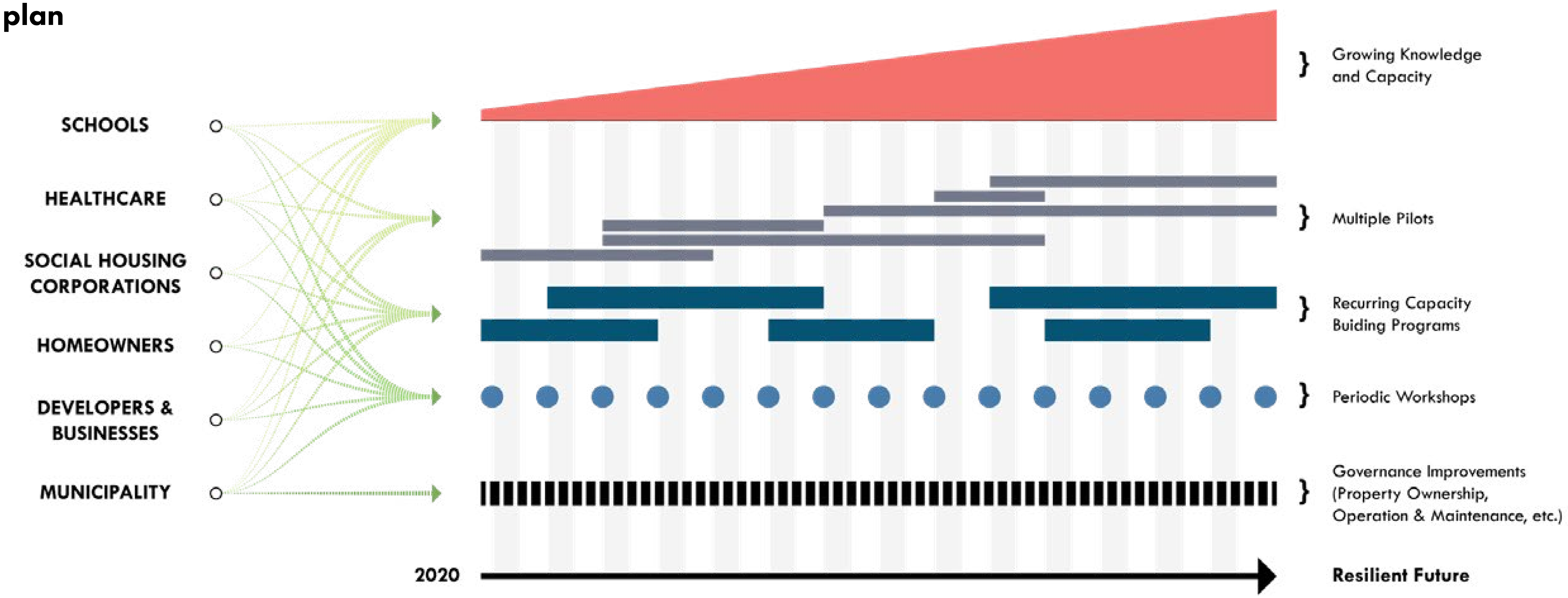
- The current level is relatively low, but with potential to raise;
- There is awareness, but only on a personal level. It should be incorporated in the organization;
- Inspirational leadership is needed. Not only on an official level, it also requires administrative (bestuurlijk) leadership, and alignment;
- Create enthusiasm for new things that are not regular. Get out of your comfort zone and do new things;
- Share and discuss what you want to achieve;
- In the current situation stakeholders insufficiently anticipate and operate scattered;
- There is a reluctance to engage the private sector.
- Climate must be higher on the agenda: there is a sustainability plan with a 15 % rule, but this rule is not decisive

The next steps are to leverage this process to strengthen local capacity through an engagement process. Building capacity today will start to create momentum for climate-adaptive development in this community.

This engagement and capacity building will be a multi-year process, wherein actors will cross pollinate and work with each other.



Multi-year plan

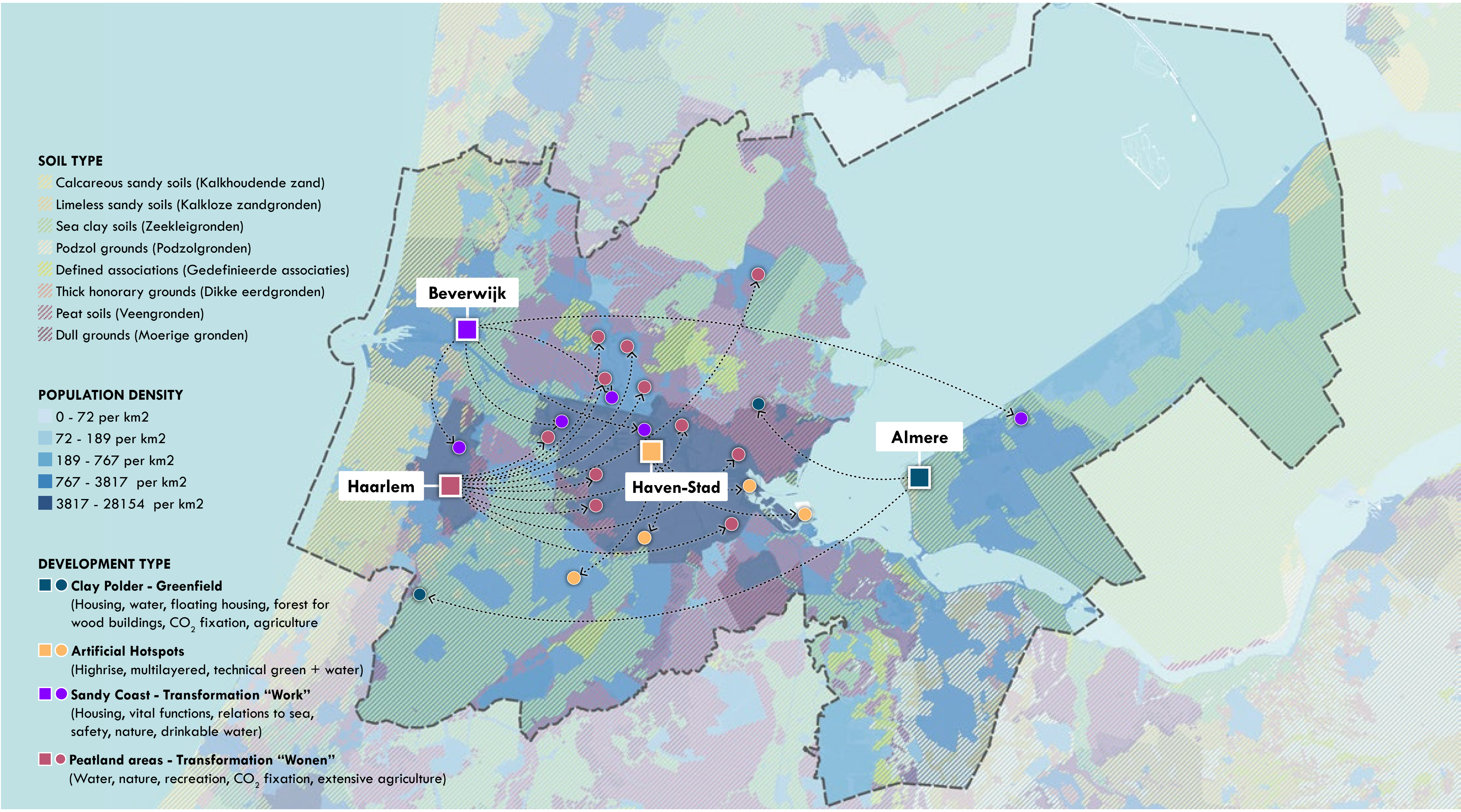


Moving forward

MOVING FORWARD

The lessons learned from the demonstration projects are valuable not only for these four areas but to address the larger challenge of planning for urban development in the face of a changing climate and the uncertainties it brings, in the MRA and beyond.

There are two major issues in the backdrop of the discussion of climate adaptive development, which relate to urbanization strategies at large. As a fundamental question and choice, there is urgency for the MRA to construct a lot of new housing and expand supply. Where development takes place in existing neighborhoods and urban areas without factoring in future stresses, it will come about through infill, reducing available land and adaptive capacity and leading to higher adaptation costs later. If city and regional governments fail to develop longer-term guidance and embed climate-robust principles in the area development strategy, the current trajectory will result in a significant challenge down the road. The second question concerns where development should occur. The Almere proposition underscores that large-scale greenfield developments have inherent flexibility and a lot of opportunities to design in climate-robust principles. However, sites such as this are located in places that pose a higher systemic risk.



The Big Issue

First, the region is filling up to capacity.

Underestimating the impacts of climate change will result in a lack of space for future adaptation. This limits adaptive capacity on a systemic level and on a local level.

Delayed adaptation will lead to high costs in the future, which are likely to fall on the public. Decisions about development should weigh future adaptation and so-called 'transfer' costs.

