Interreg
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SUSTAINABLE WATERS
City Blues

NATURE-BASED SOLUTIONS FOR CATCHMENT LEVEL CLIMATE CHANGE ADAPTATION AND CITIZEN WELLBEING

Baltic Sea Region Benchmarking & Baseline Scenarios for nature-based solutions in the partner cities

D1.1 Baseline scenarios for nature-based solutions in the partner cities

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Summary

Research and public awareness on planning, design, operation and maintenance of nature-based solutions (NBS) for adapting urban areas for climate change has rapidly increased in the last decade. Therefore, the number of nature-based stormwater solutions constructed in the urban environment has changed the process of designing solutions and managing water in urban environment.

Implementation of NBS has more public interest compared to pipe-based solutions, as it requires more space and the functionality or dysfunctionality of the units can be easily assessed. Therefore, co-creation and co-operation models have been proposed to engage general public in the planning phase considering the impact of NBS to the living environment. Moreover, this has led to multi-benefit design approaches where NBS are considered to increase biodiversity, public health and water quality, and at the same time, to reduce stress, flood risk, water scarcity and temperature in warm summers, to name a few examples. The design of such multifunctional units is much more complicated compared to the existing pipe-based stormwater systems. NBS are highly engineered solutions mimicking the natural processes in semi-controlled environment. Similarly to nature, the units are constantly and periodically changing its performance depending on seasonality and maintenance schedule and approaches. Therefore, we need to consider the engagement, operation and monitoring throughout the life cycle of NBS with potential feedback and feedforward loops.

The report gives an overview of the main City Blues project concepts and challenges on NBS planning, design, operation, monitoring and maintenance. Background information on the current operational models for NBS implementation are reviewed, and best practices for each step in the NBS life cycle are given based on the existing workflow and lessons learnt from the pilot projects. Interviews were carried out with the representatives of the municipalities to define the main gaps of the operational models and to highlight the existing best practises that can be shared in City Blues and beyond. The design criteria and methods for NBS were analysed based on 23 projects of the City Blues consortium. It was concluded that quantitative design criteria are mainly used for flood reduction and water quality improvement, while for other objectives like biodiversity and social cohesion mainly qualitative approaches exist.

In order to fill this gap on methodologies and approaches, a state-of-the-art literature review was conducted to define the current knowledge and research gaps on NBS planning, design, operation and monitoring. Concrete research questions were defined for each phase to foster the capacity building in the City Blues consortium and to outline the domains that could be further tackled in the project.

The report summarizes the co-creation process performed by the municipalities to define the benchmark scenarios for the NBS implementation. The approach was piloted in a co-design workshop and later implemented by the municipalities in their working environment. The lessons learnt from the exercise will be considered in finalizing the City Blues operational model for NBS planning and implementation.

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Introduction to the City Blues concepts and challenges

