Cloudburst catalog

A co-created collection of lessons learned from 10 years with cloudburst planning and design around the world

RAMBØLL

Bright ideas. Sustainable change.

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We call it: Bright ideas. Sustainable change.

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Cloudburst Catalog

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Foreword

This catalog presents a mindset and a process to inspire place-specific, nature-based design in any part of the world.

Across the world, communities are facing the complex challenge of aging stormwater infrastructure, increased expectations of urban life and protection levels, growing populations, and the prospect of more frequent high-intensity rain events as a result of climate change.

Traditional (gray) stormwater infrastructure is no longer an adequate solution on its own. Replacing existing pipes with new and potentially larger pipes is an expensive, single-purpose solution that yields limited benefits for communities. Cities around the world have been exploring alternative infrastructure for years. However, oftentimes such solutions are implemented in isolation, ad-hoc, as single-purpose, or disconnected add-ons to existing stormwater management systems, yielding limited flood reduction and little to no natural elements or community benefits.

Instead, cities can apply a networked approach at the watershed scale to systematically supplement underground piping with above ground, multi-purpose, nature-based solutions that create space for water. Water is vital to the health of all ecosystems and has the potential to enhance physical and mental health, reduce inequalities, and enhance connectivity. By reintroducing nature as part of a future-oriented, water-first approach to community resilience, we can not only reduce flood risk but also provide wider ecosystem benefits for nature and people.

In Copenhagen, the aspiration to address extreme rainfall ("cloudbursts"), increase urban liveability, and foster long-term resilience brought about a new paradigm referred to as "cloudburst management". This paradigm introduces a water-first, systems-thinking approach to foster resilient and connected communities.

A decade later we collect and reflect on our ongoing work with cloudburst programs around the world. We continue to adjust our mindset and methodologies to ensure that our work has the positive impact that we aspire for. For instance, we now call it "cloudburst-thinking" instead of "management" for two reasons:

1. Firstly, to reiterate that we refer to a mindset, not an infrastructure.

2. Secondly, to underline that we should not control water - rather, we want to embrace it, let it guide our designs and give it back space to enrich our lives.

This catalog is meant as an inspiration to colleagues around the world who wish to advance multi-purpose, nature-based designs to create sustainable societies where people and nature flourish. Please enjoy!

Trine Stausgaard Munk
Head of Sustainability
Ramboll

Key terms

Benefit-Cost Analysis (BCA): A method to assess the societal and economic benefits and costs of a project.

Blue-Green Infrastructure (BGI): Stormwater management practices that connect urban hydrological functions (blue) with vegetation systems (green) and community priorities (co-benefits). BGI offers valuable solutions for urban areas facing the challenges of climate change and reduces the need for traditional gray infrastructure. Multi-functional BGI co-designed with communities generates social, economic, and environmental value. BGI is a subset of Nature-based Solutions.

BGI Network: A flexible and multi-functional system of BGI. A network of natural and semi-natural spaces strategically designed within urban areas to provide multiple ecological, social, and economic benefits.

Complexity: The unpredictable and relational dynamics found within living systems. Here, connections cannot be predicted, fully known, or controlled. Instead, complexity can be sensed through careful whole-systems activation

Business case: Used interchangeably with Benefit-Cost Analysis

Cloudburst: A sudden, heavy downpour where a large amount of rain falls in a short amount of time. Cloudburst events can overwhelm storm sewers causing flooding, property damage, disruptions to critical infrastructure, and pollution to waterways. Cloudburst is often used interchangeably with other terms such as extreme rainstorm, extreme rain event, or extreme precipitation. Cloudburst is commonly used for rain events that exceeds traditional design criteria.

Cloudburst Masterplan: Another term for a BGI Network. It is a catchment-based strategic plan designed to manage and reduce the impacts of sudden, heavy rainfall (also known as cloudbursts) in urban areas.

Co-Benefits: describes the added benefits of BGI, in addition to the primary purpose of flood risk reduction and/or pollution prevention. Co-benefits of BGI can include improved air quality, recreational value, physical activity, micro-climate, traffic safety, biodiversity, and noise reduction.

Design Storm: A design storm is a defined rain event including potential climate factors, whose Intensity, Duration, and Frequency (IDF) are selected as a desired level of protection (Return Period) and design criteria for resilience planning.

Life-affirming: Working in concert with the cyclic and generative capacity of all living systems. Thoughts, intentions, actions, and designs should all be aligned with the principles of living systems. It is as much a mindset of abundance as it is a design philosophy to nurture and activate the conditions conducive to life.

Living systems: The open and self-organizing nature of all socio-ecological beings and communities. In living systems, the whole is greater than the sum of the parts.

Nature-based Solutions (NbS): Nature-based Solutions are broad strategies that leverage the inherent qualities of nature to address various societal challenges, including those related to urbanization, climate change, and environmental degradation. NbS encompasses a wide range of approaches that utilize nature or natural processes to provide benefits to both the environment and human well-being, including for instance Blue-Green Infrastructure.

Place: The proximate whole, nested within a greater whole, having a unique essence and developmental potential. Place is where past, present, and future converge, and complex relationships between living and non-living stakeholders create a unique story and vibrant presence.

Return Period: The return period defines how frequently and how intense rain events of the same magnitude will occur in a specific location. For example, a '10-year event' would have a 10% chance to occur every year. This does not guarantee that this rain event would occur once every 10 years but would instead provide the probability that the storm would occur in a given year.

Service Level: The stormwater service level describes the expected or designed capacity of the storm sewer system. Service Levels are often expressed using a Return Period, such as a 5-year rain event. When the service level is exceeded the stormwater drainage system may overflow and cause flooding and/or pollution.

Performing arts on the water in Tanner Springs Park

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Introducing cloudburst thinking

What is cloudburst thinking?

Cloudburst thinking refers to the paradigm shift in urban planning and stormwater management that originated in Copenhagen and has since been pioneered by Ramboll and partners worldwide.

Cloudburst thinking introduces an integrated and place-based planning methodology that combines an inclusive and just process with in-depth hydraulic and urban analysis, climate risk assessment, nature-based designs, and socio-economic business cases.

It recognizes that urban stormwater management is a highly complex challenge that requires collaboration between the engineer, designer, anthropologist, biologist, economist, community engagement specialist, and many other diverse profiles. It acknowledges that present standards are not adequate responses to this complexity and inspires tailormade solutions to each place.

This requires collaboration across city agencies, decision-makers, and relevant stakeholders and a fundamental upskilling to move from top-down, city-wide implementation of standards, to bottom-up, tailor-made solutions co-created with and for each place.

These tailor-made solutions are connected in a flexible, multi-functional, and nature-based city-, district-, or catchment-wide network referred to as a “Cloudburst Masterplan”. This network will not only complement and/or replace gray stormwater infrastructure to cope with future climate conditions, but also act as a guide for all other urban transformation in the city, thereby both giving a voice to water and elevating citywide flood resilience.

Cloudburst thinking offers an opportunity to reintroduce biodiverse and rich nature into urban spaces to recreate a more natural water cycle and facilitate a human reconnection to nature.

In addition to stormwater management and flood reduction, the cloudburst masterplan can be designed to regulate urban temperatures, clean air and water bodies, offer new recreational spaces, inspire physical activity, provide new job opportunities, and help reduce stress.

By co-designing with place and communities we can maximize the positive impacts and improve everyday lives, even when it does not rain.

The concept of cloudburst management originates from the City of Copenhagen. In Denmark, a cloudburst is defined as more than 15 mm of rain in 30 minutes. However, the term is often used to describe short duration, high intensity rain events that quickly saturate existing drainage infrastructure, potentially causing extensive flooding.

A young family caught off guard by the sudden and game-changing cloudburst in Copenhagen on July 2nd 2011.

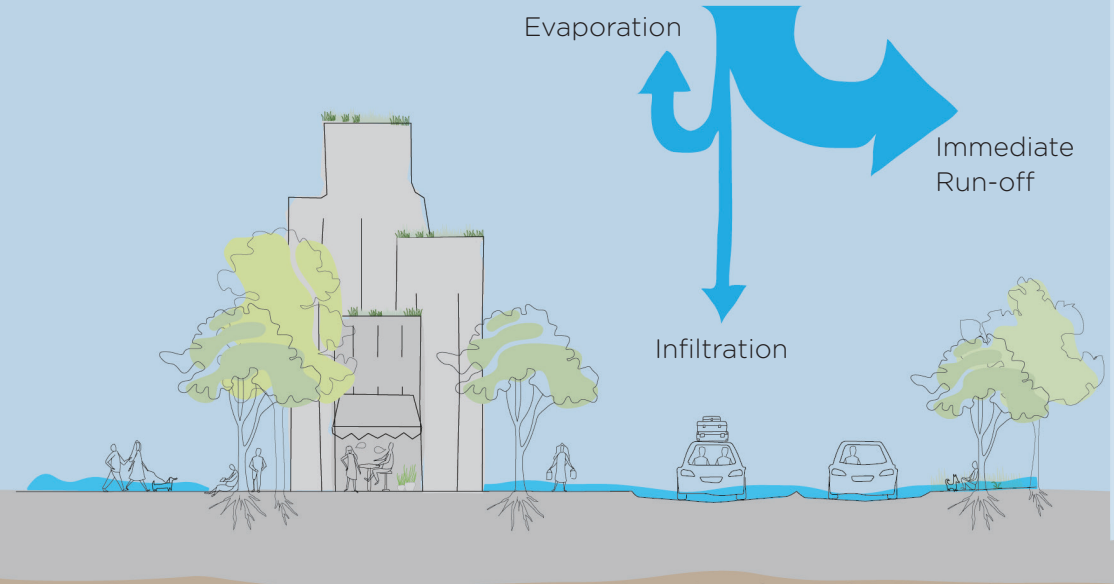
The Copenhagen journey on cloudburst management

©Frank Peters - stock.adobe.com

The Cloudburst Management Plan for the City of Copenhagen was published in 2012. It has inspired cities around the world to take a more future-oriented, water-centric, and community-led approach to their urban planning and design approaches. It was followed by a Climate Change Adaptation and Investment Statement in 2015, which included a total cost estimate for cloudburst-proofing Copenhagen and a business case demonstrating that the cloudburst program could in fact pay for itself.

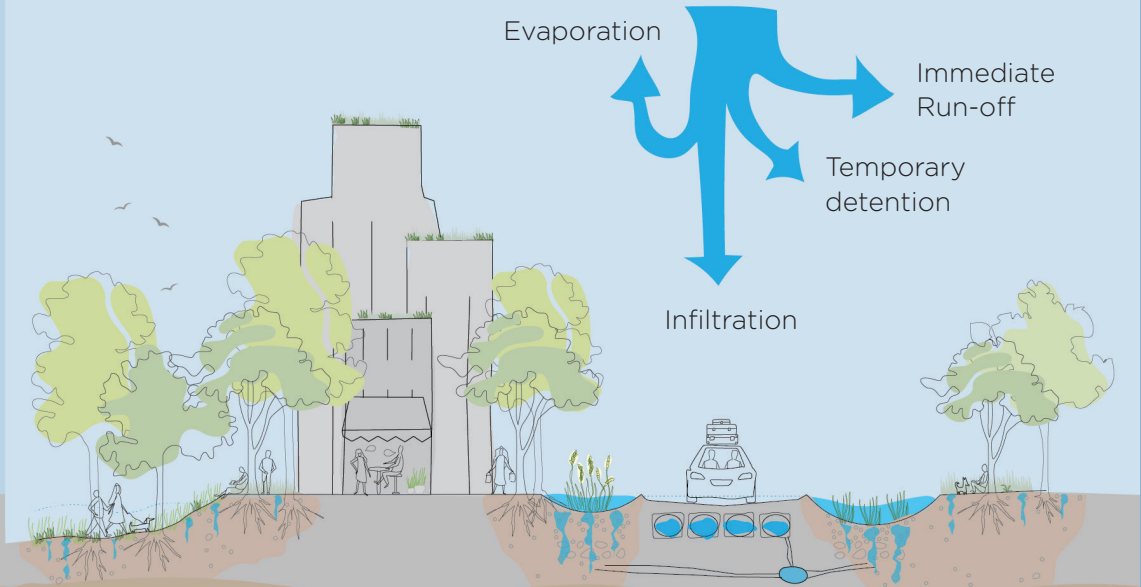
Source: Left: The City of Copenhagen. (2012). Cloudburst management plan. The City of Copenhagen Technical and Environmental Administration. https://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf
Right: Københavns Kommune. (2015). Climate change adaptation and investment statement: Part 1. https://kk.sites.itera.dk/apps/kk_pub2/pdf/1499_bUxCjgovgE.pdf

Can we restore a more natural water cycle in our urban communities?



Traditional approach

Urbanization and land-use change have dramatically altered the natural water cycle causing high stormwater run-off velocities and volumes in cities when it rains

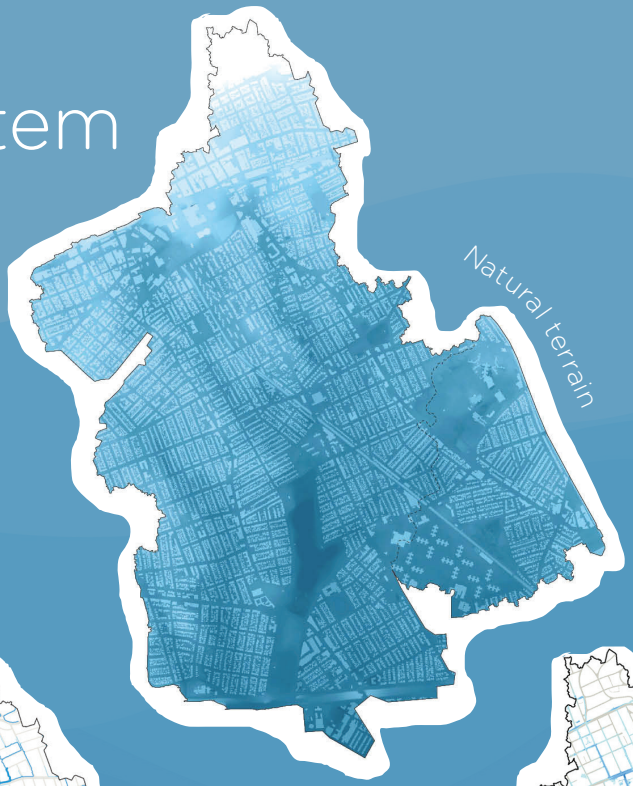


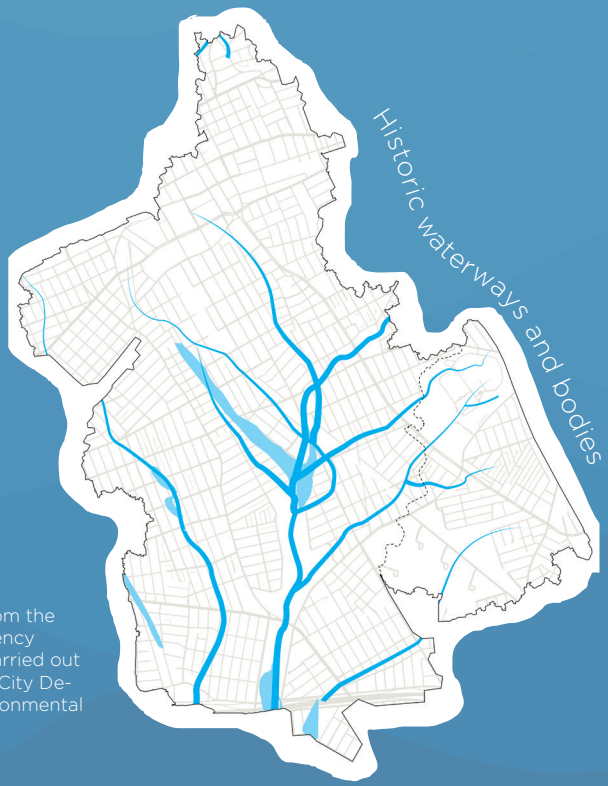
Cloudburst approach

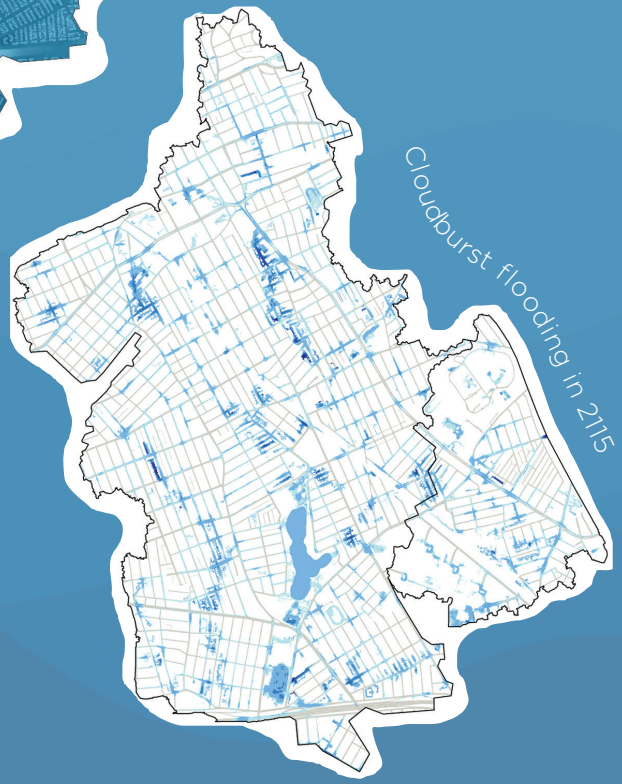
Restoring a balanced urban water cycle by reintroducing nature and creating space for water thereby increasing evaporation, slowing down and reducing stormwater runoff, while also considering groundwater levels and quality.

Understanding the water system at the watershed scale

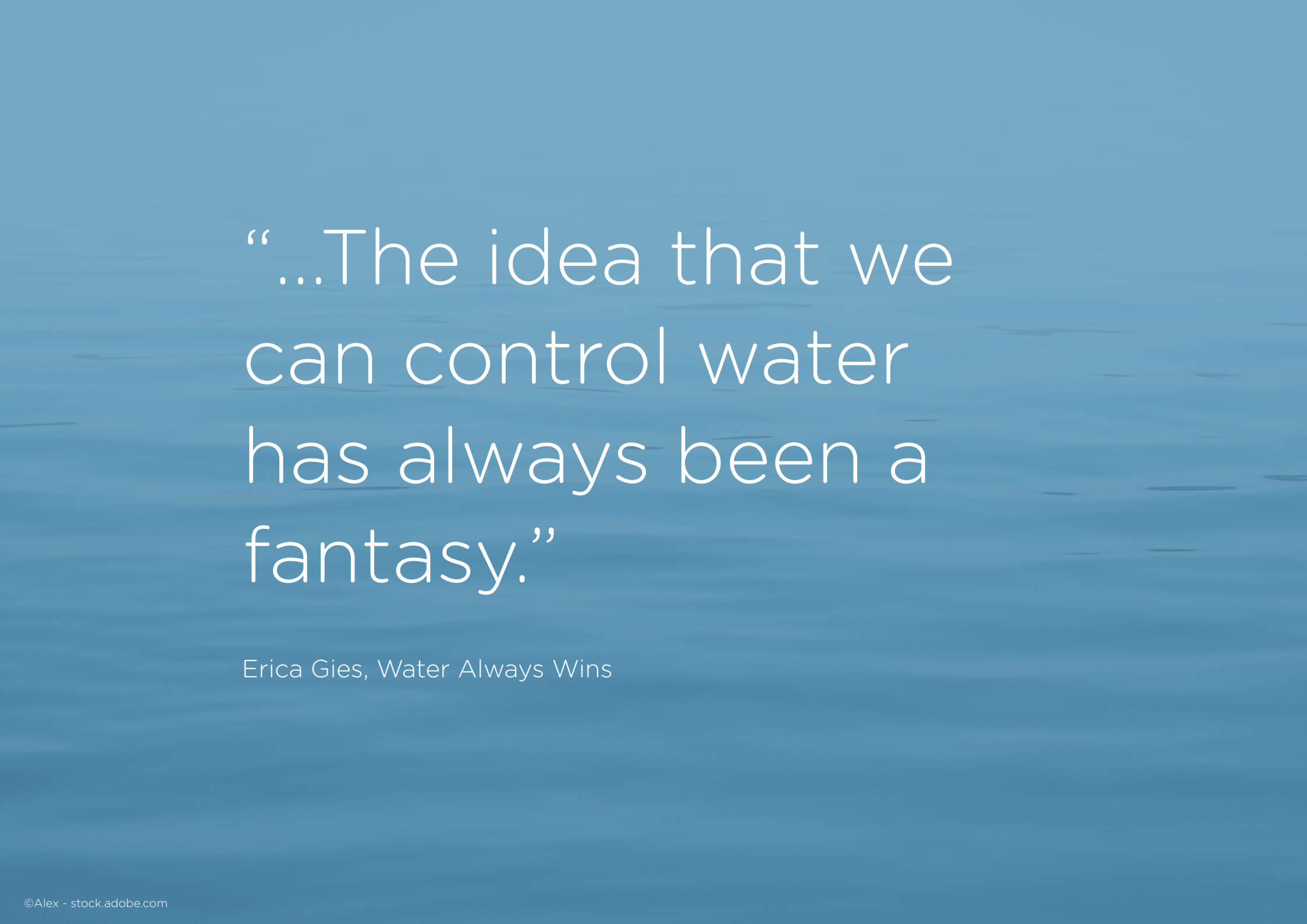
To restore a natural water cycle in urban areas we need to understand the historic water systems, how it flows today through the watershed, over the urban landscape, and in the underground pipe network, as well as future flows depicted by climate change models.







Example maps from the Cloudburst Resiliency Planning Study carried out for the New York City Department of Environmental Protection (DEP)



As the landscape architect for Ringsted Square, Neil Goring envisioned a space where water would be the storyteller. He integrated natural water features into the landscape, allowing the flow of water to shape and define the urban environment. Through his design, the square became a living, breathing space—dynamic, inclusive, and guided by the ever-changing nature of water.

> I love working with water and landscapes because they reveal an elemental truth. Water will ultimately go where it wants to go, scaping diversity in the landscape, guiding us to understand the phenomenological nature of place. The challenge lies in how we interact with it.
> In many ways, water itself is the most genuine and inclusive lead designer.

Neil Goring
Landscape architect

Research documents the immense potential in designing as water

Water can significantly enhance physical health in a multitude of ways

Studies indicate that people tend to exercise longer in blue spaces compared to green or urban spaces. Physical activities in water can positively impact self-esteem, resilience, and the sense of self. Swimming in natural water bodies can reduce fatigue and promote overall mental health. It even has a treatment potential in major depressive disorder.

“The physical properties of water, the exploration of the body’s reaction to hot and cold stimuli, and osmotic pressure, stimulating the nerves to conduct these impulses into the body, where they will act on the immune system, increase circulation, improve digestion, and reduce the sensation of pain” (Bastos (2016) as cited in Queiroz e Barbosa (2022)).

Studies also suggest that the mists and sprays from water bodies can help reduce respiratory inflammation and improve lung function.

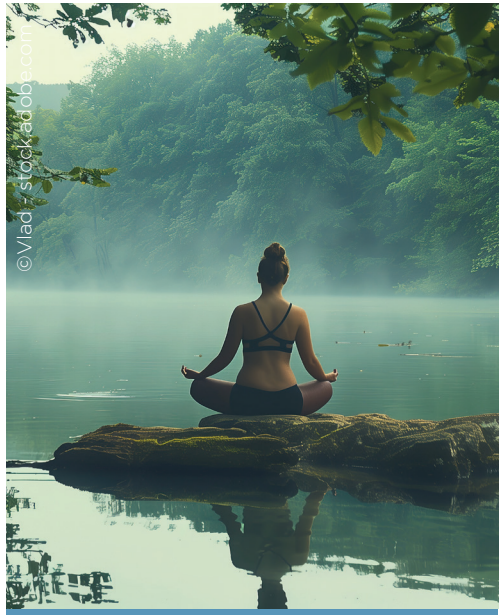
Sources: Bell, S., Fleming, L. E., Grellier, J., Kuhlmann, F., Nieuwenhuijsen, M. J., & White, M. P. (2021). Urban Blue Spaces. Routledge.
Britton, E., Kindermann, G., Domegan, C. and Carlin, C. (2018). Blue Care: A Systematic Review of Blue Space Interventions for Health and Wellbeing. Health Promotion International, 35(1). doi:https://doi.org/10.1093/heapro/day103.
Queiroz, J. and Barbosa, B. (2022) ‘Dance in the water: academic research as educational praxis’, Revista: Ensino de Perspectivas, 3(1), pp. 1-14. Fortaleza. ISSN 2675-9144.
Völker, S., & Kistemann, T. (2011). The impact of blue space on human health and well-being – Salutogenetic health effects of inland surface waters: A review. International Journal of Hygiene and Environmental Health, 214(6), 449–460. https://doi.org/10.1016/j.ijheh.2011.05.001

Water is imbued with magic, mysticism, and reverence.

Throughout generations water has served as a vital ingredient in a wide range of beliefs and rituals. Water plays an important role in births, weddings, baptisms, and death ceremonies across various traditions, cultures, and religions.

Water can help reduce inequalities for vulnerable groups.

Residents living closer to blue spaces have higher life satisfaction and better mental health than those farther away, especially individuals economically disadvantaged. Having a view of water from home is especially significant for elderly individuals with limited mobility.