Second, future uncertainty under climate change complicates choices about where to develop and which measures to implement.

Should we prioritize infill or green field development?

> Building in infill locations will limit local adaptive capacity resulting in higher adaptation costs later
>
> vs.
>
> Large-scale greenfield developments are easier and cheaper to make climate-robust with adaptive capacity built in, but they do pose a higher systemic risk.

Therefore: the MRA should study this dilemma in an integrated way at a regional level to provide coordinated guidance and planning.

Barriers to such a plan

- **Current planning underestimates the magnitude of climate change's impacts** and how quickly they are coming our way, leading to a lack of insight in long term adaptation costs. This **prevents mobilization** through shared interests and a joint dependence on 'common sense'.
- **Climate adaptation has a limited role in RO** compared to energy transition and circular economy, for example. 'Climate adaptive' is not commonly understood and there are few national or regional standards or policies.
- **Climate adaptation is steered by a small group of professionals who do not work in a coordinated way** (each subtopic has its own silo). For example, planning for systemic risks is performed relatively independently from planning for local risks and stresses.
- **Climate risks are not considered holistically in the Netherlands.** This is a legacy of expertise in water management and results in limited use of integrated solutions and insufficient reservations for the future. For example, the resources, data, and methodologies to address heat stress do not meet the demand.
- The Dutch like straight lines.

Appendix

APPENDIX: BANKABILITY

Exploring strategies to implement measures to adapt to climate change and raise the resilience level in the Amsterdam Metropolitan Area (MRA)

Paradigm shift from risk-based towards profit-oriented

Times change and insights regarding the impact of climate change grow. The Netherlands is still seen as a frontrunner country to mitigate risks and impact of flooding; complacency being a next risk to consider.

The climate change extremes experienced in the final years and insights gained by research make us aware the impact in long-term (beyond 2050) might be more extreme than anticipated to now. Combine this with the knowledge that in densely populated areas in the Netherlands the system resilience has diminished; main water management systems of which the borders have been reached. To be capable to deal with long term climate change impacts there is for certain a need to raise the resilience level in parts of the Netherlands. Resilience to deal with flooding and resilience to deal with both heat stress and drought. Soil subsidence, drought and shortage in water supply are experienced in the Netherlands as well and rank high on the agendas of Dutch research institutes and have main policy focus. Heat stress just recently receives the attention it deserves. Even in 2014, in a major European research program many participants assumed heat stress did not have to be considered north from Paris.

In case the Netherlands really anticipates on more extreme climate change scenario's, the focus of implementation of measures must shift from 2050 impacts to impacts expected in 2070 or 2100. It might become clear transitions cannot be avoided. Transitions in a physical way (e.g. adapting urban areas), transitions in a financial way, transitions in an organizational way.

In the demonstration projects of the Resilience by Design project MRA, it has been explored how to raise the resilience level and how to get the transition being implemented. More concrete: how to get measures to raise resilience implemented and how to catalyze these. Explorations to answer the central question of MRA; 'How to ensure that climate adaptation will become a "normal" part of integrated investment decisions now and in the future in area development processes within the MRA? From resilience on paper towards physically achieved resilience in city, city district and on street level. Delay of the transitions needed within the densely populated areas of the Netherlands might lead to huge socio-economic losses and or huge investments coming decennia that could be avoided.

As part of the Resilience by Design study for MRA four building blocks have been applied on a general level and been tested. All cases with a long-term focus and the challenge how to deal with more extreme climate scenario's, extremes and changes to be expected beyond 2050. The results give insight in ways to raise bankability of climate adaptation measures alongside and being part of infrastructural investments and give insight in how to analyze and raise the capacity level required.

Resilience by Design, the overall concept applied, could be characterized as a holistic design approach with a focus on adding value in both an economic and a social way. With all stakeholders (public and private) at the table the interests and ambitions are analyzed, shared and integrated in the design. The building blocks elaborated in this appendix support this Resilience by Design approach, enhance the feasibility of ambitious transitions and catalase implementation.

In this appendix the following building blocks (e.g. approaches and instruments) have been explained in more detail:

- **Optioneering supported by the Bankability Resilience Tool** (BaRT). This building block shows, on city district level, how to enhance the feasibility of climate inclusive transitions, shows the bankability of climate-inclusive transitions. The focus of design should, more than in regular approaches and many design sessions up to now, be focused upon value adding. Both social and economic values. The Bankability Resilience Tool supports this approach while calculating and showing all costs and benefits and allocate these to the stakeholders
- A **decision tree** has been developed and applied to support the investment decisions in case of uncertainties regarding climate adaptation in are development;
- The requirement of nine competences at high level has been shown by the **Capacity building** approach. Competences required to be able to deal with disruptive changes like climate change in an effective way;
- **Life @ Urban Roofs** shows all values including social values and strengthens the business case for multifunctional roofs.

Table 1 shows the ways or building blocks that have been explored to enable and catalyze measures to raise the resilience level or even speed-up resilience

Table 1. The 'financial' building blocks that have been explored

Building block	Demonstration project and the focus and scope of the research			
	Beverwijk	Almere-Pampus	Havenstad	Haarlem-Buitenrust
Resilience by Design	X	X	X	X
Optioneering using the Bankability Resilience Tool (BaRT)		X (district level, bankability)		
Decision tree			X (district level including adaptive capacity	
Capacity Building				X
Life@Urban Roofs	X (building level, collaboration, bankability)			

Raising bankability by value engineering on city district level

Demonstration project Almere – Pampus

The challenge

In current plans the municipalities have to realize sufficient resident buildings between 2020-2050 in three sub-areas of which Almere Pampus is one. Currently the Almere Pampus area is mainly in agricultural use. To reach current agreements 48.500 houses are needed. Almere Pampus will turn into an urban district that will at least contain 25.000 homes, but can grow to 40.000 houses, depending on the chosen perspective. Which housing program will be used will be determined at a later stage

Figure A. *Aerial picture of the Almere Pampus area to be occupied*

The challenge for Almere Pampus is to develop in a way that the resilience level will be high enough to deal with mid-term and long-term climate change impacts. In the MRA case to answer the central question: How to ensure within the Almere Pampus transition climate adaptation is part of the integrated investment decisions?

As part of the MRA-project, based upon assumptions regarding the area development within the demonstration project Almere Pampus, the following main questions has been explored:

> Could the integration of a blue green resilience layer within the Almere Pampus transition, in order to secure a resilience level to deal with mid-term and long-term expectations regarding the increase of and extremes in precipitation, be more logical if approved to be bankable.

The mindmap (figure B) shows the costs and benefits that have been taken into account while exploring this question.

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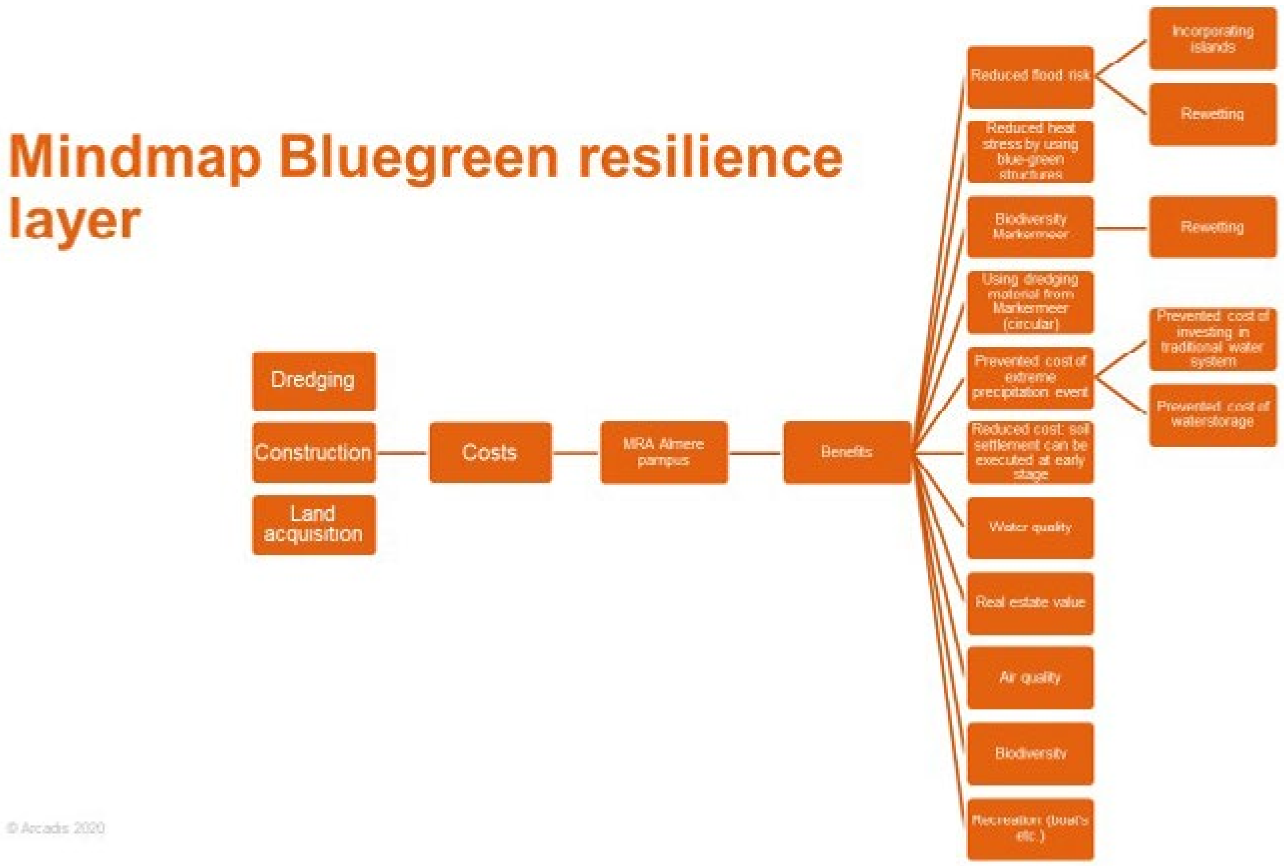
Figure B. Blue green resilience layer Almere Pampus (alternative 3)