Catchment level urban water management

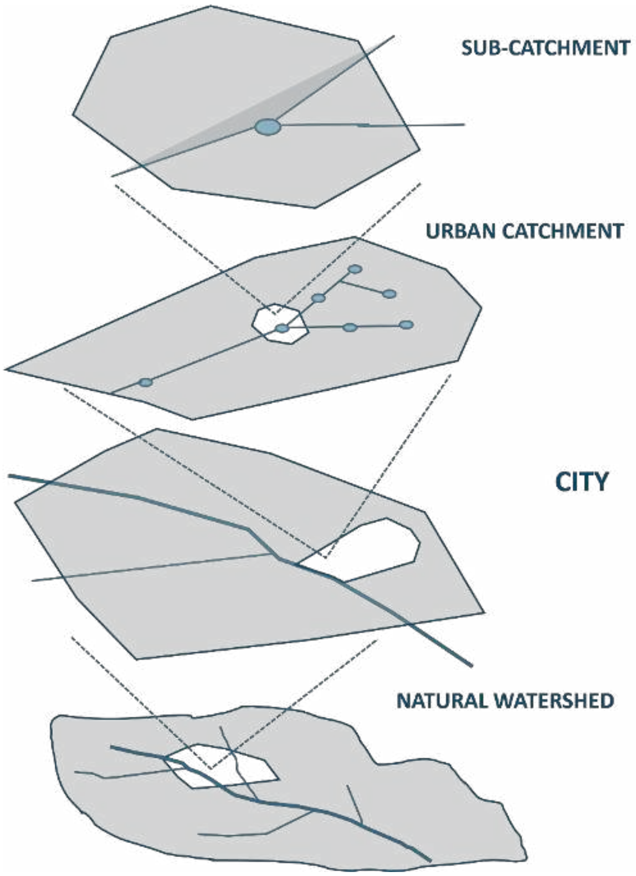


Figure 1 Catchment hierarchy [1]

Understanding the hydrological regime of watersheds and how the urban catchment hierarchy is affected is crucial for urban resilience and planning. As cities expand, urban development often changes natural drainage patterns, altering the flow of water and creating a need for engineered drainage systems. Many cities worldwide have historically settled near water bodies, such as rivers, lakes, and seas, owing to the benefits they offer for transportation, trade, and access to water for drinking and industrial purposes. Understanding the hydrological regime of watersheds and how the urban catchment hierarchy is affected by this is crucial for urban resilience and planning.

Urban catchments often overlie **natural watersheds** or portions of larger watershed systems. Typically, there are several urban catchments within a city; however, in the case of smaller urban settlements, cities can serve as single urban catchment areas. It encompasses land surfaces, rooftops, roads, and other impervious surfaces that contribute to the stormwater runoff. An **urban catchment** is a defined area within a city or urbanized area where rainfall and surface runoff are collected and drained by a network of channels, pipes, and natural features such as streams or rivers. Within urban areas, the urban catchment hierarchy (Figure 1) reflects the organization of drainage systems to manage stormwater runoff effectively [1]. **Sub-catchments** collect runoff from small neighbourhoods and are typically connected to a single inflow of the urban drainage system. Urban catchments are managed through drainage infrastructure to prevent flooding, control pollution, and protect the water quality in downstream water bodies. The natural topography and drainage patterns of the landscape influence the layout and organization of urban catchments. Streams, rivers, and other natural waterways within urban areas are often part of broader natural watershed networks. Cities must consider natural drainage patterns and hydrological processes when designing and managing drainage systems, land use planning, and infrastructure development. Failure to account for these factors can lead to an increased flood risk, infrastructure damage, and environmental degradation.

Nature-based solutions (NBS)

There are various definitions available for nature-based solutions (NBS). Among many, formal definition has been agreed between intergovernmental organizations like IUCN or European Commission.

According to IUCN "Nature-based Solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits" [2]

European Commission defines NBS as „Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."[3]

NBS have diferent types and they respond to a variety of societal challenges (Figure 2). In City Blues we focus on improving the water quality of the **urban rivers and streams** performing as NBS. This will be done both by restoring the ecosystems through creating riverine parks and wetlands and establishing sustainable urban drainage systems (SUDS) for the built-up areas.