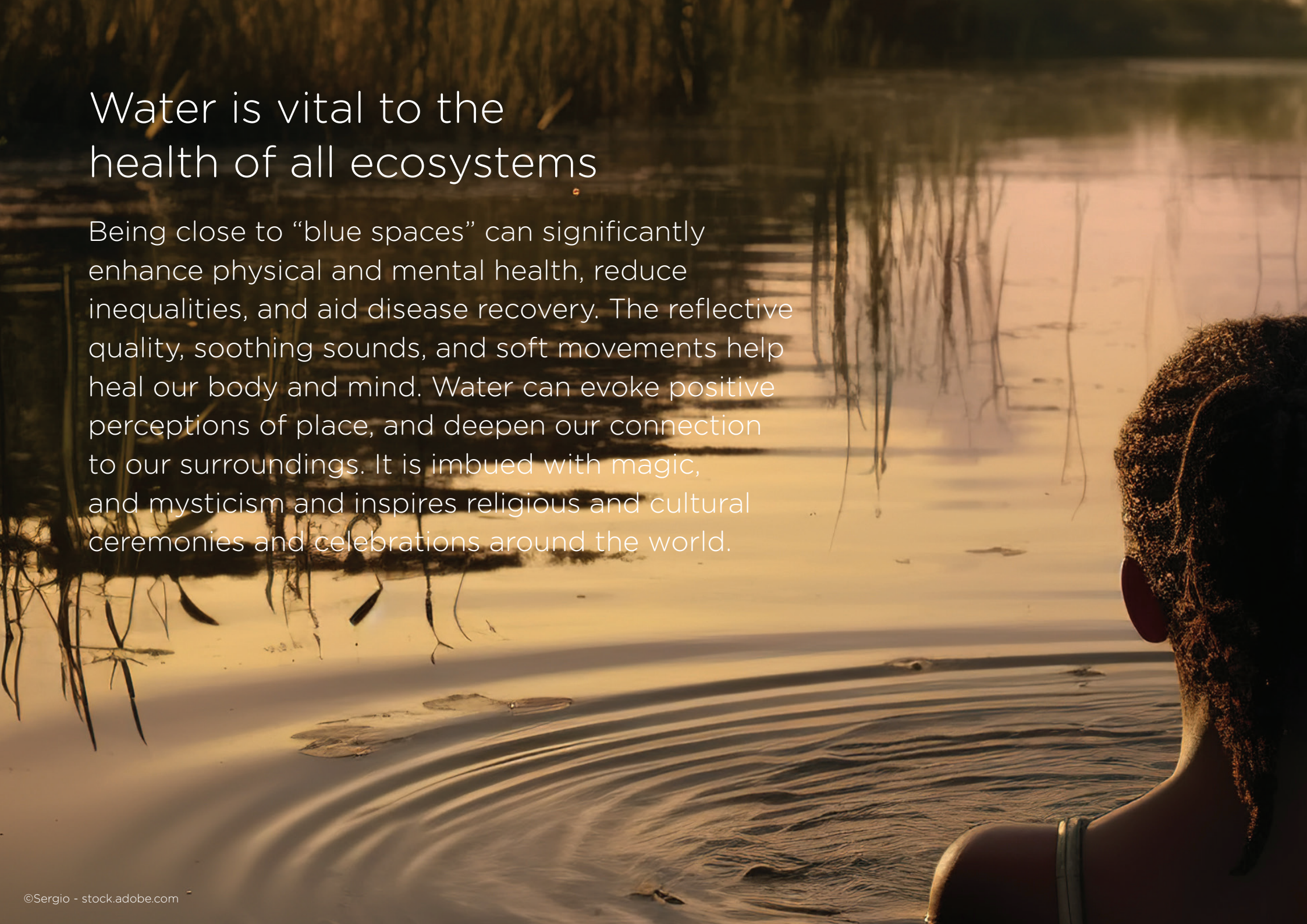


Water is an ally in promoting good mental health.

Water offers calming elements that reduce stress, such as soothing light, soundscapes, dynamic patterns, and personal associations. Listening to water sounds can aid the restoration process. Compared to other environments, water has the biggest impact on emotional states.

Water can evoke a positive perception of a place.

Water can deepen the visitor's connection to place. The landscape can evoke emotions and "a symbolism" difficult to achieve with any other natural element. Throughout history, water has guided the formation of urban settings serving as both a transport corridor, a source of life, and a divine gateway.



Water is vital to the health of all ecosystems

Being close to “blue spaces” can significantly enhance physical and mental health, reduce inequalities, and aid disease recovery. The reflective quality, soothing sounds, and soft movements help heal our body and mind. Water can evoke positive perceptions of place, and deepen our connection to our surroundings. It is imbued with magic, and mysticism and inspires religious and cultural ceremonies and celebrations around the world.

> When we imagine the future of our communities, we must imagine it as multi-purpose, nature-centric, and self-maintaining. Collectively, we have to put imagination into practice by shifting to a new paradigm of design that centers around equity and life - all life. Water could be the most inspirational and life-giving stakeholder to help us do just that!

Emory Lee

Climate Adaptation Planner


“Most of the earth’s surface is covered by water, and most of the human body is composed of water—two facts illustrating the critical linkages between water, health and ecosystems.”
World Health Organization (2017) as cited in Britton et al. (2018)
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But sometimes water becomes a risk to life

Too little water

Long periods of drought can jeopardize life and livings systems as waterways and crops dry out and overall access to water is greatly reduced. Water crisis and water scarcity is among the largest global risks.

Too much water

Excess water can flood complete communities, causing loss of livelihoods, health risks, and damages to living and non-living systems and infrastructure. Extreme weather and climate adaptation failure is the largest global risk.

Contaminated water

Extreme weather events can cause contamination of water supply, and breakdown of sanitation systems posing serious threats to human and ecosystem health and safety. Nine out of 10 climate events are water related.

Source: World Economic Forum. "Why Water Security Is Our Most Urgent Challenge Today." World Economic Forum, 12 Oct. 2023, www.weforum.org/agenda/2023/10/why-water-security-is-our-most-urgent-challenge-today/.

Inspiring cloudburst resilience planning

How do we design for community resilience?

While cloudburst thinking is a mindset, cloudburst resilience planning is a well-applied process. It is based on experiences from Denmark and around the world. It expresses a symbiotic relationship between a water-first and community-led approach, and between a digital foundation and an intuitive connection with water.

It centers around spatial overlay of datasets and technical analyses to identify potential synergies and cumulative effects and provide a solid basis for informed decision-making. It requires systems-thinking and an inclusive, place-based approach to develop a connected and flexible network of interventions. The purpose of the cloudburst resilience planning approach is to reduce climate risk while also increasing community and ecosystem value for generations to come.

Developing cloudburst networks is an ever-evolving process. It is of paramount importance that the network is designed for flexibility by promoting diversity and being connected across scales. Cloudburst networks are designed to co-evolve with changing conditions. As urbanization, society, or climate changes the cloudburst network will have to adapt too.

The following section walks through our simplified 4-step approach to cloudburst resilience planning.

Elevating urban resilience through cloudburst thinking

Adapted from the UN-Habitat, we define resilience as

"...the ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses while positively adapting and transforming towards sustainability."

Designing for resilience "...is about facilitating positive emergence, co-creating collaborative networks of relationships that nurture the conditions in which we (life) can meet uncertainty with creativity, adaptive capacity and a readiness to transform in response to change and disruption."

Daniel Christian Wahl, 2016

Our cloudburst resilience planning approach can be simplified into four overall steps

1 Understanding patterns & potential of place

The initial flood assessment documents how the flood hazards manifests in place and time. A thorough exploration of community vulnerability help us understand what and who can be exposed to flooding, why, and how severely. A holistic climate risk assessment shows the socio-economic consequences of flooding over time and space.

2 Inviting community-led visioning with place

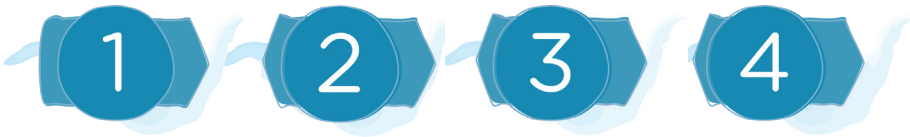
The climate risk assessment informs the co-creation of a community resilience vision and cloudburst resilience plan through systems-thinking and a place-based approach. Special attention is giving to aspects influencing climate justice. Through a water-first approach community priorities are synergetically interwoven with hydraulic connectivity and urban design.

3 Co-creating and evaluating design pathways and goals

The effects of the proposed vision and designs are evaluated against desired design outcomes through further flood and climate risk modeling, and community engagement. Step 2 is repeated until the desirable outcomes are documented and approved.

4 Nurturing co-evolving ecosystem conditions

Cost, benefits, and co-benefits are evaluated in a holistic business case to enable co-financing of the cloudburst resilience plan. The business case illustrates the socio-economic value over time to support the implementation pathways and financing of the cloudburst resilience plan.



On the following pages you will see these numbers guiding you through the four steps in the cloudburst resilience planning process

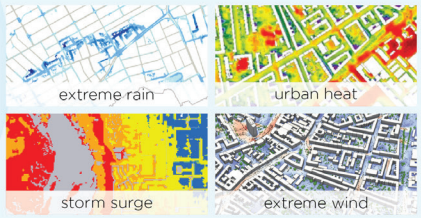
Four steps to activate a water-first, community-led approach to build resilience

An ever-evolving process that invites conditions conducive to life.

1 Understanding patterns & potential of place

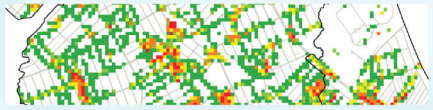
Sensing connections and stories of place

Modeling climate hazards for a "do-nothing" scenario



Co-exploring and documenting exposure and vulnerability

Quantifying and qualifying climate risk

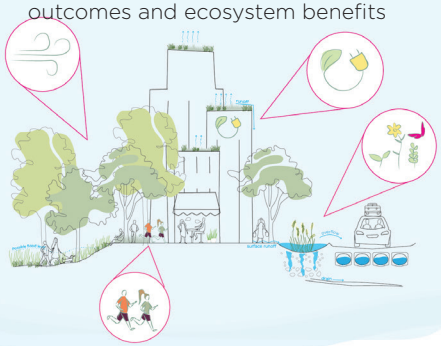


2 Inviting community-led visioning with place

Co-creating community resilience visions

Co-developing a community resilience network

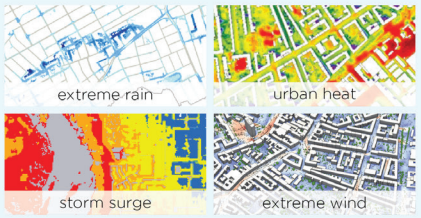
Designing for nature-positive outcomes and ecosystem benefits



3 Co-creating and evaluating design pathways and goals

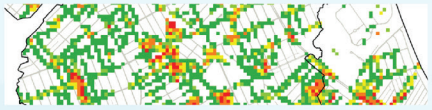
Evaluating proposed interventions and their consequences

Modeling climate hazards for proposed interventions



Co-creating place-based designs and pathways

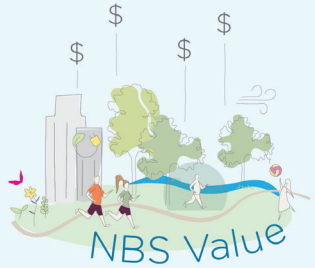
Quantifying and qualifying residual climate risk



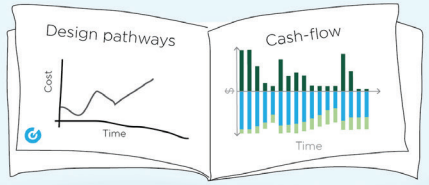
4 Nurturing co-evolving ecosystem conditions

Developing a governance, co-financing, and maintenance plan

Quantifying the socio-economic value of the resilience plan



Communicating costs and benefits in an investment statement



Climate resilience planning is an ever-evolving process

1

How can we understand the uniqueness of place?

Which explorative questions can help us sense into the patterns of place?

What is the local capacity to maintain cloudburst interventions?

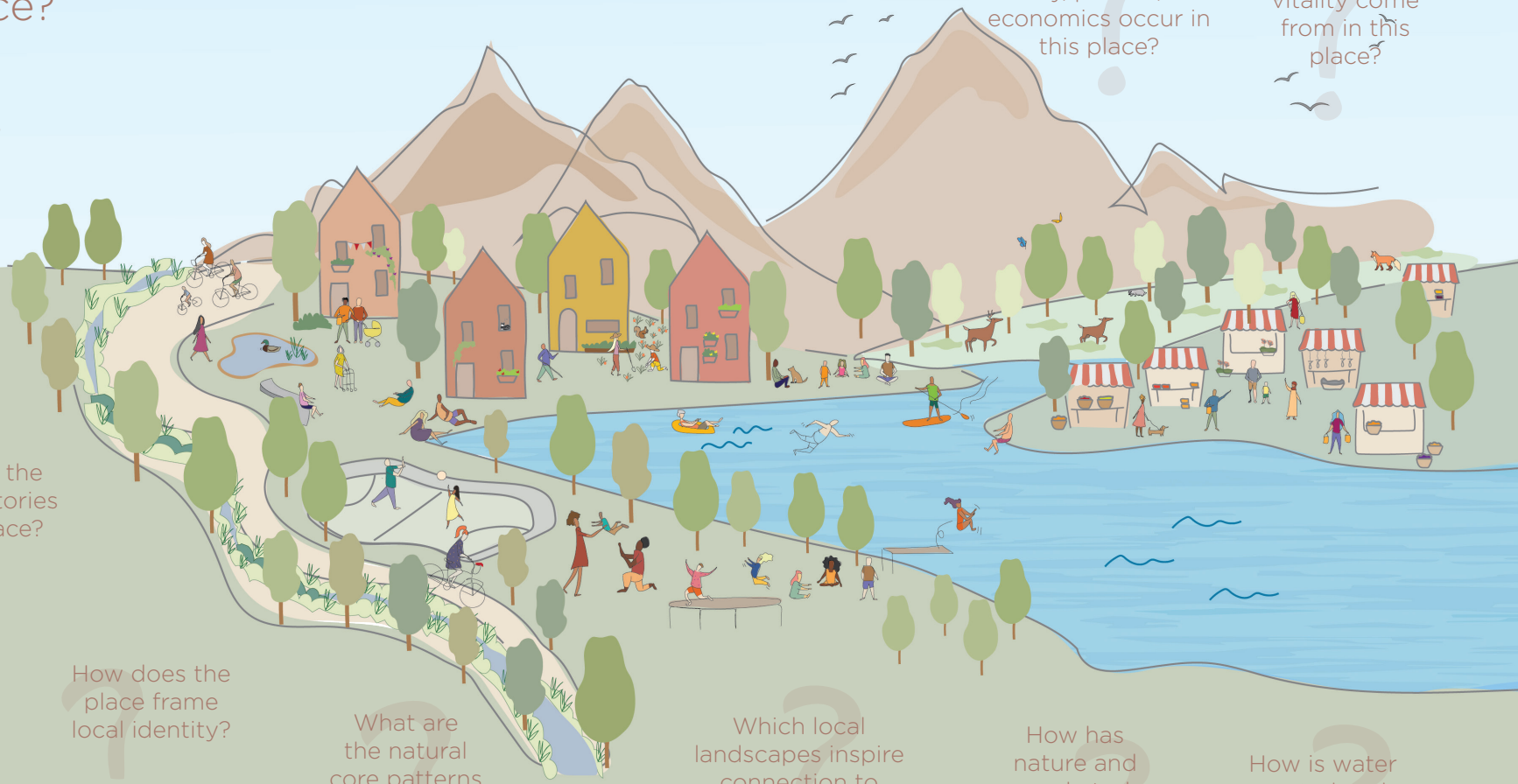
What local sayings and emotions are tied to water here?

How can we sense the inherent value and essence of this place?

What intersections of culture, environment, history, politics, and economics occur in this place?

Where does vitality come from in this place?

What balances and imbalances does this place hold?



Where do we find indigenous wisdom in this place?

What are the different stories of this place?

How and by whom has this place been stewarded through time?

How does the place frame local identity?

What are the natural core patterns embedded in this place?

Which local landscapes inspire connection to place?

How has nature and people truly thrived here?

How is water nested and connected in this particular place?

How do we design with place?

We are inspired by the Story of Place as we apply cloudburst resilience planning in any location

Sense

Understand the relationship to place

Reconnect

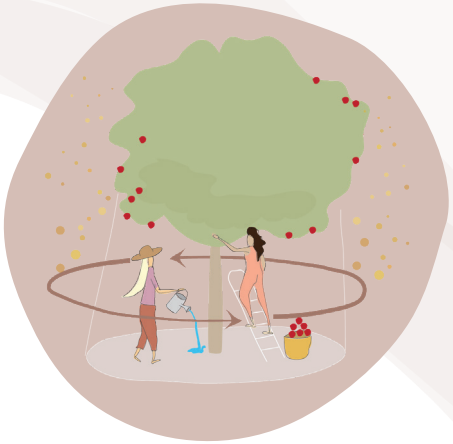
Design for harmony with place

Evolve

Design for co-evolution

Inspired by the Story of Place® by the Regenesis Group

Four concepts that inspire our place-based approach



Reciprocity

Our designs seek to achieve symbiotic relationships through generous dynamics where we give more than we take and aim towards the right relation and right scale.

Place-sourced

A unique and complex web of voices, systems, and relationships from the past, present and future shape a place - all to be considered appropriately in designing with place.

Process oriented

As we design for conditions, not static outcomes, we value the ever-evolving process over the end design. The process is fundamental to reaching our design aspirations.

Community-led

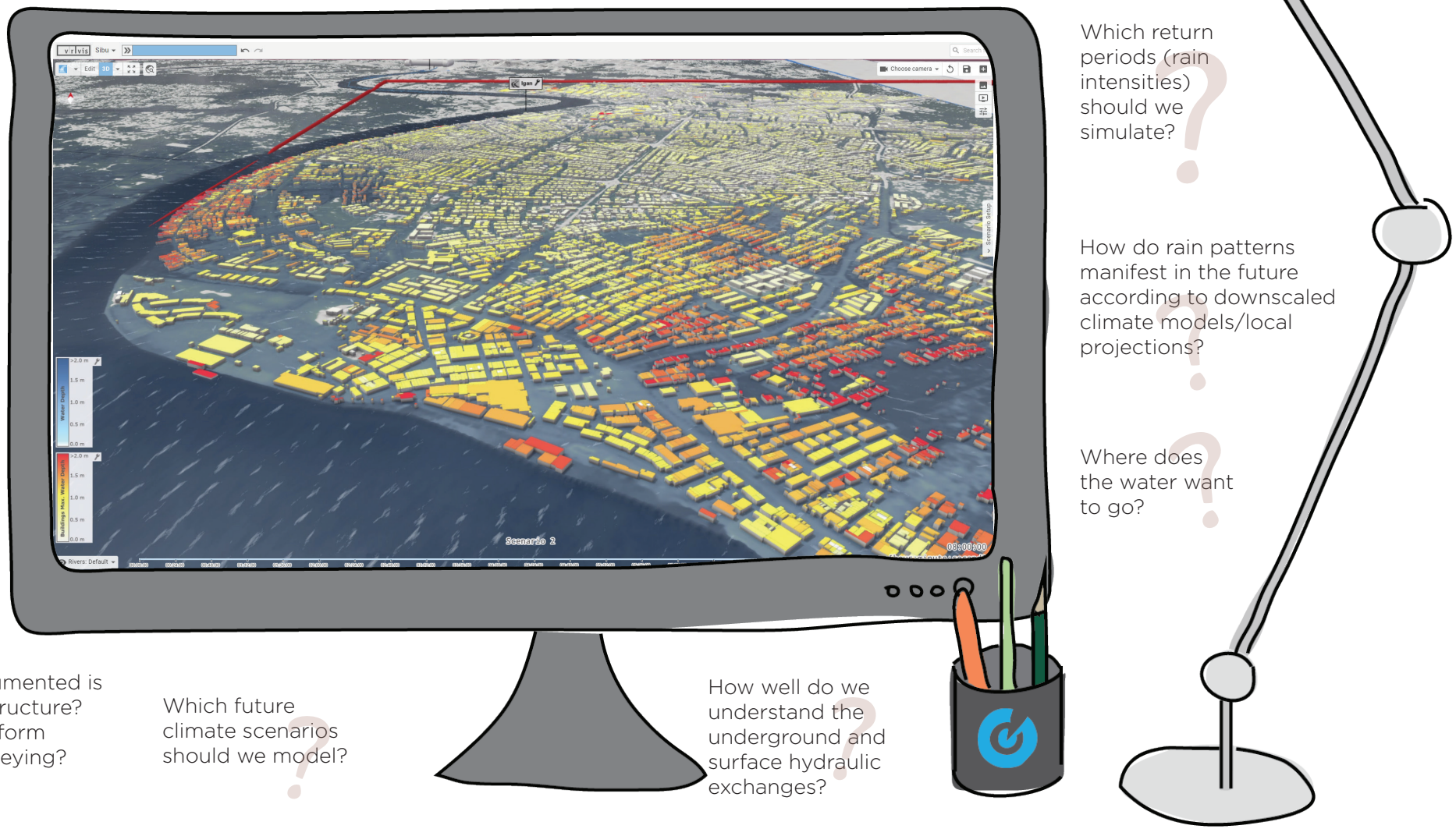
Community ecosystems actively shape design decision, passing knowledge and traditions through generations.

Inspired by ASU, *Indigenous Design Collaborative - Design process*
https://design.asu.edu/research/indigenous-design-collaborative/design-process

"The way we perceive places such as streets, communities, cities or ecoregions—influences our well-being, how we describe and interact with a place, what we value in a place, our respect for ecosystems and other species, how we perceive the affordances of a place, our desire to build more sustainable and just urban communities, and how we choose to improve cities. Our sense of place also reflects our historical and experiential knowledge of a place, and helps us imagine its more sustainable future."

Adams, J. D. (2016, May 26). Sense of place. The Nature of Cities. https://www.thenatureofcities.com/2016/05/26/sense-of-place/

How do we explore and understand the complexities of too much rain?



Nesodden Municipality in Norway was hit by the extreme weather "Hans," which led to flooding and extensive inundation in the Ursviksbekken catchment area. The flow exceeded the capacity of the piped system and followed natural waterways on the terrain, causing backwater and damage to adjacent houses. Following the flood event, Ramboll was engaged by Nesodden Municipality to conduct a flood risk assessment of the catchment connected to Ursviksbekken. The flood risk assessment informs the plan and design of adaptation measures in the catchment area. Ramboll has subsequently been requested to conduct additional climate risk assessments throughout the municipality.

"In the development of the Nesodden cloudburst plans we applied new and innovative tools enabling us to visualize different solutions quickly, resulting in great and effective cooperation with the municipality"

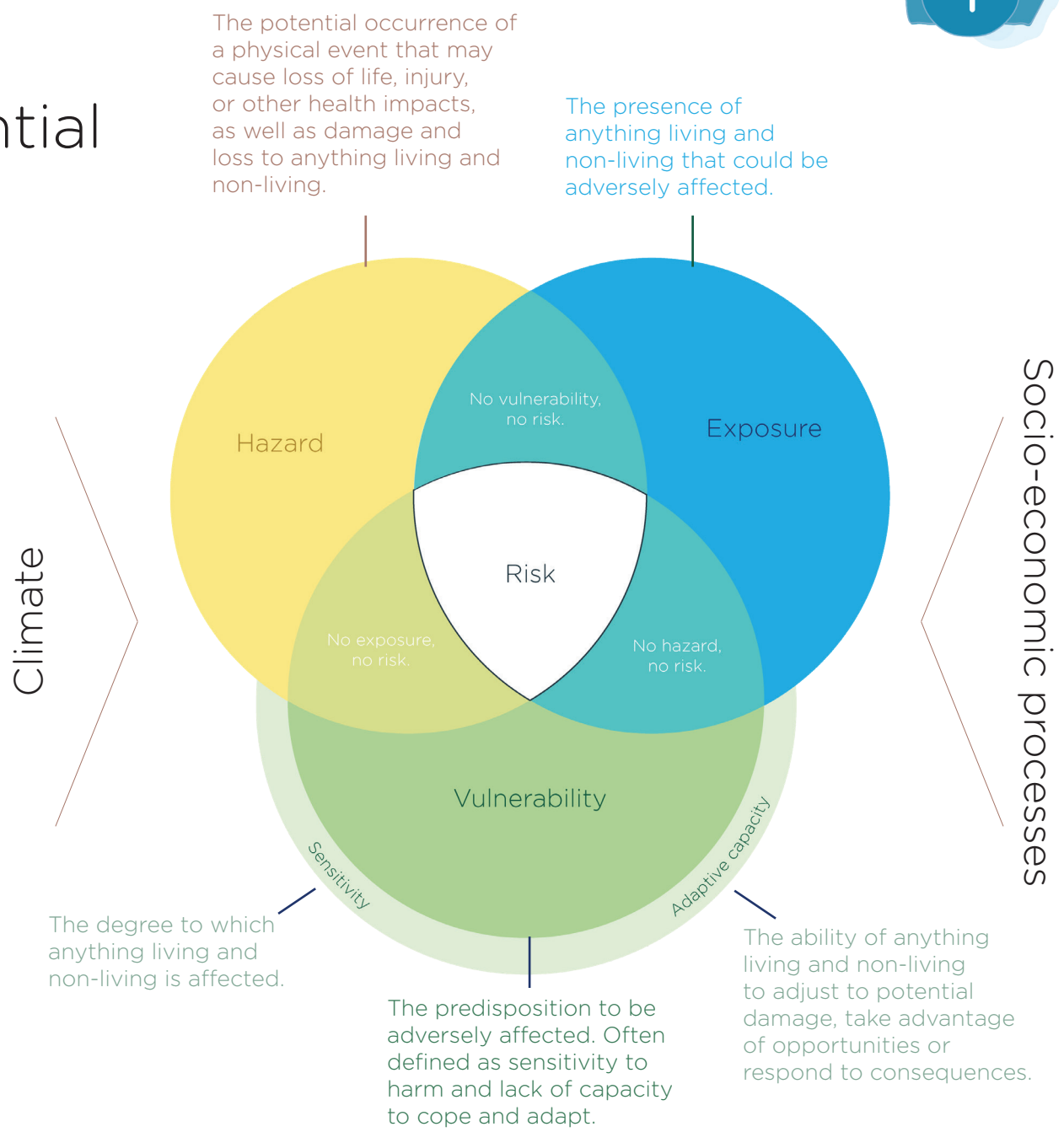
Halvor Hardang
Hydraulic modeling specialist

How we define risk influences our potential impact

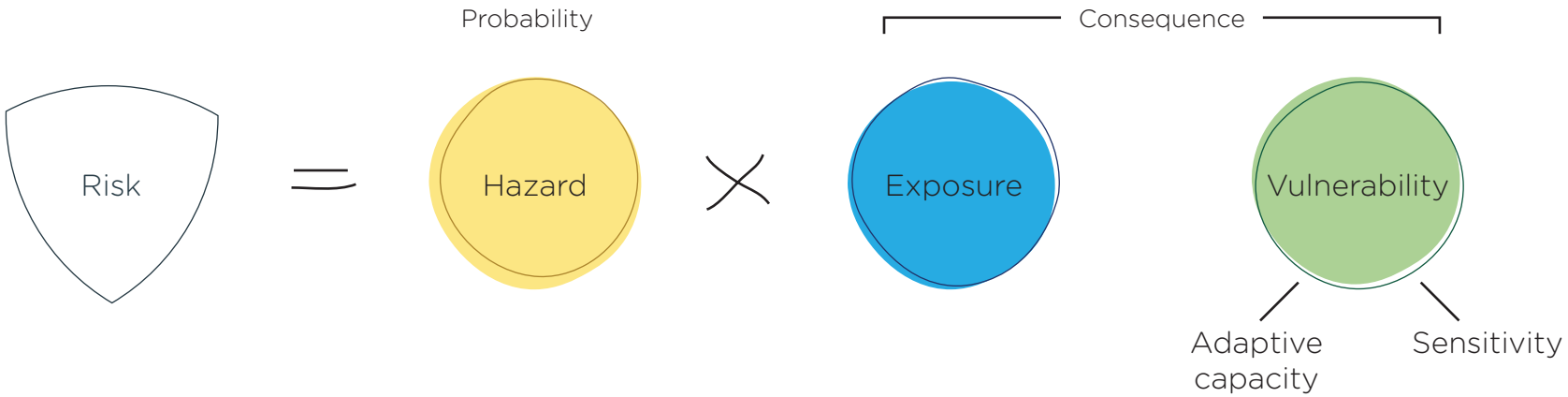
According to the Intergovernmental Panel on Climate Change (IPCC), climate risk is defined as the potential for adverse consequences for human or ecological systems from impacts of climate change as well as human responses to climate change.