Figure C. Mindmap showing casts and benefits being integrated in the BaRT calculations Almere Pampus alternative 3



Two related questions have been part of te research as well;

- Could insights in both costs and benefits support the decision regarding prevention of flooding between measures in the public domain and measures on top of new buildings;
- Are the benefits of early and resilient land prepping and natural development a reason to consider this, because of being bankable or economically attractive?

The research

To explore and answer the main question the Bankability Resilience Tool (BaRT) has been used. BaRT is a cost-benefit model that contains modules to identify economic and social benefits of measures to adapt to climate change. Most benefits are monetized, costs and benefits are allocated to stakeholders. Past performances of 'Optioneering using BaRT' in Northwest European cities show the benefit-oriented approach enhances the bankability of transitions and measures to adapt to climate change. The results of the BaRT calculations in the Almere Pampus case need to be seen as indicative while it is based upon a premature high-level plan for this area.

Insights gained

Integrating a blue green resilience layer, adapted to the precipitation levels and extremes expected in mid- and long-term, provides the most positive business case of all 4 alternatives; if all costs and benefits are taken into account. The more traditional sewage systems seem to be less profitable (see Figure D). This is the consequence of the benefits to be expected (real estate value, health, biodiversity, air quality) and the costs avoided (costs of a traditional sewage system, costs to create basins for water conservation). This despite the fact that benefits regarding mitigation of heat stress have not been taken into account (a suitable and scientifically proven module lacked).

Oversizing the blue green infrastructure (alternative 4, maximum resilience) leads to a less profitable business case, the acquisition of additional area requires more investment while the additional benefits are limited.

Figure D. Four alternatives compared based upon BaRT-calculations

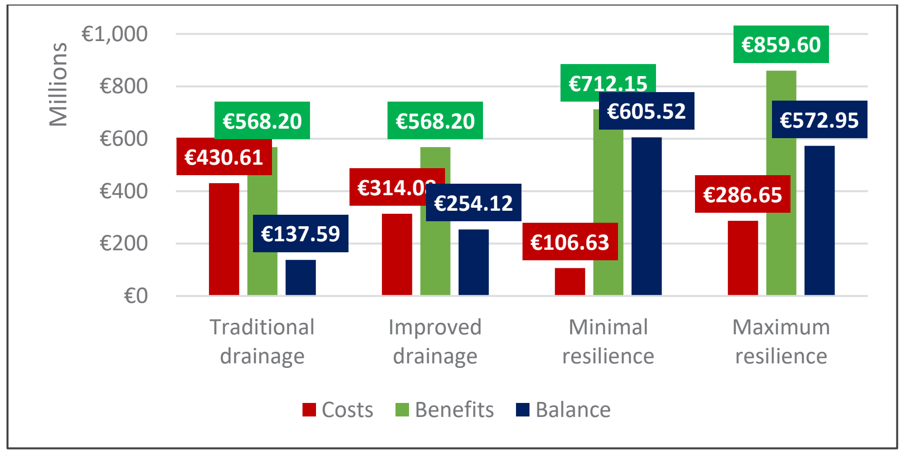
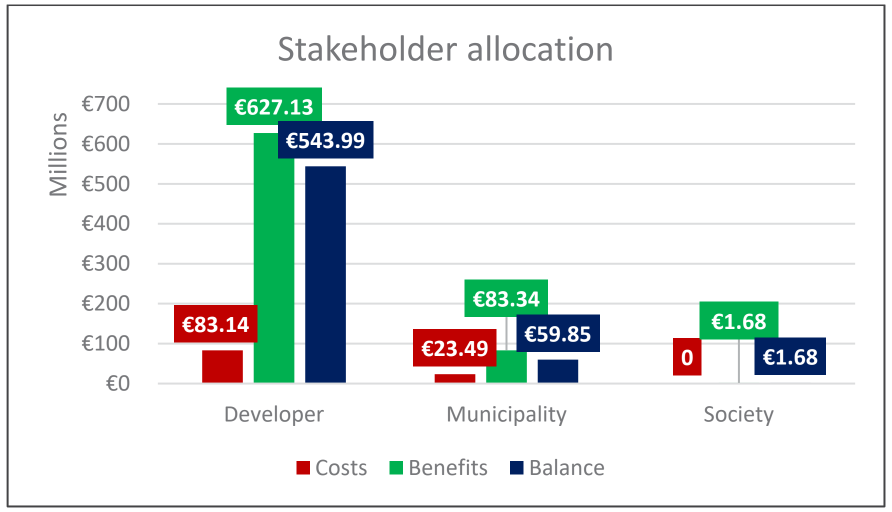


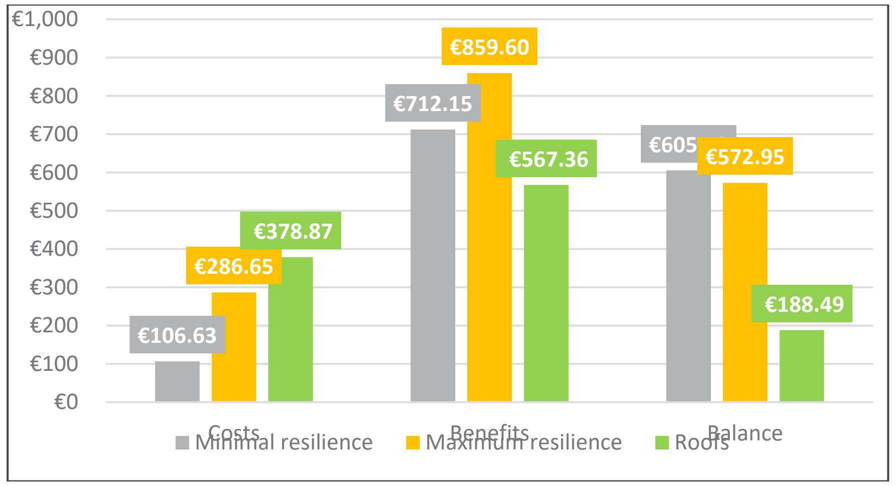
Figure E shows the share of costs and benefits of the three main stakeholders. The calculations make clear the project developer profits most of this integrated blue green layer. Both municipality and society show a smal but positive balance.

Figure E. Stakeholder allocation of costs and benefits Almere Pampus alternative 3 (alternative with blue green resilience layer required)



Measures in the public domain to manage the rainwater now and in the future have a more positive business case then measures on top of the new houses (figure F). One of the reasons is that measures on rooftops are not sufficient to manage all precipitation circumstances. An additional sewage system will be needed. Besides the (additional) benefits of a blue green resilience layer appear to be much higher then the benefits of multifunctional roofs.

Figure F. Comparing measures to deal with precipitation in the public domain (blue green resilience layer) and the private space (roof tops).



The bankability of early preparation of land (10-30 years before occupation) has been explored based upon expert judgement. Pros and Cons have been analysed. Early preparation seems not te be economically viable. Despite the business case several pros and cons could be taken into consideration if the area is available.

Pros:

- Early land reclamation preparation ensures a longer time for settlement of the reclaimed land, thus results in a **lower risk profile** regarding subsidence of buildings and infrastructure;
- New area can (temporary; +/-25yrs) act as a **nature reserve** that helps to achieve nature-related (KRW, N2000, etc.) / nitrogen objectives (as short term gain);
- The added value of a **green blue infrastructure** will only be there after around 10 years. At least regarding the raise of real estate value. So early preparation will ensure this added value.

Cons:

- **Pre-investing** in early construction is probably not feasible in pure financial terms (longer loan terms, etc.). In general you could say the benefit-cost ratio will only grow if there is a positive economic impact in the housing market;
- **Mobilization costs** for dredging works are relatively high! Therefore, spreading activities over time yields a non-regular approach.