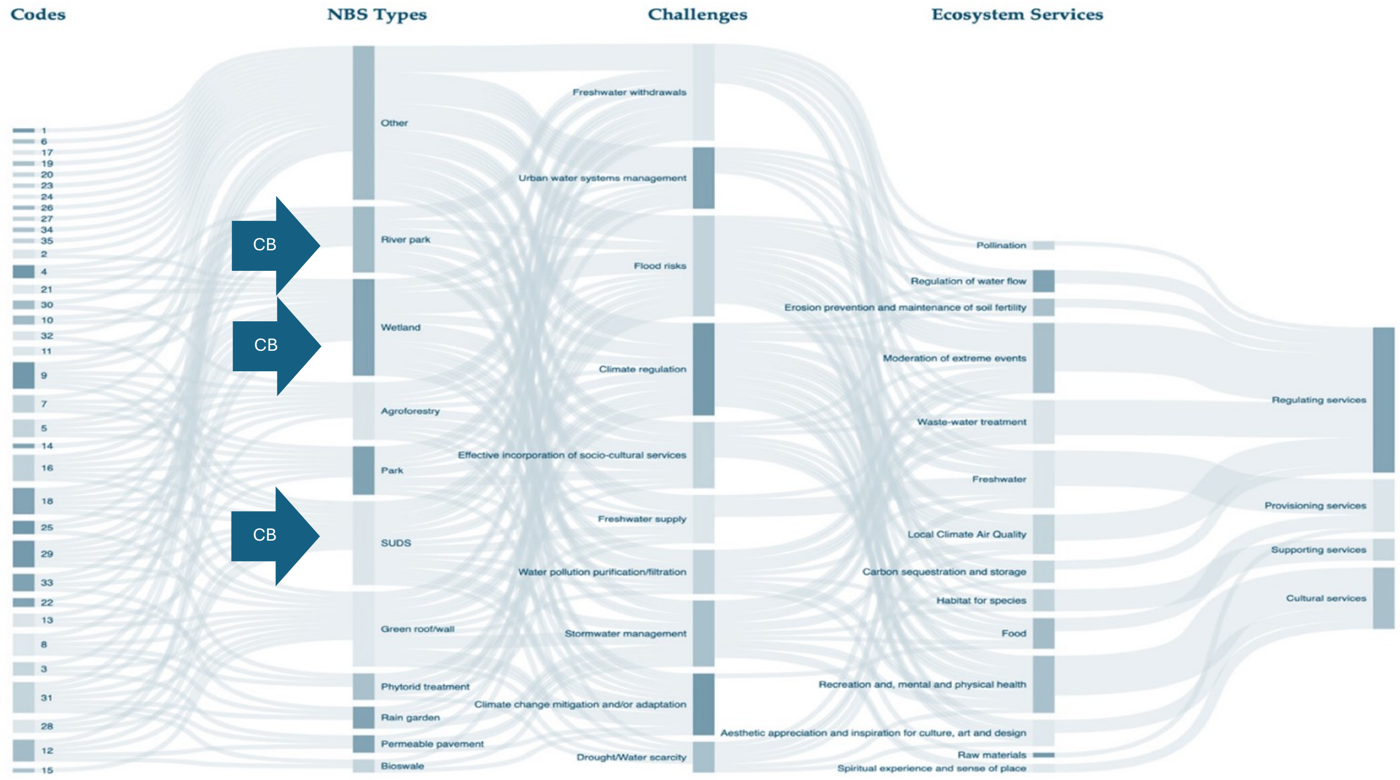


Figure 2 NBS types, challenges and delivered benefits/ecosystem services and targeted scope of CityBlues (blue arrows CB) [4]

Benefits of NBS

Implementing NBS offers numerous advantages as they provide additional ecosystem services in addition to addressing the primary challenge. The benefits and categories of NBS vary depending on the project focus, the spatial and environmental settings in which they are established, and the bio-geographic conditions of the site [5].

The City Blues project identified nine possible benefits during the application phase, including:

- **Flood risk**, rainfall intensity exceeding infiltration capacity (pluvial flooding) and high-water levels in surrounding and receiving water bodies (fluvial flooding).
- **Biodiversity and green space provision**, decreasing biodiversity loss (restoration of the habitat of a specific species) by increasing green space compared to grey areas.
- **Public health and well-being**, providing green areas like parks where people can walk and spend free time (run, walk, leisure, etc.).
- **Safety of operations**, operational safety is defined as the absence of unacceptable risks, injury or harm to the health of humans, whether direct or indirect, resulting from damage to equipment or environment.
- **Urban heat**, reduction of average air temperature in the urban areas.
- **Environmental protection** (including water quality), ensure better water, air and soil quality.
- **Material efficiency**, NBS implementation in the built environment: green building materials, systems for the greening of buildings, and green urban sites.
- **GHG emissions**, reduce carbon dioxide CO_2, methane CH_4 and nitrous oxide N_2O emission.
- **Social use and cohesion**, social cohesion refers to the strength of relationships and the sense of solidarity among members of a community.