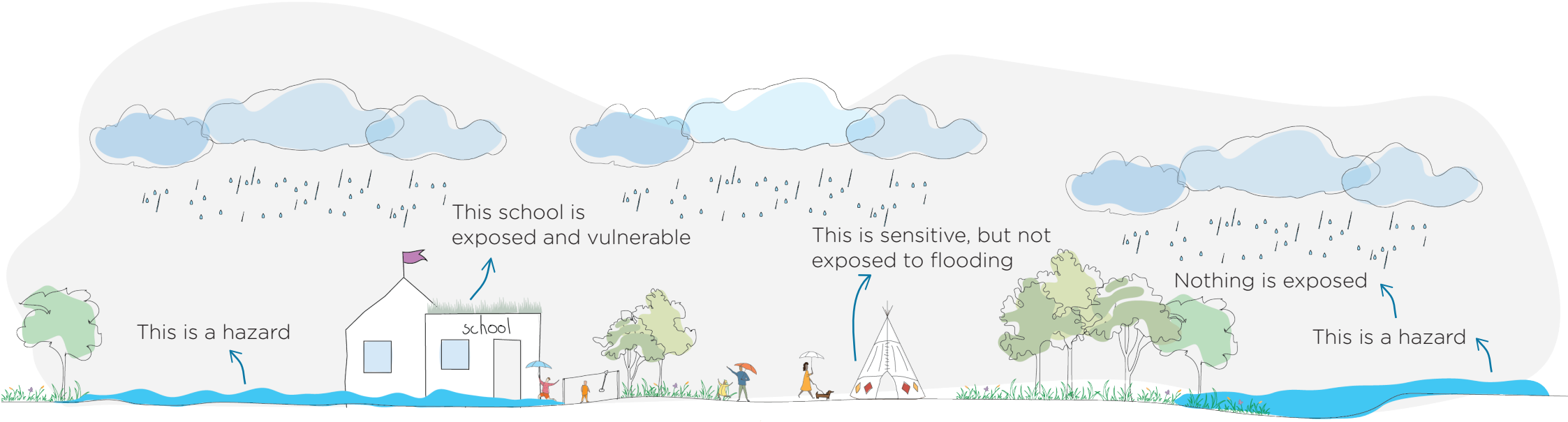
In the context of **climate change impacts**, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards.

In the context of **climate change responses**, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives.



Understanding the math behind climate risk





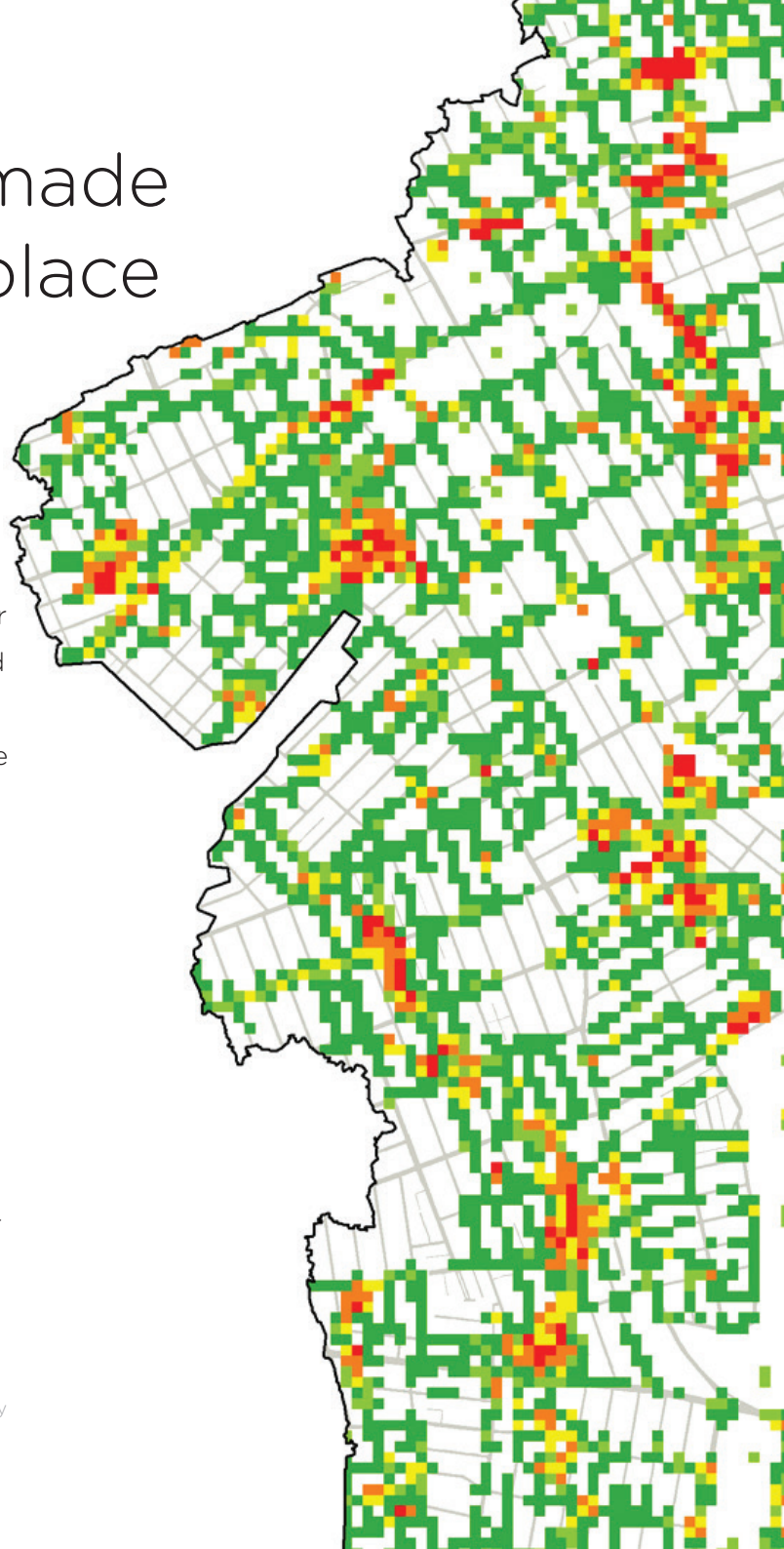
Climate risk assessments are tailormade and inspired by the uniqueness of place

As we define climate risk we have to consider "what" and "who" can be at risk and to which degree. Often climate risk is defined too narrowly. According to IPCC "Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species" (IPCC, 2021).

To avoid maladaptation and increases in inequity, we need to think about climate risk more holistically. Although we cannot quantify everything with the tools available to us today we can do much more than an infrastructure-focused assessment.

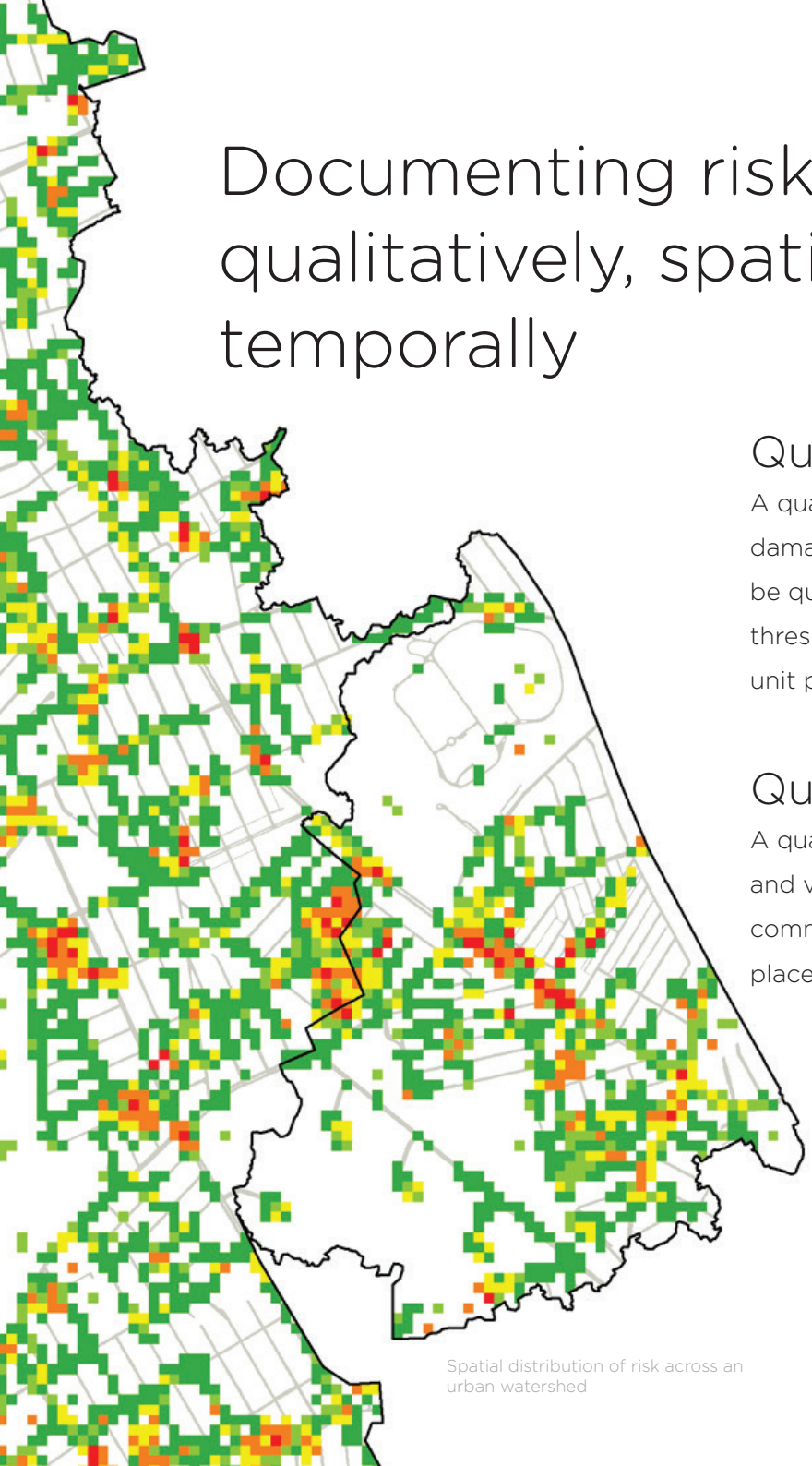
The climate risk assessment will create the baseline for all subsequent actions and investments. If our climate risk assessments are flawed so are our adaptation responses. Climate risk assessments start with a thorough understanding of community vulnerability. Tangible aspects are translated into a spatial risk register of all living and non-living entities that could potentially be exposed, with a scoring/quantification of their potential vulnerability. The climate risks are assessed over time for a given hazard and are often expressed as "Expected Annual Damages" (EAD) in $/year as well as a climate risk map illustrating the spatial distribution of risk for a given scenario.

In addition to this quantitative approach we need to explore climate risk qualitatively with affected communities. This includes mapping of places and entities of cultural, social or "natural" value, a thorough understanding of social cohesion, community networks, and their adaptive capacity, and of the interconnectedness of systems in this particular place across local, regional, and global scales



Intergovernmental Panel on Climate Change (IPCC). (2021) Sixth Assessment Report: The Physical Science Basis. Cambridge University Press. Available at: https://www.ipcc.ch/assessment-report/ar6/

Documenting risk quantitatively, qualitatively, spatially, and temporally



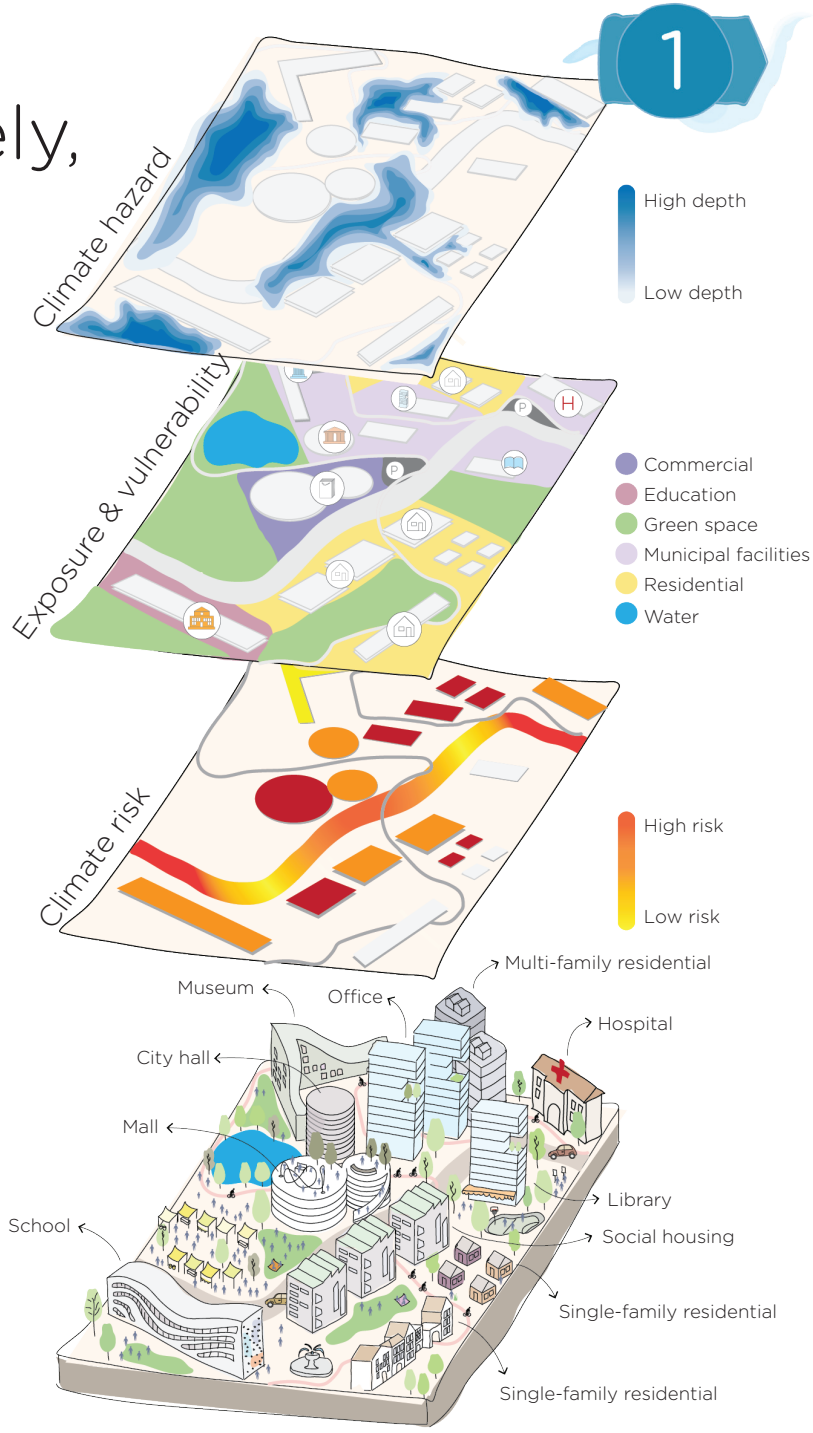
Spatial distribution of risk across an urban watershed

Quantitatively

A quantification of the expected annual damages per year for anything that can be quantified ($/year). This includes thresholds for exposure activation and unit prices or depth-damage curves.

Qualitatively

A qualification of ecosystem exposure and vulnerability co-explored with communities through inclusive and place-based design approaches



How do we better understand the complexity of the nested injustice in climate risks?

Consequence

Probability

Climate-related **hazards** are not evenly distributed

Exposure

The presence of entities to be **affected** varies greatly

Vulnerability

Sensitivity

Some entities are more **sensitive** to the effects of climate change than others

Adaptive capacity

Some communities do not hold the **capacity** to adapt or respond adequately to climate change impacts

1

Defining climate justice

"Climate justice is the moral and ethical principle that seeks to address the disproportionate impact of climate change on vulnerable communities and future generations"

United Nations

Exploring some of the aspects of climate justice

We need to be mindfull of the multi-dimensional and complex nature of climate justice as we design for the future

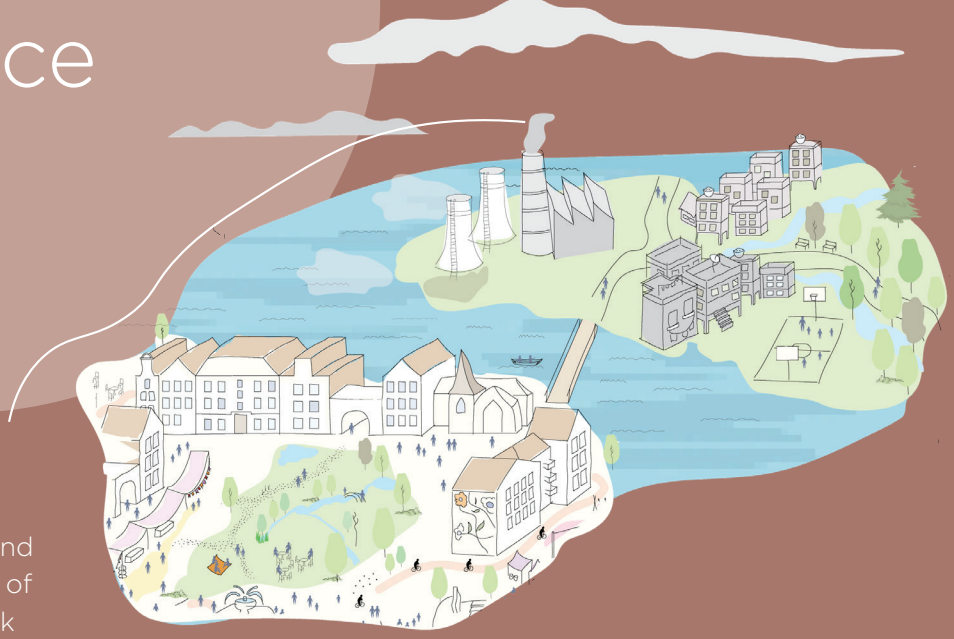
Procedure

How might we foster diverse and inclusive participation, and empowerment in design processes and decision-making?

Climate justice

Recognition

How might we better explore and understand the underlying and historic determinants of procedural and distributional justice? How might we challenge existing discourses, intentional or unintentional, that marginalize and exclude certain stakeholders?



Distribution

How might we design for equitable spatial and statistical distribution of costs, benefits and risk

Reality

Some receive more support than they need. Many receive less support than they need.

Equality

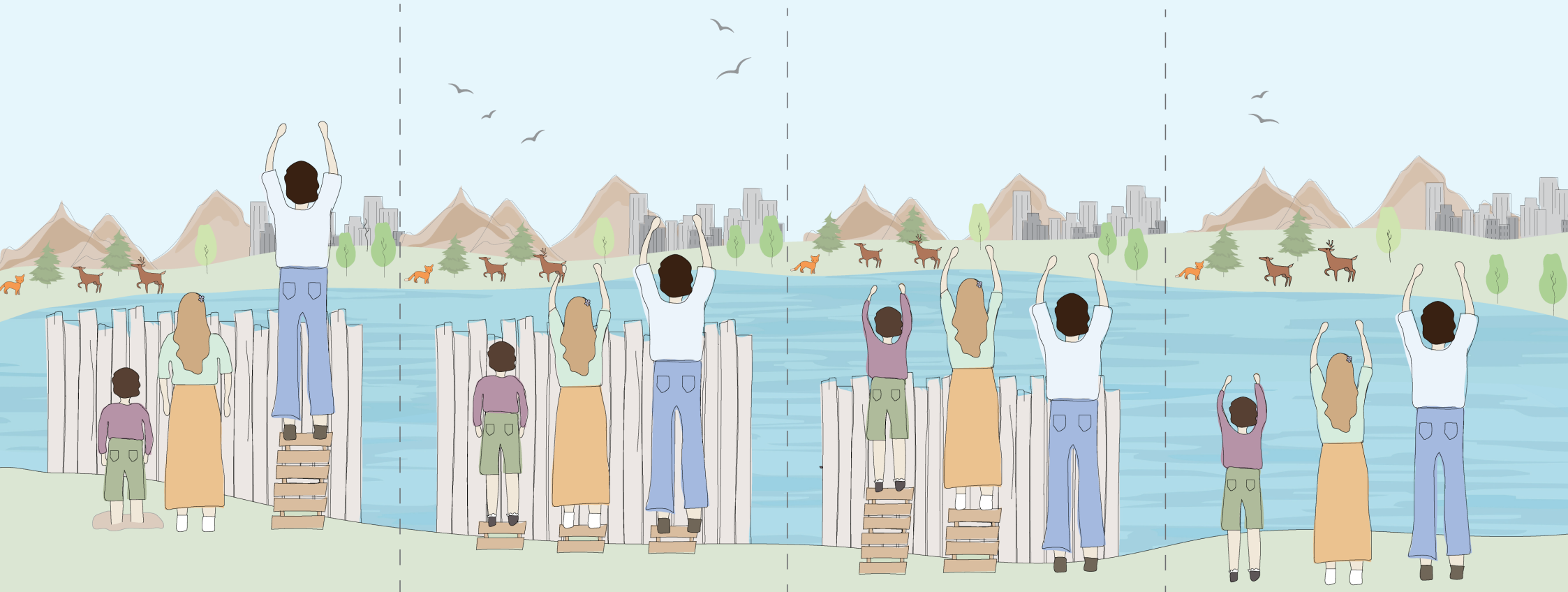
Everyone receives the same support, regardless of individual needs.

Equity

Everyone receives support tailored to their individual needs.

Justice

No one needs support because the structural and systemic barriers have been removed.



Climate justice in the past, present and future

1

What are our funding sources?

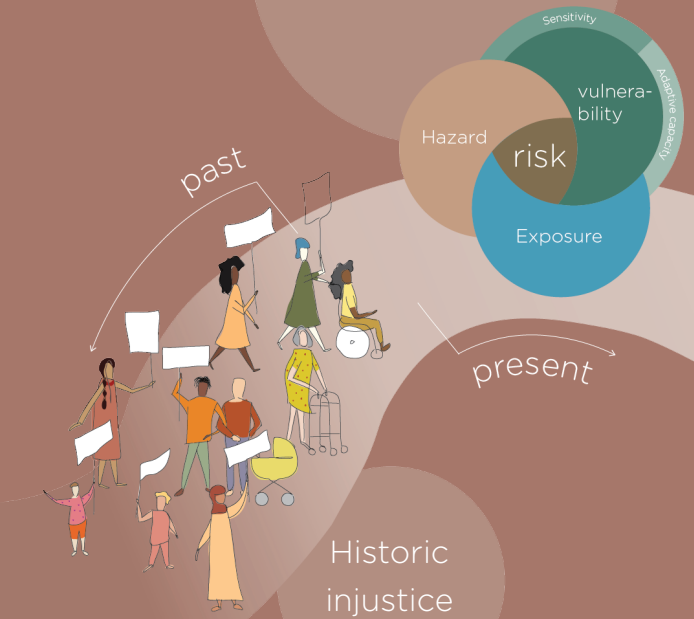
How do we co-create with place?

How do we design conditions for generations?

How do we work across scales?

How do we define climate risk?

Who do we partner with?



Where and what do we prioritize?

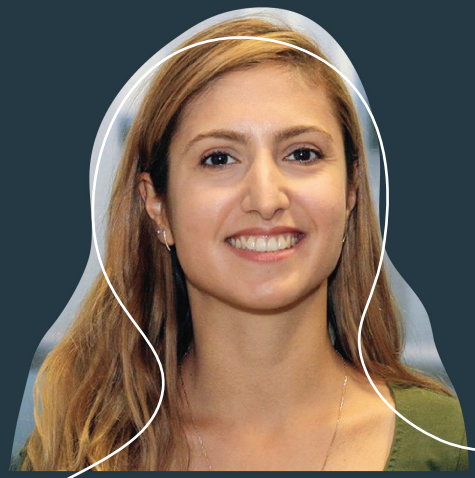
How we hold an open space for listening?

future

There are critical openings on the climate resilience journey where justice becomes particularly important and actionable

In close collaboration with other consultants Ramboll supported the NYC Department of Environmental Protection (DEP) in developing an Integrated Water Management Plan (IWMP). The IWMP included cloudburst neighborhood pilots across the city, including Clinton Houses campus under the New York City Housing Authority (NYCHA). The pilots evaluate cloudburst opportunities to alleviate flooding from a 10-year cloudburst event.