To create a more positive business case the acquired and available area could be deployed for temporary profitable functions (e.g. renewables like solar panels to generate solar energy, profitable if a period >22 years allowed).

Early area preparation offers a variety of opportunities as well:

- Create **more and stronger gradients** in lake bed level and along shores (more variation). This has a positive influence on KWR/ N2000 objectives and needs to be expressed in economic values;
- Land reclamations/islands/shoreline extensions **can reduce hydraulic loads** on flood defenses and result in higher safety level and make the development more robust to changes in water level/waves;
- Large scale system changes (**land/water re-creation**) might **boost innovations** in the field of dredging and hydraulic engineering; in this case: gradual build-up of shallow areas and/or islands;
- Removing substantial amount of sediment from the lake (to create islands) creates:
  - Large fresh water basin, which can be expressed in economic value;
  - Cooling effect, lower average water temperature, (partly) balancing atmos. warming, positive effect on ecosystem which can be express in economic value;
  - Step-wise creation of foreshores/shallows/islands (instead of instantaneous creation); for example by using sediments from regular dredging activities in the areas (if any), or by mobilizing contractors in low market periods.

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The decision tree as a decision-support tool for investment under uncertainty for climate adaptation in area development

Case Haven-Stad Amsterdam
Authors: Robert de Kort, David Witvoet, Ron Vreeker, Rosalie Fidder

Climate adaptation is given a place in an increasing amount of area developments within the MRA and other Dutch regions. When drawing up the urban plan and filling in the plots, climate adaptation norms are included, aimed at reducing the vulnerability of the area to flooding, heat, drought and flooding. These norms have a target year of 2050, and thus represent the current expectation of the extreme weather and sea level rise in 2050. The pace of climate change is uncertain, which means there is a risk of over- or under-investment in climate adaptation measures. Additionally, the lifespan of infrastructure and buildings is more than 100 years, and a residual task arises when the norm's target year (2050) is reached. Solving this residual climate adaptation task by taking additional measures (e.g. for water retention or cooling of urban areas) normally requires high additional investment costs, which end up with the public authorities. This is undesirable since public spending is under strain.

In this paper, we discuss how an SCBA and decision tree is used in planning phase to anticipate the uncertain pace of climate change, to realize future-proof, climate-adaptive areas. Case study is the large-scale area development Haven-Stad in Amsterdam, where 40,000 to 70,000 homes will be built in an area of 650 ha in the period up to 2040. The development is currently in planning phase.

Problem statement

The climate-proofing norms for areas and lots in the MRA stem from the "Basic safety level for new construction in Amsterdam". Here, for example, the required water retention of an area development is determined, or on the expected groundwater level or heat stress. The level of these norms (for example rainfall intensities, cooling, or flooding scenarios) are based on the currently expected development extreme weather events under climate change in 2050.

We argue that given the pace and intensity of climate change is uncertain, the application of norms aimed at 2050 will lead to insufficiently climate-proof areas in the future. The buildings, infrastructure and other facilities in newly developed areas are built for at least 100 years. When applying the current norms in a rigid plan, there will be a residual task after or before 2050, depending on the pace of climate change. Moreover, in practice there is little, or no space left to anticipate more severe climate scenarios and the increasing intensity and duration of extreme weather events in the future.

In large area developments with a high density specifically, where planning and implementation run for 20 years or longer, we see a risk. The configuration of infrastructure and layout of public and private areas for water management and cooling may can be overtaken by the pace of climate change or will reach this point within the foreseeable future after completion. While in planning phase it is still possible to include infrastructure for climate adaptation in the total area development and associated risk, investments and coverage, this space is often no longer available after the development has been completed. The residual adaptation-task, from approximately 2050 to the end of the life of the buildings and infrastructure, will then lie with public administration. High investment costs will be incurred for the completion of this residual task, because due to the pressure of space, functions will need to be are exchanged or expansive, multifunctional solutions have to be realized.

In summary, we ask ourselves the following question:

How can we make climate adaptation an integral part of investment decisions that includes the uncertainty and scope of climate scenarios to the development of our built environment appropriately?

Decision tree and SCBA as decision support tool

Various approaches are possible for realizing a climate-proof area development. For example, in the planning phase, a choice can be made to design the water system and green facilities for light or heavy climate scenarios, aimed at 2050, 2100 or further. How to make this choice? By allowing flexible designations to parts of the urban plan, for example by allowing temporary functions, it is easier to find space for water storage or cooling at a later time than when an urban plan is completely fixed. Area development also has need a for flexibility to be able to anticipate changes in market demand. In the decision tree, climate adaptation is brought into the ground exploitation business case to make informed investment decisions.

We use a decision tree to gain insight into the ratio and volume of costs and benefits of the potential climate proof designs, not only upon completion, but also further in time when the area is in use, and there is a risk of economic damage if too much, too little or no water retention was realized. This creates an overall picture in which investment costs, but also the risk of damage due to underinvestment, come together. The desired level of investment and risk management can then be weighed up within the context of the total ground exploitation model.

To fill the decision tree, we develop various design alternatives for climate proofing an area. In these alternatives, functions are combined that, in terms of water retention, meet the expected precipitation intensity in 2050 or 2100. The alternatives can be further expanded for multiple protection levels and climate scenarios. In this simplified case, we opt for three alternatives where water retention for 2050 or 2100 provides for an equal protection level (T = 100). To illustrate, three alternatives are worked out in the figure below.

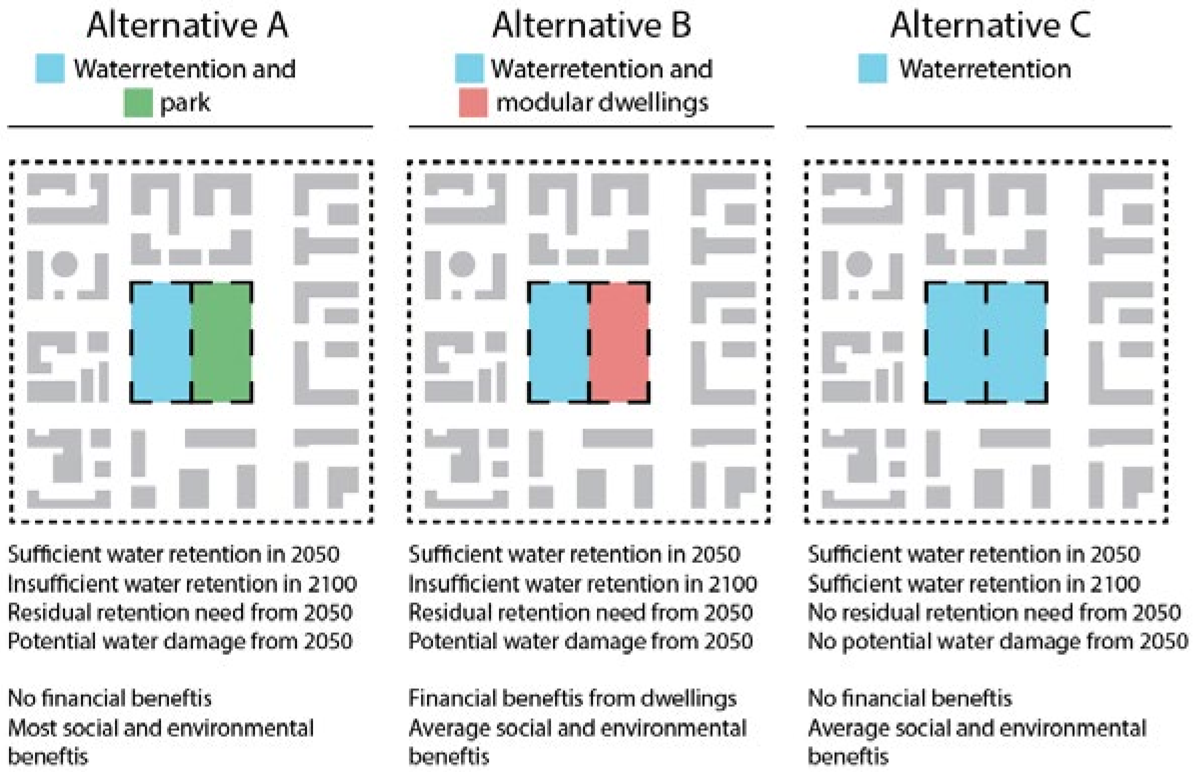


Figure 1 Alternatives for climate-proofing of a hypothetical area

We set up the decision tree and form alternative, mutually exclusive and jointly complete adaptation paths so that we gain insight into questions such as: "Are we following the status quo and design the area for a sufficient water retention until 2050, or do we anticipate on the retention requirements of 2100? " "And when do we make this decision, immediately when drawing up the urban development plan, or do we evaluate at a later time (5-10-15 years) during the development of the area and when more is known about the development of the climate? ". We combine the alternatives, and the ground exploitation and social cost benefit-analysis (SCBA) is produced for each path. The valuation of direct and indirect water damage depends, among other things, on the risk-acceptance level, and can be determined with the relevant stakeholders. The result is an integral picture of the benefits and costs of each adaptation path. The climate adaptation plan is determined based on the insight how the various paths relate to each other.