NBS in catchment-level urban water management for climate adaptation and citizen well-being

NBS have gained more attention in EU, national and regional climate adaption plans as one cure-for-all mitigation measure to reduce flood risks, droughts, improve water quality and citizen well-being. For water management, NBS are treated as decentralized systems often considered as stand-alone units to reduce peak flows and adjust the inflow to the urban drainage system (UDS) in case of intense rainfall events. At the same time, it is often expected that the implementation of NBS will serve multiple benefits renaturing the urban space and increasing greenery in dense areas. This is not always supported by the planning and design as in today's practice NBS are often constructed as monofunctional solutions not fully considering the interconnections. The lack of standardized calculation methods and quantifiable measures for NBS co-benefits is holding back the realization of the NBS full potential.

NBS can be classified to no-tech, low-tech and high-tech green indicating that the level of expected ecosystem service performance should be considered already in the planning phase [6]. The no-tech solutions usually imply to volumes of soil and lots of space type of solutions that are often implemented in sparsely populated (urban) areas. The low-tech NBS are designed to passively detain rainwater for later infiltration or evaporation. These solutions are usually considering the low-to-modest rainfall events and fail to perform in case of random maintenance, long droughts or extreme rainfall events. The research on high-tech sensor-managed data-driven NBS is taking its first steps but has potential to be fully integrated with the existing UDS management.

All these NBS types could be suitable for catchment level urban water management. The implementation potential and expected performance of ecosystem services needs to be considered in addition to spatial limitation also in the planning, design, operation and maintenance phase. This means that the whole life cycle of the NBS needs to be reckoned prior to the implementation to break the silos between the different actors in the municipalities and increase the potential impact of the intervention. Cities need functional and easy-to-follow operational model for planning integrated urban water management to consider water related risks at all stages in the city development.

Operational model for implementing NBS projects across the whole life cycle

City Blues project has set an objective to develop a **joint operational model for planning, design and implementing NBS in Baltic Sea Region (BSR)**. At the launch of the project, all partner cities apply different operational models that have evolved through local pilots, previous projects, and national frameworks. Existing baselines and capacities vary among cities, as the experiences in implementing catchment scale water management as well as establishment of NBS differs significantly.

Since cities are situated in various countries and thus adhere to distinct regulatory conditions, local challenges and opportunities also differ, which results in differences remaining between them. Therefore, the expected joint operational model developed in City Blues, will not be a standardized norm, but rather **a set of validated best practices developed, tested and transferred across the consortium** via mutual learning and experience exchange.

Life cycle for NBS implementation

The life cycle of NBS involves a comprehensive set of approaches that encompass different stages and methodologies. It is crucial to recognize that the life cycle extends beyond the conventional project implementation process. Ecosystem functions can change over time, which can create uncertainty. Adaptive management techniques may be necessary to address these changes [7]. Accommodation of these shifts needs to be foreseen in the planning, design as well as operation and maintenance. The multiple benefits, the NBS are expected to deliver require more broader engagement of possible stakeholders and the success of the solution depends on consultations and involvement in various phases of the project. Various NBS are applicable to different spatial scales and attain maximum efficacy at distinct time scales, while simultaneously posing the risk that natural succession may counteract the impact of certain designed elements.

Therefore, monitoring feedback and continuous engagement of community are necessary to guarantee a certain control over the dynamics of NBS projects and apply adaptive management (Figure 3).