"We often propose technological solutions to address climate and infrastructure challenges with the best intentions. However, we fail to acknowledge that not everyone benefits equally from these solutions. Incorporating analyses of social vulnerabilities and impacts into our projects is crucial to ensure fair and equitable responses moving forward. A place-based analysis is a good starting point."



Andreea-Alexandra Florea
Urban planner

Co-creating resilient communities by exploring questions together

To build truly resilient communities we need genuine co-exploration. Curious collective questioning can help us explore new dialogues and approaches

How do we find courage to challenge conventional thinking?

How do we collectively activate our whole-systems thinking?

How do we keep the conversations going?

Have we identified the appropriate representatives of each stakeholder group that needs to be present in order to create an inclusive vision?

How can we encourage participation of both living and non-living stakeholders?

Which connections in this place are fundamental to ecosystem and community health and resilience?

How can we protect and replenish diversity and abundance?

How do we nurture the local ecosystems and strengthen connectivity?

How do we foster meaningful partnerships for change?

How can we use as little space as possible for our human infrastructures and create high-density living spaces that integrate nature into the community fabric?

How do we challenge regulation?

How can we co-create a guiding community narrative shared by all?

What are our basic guiding values as we aim to achieve our vision, and what might the milestones along the way look like?

Is our vision desirable environmentally, socially and economically; and is it meaningful to all stakeholders?

How can we inspire all community members to co-create the collaborative advantage of responsible participation?

What are the different issues we need to include in order to shape a grounded, comprehensive, and vibrant vision?

How do we keep co-evolving with the place?

Inspired by Daniel Christian Wahl

Community co-design

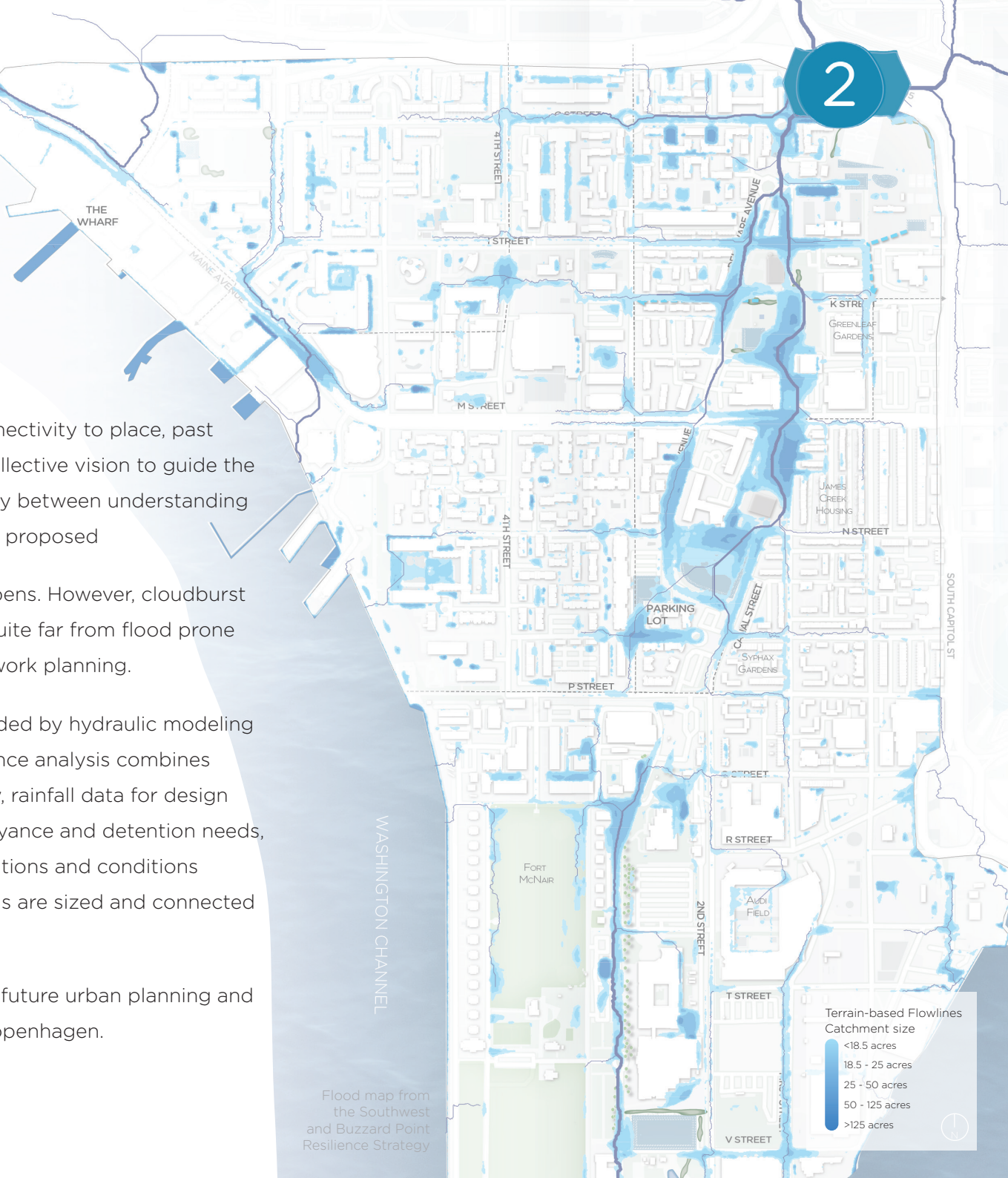
Letting water guide a connected and flexible cloudburst network

A mix of detailed data-driven analysis and in-depth connectivity to place, past and present, inspire an inclusive co-development of a collective vision to guide the cloudburst network. It is a continuous explorative journey between understanding what is, co-designing what could be, and testing what is proposed

Far too often flooding is addressed where flooding happens. However, cloudburst flooding needs to be addressed upstream, sometimes quite far from flood prone areas. This requires a systems-thinking approach to network planning.

Understanding where a community floods and why is aided by hydraulic modeling connected to a “water balance analysis.” The water balance analysis combines information about existing stormwater network capacity, rainfall data for design storms, land-use data to evaluate runoff volumes, conveyance and detention needs, and connectivity between proposed cloudburst interventions and conditions beyond the watershed.. This ensures that all interventions are sized and connected appropriately both within the watershed and beyond.

This approach allows water to become the backbone of future urban planning and design, as it was in the past and has become again in Copenhagen.



2

Which questions might help guide our design conversations?

Where can we help natural processes unfold?

How can we ensure co-financing for phased implementation, continued maintenance, and adaptations to ensure a long life-expectancy and relevance?

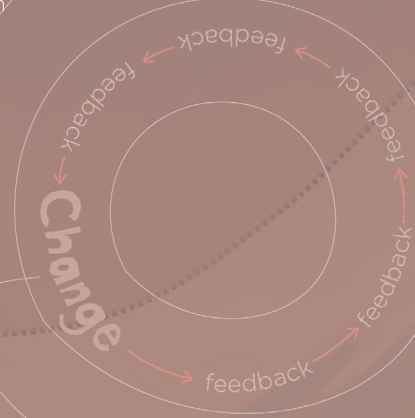
How might we design the network to be resilient towards a multitude of scenarios and flexible to adapt to changing conditions?

Where do we need to and where can we create additional retention space for water to alleviate (downstream) flooding?

How much volume is needed in the retention spaces to create a flexible water balance for multiple design storms?

What is the change that we hope to bring about?

How do we connect the flood-prone areas with the potential water retention spaces through cloudburst design?

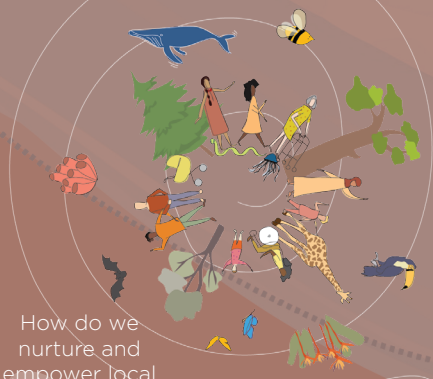


How does water flow within and beyond the watershed? Where does water collect?

How is the exchange between underground and surface flows?

How do we nurture the local ecosystems and help create abundance?

How do we nurture and empower local capacities to steward this place?



How can we design for positive emergence?

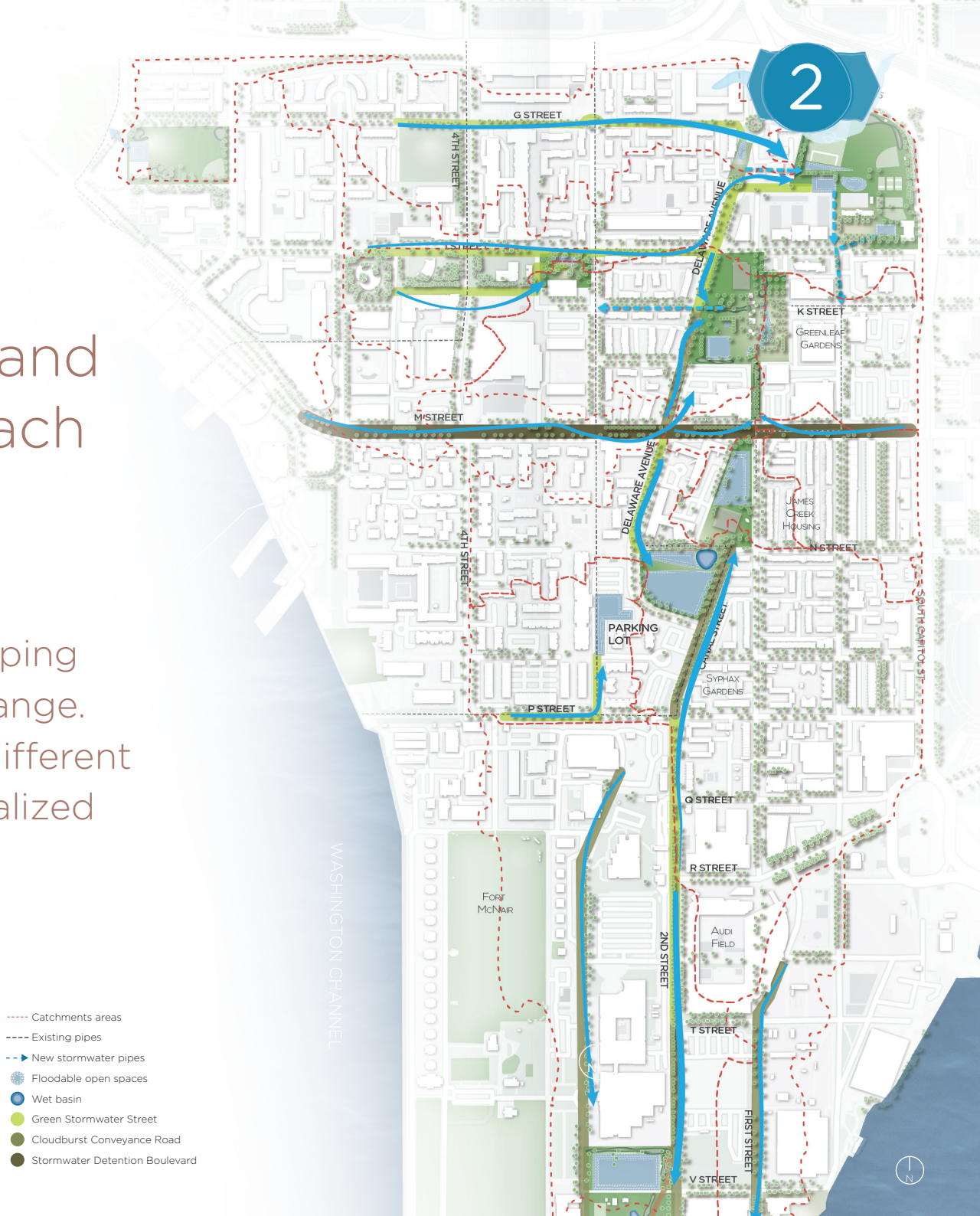
How do we continuously co-create with communities and place?

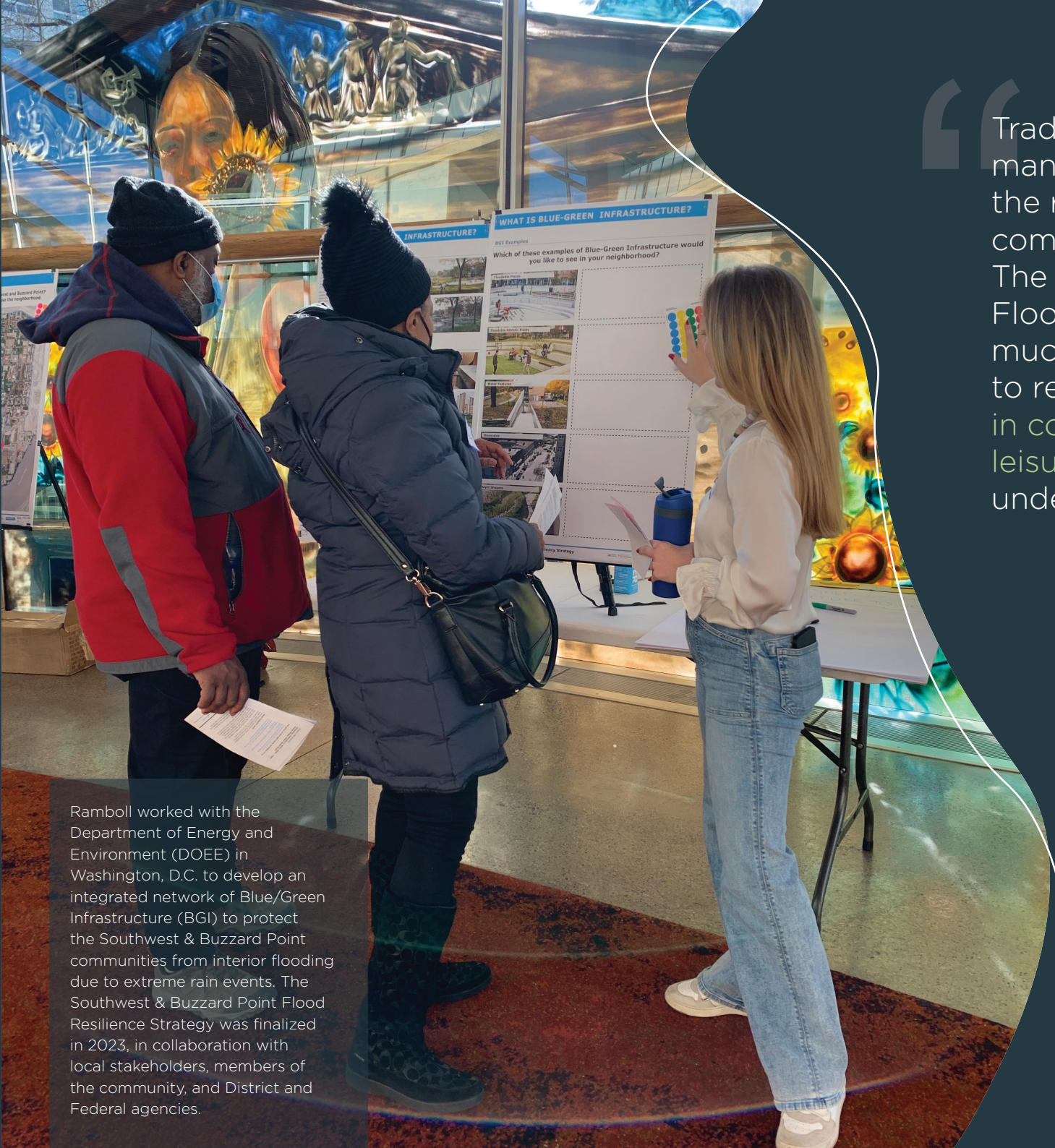
How might we design and construct cloudburst interventions so they leave the world a better place for all generations?

Cloudburst networks are expressions of a symbiotic relationship between a water-first and community-led approach

"...Diversity is life's strategy for keeping its options open in response to change. Nurturing diversity at and across different scales is best achieved by decentralized and networked distribution of vital systems functions."

Daniel Christian Wahl, 2016





Ramboll worked with the Department of Energy and Environment (DOEE) in Washington, D.C. to develop an integrated network of Blue/Green Infrastructure (BGI) to protect the Southwest & Buzzard Point communities from interior flooding due to extreme rain events. The Southwest & Buzzard Point Flood Resilience Strategy was finalized in 2023, in collaboration with local stakeholders, members of the community, and District and Federal agencies.

> Traditional approaches to stormwater management fail to recognize the role of urban infrastructure in community cohesion and well-being. The Southwest & Buzzard Point Flood Resilience Plan integrates much-needed design interventions to reduce flood risk with investments in communal spaces for recreation, leisure, and biodiversity in historically underserved communities.

Sophia Ertel
Climate Adaption Engineer

3

Evaluating the consequences of our proposed solutions

How is vulnerability today and in the future affected by our interventions?

Where are the consequences of our interventions felt?

How are benefits and costs distributed?

How is the residual risk levels in relation to expected levels of service and protection?

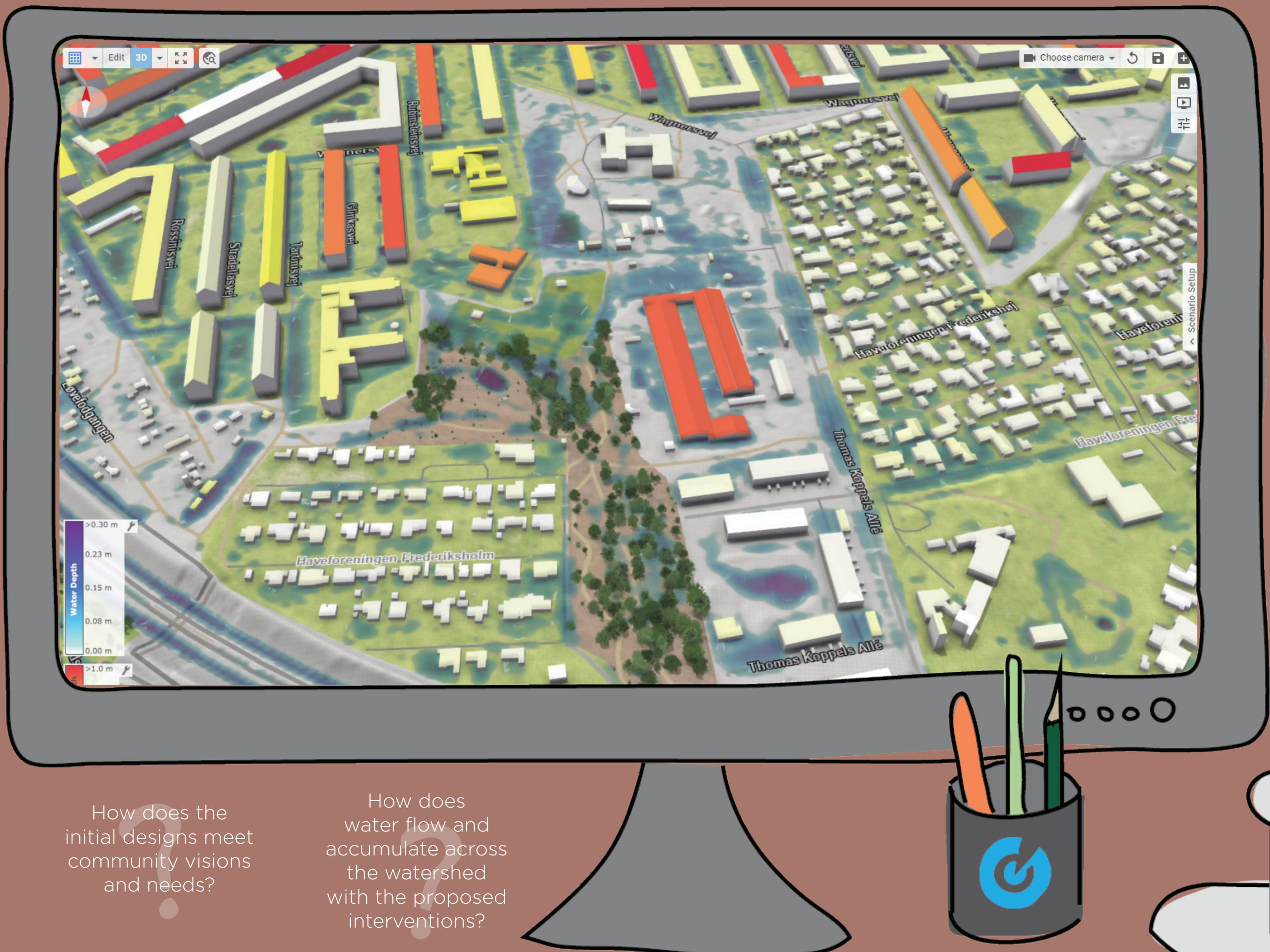
Who feels ownership of these interventions?

How will our interventions impact future generations?

What are the trade-offs and unforeseen implications?

How is our interventions impacting social cohesion?

How have we succeeded in turning a challenge into an opportunity?



How are our interventions operating in synergy with the systems of place?

How does the initial designs meet community visions and needs?

How does water flow and accumulate across the watershed with the proposed interventions?

How do our interventions nurture the potentials of place?

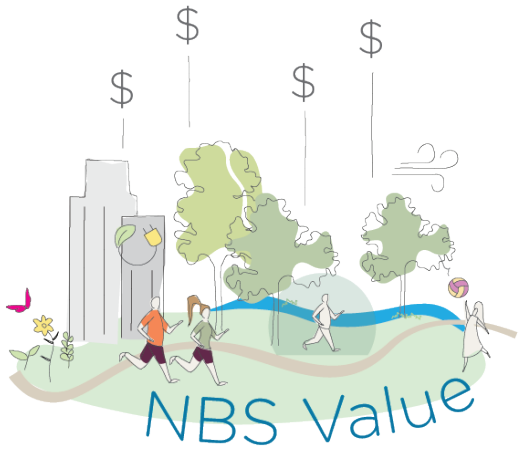
The Skien cloudburst plan in Norway is designed in response to the expected increase in rainfall intensity and frequency in the municipality. A thorough climate risk assessment has guided the development of a network of blue-green solutions that will help reduce stormwater-driven flooding. The cloudburst plan will also introduce and reinforce other qualities such as recreation, learning, biodiversity, attractiveness and more.

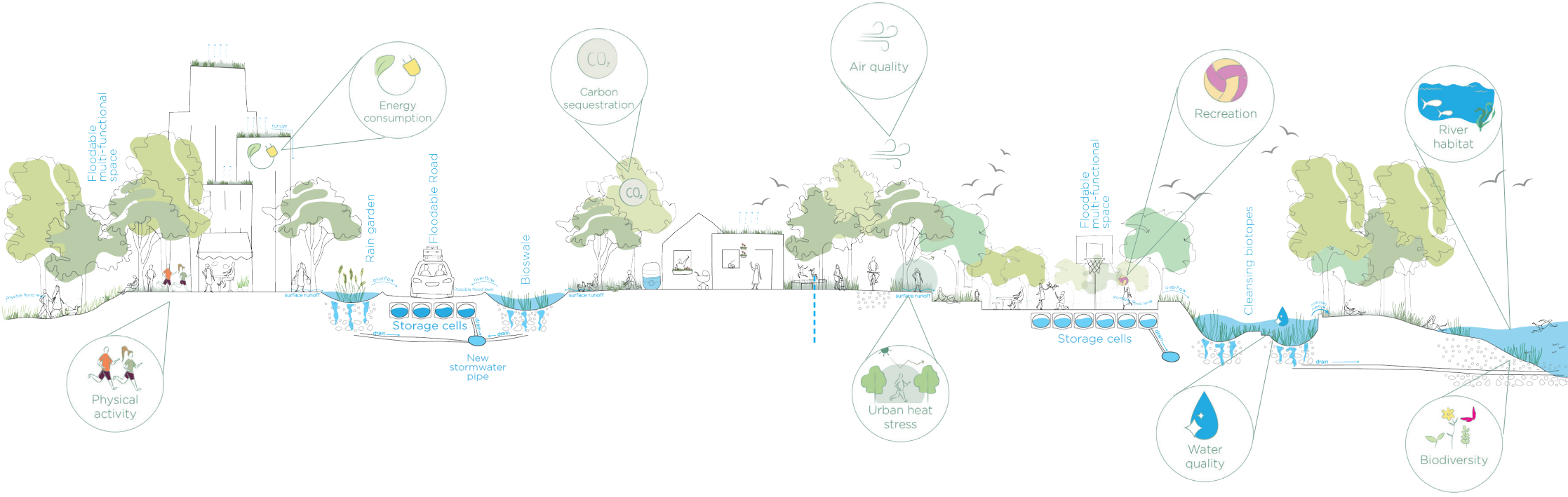
> Too often climate risk is defined overly narrow. Working with climate risks, resilience, and injustice is so much more than a "business case" at project level. It is a need for a flexible strategy that can accommodate and adapt, as new knowledge, regulations, needs, and hazards change. We will never "finish" working with climate resilience - it needs to be ever-evolving strategies.

Marianne Skov
Climate risk specialist

Capturing the socio-economic value of community co-benefits

Ramboll's NBS Value tool contains a large database with best-practice studies and valuation methodologies for calculating the socio-economic value of community co-benefits. We continuously work to broaden the database to capture even more value from community-led design.

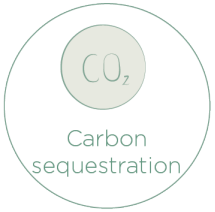




Quantifying the co-benefits of cloudburst networks

Nature can decrease urban temperatures and mitigate the urban heat island effect.

Urban heat stress considers reduced mortality rates by implementation of green areas. This is quantified by calculating avoided extreme heat days for residents within 300m of new medium/large BGI. The valuation uses avoided mortality costs per person for each excess heat day.



Trees can reduce CO2 from the air by binding it in the organic material through photosynthesis.

Carbon sequestration values CO2 removal by trees or wetlands. Quantification uses the number of trees planted or wetland area. Valuation is based on removal rates and carbon permit market prices.

Increasing the share of nature in cities can restore and enhance biodiversity through addition of native and diverse plant species.