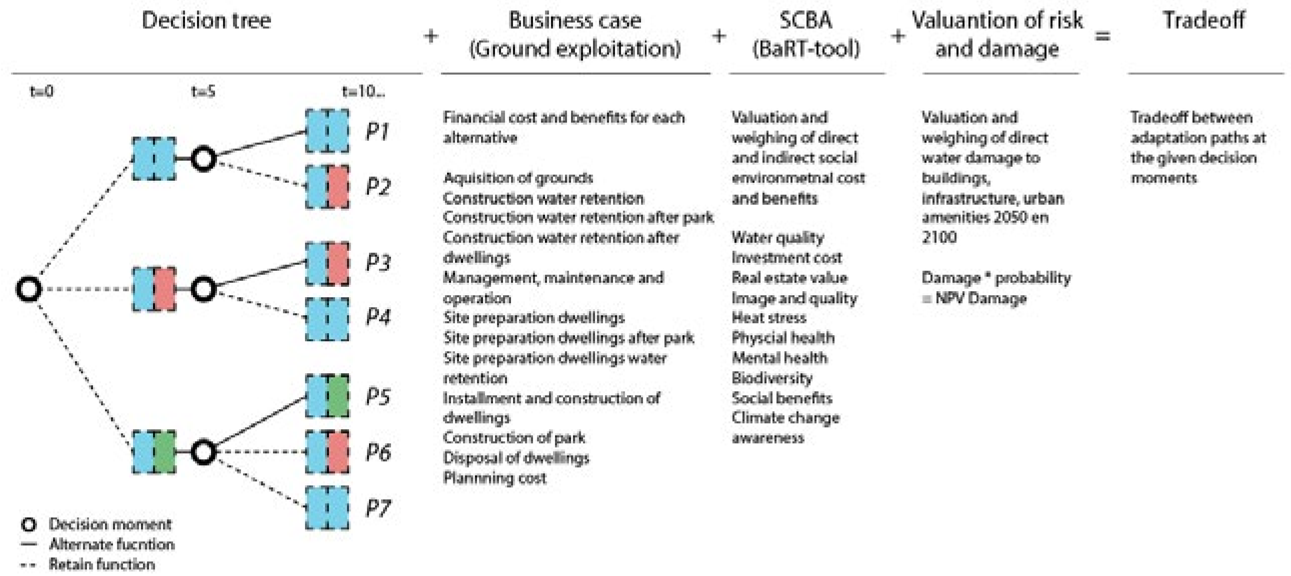
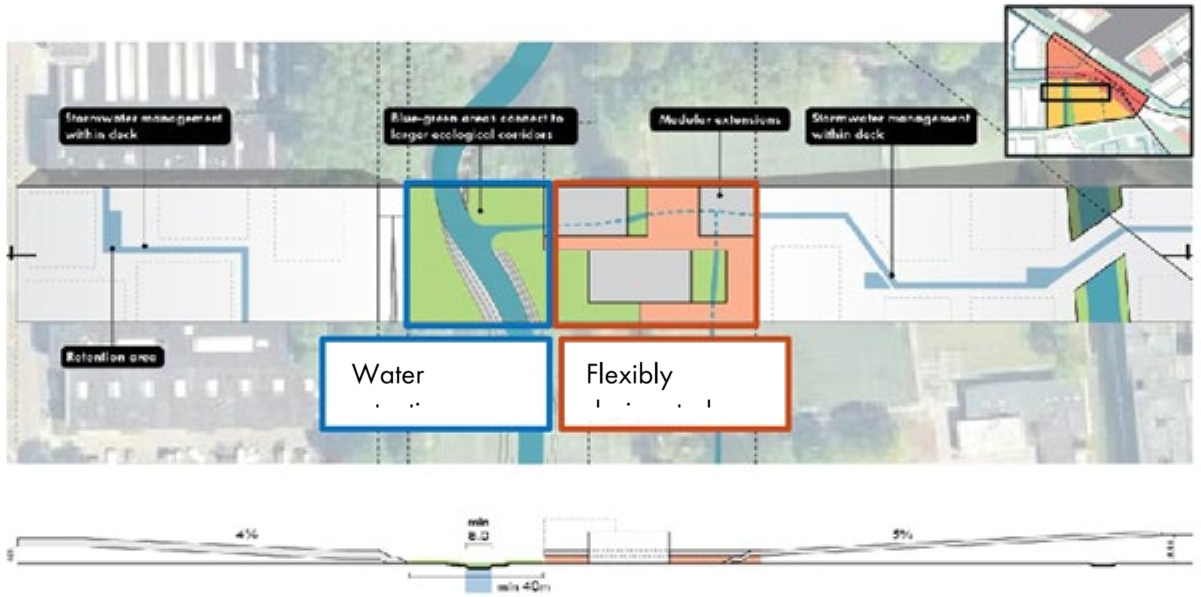


Figure 2 Steps in for investment under uncertainty for climate adaptation in area development

Application of decision tree in Haven City

To illustrate, we apply the described step-by-step plan to the Port City case in Amsterdam. Part of the Resilience-by-Design design is a green zone, part of which can be flexibly arranged. Thanks to the flexible design, we give ourselves the opportunity to make choices over a longer period and to respond to the development of technology and climate models, for example.



- Area can be flexibly arranged for 2,400m2
- Potential for water retention for approx. 11,000 m2 of buildings in addition to the current standard.
- Layout as a park 1,000m2 / water retention 1,400m2 or 2,400m2 / temporary student housing 1,000m2
- Climate scenario 1: 2050 (1,400m2 water retention)
- Climate scenario 2: 2100 (2,400m2 water retention)

Figure 3 Case characteristics

We apply the decision tree from Figure 2, where the flexibly designed part of the area is designed as additional water retention, park or modular temporary student housing. Table 1 and Table 2 show the starting points used in drawing up the business cases for the various adaptation paths (see Figure 2 Steps of investment decisions in the event of uncertainty surrounding climate adaptation in area development, P1 to P7).

Cost	volume	unit	€ / unit	total
Acquisition of grounds	2400	m2	250	€ 600,000
Construction water retention	1	m2	32	€ 32
Replace park by water retention	1	m2	37	€ 37
Replace dwellings by water retention	1	m2	47	€ 47
Site preparation dwellings	1	m2	100	€ 100
Site preparation dwellings when replacing park	1	m2	105	€ 105
Site preparation dwellings when replacing water retention	1	m2	122.5	€ 123
Installment and construction of dwellings	120		5000	€ 600,000
Construction of park	1	m2	34	€ 34
Disposal of dwellings	120	Pcs.	5000	€ 600,000
Planning cost	30% of cost excl. ground acquisition			
Benefits	**volume**	**unit**	**€ / pcs (average)**	**total**
Net income from temporary student housing p / yr.	120	Pcs	3152	€ 378,231
Loss of rent and ongoing costs due to relocation 0.5 yrs.	120	pcs	-2819	€ -338,242

Table 1 Base for design alternatives cost

Table 2 Base for design alternative cost

Adaptation path	Design 2020 - 2050	Design 2050 - 2100	NPV ground exploitation
P1	Full water retention	Full water retention	€ - 675.000
P2	Full water retention	Water retention + dwellings	€ 490.000
P3	Water retention + dwellings	Water retention + dwellings	€ 2.710.000
P4	Water retention + dwellings	Full water retention	€ - 200.000
P5	Water retention + park	Water retention + park	€ - 715.000
P6	Water retention + park	Water retention + dwellings	€ 505.000
P7	Water retention + park	Full water retention	€ - 680.000

Table 3 Results NPV ground exploitation adaptation paths decision tree

In this case, the decision tree and business case based on the ground exploitation are worked out. Figure 2 shows that following these steps, a SCBA is performed after, followed by an assessment of the risk of water damage. These last steps are not covered by the case study. The following insights are obtained based on the filled decision tree and business case.

- The application of modular buildings, in this case dwellings, offers opportunities to generate additional financial benefits and the possibility to repurpose the plot later for climate adaptation.
- The chance of damage can be weighed against the direct costs and benefits that additional water retention will bring. In this example, the difference in value of the realization of water retention aimed at 2050 and 2100 (P1 vs P2) is € 900,000. So if the expected damage within the period in which both scenarios occur is higher than € 900,000, then it is interesting to go for extra water retention.
- By including social costs, benefits and the risk of damage in the result, it can be said that with 3 million in damage or, for example, added value of the surrounding property, designing it as water retention is an interesting proposition.
- This choice can also be postponed by 5 years (3 and 4). The trade-off here is a plus of 900k or a decrease of the result of 3mln. Again, the assessment can then be made based on the knowledge then available whether the damage or costs of, for example, alternative measures outweigh the stated 3 million.
- Through a revaluation later with additional knowledge from the area development or the climate, the choice can be made again at that time and so on. This can be done at logical intervals with annual revisions of the plan, every 5 years or with developments in legislation and regulations, technology, and climate models.