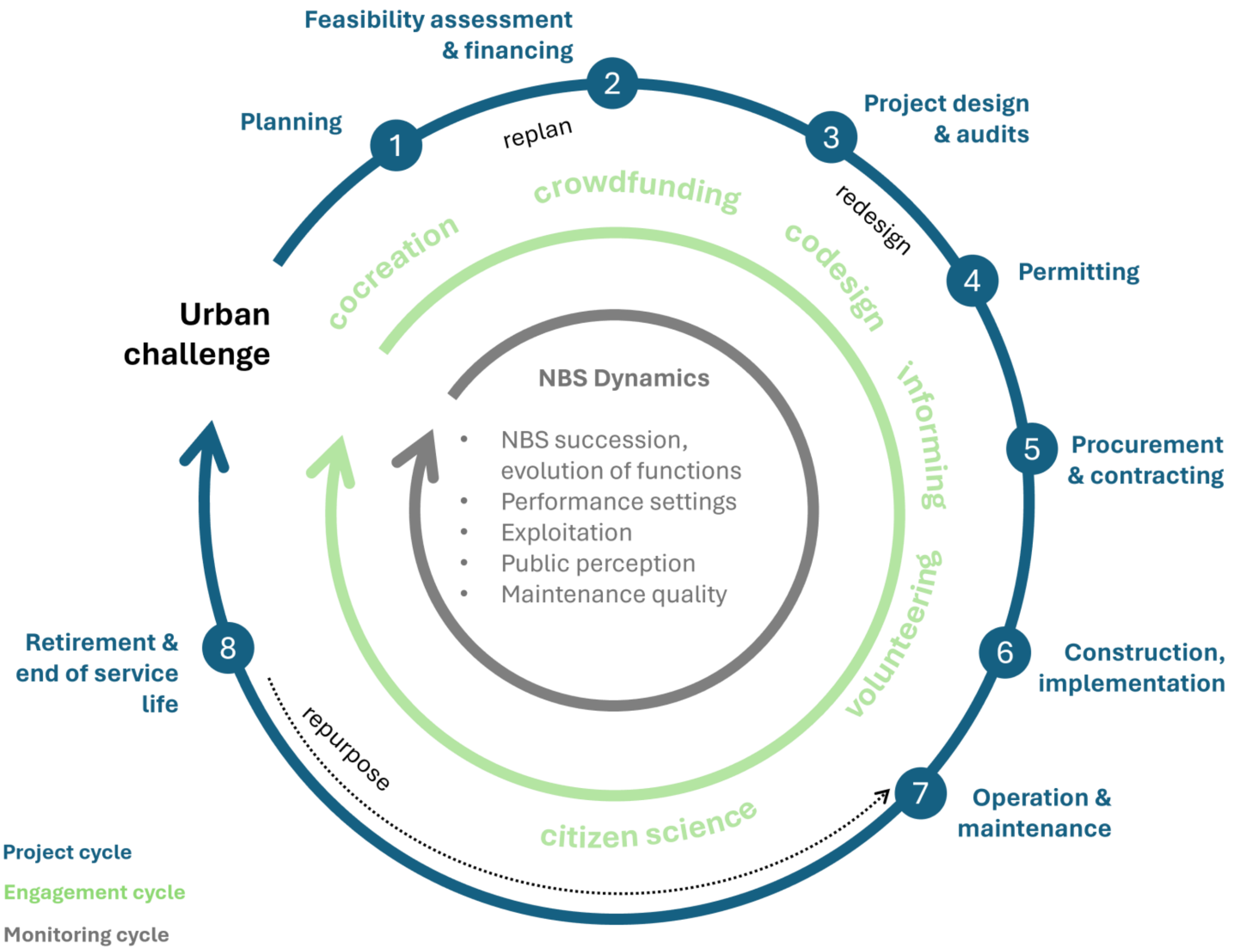


Figure 3 NBS project life-cycle, with emphasis on engagement cycles and monitoring cycles

Current status on implementing nature-based solutions in the Baltic Sea Region

City Blues benchmarking for identifying knowledge gaps in the current operational models

City Blues project brings together a group of cities – **Aarhus, Malmö, Stavanger, Tampere, and Tartu** (Figure 4 Pilots in City Blues) that have different backgrounds in urban water management as well as in implementing nature-based solution for urban challenges.