The biodiversity co-benefit measures the value people place on protecting and restoring habitats and species diversity. It is quantified by the BGI area and nearby households. Values are determined from questionnaires on willingness to pay for biodiversity conservation.

Increased access to new or improved recreational spaces contributes to mental and physical health.

Recreation estimates the value of natural areas due to increased opportunities for walking, sitting, and social gatherings. This is estimated using preference-based valuation methods.

Nature has the ability to treat and purify water, removing pollutants and improving the water quality.

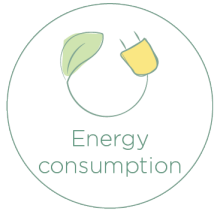
Water quality is assessed based on expected annual load reductions including total nitrogen and total phosphorous removal. Valuation uses the reduced cost of water treatment.

Improved outdoor space for recreation increases physical activities which contribute to the general health of the community and reduces the societal costs associated with an inactive lifestyle.

Physical activity assessment considers the societal value of increasing physical activity. It quantifies the number of households within 500m or 1000m of the BGI. The valuation is based on costs from inactivity, lost earnings from sick days, and percentage of inactive adults.

Air pollutants affect human health and cause respiratory diseases. Increased vegetation removes pollutants and helps avoid medical treatment and lost productivity.

Air pollution removal describes ecosystems' ability to improve air quality. Air pollutants cause health issues like respiratory diseases and cancer, leading to economic costs for medical treatment and lost productivity. Quantification involves measuring air pollutant removal.



Trees can provide shade to reduce heat energy absorbed by hard surfaces and increase transpiration that cools the air.

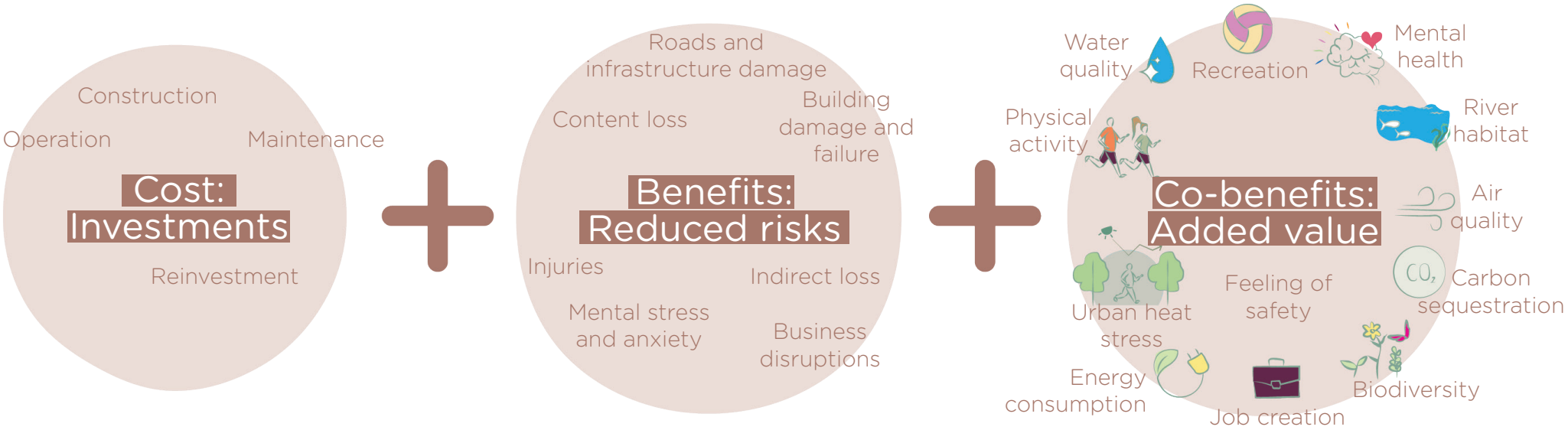
Thermal comfort estimates the value of green spaces' cooling effects for nearby occupants and buildings. It is quantified by the number of trees and valued by the associated reduction in energy costs from cooling effects.

Restoring rivers and other aquatic environment contributes to improved wildlife, especially fish species, and habitat conservation.

The value of aquatic environment is determined by the length of the river restoration project (in km) and the number of households within 1km from the river. The monetary value of each restored km is derived from questionnaires on willingness to pay for conservation of riverine habitats and wildlife.

How can the business case support investments into community resilience?

By connecting spatial climate risk modeling with our “NBS Value” tool we can include the wider socio-economic value stemming from the cloudburst network



Cost: overall financing expenses, construction costs, and maintenance & operational costs (including reinvestment of components with shorter lifespan than the overall costing period).

Benefits: reduced risk from flooding such as physical damages to properties, loss of service/function, displacements costs, loss of livelihoods, or emergency management costs.

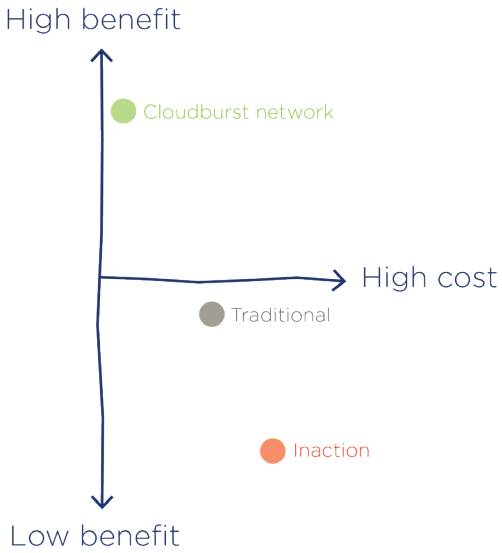
Co-benefits: long-term added values derived from the natural elements introduced through the cloudburst network. Some co-benefits are measured as saved expenses to society, other as created values.

Behind every community resilience strategy there is a unique business case

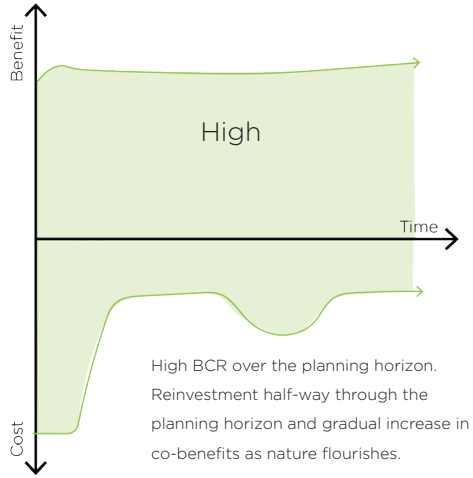
The wider ecosystem benefits resulting from multi-purpose and nature-based designs can be captured in a business case

A benefit-cost analysis (BCA) measures the wider positive and negative impacts of a project. Costs and benefits are calculated regardless of who pays for or receives them (i.e., federal government, local government, or residents and property owners) and relates the project to its wider socio-economic impact beyond the project boundary. Additional benefits beyond the primary benefits of reduced risk from flooding are often referred to as co-benefits and counted as part of the "benefit" in the equation.

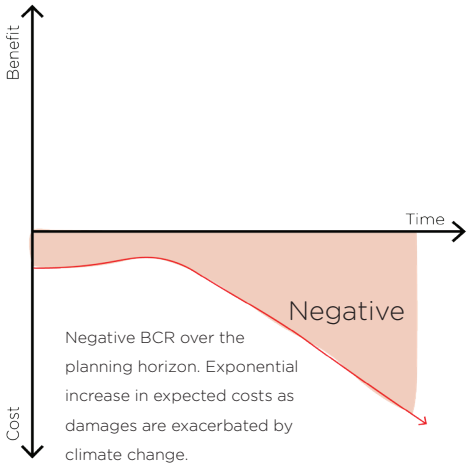
Benefit-Cost Ratio (BCR) expresses the relationship between benefits and costs. A positive BCR indicates return on investment.



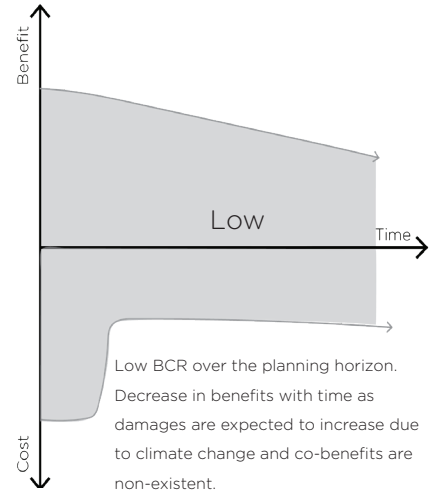
BCA - Cloudburst network



BCA - Inaction



BCA - Traditional Infrastructure



"There are risks and costs to action. But they are far less than the long range risks of comfortable inaction."

John F. Kennedy

Ramboll revitalized Remiseparken in Amager (Copenhagen, Denmark), a once dilapidated and neglected urban area located south of Copenhagen. The area has been transformed into a lively urban park adorned with newly planted trees, bushes, and vibrant flowers. The park has also implemented effective cloudburst management solutions, such as a basin and a long gutter, ensuring efficient stormwater management.

© Coast studio

"Developing nature-based and multi-functional interventions for climate resilience keeps me inspired and challenged on a daily basis. Inspired because we see the strong vision, planetary value, and common purpose go hand in hand with socio-economic benefits as we reintegrate real nature and increase liveability with the communities we serve. And challenged because we are limited by regulation, administrative barriers, and a lack of courage and curiosity to explore, trust and co-invest in these innovative designs. My hope is to see more purposeful partnerships collectively."

Christian Nyerup Nielsen
Global division director

Co-creating cloudburst typologies

Scalable, connected and designed from place

Cloudburst typologies introduce universal principles for nature-based design for stormwater management. The typologies are place-based and place-sensitive. While the common principles can be applied anywhere, they will have their own unique expression and combination of functions and elements depending on place needs and priorities.

Cloudburst typologies are designed to enhance community benefits and increase liveability for residents and visitors in a specific location. This means that the design features, choice of natural elements, and space for activities and programming may look very different from place to place.

The typologies can also be designed at a variety of scales. The volume of water that a given cloudburst project—and the overall network—is designed to handle depends on the neighborhood topography, catchment size and location in the catchment, land-use of the neighborhood, and the agreed flood reduction ambitions. For example, the further downstream a project, the larger volumes of stormwater the project will typically need to convey and/or detain.

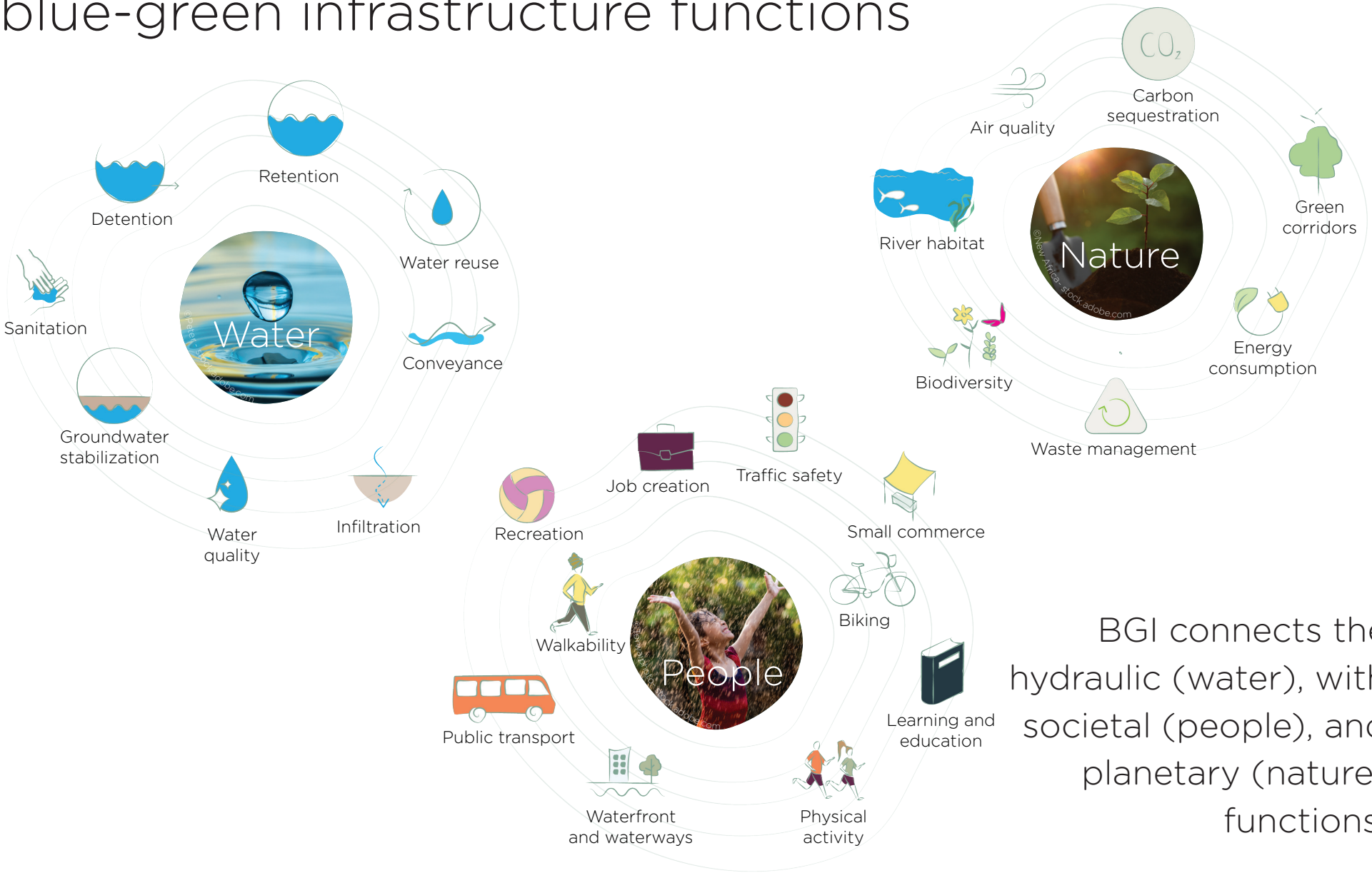
The location of the cloudburst intervention and the intensity of the rain influences the choice of the typologies. In upstream catchments and for smaller, more frequent rain events using typologies such as green roofs, permeable pavers, and rain gardens are often adequate. In downstream catchments and for larger rain events the networks typically require more substantial stormwater interventions that are integrated into the urban landscape to convey and detain larger volumes of water. These projects typically include segments of parks or rights-of-way that are designed for temporary stormwater management.

On the following pages we introduce some of the fundamental thinking in designing cloudburst interventions and networks.

Elevating blue-green infrastructure to cloudburst typologies

[1]European Commission, *Directorate-General for Research and Innovation, Evaluating the impact of nature-based solutions – A handbook for practitioners, Publications Office of the European Union*, 2021, https://data.europa.eu/doi/10.2777/244577

Cloudburst typologies are inspired by blue-green infrastructure functions



BGI connects the hydraulic (water), with societal (people), and planetary (nature) functions.


How can we reimagine
our future communities
together?

We combine hydraulic functions inspired by place to restore, recreate, and strengthen the natural water cycle

Detention is temporary storage of stormwater runoff connected to a drainage system. It can be temporary floodable spaces that serve other purposes the majority of the time.

Retention is storage of stormwater runoff that is not connected to a drainage system. It is either re-used, infiltrated or part of a permanent water body.

Water can be captured and re-used for a multitude of different uses to supplement traditional water supply.

Sanitation refers to reliable sewer systems for appropriate hygiene and dignity.

Conveyance is the transport of water to where it can be detained/retained or discharged.

Groundwater stabilization includes aspects of groundwater recharge and balanced groundwater extraction.

Infiltration allows water to seep into the ground, moisturize soil, cleanse naturally, allow uptake from root systems, and support groundwater recharge.

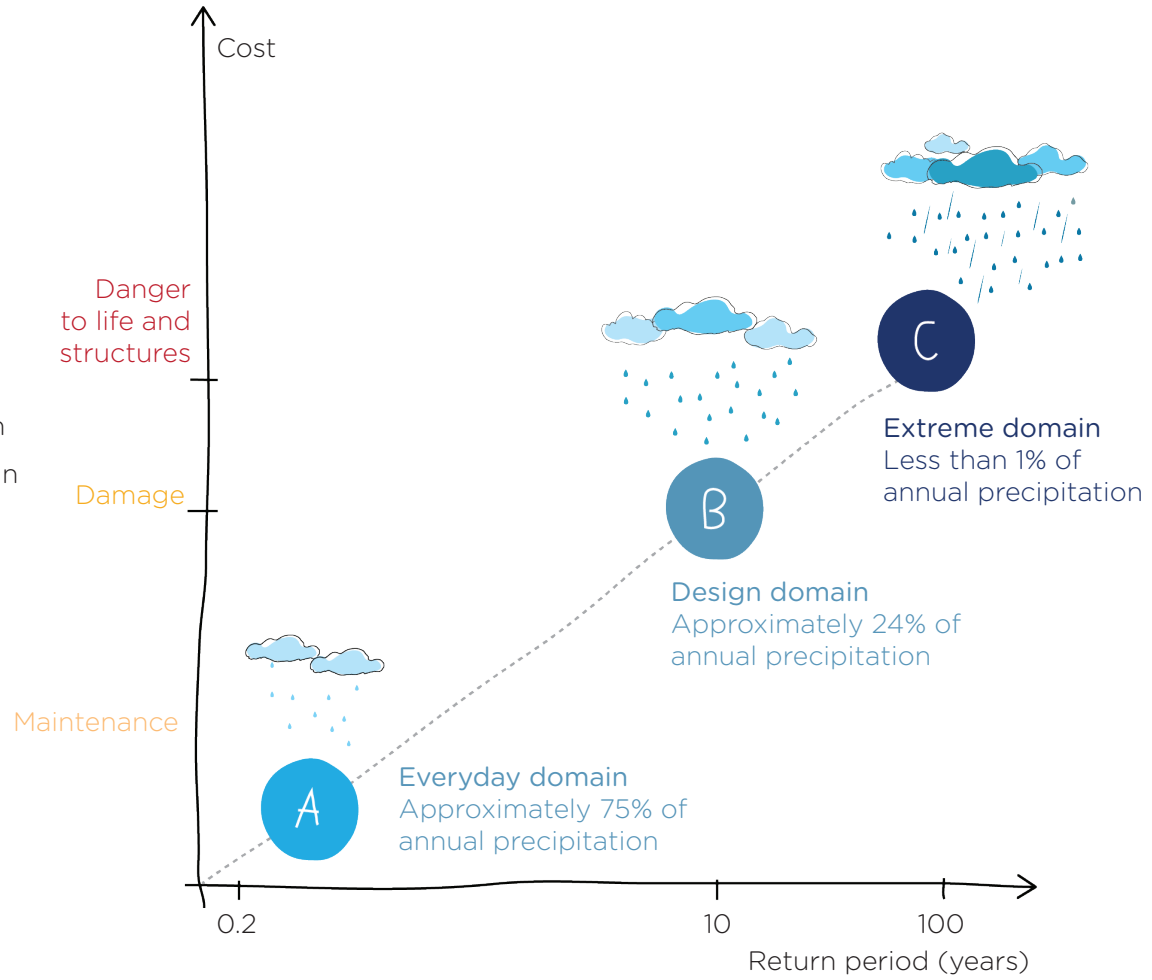
Water quality refers to cleansing and purification of stormwater runoff for aquifer recharge, diverse uses, and habitats.

The different rainfall domains need to all be considered in planning and design

A **Everyday domain:** Rainfall events that utilize the capacity of the urban drainage systems without causing any direct wet weather discharges to the environment. This covers approximately 75% of annual precipitation.

B **Design domain:** Events that traditional urban stormwater infrastructures are designed to manage. The domain covers from rainfall events that cause controlled overflows to surrounding water bodies and up until, but not including, rare rainfall events that are not considered feasible to convey using traditional sewer systems. In other words, this domain is capped at the point where floods from an engineering point of view are considered to be acceptable. It is the most well defined and regulated of the three domains. Performance requirements to sewers vary internationally, but everywhere in the world people have expectations for how sewers are designed and operated. In many places, this will be regulated in detail by central guidelines and standards. When combined, the Everyday and the Design domains cover approximately 99% of annual precipitation.

C **Extreme domain:** The rare rainfall events that cause floods in the urban environment, where the sewer system no longer is sufficient to control the rainwater and where overland flows are substantial or even dominating the drainage of the affected area. This domain accounts for less that 1% of annual precipitation.



Adapted from: Sørup, H. J. D., Lerer, S. M., Arnbjerg-Nielsen, K., Mikkelsen, P. S., & Rygaard, M. (2016). Efficiency of stormwater control measures for combined sewer retrofitting under varying rain conditions: Quantifying the Three Points Approach (3PA). Environmental Science & Policy, 63, 19-26, and Dansk Byplanlaboratorium, 2016: Lokal Afledning af Regnvand - Byems Hverdagsregn. www.byplanlab.dk/sites/default/files/LAR_pjece2016_opdateret_Juni_0.pdf?0.9193419306538999

As part of Cloudburst Masterplan for the City of Copenhagen multi-functional stormwater detention locations have been identified in the Carlsberg neighborhood. Open areas, playgrounds, and soccer fields have been lowered to temporarily detain excess stormwater during extreme rain events but otherwise provide upgraded community spaces.

"I am a huge fan of using nature-based solution when dealing with the changes we face. It is very rewarding, on top of being super challenging. However, the idea that we design cloudburst solutions for a theoretical 100-year event 100 years in the future is not ideal. It is often far too expensive compared to the prevented damage. Instead, we should be designing flexible solutions that can be continuously adapted as climate and society change."

Michael Fabritius Tengnagel

Chief consultant & civil engineer

Cloudburst typologies embrace a flexible design approach

A Everyday domain

Stormwater is captured and treated in rain gardens and bioswales before being released into the existing drainage system.

B Design domain

Stormwater is transported safely in streets and temporarily stored in floodable public spaces before release into the existing drainage systems.

C Extreme domain

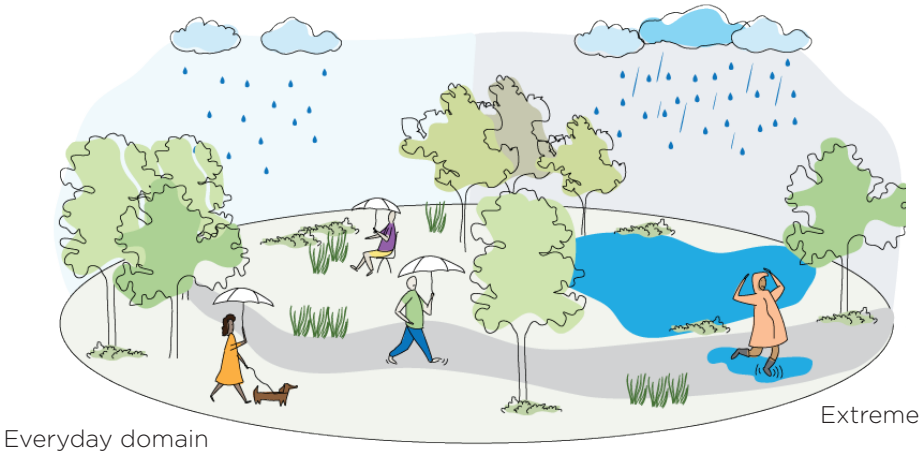
Flood management is supplemented with flood early warning systems and emergency response plans to ensure controlled flooding.


More than 99%
of the time it provides
community value
Less than 1%
of the time it floods

Embracing the complexity of place-based design

The desired level of service, the urban landscape and topography, and the placement in the catchment all inform unique cloudburst strategies for place.

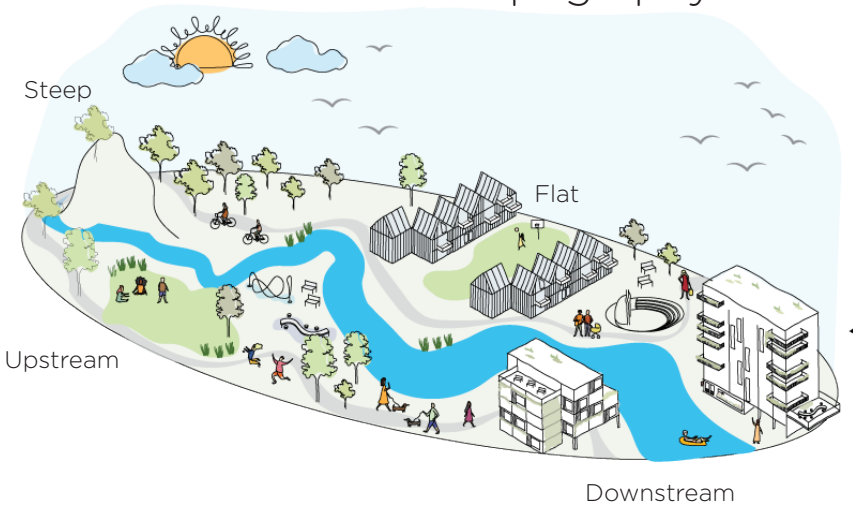
Which levels of service and protection do we design for?



Everyday domain

Extreme domain

Where are we in the catchment and how is the topography?



Which spaces and land-use do we have to work with?

Expressions change across domains

Conveyance

Conveyance paths on terrain are designed to move water through the public realm. Paths can vary from small, temporary streams to large channels, depending on necessary capacity.

Detention

Detention areas are urban spaces designed to reduce peak stormwater flow. Detention areas can be permanent waterbodies or usable public spaces designed for temporary storage during extreme rain events.