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Integration in planning process

The decision tree is used in an iterative planning process, in which a climate-adaptive design is made based on a system analysis and climate analysis. Using the decision tree and accompanying SCBA, the design is evaluated and adjusted based on substantiated investment decisions (Figure 4).

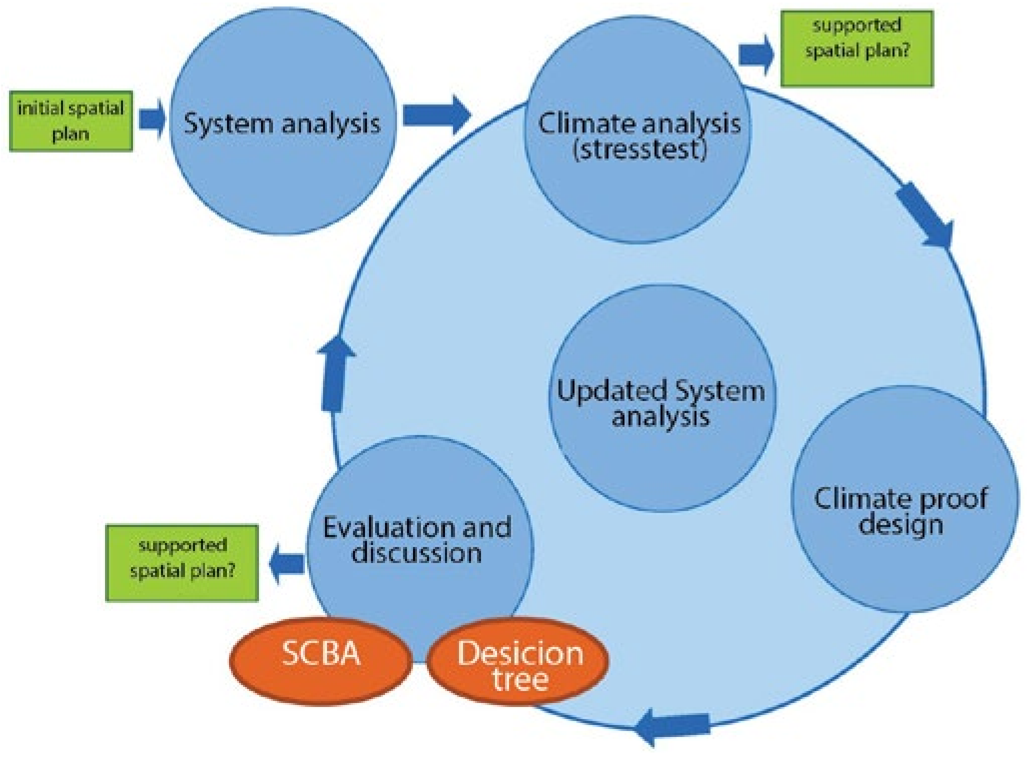

Figure 4 Dialogue supporting assessment framework (Bron: Klimaat in ruimtelijke keuzes, het dialoog ondersteunend afwegingskader (DAK); theorie en praktijk. Kennis voor klimaat 2011)

Conclusions

The decision tree creates a much-needed connection between the business case (ground exploitation) and SCBA and thus an integrated view that is in line with public values and quality. The valuation of risk damage and acceptance of risk is important to complete the assessment.

The SCBA and decision tree form the basis for the business case (financial conditions are currently favorable) and provide a balance in measures, investment moment and flexibility and public / private ratio. Based on this business case, we substantiate the contributions and added value for both public and private parties in the development.

Where the extra investment with public money is normally unprofitable, it is demonstrably profitable from the SCBA. The flexibility in a plan is valued in this way. For which additional public or private investment space can be found and cash flow can be generated. This depends on the use of the financial and legal instruments.

The considerations of measures due to the flexible interpretation of the plan area and their valuation provide insight into the costs and benefits. From the end user back to the moment when the investment decision (branches of the decision tree) is taken, the business case provides insight into the financial and social effects per stakeholder. That is the next step to this proposed method. The business case per stakeholder is the basis for the financial strategy to properly structure the money flows. This can be done by feeding a fund, making smart links with natural (re-) investment moments, contributions from anterior agreements, an SLA, or obligations (basic instruments / legislation and regulations).

Insight into social values for private investments in multifunctional roofs

Case Bazaar Beverwijk
Robert de Kort, Eric Schellekens

Investments in climate adaptation are largely funded by public authorities in the Netherlands. The benefits of these investments fall to society. Under the influence of climate change, extreme weather and its consequences will increase in intensity and frequency. The need for more (costly) adaptation measures will therefore increase further. Governments cannot bear these investments alone, which is why it is important that the private sector participates. In addition, not all measures can be taken in the public space, as 60% of the average surface area of the built-up area is in private hands.

In the multifunctional roofing program of the municipality of Rotterdam, the Life @ Urban Roofs project has experimented with stimulating private investments in climate adaptation. This has resulted in research into the social benefits of multifunctional roofs and a calculation tool. We apply the lessons and the instrument from this project in the MRA, in the case Bazaar Beverwijk. Based on a social cost benefit analysis (SCBA), the social benefits of a multifunctional roof are made transparent. With this insight, the private interest can be better demonstrated, after which the discussion about capitalizing on these values and collective financing can be conducted.

Case Bazaar Beverwijk
Beverwijk's bazaar is a unique combination of outlets, boutiques, shops, stalls and restaurants, and is world famous in the Netherlands. It covers a spacious area, which is largely paved. This makes the bazaar vulnerable to flooding (by downpours) and heat stress. It is a busy area, the public space of which is used by visitors to walk, stay, eat and park. The buildings on the site mainly consist of large halls. There is great potential for multifunctional roofs, so as not to burden the public area further and still make the area climate-adaptive and seize opportunities for the energy transition.

Financial business case and social benefits
The investor in a multifunctional roof, or other adaptation solutions, only benefits from the direct financial benefits. The social benefits of a multifunctional roof are much greater than the financial benefits alone, but are not part of the business case. Example: if a developer installs an intensive green roof, it is good for biodiversity. The whole of society enjoys the benefits of this, but the developer gets nothing in return for these benefits. The developer does, however, enjoy benefits that arise from subsidies or other schemes. Table 1 provides an overview.

Financial cost and benefits	Social cost and benefits
Investment cost	Investment cost
Management and maintenance costs	Management and maintenance costs
Benefits energy production	Benefits energy production
Exploitation proceeds	Exploitation proceeds
Subsidies water retention	Real estate value (comfort, noise, etc.)
Subsidies green roof	Less vacancy (increasing popularity of property)
Energy production benefits	Image building owner
	Business climate district and city
	Avoided cost alternative water retention
	Water quality
	Climate (CO_2 emission)
	Air quality (SO_x, NO_x...)
	Climate awareness
	Heat stress
	Avoided health care cost
	Avoided loss of productivity
	Biodiversity
	Social cohesion

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	Cultural history
	Project implementation speed

Table 4 Financial and social benefits and costs of a multifunctional roof

To make adaptation measures more affordable, it is important to gain insight into the form and scope of these social benefits. This is the starting point to cashing in. To provide this insight, we quantify and monetize the social benefits where possible, see Table 2.