A Everyday domain

Urban swale - Arkadien Asperg
(Stuttgart, Germany)

Green stormwater street - Kong Hans Alle
(Copenhagen, Denmark)

B Design domain

Bioswale - Carlsberg City
(Copenhagen, Denmark)

Floodable soccer field - Carlsberg City
(Copenhagen, Denmark)

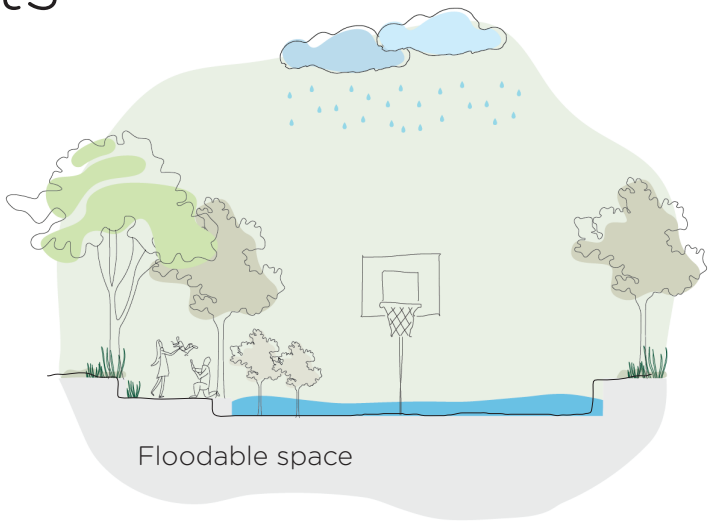
C Extreme domain

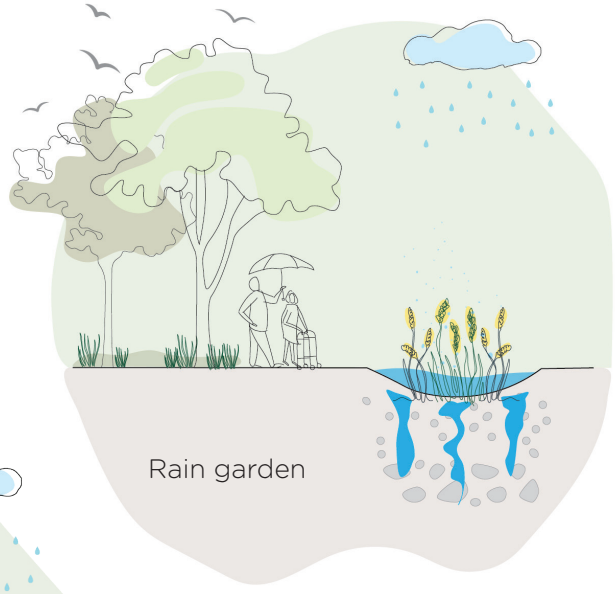
Floodable plaza - Potsdamer Platz
(Berlin, Germany)

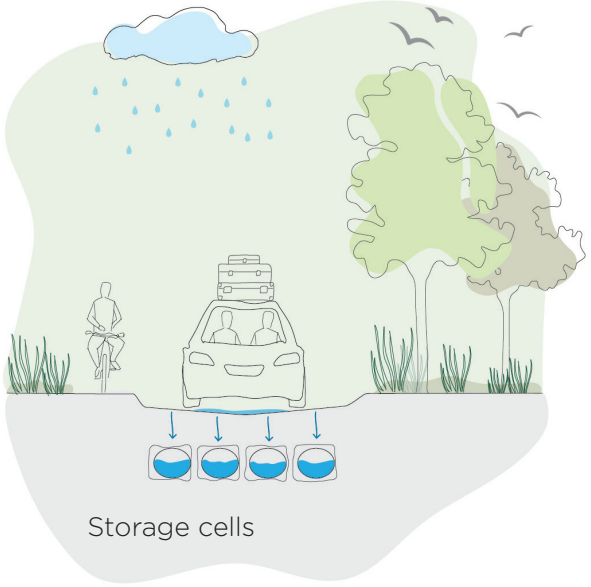
Floodable park - Bishan Park
(Singapore)

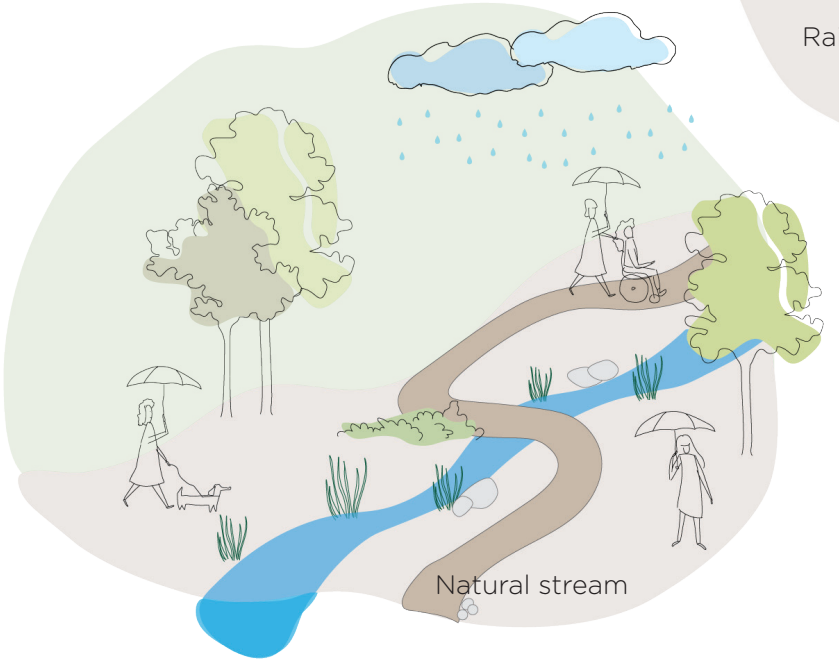
Developing place-specific cloudburst elements

Different combinations of BGI functions will result in different cloudburst elements.





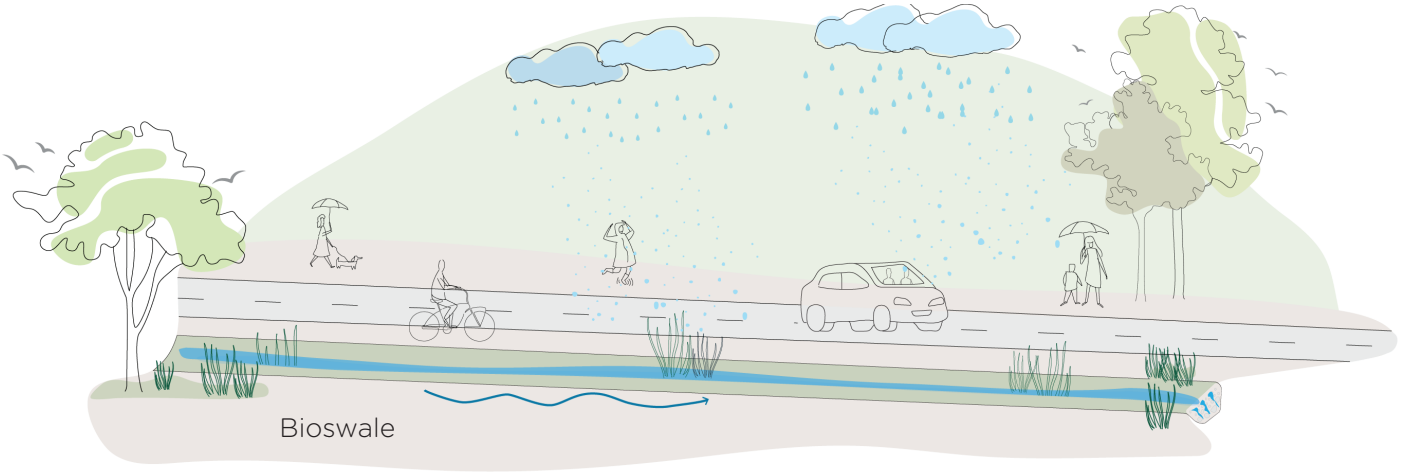


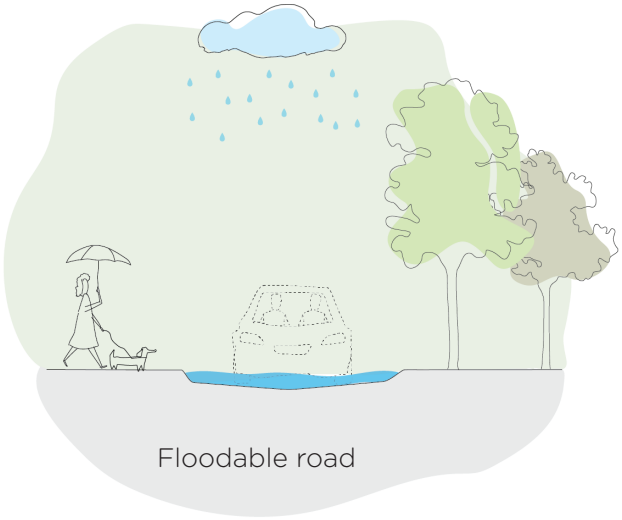


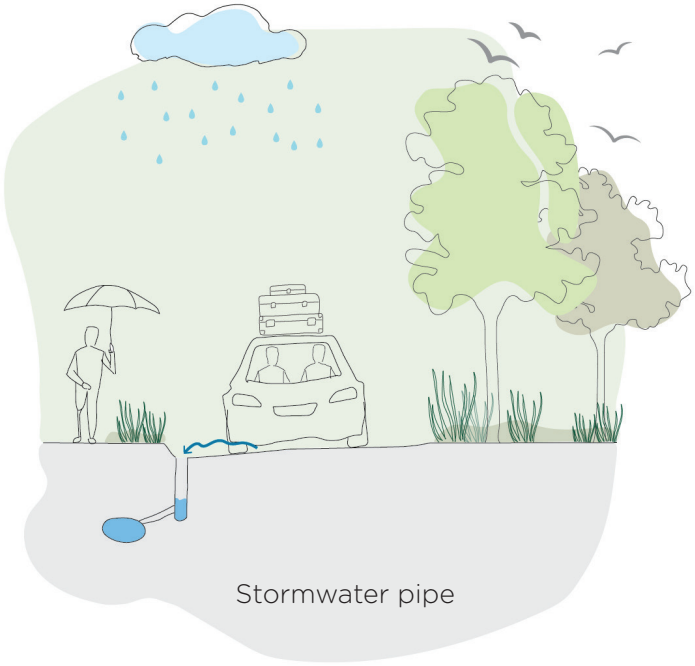
It’s the co-creative tailoring of elements through a collective understanding of place that makes cloudburst resilience impactful.

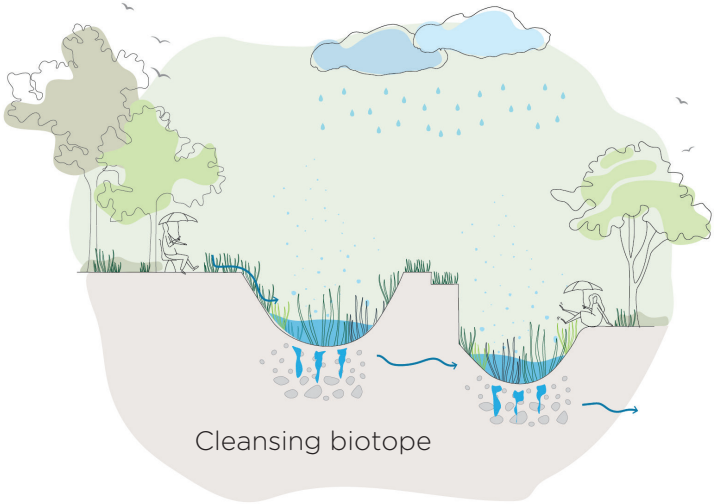
Typical elements can include storage cells, floodable public and private spaces, floodable roads, bioswales, rain gardens, cleansing biotopes, and new integrated stormwater piping.

Other elements could include green roofs, vegetated facades, elevated raingardens, and rain barrels.





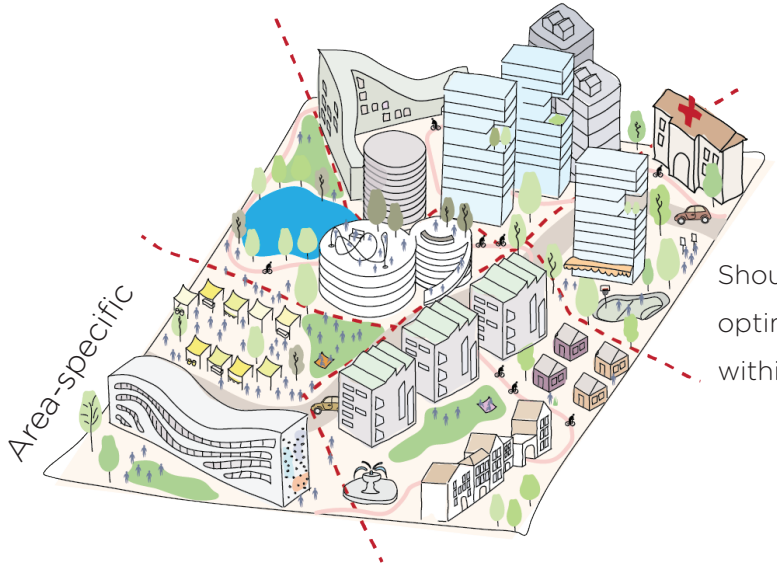




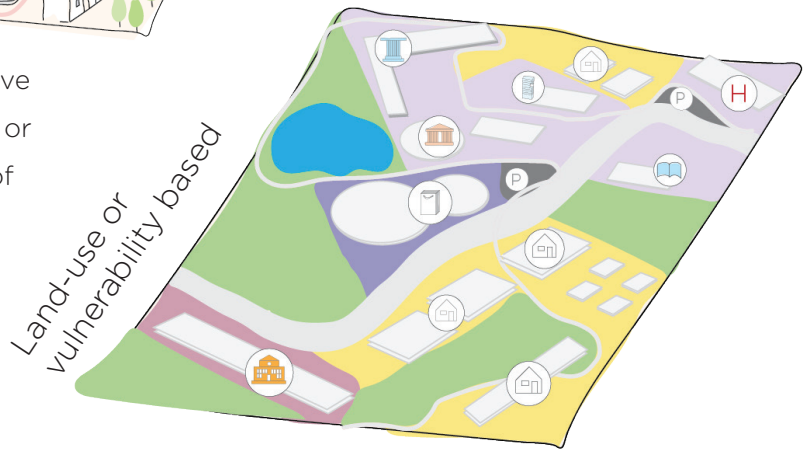

Each place is unique. What does that mean for our cloudburst resilience strategies?

How do we define equitable levels of service and protection?

Should the entire administrative area of a municipality, region, or country have the same level of service everywhere?



Should we calculate an optimal level of service within each defined area?

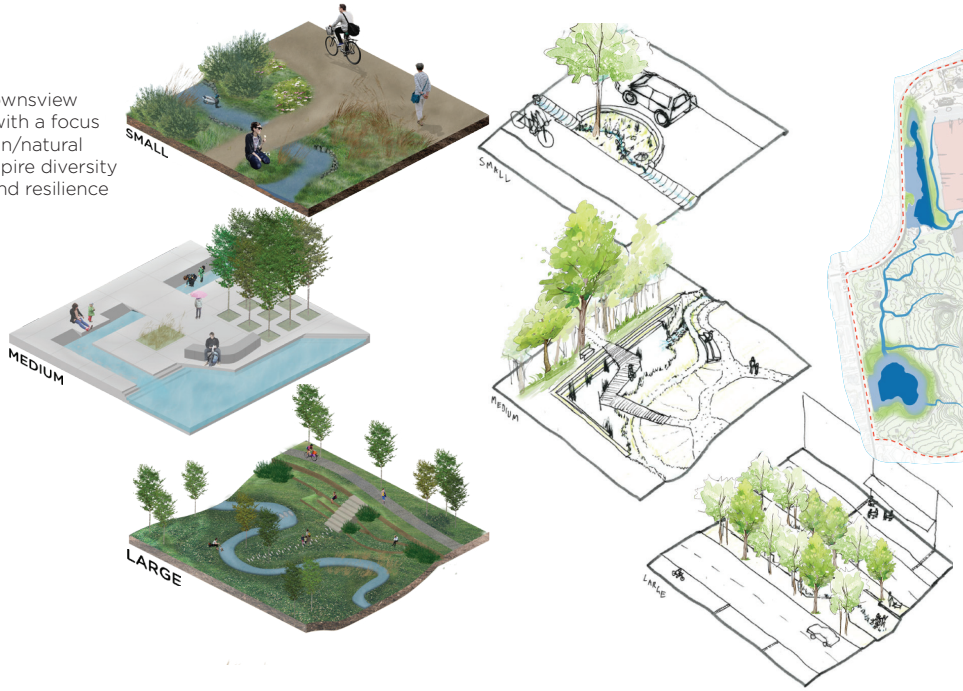


Should we differentiate level of service based on land-use and/or vulnerability?

Levels of service can be defined for whole administrative areas, based on land-use and vulnerability, estimated for specific areas, or a combination thereof. A flexible design approach connects levels of service across intensities and volumes and can adapt and evolve as conditions change.

Combining cloudburst elements into place-inspired typologies

Typologies for Downsview were developed with a focus on scale and urban/natural expressions to inspire diversity in urban design and resilience strategies.



A cloudburst masterplan was developed to guide the transformation of the old airport of Downsview into a vibrant and resilient new neighborhood. A mix of urban multi-purpose and/or nature-based typologies were developed to inspire diversity of solution across the watersheds.

Downsview - Toronto, Canada

The cloudburst concept plan for Downsvieww

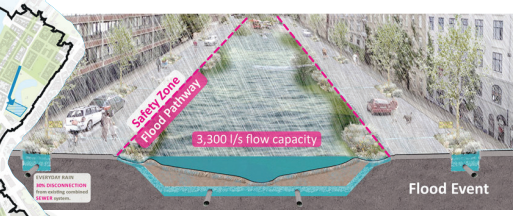
Hekerbeek, Netherlands

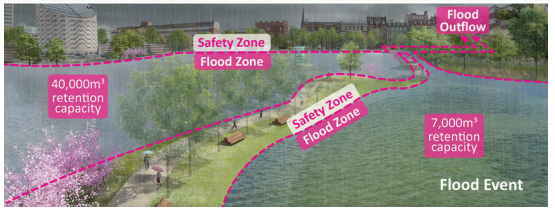
The cloudburst masterplan for the Hekerbeekdal catchment in the Netherlands was shaped by the voices and needs of the local community. In addition to create space for stormwater run-off, key focus areas were social cohesion, tourism, traffic safety and connectivity to the rural communities.

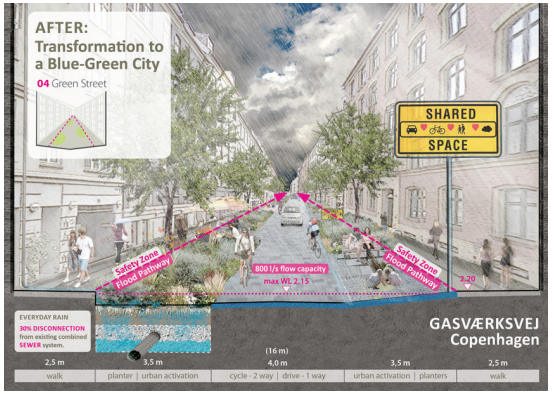
Hekerbeek's rural-urban typologies for rethinking streetscapes and public spaces to enhance traffic safety and social cohesion

Hekerbeek's Cloudburst Masterplan

One of the catchments in the Copenhagen cloudburst plan







Copenhagen, Denmark

The city-wide cloudburst masterplans in Copenhagen first introduced the multi-purpose design to reduce stormwater-driven flooding. A total of 300 projects were identified across the capital. Key concepts were water-retaining boulevards, plazas, parks, and creeks, forming a multi-functional flood-resilience system that also revitalizes urban spaces.

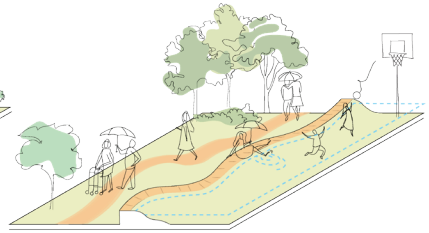
Bukit Assek's emerging cloudburst masterplan and cloudburst typologies has a strong focus on upgrading community spaces and enhacing groundwater management

Sibu - Sarawak, Malaysia

The Bukit Assek cloudburst masterplan is tailored to the unique characteristics of Sibu. Educational signage will explain BGI functions. Large wetlands will attract wildlife, foster community spaces, boost tourism, and enhance property values, all while preventing flooding. While cloudburst interventions often favor below grade volumes for Sibu solutions focus on also adding above-ground storage.

Raised raingarden

Green facades and roofs



Elevated multi-functional detention area

Reimagining floodable open spaces

Floodable open spaces

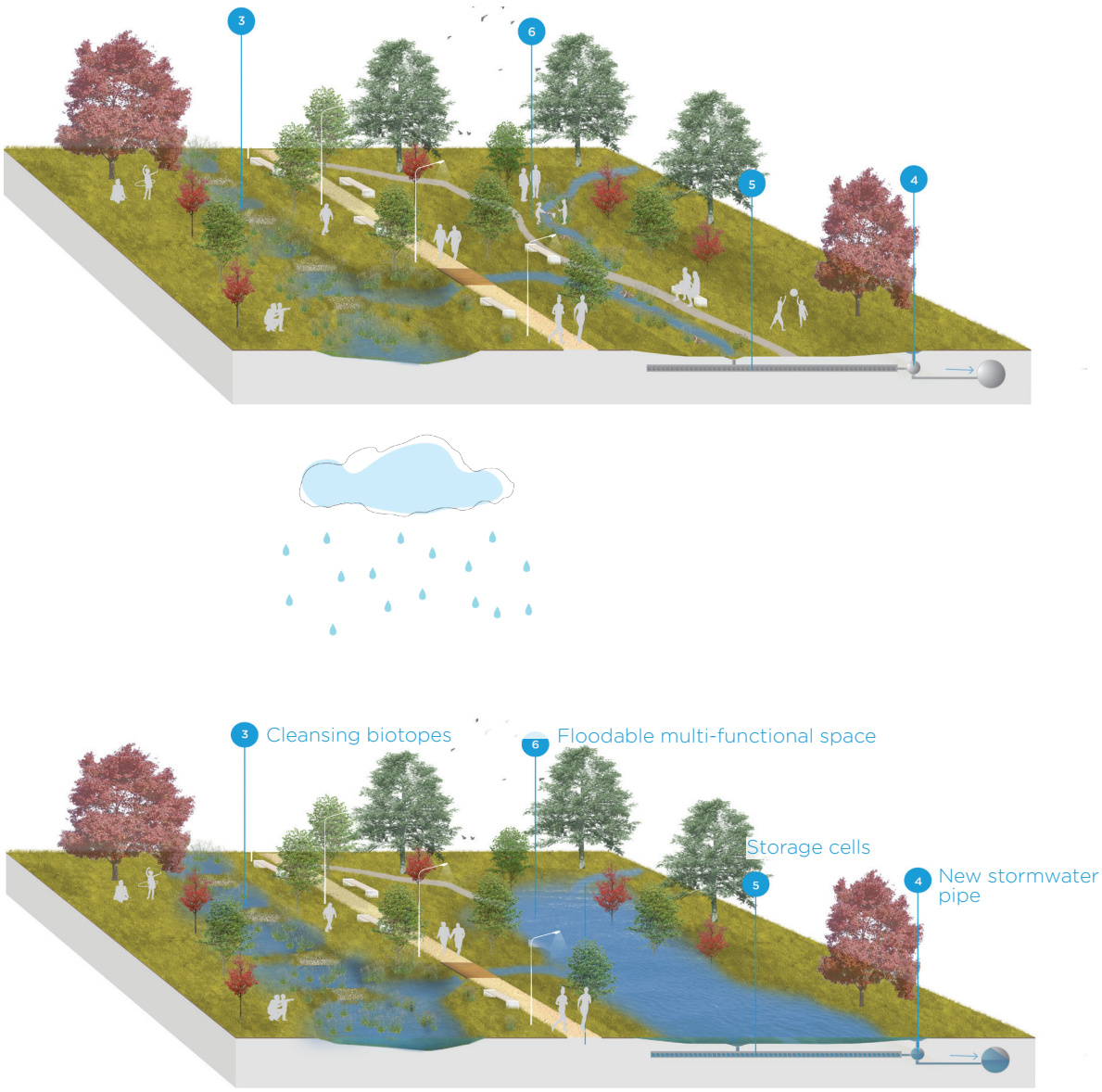
Floodable parks, plazas, parking lots and other open spaces present a great opportunity to manage everyday rain and temporarily detain larger volumes of stormwater during extreme events. Floodable open spaces can be located throughout the catchment and can be designed at various scales, depending on how much space is available, compatible uses, community preferences, and the volume of water that needs to be detained.

Floodable open space typologies are designed to manage daily rain without any impact on the recreational functions of the space. During extreme rain events, floodable open spaces can be used for controlled inundation to detain water and prevent flood damages elsewhere. After the storm has passed, the open spaces can be drained, cleaned, and returned to their recreational uses.

In the following pages, a selection of floodable open space typologies developed by Ramboll around the world are illustrated for inspiration.

Floodable passive parks

Floodable passive parks are generally areas of parks that are not programmed for specific athletic activities. These could include open lawns, constructed wetlands, sculpture gardens, walkways or areas designated for biodiversity and habitat.



Bishan-Ang Mo Kio Park, Singapore.

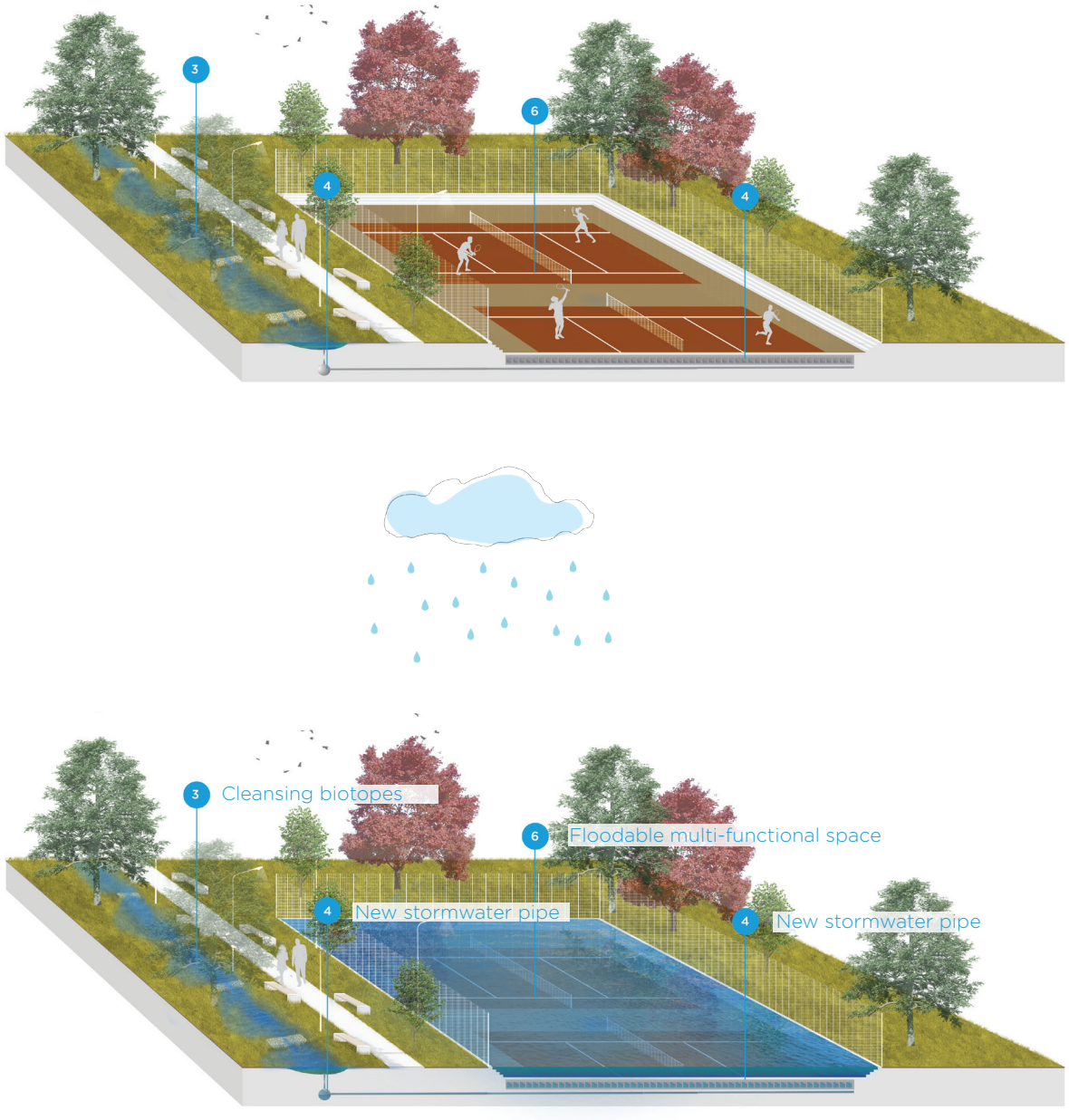
The project of Bishan-Ang Mo Kio Park sought to transform water bodies into vibrant spaces for community bonding and recreation.

As part of the park upgrade, the project involved converting a 2.7 km straight concrete drainage channel into a sinuous, 3.2 km long natural river that meanders through the park.

This transformation allows for fluctuating water levels, providing for both benefits for park users and the environment.

Floodable athletic fields

Floodable athletic fields could include grass, turf, or hardscape sports facilities (e.g., football fields, soccer fields, tennis courts, basketball courts, etc.). The field is excavated to be at a lower elevation than surrounding park space, so that it can detain large amounts of stormwater during extreme rain events.

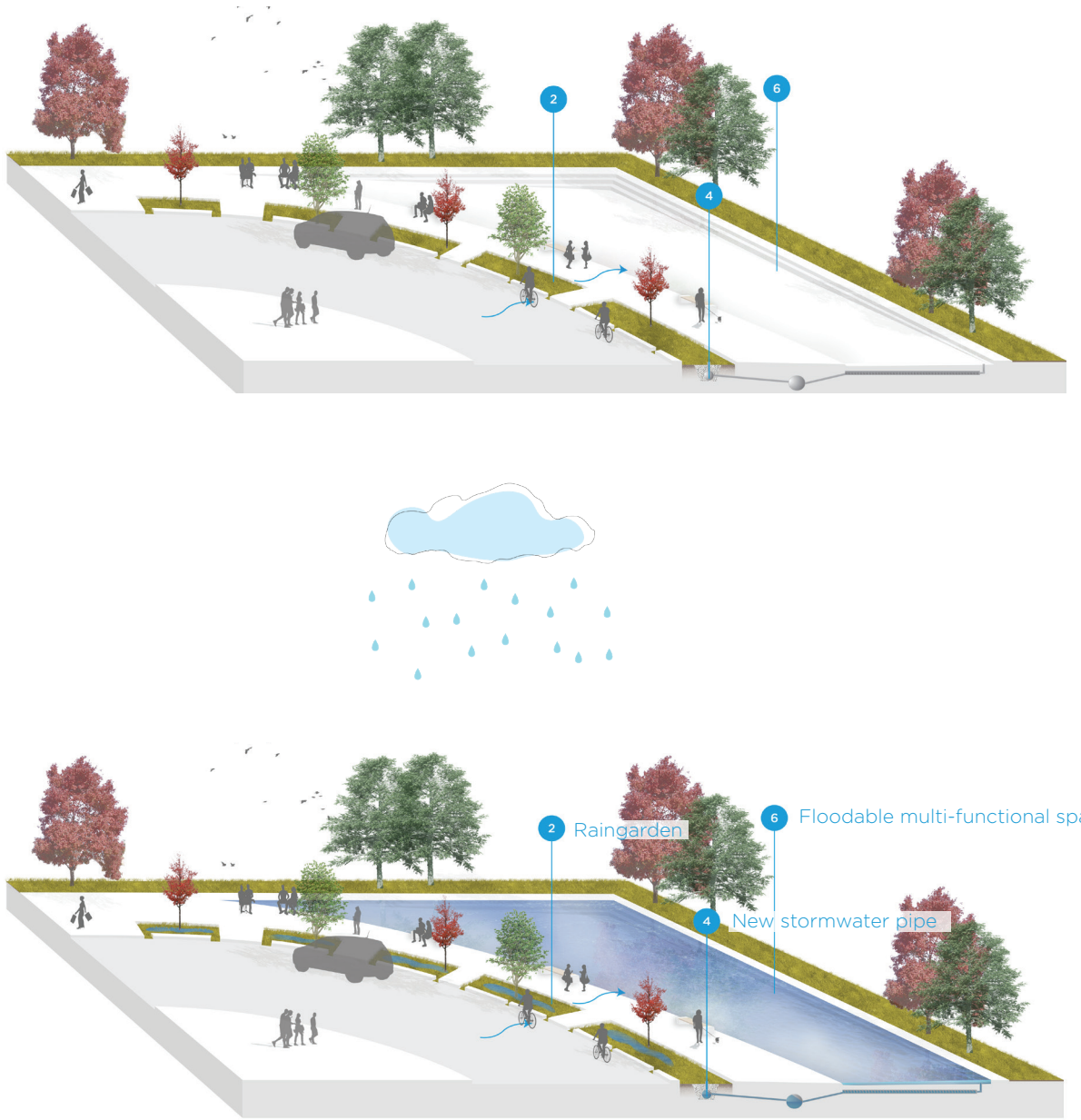


Carlsberg City, Denmark

An old brewery site, located in the central part of Copenhagen on a small hill identified in the city-wide Cloudburst Masterplans as a prime opportunity site for reducing run-off and flooding in downstream areas. New green urban spaces designed to detain rainwater and recreational activities. The basins are designed to handle a cloudburst event with a statistical return period of 10 years. The basins are filled up consecutively by using local flow regulators to retain the water.

Floodable urban plazas

Floodable urban plazas are open space elements in high-dense areas that generally include more hardscape expressions. Urban plazas are lowered and levelled to allow for temporary stormwater detention and/or permanent water features.

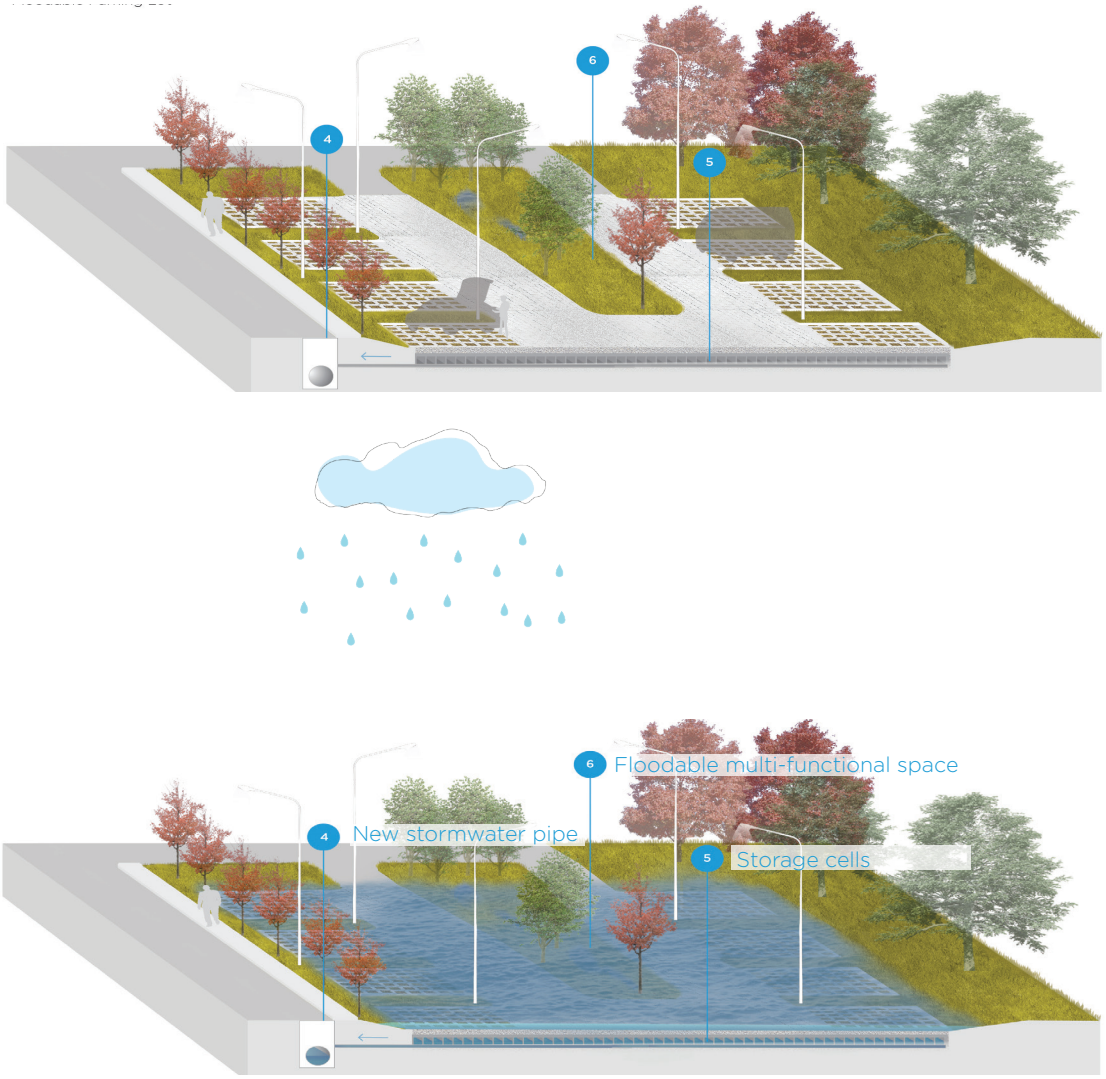


Potsdamer Platz, Germany.

At Potsdamer Platz, a combination of green and non-green roofs is harvesting the rainfall. Rainwater is used for toilet flushing, irrigation and fire systems. Excess water flows into the pools and canals outside creating an oasis for urban life. Vegetated biotopes are integrated into the overland landscape and serve to filter and circulate the water that runs along streets and walkways, all without the use of chemicals. The idea behind this important urban waterscape is that the rainwater should be used where it falls.

Floodable parking lots

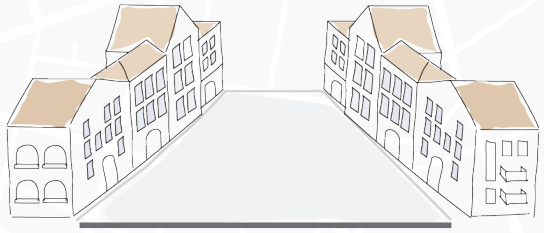
Floodable parking lots are lowered parking areas that allow for temporary stormwater detention without damaging parked vehicles. Parking lots typically make up a substantial portion of underutilized single-purpose urban spaces. For some parking lots a reduction in number of parking spaces to allow for even more BGI could be considered.



Zollhallen Plaza, Germany.

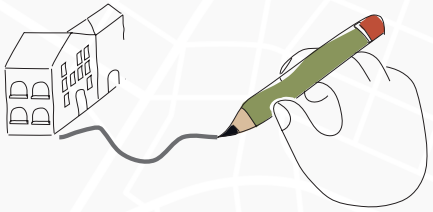
Zollhallen Plaza is carefully redesigned to beautifully integrate contemporary urban design, railyard history, and stormwater management. Here, beautiful planters provide infiltration points to recharge groundwater. Subsurface gravel trenches with innovative in-built filter medium reduce the hydraulic overload on the sewer system. The plaza is disconnected from sewer system and is designed with indented flood zones.

Reimagining floodable open spaces



From traditional open spaces ...

... to multifunctional cloudburst open spaces



Endless opportunities to re-design - all inspired by place!

Floodable athletic fields

Floodable passive parks

Floodable parking lots

Floodable playground

Floodable urban plaza

Jordal Sports Park includes a transformation of an underused space into a vibrant urban neighborhood for both residents and visitors . The development incorporated walkways, cycle paths, skate parks, and playgrounds connected through a holistic park design for all generations. The project included daylighting the natural stream of Hovinbekken to nurture habitat, biodiversity, and recreation throughout the area.

> Jordal Sports Park is a great example of a successful transformation that benefits the whole community. Jordal has become a bustling park where water has the center stage.

Jakob Myking

Project manager

Reimagining floodable streetscapes

Floodable streetscapes

Floodable streetscapes are designed to detain, slow, and move water through the catchment area as a supplement to existing stormwater networks. Floodable streetscapes create connections between floodable open spaces and existing stormwater infrastructure to form a flexible network to reduce extreme or uncontrolled flood situations.

Water naturally flows downhill, increasing in volume toward the bottom of the catchment area. Similarly, floodable streets will be designed with increased flow capacity as we move down the catchment or sub-catchment area. Some floodable streets are also designed to temporarily detain stormwater similar to floodable open spaces, yet in much smaller volumes.

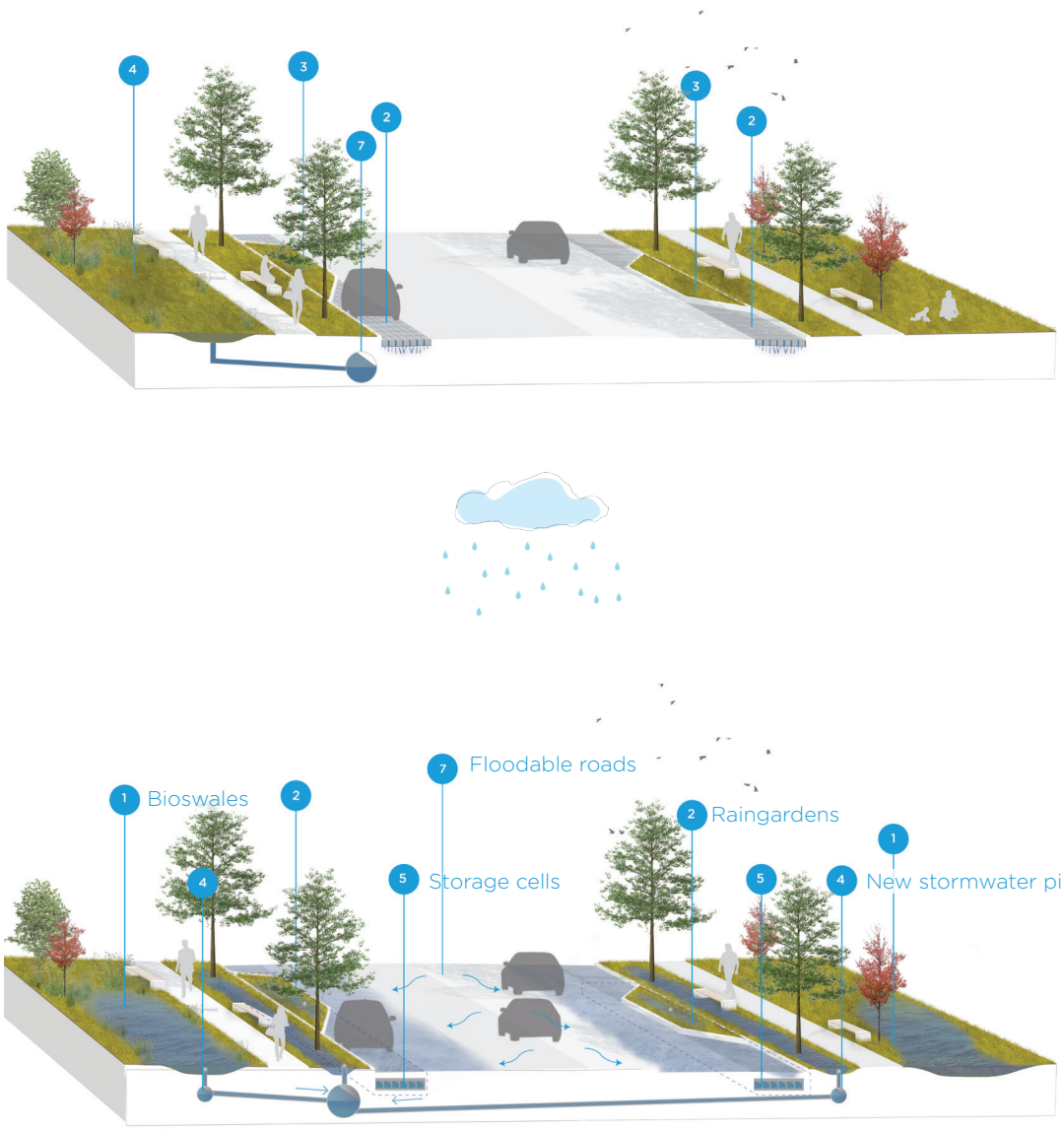
As cloudburst elements are applied in streetscapes they adapt and transform in numerous combinations and versions to make up place-based typologies. Urban expression, availability of space, and conveyance and/or detention requirements all influence the design identity of a floodable street.

In the following pages a selection of floodable streetscapes developed by Ramboll around the world are illustrated for inspiration.

Saint Anna Square, Copenhagen

Green Stormwater Streets

Green Stormwater Streets are generally small scale rights-of-way incorporating cloudburst elements to detain, slow, filter, and cleanse smaller volumes of stormwater runoff from impervious surfaces, such as streets and sidewalks. Green stormwater streets are typically used in upstream areas within a catchment.

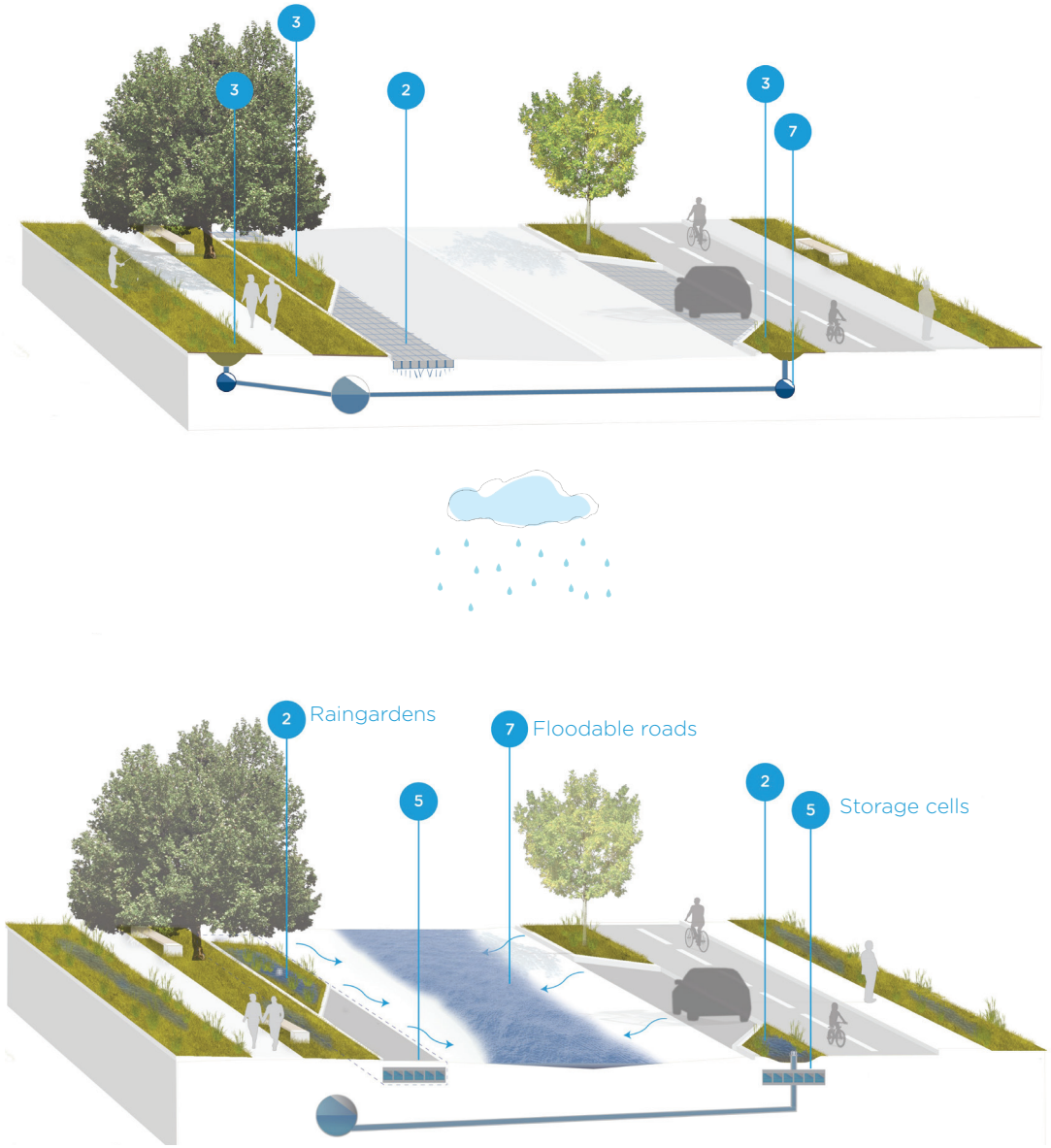


Kong Hans Alle, Denmark.

The project on Kong Hans Allé has successfully established a new bike path, providing a safe route for children attending local schools in Gladsaxe. To address the area's significant flooding issues, a climate adaptation project was incorporated. This has transformed Kong Hans Allé into one of Denmark's first cloudburst "green streets." The project includes surface-water-collecting garden beds and a specially designed 'rain park,' which alleviate the combined sewer system during heavy rain events.

Cloudburst Conveyance Roads

Cloudburst Conveyance Roads are generally small to medium-sized right-of-ways that incorporate cloudburst elements to detain, slow, convey, filter, and cleanse stormwater runoff. Cloudburst conveyance roads are typically located further downstream in the catchment or sub-catchment area and demand more space for stormwater conveyance and detention than the Green Stormwater Street. Additionally, Cloudburst Conveyance Roads apply reprofiling of roads to manage larger flows, hold water in the right-of-way, and avoid damages to adjacent assets, typically through a V-shaped, or crown-shaped profile.



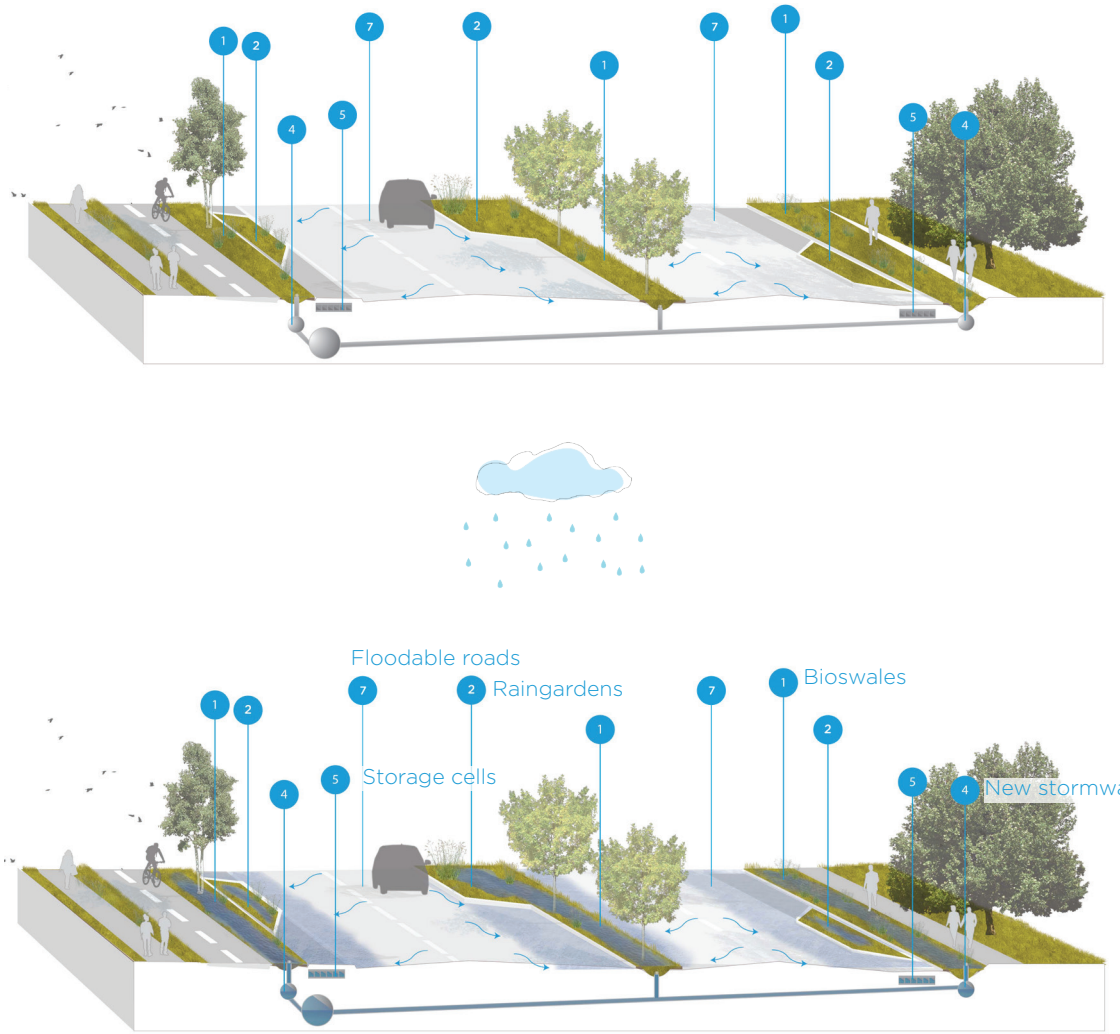
Saint Anna Square, Denmark.