Effect	Description	€/ qualitative
Investment cost roof	Additional costs € per m2 roof compared to the reference alternative	€
Management and maintenance costs	Additional costs € per m2 roof compared to the reference alternative	€
Energy	Proceeds from energy production	
Image and business climate	Effects on the image and business climate are approached from several indicators: Property value: A 2 - 10% increase in property value due to green roof is assumed. The property value increase reflects the following sub-effects: aesthetic valuation, soundproofing, productivity and comfort). Although an increase in the property value can in principle be a financial benefit as well as a social benefit, a change in property value is only included as a social benefit. The basic principle is that the owners will not increase the rents. This means that these benefits are reflected in the form of a higher quality of living for the tenants of the buildings but are not reflected in the business case for the real estate owners. Vacancy / average number of responses to housing. In the case of private homes, the vacancy and the associated loss of rental income are considered. Image owner: does the project contribute to a green / innovative profile of the owner of the property? We discuss this indicator qualitatively. Business climate of the neighborhood and city: does the project contribute to an improved business climate for residents and businesses? We discuss this indicator qualitatively.	Real estate value and vacancy: € • Responses to housing (for social rent), image owner and business climate of the district and city: Qualitative
Water retention	For water retention, the physical measure is the number of extra m3 of water retention through the project. In the valuation of the effect, a distinction is made between the financial business case and SCBA Financial: amount of relevant subsidies. Social: shadow costs / avoided costs alternative retention facility (€ 500 per m3).	€
Water quality	In principle, the reduction in the number of m3 rainwater reaching the sewer system can locally reduce the number of sewage overflows into surface water. This benefits the quality of the surface water.	Qualitative

Climate	Climate is valued on the basis of avoided emissions from fossil power plants (Handboek Milieuprijs). The capture of CO_2 by roofs is limited.	Avoided emissions: €
Air quality	The effects of avoided emissions from fossil power stations are valued on the basis of the Environmental Prices Handbook. This includes environmental awards for more than 2000 environmentally hazardous substances. The use of the environmental awards in the Handbook is recommended by the Ministry of Infrastructure and Water Management. The benefits are determined by the saved CO_2 emissions and air pollutant emissions that are avoided (particulate matter, NOx, SO_2). The effects of particulate matter on air quality through capture are limited (RIVM, 2007) and are therefore not included.	Avoided emissions: €
Heat stress	Heat stress disappears in two ways: the effect on energy in the building (albedo and insulation) and the effect on energy outside the building (cooling of the environment through evaporation). The effect on energy costs in the building is nil. The effect on the energy outside the building (cooling of the environment) is via the health effect (see below, other is described qualitatively).	Qualitative
Health	The health effect has been approached from two sub-effects: Avoided healthcare costs: 0.835 fewer patients per 1000 inhabitants with 1% more green space within a radius of 1 km around the home; € 868 1 per patient (TEEBstad). For roofs it is assumed that 0.835 / 5 = 0.167 fewer patients within a radius of 200 meters. It is believed that only residents of the property will benefit. Prevention of loss of work: € 6,341 per patient. Assuming that 0.835 fewer patients per 1000 inhabitants with 1% more green space, this amounts to € 5,294.74 less work loss per year (TEEB stad).	• Health effects (physical and mental): € • Welfare effects: Qualitative
Implementation speed	Special features of the building (monument status, view, etc.) can have an influence on the implementation speed of the project.	Qualitative
Biodiversity	We use the non-use value of biodiversity: € 8-20 per person (with a view of greenery) per year (Witteveen + Bos 2011).	€
Social cohesion	With this effect we describe whether the project leads to extra opportunities for meeting (on ground level or on the roof) and less crime through greening.	Qualitative
Climate awareness	When the project is visible to users of the building, it can lead to extra awareness of the climate challenge.	Qualitative
Cultural history	Inspiration from historical water system solutions. For each project it is examined whether historical water system solutions are present and whether these can be made visible.	Qualitative

Table 5 Valuation of social benefits

The valuation of social benefits is used to calculate 3 design alternatives for multifunctional roofs in Bazaar Beverwijk.

Case Bazaar Beverwijk

In the case study, we focus on climate adaptation at building level by applying multifunctional roofs. By calculating three alternatives, we gain insight into the added value of these roofs.

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- Gray roof (reference alternative); replacement of the existing roof with a conventional roof package (not multifunctional)
- Green-blue roof; primarily aimed at retaining rainwater during extreme showers
- Green-blue yellow roof; multifunctional for retaining water, increasing biodiversity, generating energy and other social benefits.

In this case, all alternatives are applied to a roof of 6800 m2, as part of a new building to be developed. Costs for strengthening of the construction for the bearing capacity of the roof are not part of the SCBA. The analysis period is 40 years. The replacement period of a conventional roof package is 20 years, that of a multifunctional roof is 41 years. The discount rate is 3.0%. The costs and configuration of all three alternatives are listed in Table 3.

	Grey roof	**Green-blue**	**Green-blue-yellow**
Investment cost blue roof (water retention) /m2	0 m2 € 0	6.800 m2 (24mm) € 102.000	6.800 m2 (70mm) € 340.000
Investment cost green roof (bio diversity) /m2	0 € 0	6.800 m2 € 68.000	6.800 m2 € 68.000
Investment cost yellow roof (energy) /m2	0 € 0	0 € 0	3.000 m2 € 264.000
Construction cost	Remove current roof and apply PDM E50 / m2 € 340.000	Remove current roof and apply PDM E50 / m2 € 340.000	Remove current roof and apply PDM E50 / m2 € 340.000
Management and maintenance	€ 192.000	€ 126.000	€ 126.000

Table 6 Cost and configuration design alternatives

The result of the SCBA is included in Table 4.

	Grey roof	**Green-blue**	**Green-blue-yellow**
Cost	€ 605.000	€ 668.000	€ 1.327.000
Benefit	€ 0	€ 189.000	€ 3.414.000
Result	€ - 605.000	€ -478.000	€ 2.086.000
Real estate value	€ 0	€ 110.000	€ 110.000
Water retention	€ 0	€ 79.000	€ 231.000
Climate	€ 0	€ 0	€ 203.000
Air quality	€ 0	€ 0	€ 227.000
Avoided healthcare cost	€ 0	€ 0	€ 6.000
Avoided productivity loss	€ 0	€ 0	€46.000
Biodiversity	€ 0	€ 0	€ 442.000
Energy proceeds	€ 0	€ 0	€ 2.145.000
Image	No	Yes	Yes
Business climate	No	Yes	Yes
Social cohesion	No	No	Yes
Water quality	No	Yes	Yes
Climate awareness	No	Yes	Yes
Heat stress	No	Yes	Yes
Implementation speed	No	Yes	Yes

Conclusion

Compared to conventional roof replacement, multifunctional roofs bring many additional benefits to Bazaar Beverwijk. This will enable a large part of the climate adaptation task to be fulfilled in this area, to capitalize on opportunities for energy transition and improving the quality of the area. To capitalize on these social benefits, new coalitions are needed, in which private and public parties work together. The benefits presented then provide the basis for this discussion.

Capacity Building; fundamental need to collaborate in an effective way in order to deal with disruptive changes like climate change

Demonstration project Haarlem-Buitenrust

The challenge

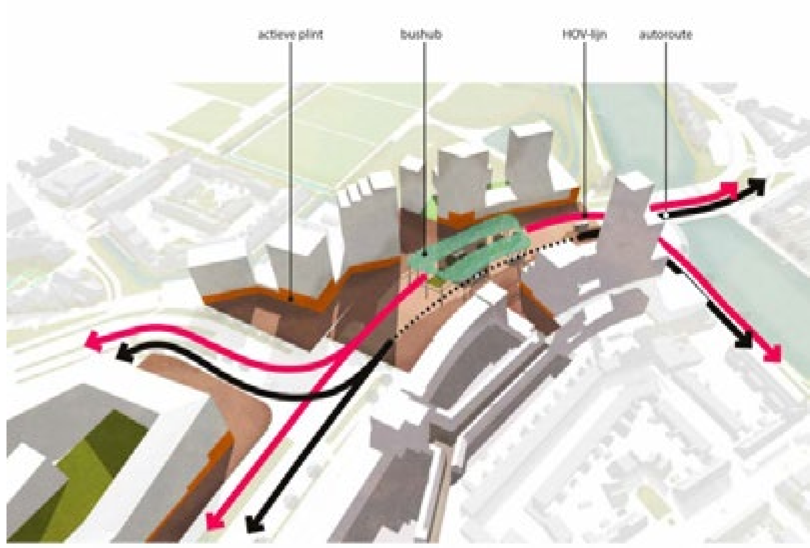

Figure A. Visualization of one of the transition opportunities

Haarlem has started with developing plans for a transition of the Haarlem-Buitenrust city district (see figure A); initiated by the need of a fast-public transport hub, expanding to improve mobility and to generate the complete transition of the neighborhood. This has created opportunities to transform Buitenrust into a new metropolitan area characterized by mixed use, combining residential, commercial, cultural, institutional and entertainment uses. In order to realize this new metropolitan area it is acknowledged that a concrete plan for the entire area is needed rather than multiple separate projects. For successful implementation, this demands collaboration of all stakeholders involved.

Besides collaborative challenges, the development is complex due to the exact characteristics of the area. The design needs to consider multiple challenges such as flooding (as the area is below sea level), traffic congestion, 'paalrot' (rotting wooden fundaments of the houses), heat stress, and social issues.
Transitions are needed but will be complex, many stakeholders need to collaborate and participate, long-term impacts need to be considered regarding the (infrastructural) investments in assets with life cycles > 30 year.
These pressing challenges, inclusive the time constraints, make the Haarlem-Buitenrust district a perfect pilot area to further explore the question: *"How to ensure that climate adaptation will become a "normal" part of integrated investment decisions now and in the future, in area development processes within the MRA?"*

Approach
Any organization, consortium or alliance which has a gap in the high level of main specific organizational competences, will be less capable of not capable to deal with climate change in an effective way. In order to integrate climate adaptation in investment decisions of area development processes, it is important to understand the capacity that is needed for mainstreaming climate adaptation.