Saint Anna Square was built in the 18th century and for many years an underutilized urban space. Today, it is a showcase for urban resilience and designed to handle flooding events. In 2011, the area was heavily devastated by a cloudburst that damaged several buildings, and today, Saint Anna Square is developed in such way that large amounts of water can be collected and diverted away. This is done by the creation of a large bowl-shaped reservoir that is lowered into the ground. The reservoir collects the water and directs it further through hidden pipes underground. Surface water flow is directed out into the harbor.

Stormwater Detention Boulevards

Stormwater Detention Boulevards are typically wide roadways that have existing center medians or space for medians and can be utilized to channel large volumes of stormwater in the event of extreme rainfall events.

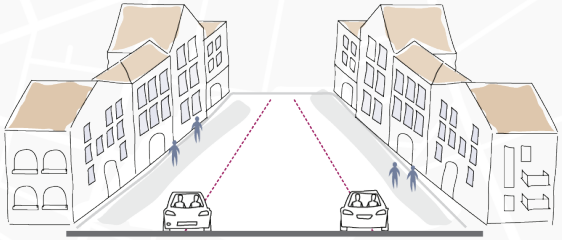
These boulevards can be designed with a V-shaped profile and raised curbs to ensure that water will flow toward the middle of the road, away from buildings. The center median can be designed to capture and convey stormwater from everyday rainfall events. In the event of extreme rainfall, the entire V-shaped road profile can be used to effectively convey large amounts of stormwater to a designated floodable open space or other recipient.



Kuninkaantammen, Finland.

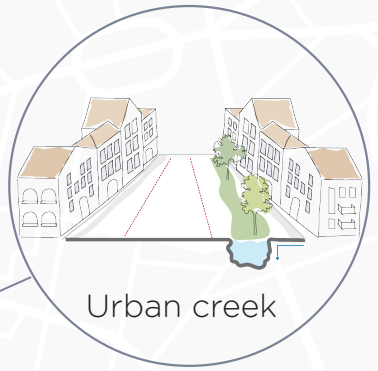
The Kuninkaantammen residential area in Helsinki has a stormwater management street. The water is diverted from the carriageway to the culverts, and from the pavement to the filtering structures. The aim is to delay and clean stormwater as much as possible's within the street area's biofiltration structure where excess water is discharged into the stormwater network through overflow wells.

Reimagining floodable streetscapes



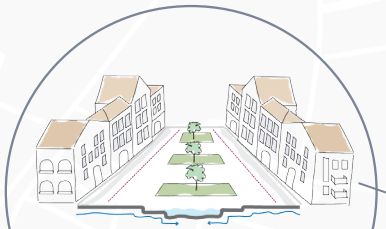
Transforming traditional roadways...

... into versatile floodable streetscapes



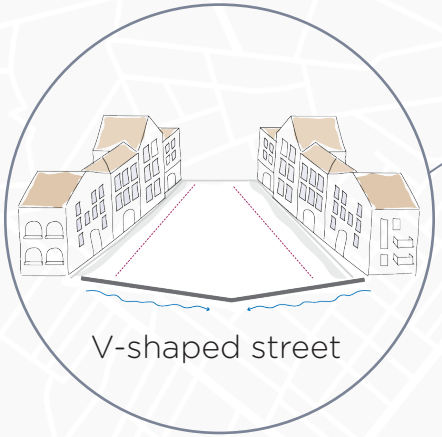
Urban creek

Endless opportunities to redesign - all inspired by place!

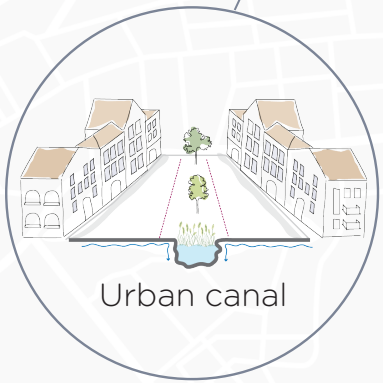


Retention boulevard

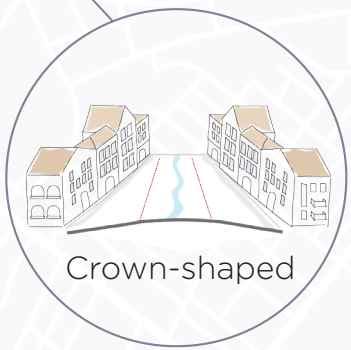
Green street



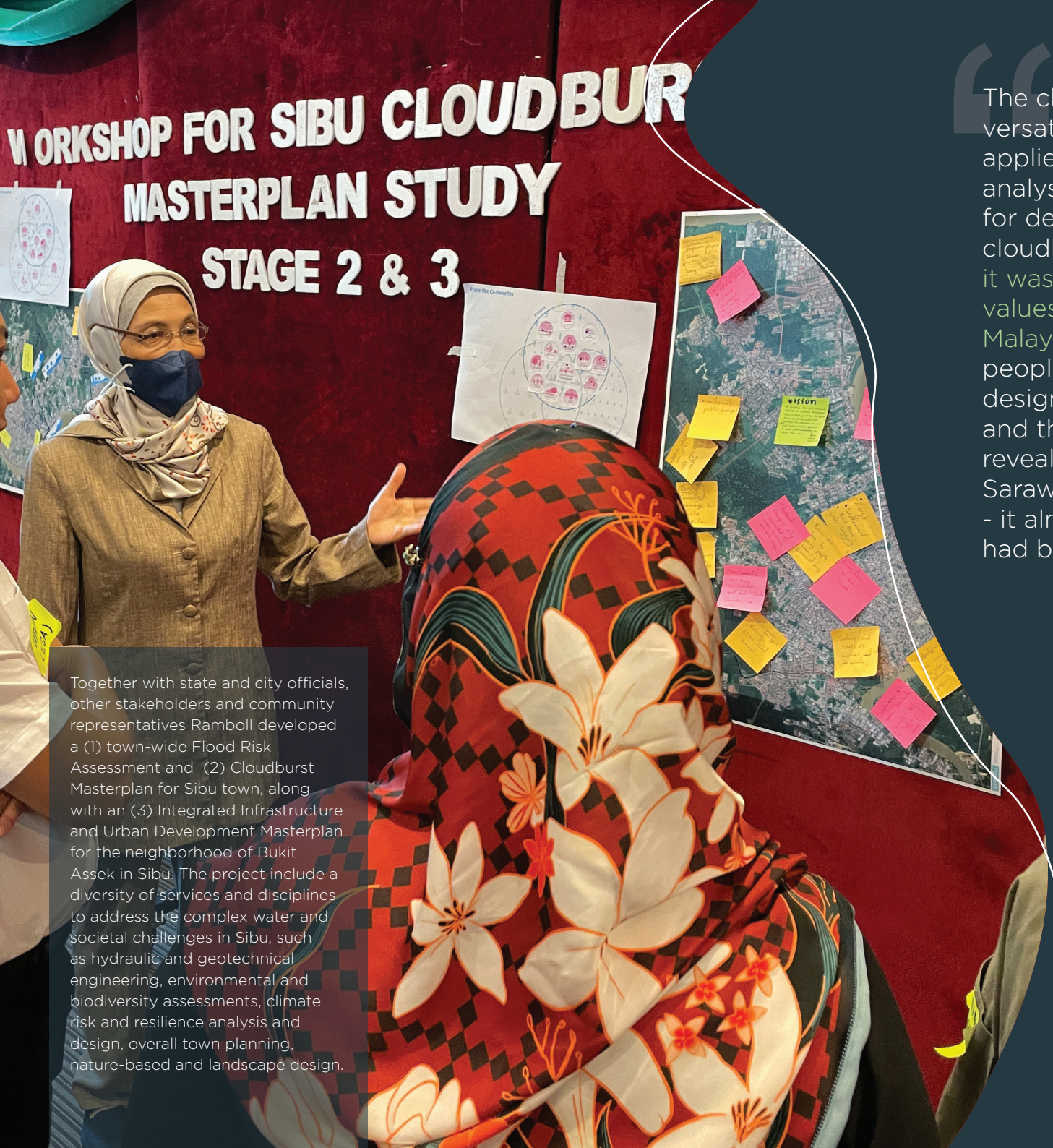
V-shaped street



Urban canal



Crown-shaped



Together with state and city officials, other stakeholders and community representatives Ramboll developed a (1) town-wide Flood Risk Assessment and (2) Cloudburst Masterplan for Sibu town, along with an (3) Integrated Infrastructure and Urban Development Masterplan for the neighborhood of Bukit Assek in Sibu. The project include a diversity of services and disciplines to address the complex water and societal challenges in Sibu, such as hydraulic and geotechnical engineering, environmental and biodiversity assessments, climate risk and resilience analysis and design, overall town planning, nature-based and landscape design.

"The cloudburst approach demonstrated its versatility as a universal methodology when applied in Sarawak, Malaysia. The technical analysis provided a robust foundation for decision-making, as it was done for cloudburst projects worldwide. However, it was the integration of local culture and values that truly set the approach apart in Malaysia. The deep connections between people, water, land and nature informed a design process that felt unique to this region and through collaborative engagement revealed interventions that harmonized with Sarawak's distinct environment and traditions - it almost felt like the cloudburst approach had been invented here."

Pritha Hariram

Climate Resilient Water Infrastructure Specialist & Head of Department

Reflections from our own work

Communities and stakeholders around the world have inspired this cloudburst catalog

After co-evolving cloudburst thinking with stakeholders and communities around the world, we have learned a thing or two.

BGI in NYC is most cost-effective and provides more co-benefits when implemented in open space areas

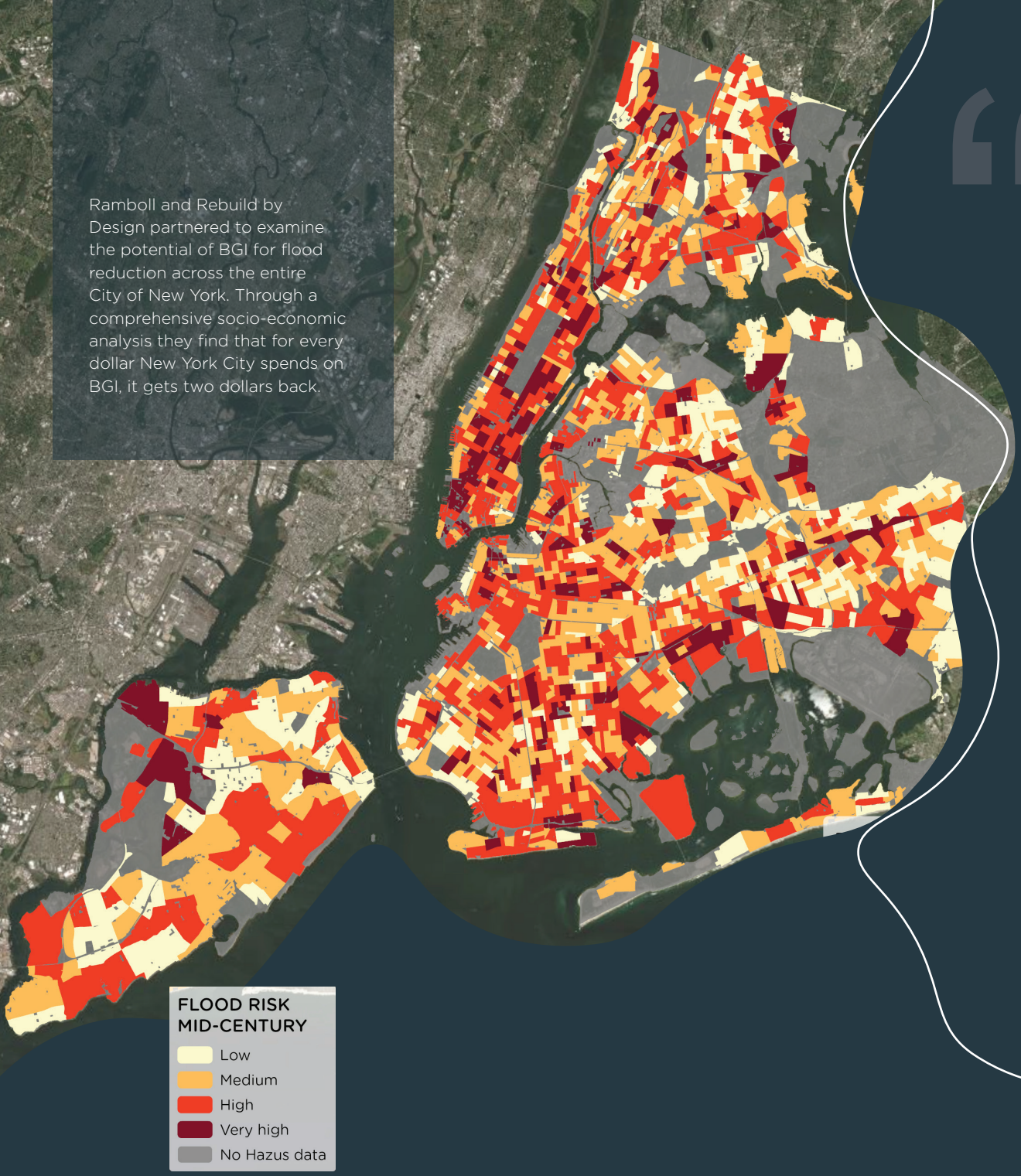
BGI implementation in parks, plazas, and campuses, whether public or private, is 2-3 times more cost-effective than in streets. This cost difference arises from the limited space available in streets for accommodating increased stormwater volumes, coupled with higher construction expenses for streetscape modifications, particularly concerning underground utilities.

Moreover, the cost estimation for BGI in parks and plazas encompasses enhancements such as new natural areas, recreational facilities, playgrounds, extensive landscaping, and other improvements that provide long-term value to New Yorkers every day. These enhancements are not as feasible within streetscapes due to space limitations.

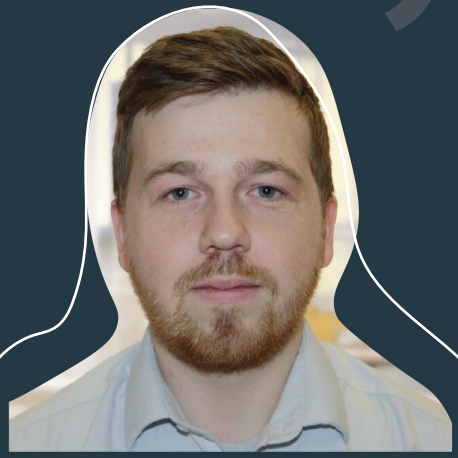
Storage in Right of Way: 18 - 23 USD/gallon

Storage in open space: 7 - 14 USD/gallon

Ramboll and Rebuild by Design partnered to examine the potential of BGI for flood reduction across the entire City of New York. Through a comprehensive socio-economic analysis they find that for every dollar New York City spends on BGI, it gets two dollars back.

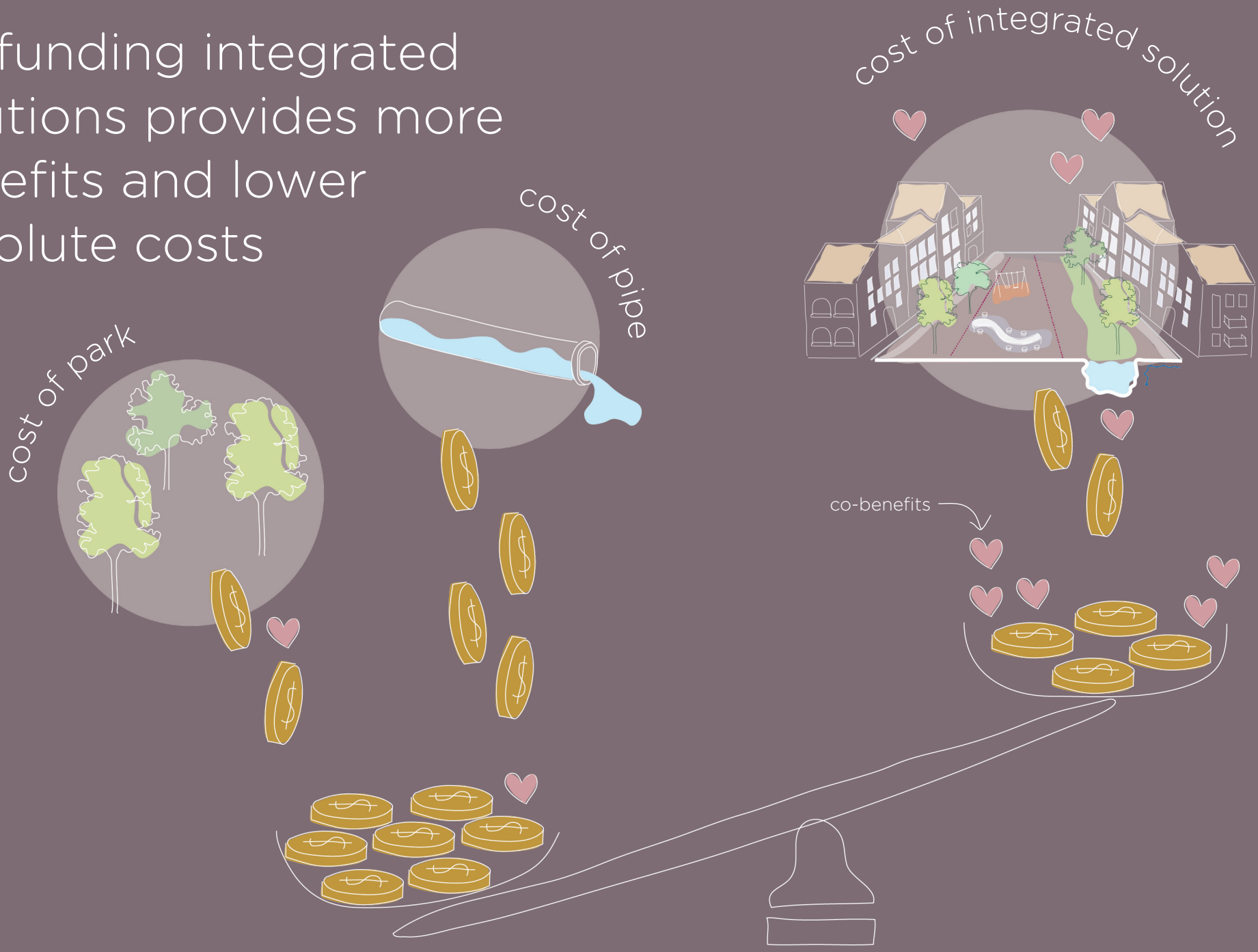


"As an engineer working with stormwater management and climate risks, integrating the urban spaces as a core component in solving problems related to flooding provides a lot of interesting solutions. It's amazing to know that our work not only helps solve these complex challenges, but also revitalizes our cities aesthetically and socially. By harnessing the synergy of blue-green infrastructure, we create resilient urban spaces that contribute to reducing the risk of flooding while also benefitting citizens and protecting our ecosystems."



Benjamin Holm
Environmental Engineer

Co-funding integrated solutions provides more benefits and lower absolute costs



"Nature-based solutions can provide 37% of the climate mitigation needed between now and 2030 to keep global warming below 2 degrees Celsius - the target of the Paris Agreement. But these interventions currently receive just 3 % of climate funding."

Erica Gies, Water Always Wins, 2022

Rifle Range Nature Park Singapore

Henning Larsen, part of Ramboll, was commissioned to enhance and protect ecological habitats within a 66ha buffer abutting Bukit Timah Nature Reserve. With more than 7km of trails, boardwalks and a freshwater wetland located in a former quarry it is also home to a rich variety of plants and over 300 species of wildlife. The 31m tall Colugo Deck above the cliff took inspiration from the flying Sunda Colugo, where visitors can enjoy the one-of-a-kind panoramic forest view over the Quarry Wetland.

Cloudburst typologies should be tailormade

Too often the urge to quickly scale up and out, and minimize maintenance costs has resulted in over-simplified local cloudburst “standards”. Most of these standards have little to do with nature-based design, are not tailored to place, and are rolled out in a mechanistic, top-down sequence, rather than a bottom-up, community-led process.

“Participating in meaningful projects that help bring value to societies by transforming climate-induced challenges into opportunities for sustainable change has been fulfilling.”

Vinodhini Devi
Design Engineer

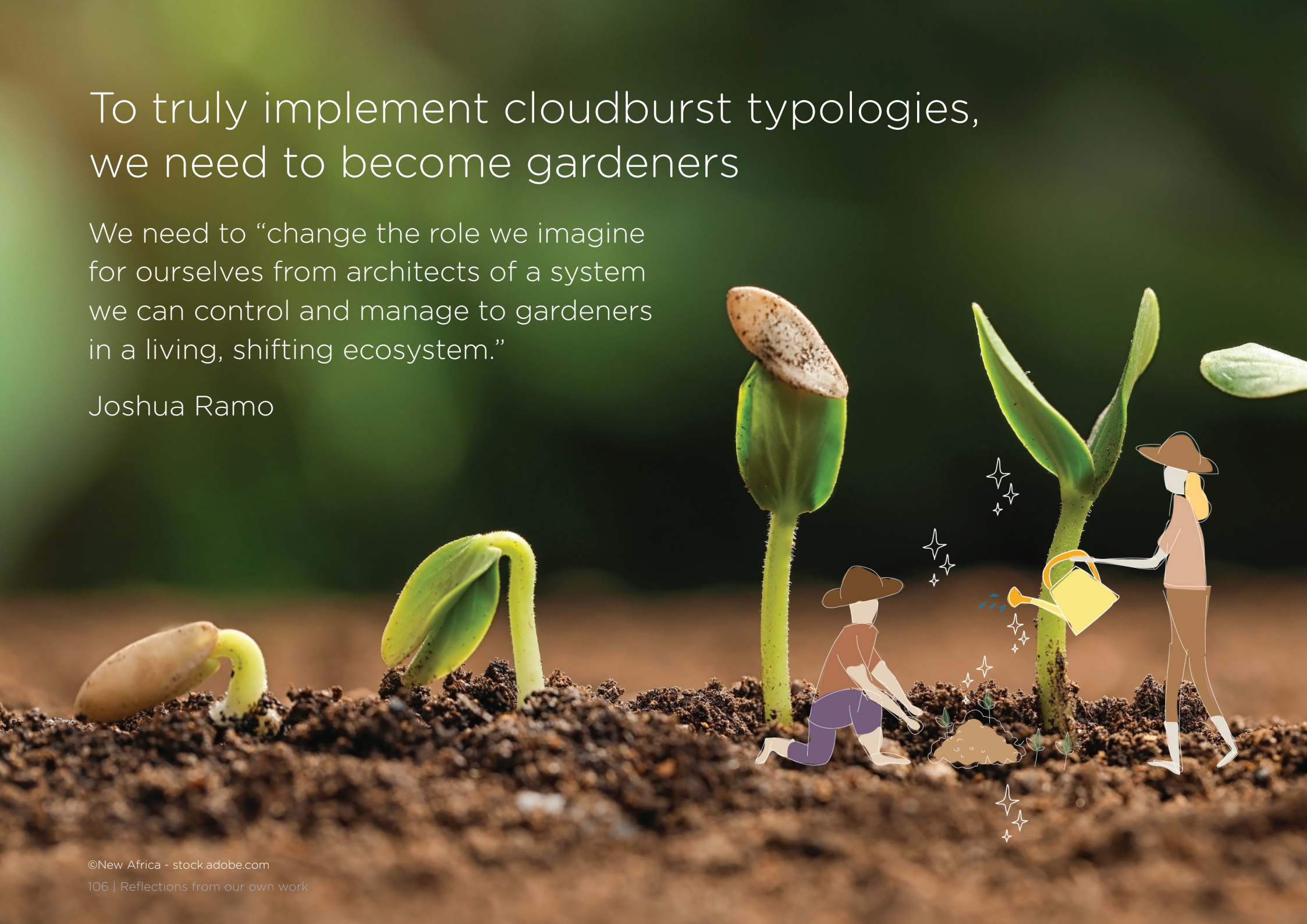
“In the development of Skien Cloudburst plan we have had a strong focus on involvement. This has resulted in high ownership in the municipality and the burst being used actively as an important tool in city planning.”

Sigmund Viig Pettersen
Design Engineer

To truly implement cloudburst typologies, we need to become gardeners

We need to “change the role we imagine for ourselves from architects of a system we can control and manage to gardeners in a living, shifting ecosystem.”

Joshua Ramo



As gardeners we treasure maintenance

Maintenance is...

- Care
- Investment
- Sustainable
- Inclusive

If we are not willing to maintain we should not implement

We aspire to design as water

Water inspires us. Connects us.
It gives us purpose.

Through presencing we activate our whole-systems thinking, our collective intelligence, and our empathy as bodies of water. Try it!

"We are all bodies of water."

Astrida Neimanis

Landing by water
Storytelling to activate our liquid mind

Sensing into water
Feel, see, hear, smell, and taste water.

Becoming water
Relearning ourselves as bodies of water.

Emerging as water
Practicing our watery self.

Join us!

We aspire to design as water with an open mind, open heart, and open will. **Together**.

Embracing a new water paradigm is not something we do on our own. We do it with you.

So join our journey into water stewardship as bodies of water.
It is fun. It is caring. And the world needs it!

"What if every single act of design and construction made the world a better place?"

Daniel Christian Wahl

Want to learn more?

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