Gupta et al. (2010) have developed the Adaptive Capacity Wheel, to assess the capacity of society to adapt to climate change (see Figure B). Adaptive capacity is often analyzed at an organizational or institutional level but area development processes can also serve a good level of analysis. In order to deal with complex issues and ensure effective collaboration it is important to understand the adaptive capacity, to identify gaps and suggest a way forward.

Figure B. Adaptive Capacity Wheel developed by Gupta et al. 2010

At the start of initiating transitions with a high complexity and to deal with disruptive changes in an effective way it is recommended to identify the existing competences gaps. Identifying gaps in order to fill these and build capacity to the required level. To identify and understand the gaps in the adaptive capacity - needed to integrate climate adaptation in investment decision for area development - the CAPT4PE model will be deployed to scan the current adaptive capacity of the Haarlem-Buitenrust district. This model has been based upon the PACT analysis of David Ballard with many successful past performances.

The actual joint capacity of various organizations can be analyzed on behalf of 9 competences, as outlined on the figure below (Figure C). Three competences on strategic level, three on tactical level and three competences on operational level. The competences are rated on a 6-point scale. A score from 4 and higher indicates that the adaptive capacity is sufficient to integrate climate adaptation in investment decisions.

Identifying gaps and pathways to improvement will help to area development processes to be capable of dealing with disruptive changes like climate change. Good to know is the earlier gained insight: If just one of the 9 competences is below 4, the organization can't deal with disruptive changes in an effective way.

Figure C. The nine competences required (on high level) within an organization in order to deal wit disruptive changes in an effective way.

Results and insights gained

The current capacity level of the expected consortium for the Haarlem-Buitenrust city district has been analyzed. Four key persons have been interviewed. Good to realize that the results of analysis should be seen as indicative. Just a few key persons haven been interviewed and a shortlist of the optional questions have been discussed.

Figure D shows the current level of the nine competences. Based upon these first results it is clear that several gaps need to be filled in order to ensure that climate adaptation will become a "normal" part of the integrated investment decisions in the Haarlem-Buitenrust district development.

The analysis of the insights gained show also that many pathways to improve the current capacity level have been started already;

- There is awareness, but only on a personal level. It should be incorporated in the organization;
- Inspirational leadership is needed. Not only on the level of city officials, it also requires administrative leadership;
- Stimulate and support the getting out of your comfort zone, to support the change agents needed;
- Discuss the dynamics, plans and ambitions with the consortium partners in order and collaborate on a holistic Masterplan for Haarlem-Buitenrust ;
- Share and discuss what you want to achieve;
- In the current situation stakeholders insufficiently anticipate and operate scattered;
- Climate must be higher on the agenda: there is a sustainability plan with a 15 % rule, but this rule is not decisive.

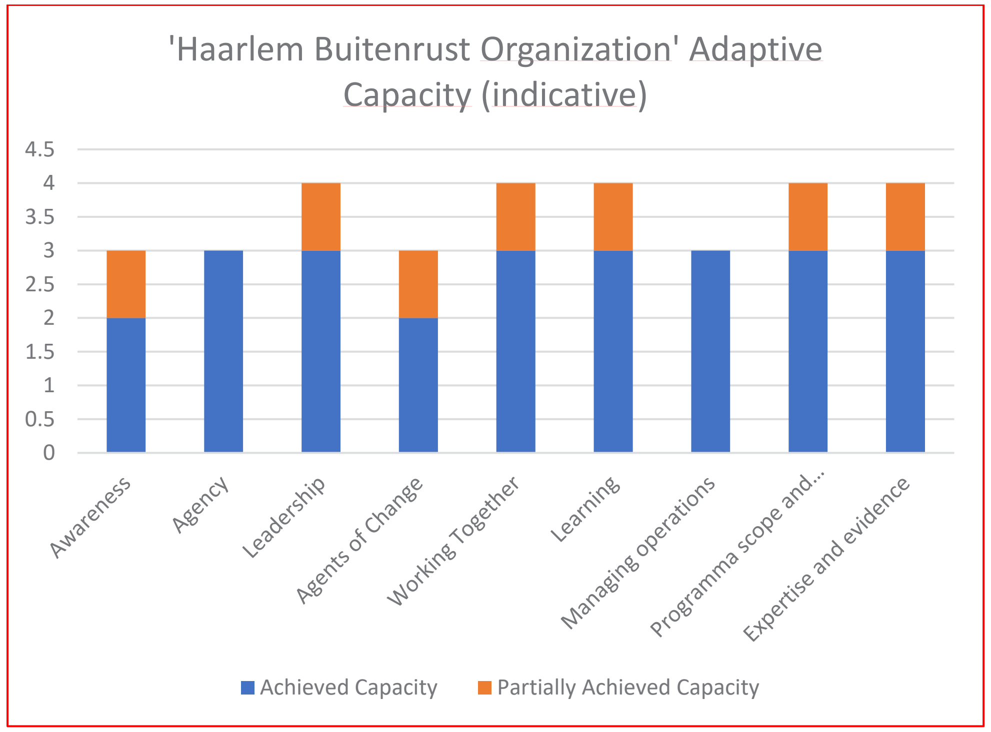

Figure D. Current capacity level (indicative) of the possible Haarlem-Buitenrust consortium

Based upon the insights gained, actions and pathways can be formulated to fill the gaps in the competences level. In general the Haarlem-Buitenrust district development needs to be approached in a more holistic way from scratch; integrating climate change challenges all over the program. In table I first actions and pathways to improve have bene elaborated on competence level (only for those competences with a gap in level identified).

Table I. Actions and pathways to be started to raise the capacity level

Competence	Current level	Actions	Step
Awareness	2 (partially achieved capacity level 3)	All partners should become aware of both opportunities and risks in the different fields. Being aware of the impact in short ter, md-term and long-term. Results of research, studies and plans available need to be shared to enable the project managers to anticipate on opportunities and risks	1
Change agents	3	Select and train possible change agents; support the development of competences needed to stretch out, develop effective collaboration	1
Leadership	3 (partially achieved capacity level 4)	Position one of the city councilors to secure climate adaptation will be integrated in area developments like Haarlem-Buitenrust district	2
Working together	3 (partially achieved capacity level 4)	Ensure as fundament voor collaboration that stakeholder interests will be identified, shared and known	2
Learning	3 (partially achieved capacity level 4)	Identify the lessons learned of look-a-like projects, create a learning program to incorporate these into new projects	3
Expertise and evidence	3 (partially achieved capacity level 4)	Analyze gaps in knowledge and expertise and focus learning and acquisition on getting this knowledge in the organization	3

APPENDIX: PROCESS AND STAKEHOLDERS

"Everyone has a plan until they get punched in the mouth" - Mike Tyson

In the original plan the project would revolve around three large meetings. It was not foreseen how COVID-19 would make a process in this form impossible, nor how the many smaller video conferences that replaced these meetings would ultimately make the process broader and more agile.

In mid-April, a series of preparatory conversations took place, in the breadth of the entire MRA. From discussions with the actors involved, a broad overview has been obtained of the current and future tasks for area transformation, the expected climate stresses and system weaknesses and the current response to these.

The team distilled four focus areas, each with distinctive spatial characteristics, actors and climate stresses. From May to August the relationship between targeted area transformations and climate stresses were explored in small workshops with these actors, giving input for a design thinking process. The results were fitted in demonstration projects for each of the focus areas.

Parallel to the focus processes, various one-to-one and group conversations with experts have linked the observations and thinking back to the MRA as a whole.The team is grateful for the broad input from the many people involved, around 300 in total.

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CONTEXT-SETTING

- DEEP DIVE URBAN DEVELOPMENT STRATEGY
- ECONOMICAL TRENDS AND RISKS
- BIODIVERSITY
- FUTURE PROOF WATER SYSTEM
- DROUGHT/SALT INTRUSION
- LAND SUBSIDENCE
- VITAL & VULNERABLE
- EXTREME RAINFALL
- HEAT

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VARIOUS WORKSHOPS WITH:
- MRA TEAM CLIMATE RESILIENCE
- MRA TEAM URBAN DEVELOPMENT STRATEGY

ONE RESILIENT TEAM

The ONE team was comprised of local and international partners who collaborated throughout.

One Architecture — team lead; urban design and urban planning
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Arcadis, Netherlands — adaptation financing and business case
Robert de Kort, Eric Schellekens, Ian Minnes, Britt Snellen, Dieneke de Weerd

Smartland — landscape architecture
Klaas Jan Wardenaar, Leon Emmen

Climate Adaptation Partners — heat and public health impacts
Janice Barnes

Over Morgen — mitigation/energy transition strategy and financing
David Witvoet, Gerwin Hop, Jeroen Roeloffzen, Maarten Verkerk

University of Pennsylvania — cultural dimensions and implications
Prof. Simon Richter

DRIFT of Erasmus University — energy transition management
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For more information on the MRA Climate Adaptation Program:
metropoolregioamsterdam.nl/programma/klimaatadaptatie/