The current operational models within these cities were analysed in the frame of the City Blues project using simple questionnaires and direct interviews with the representatives of cities. The aim of the interviews was to understand the **city level policies and practices that relate to implementing NBS for climate hazard mitigation and citizen well-being**.

Key findings as well as examples from the current operational models are described below.

Figure 4 Pilots in City Blues

Overview of the operational models in place for implementing NBS over the whole project life cycle

All cities utilize various methods for **identifying the possible challenges to respond to with NBS.** These methods include historical event documentation, risk mapping, and modelling, to identify climatic hazards such as extreme precipitation and flooding. Urban catchments are typically considered for identifying water related risks. The damage potential of water related hazards has been well acknowledged and therefore modelling of these risks is quite well rooted to the planning routines.

Cities are well informed about the benefits of NBS. Still, the solutions are typically designed either for urban water management or for provision of green spaces and restoring the biodiversity in the cities. In terms of water related challenges, the main objective for NBS is flood control and improvement of water quality. Other benefits are seen as complementary amenities. In recent years, more attention has been given to urban heat related challenges.

However, related to this climate adaptation challenge, cities typically do not apply modelling nor have specific city-level guidance available. Heat related climate risks are considered in more generic level in the climate adaptation plans.

	EXAMPLES OF OPERATIONAL MODELS FOR IDENTIFYING URBAN CHALLENGES NBS COULD SOLVE
Aarhus	Aarhus has a **city-wide model of UDS** allowing to analyse the flood risk in the city. Modelling was outsourced from an external partner using commercial urban runoff modelling software Mike+. Modelling serves as the key baseline for the catchment level masterplans (RVDPs). The modelling results (flood risk induced by standardized weather events) are visualized in the municipality GIS and thus well institutionalized into different routines of urban water management.
Tampere	In addition to comprehensive modelling, **Tampere records historic flood events and collaborates with residents to map flood incidents**. It has been observed that these recorded floods do not always correlate with modelling results, as models can fail to consider all the variables in the real urban settings.
Tartu	Tartu is currently developing a city-wide **biodiversity strategy** that will serve as baseline for planning various measures (including NBS and blue-green infrastructure) to support the diversity, ecosystem health and overall connectivity of the urban biodiversity.
Malmö	Malmo has also analysed **historic maps to identify the former riverbeds and floodplains**. Such information provides invaluable information for planning catchment scale flood management solutions.
Stavanger	Stavanger has developed an analytical tool to examine the **multifunctionality of green infrastructures**. The tool will help policymakers and planners examine blue-green infrastructure's performance related to its multifunctionality for biodiversity and ecosystem services. The analytical tool has been used to examine the performance of 156 green infrastructure units in Stavanger considering also potential multiple benefits for citizens well-being.

The **planning and decision-making process for NBS** implementation varies in the municipalities but generally involves identifying high-risk areas across cities, developing risk mitigation plans for the identified areas, prioritizing actions and evaluating the effects of possible measures. Planning is regulated by national and local laws in all cities. However, the specific mechanisms for planning procedures vary across cities.

According to the formal planning procedures, NBS are planned as any other urban infrastructure. This defines the procedure for stakeholder engagement as well as formal coordination and approval processes. Depending on the scale of the NBS, the planning process can significantly vary. The mechanisms needed to implement small bioswales on a single plot, is much different from the processes taking place for catchment level river restoration projects. Also, decision making process that leads to NBS, can either be a recovery after experienced flood incident (i.e. looking an opportunity to solve a known challenge) or more forward looking rejuvenation of larger area (i.e. exploring an opportunity to alleviate and mitigate risks in the area).

Instructions for planning NBS (mainly for water related challenges) are provided in different guidance documents, i.e.:

- Stormwater management guide of Aarhus [8] (with a set of complementary guidance supporting the Aarhus Climate Adaptation Method [9], ie. Planning guidelines for stream restoration, establishment of detention systems etc.)
- Technical handbook of City of Malmö [10]: more specifically chapters on stormwater (Vatten/Dagvatten) and project planning (Projektering).
- Stormwater Programme of City of Tampere [11].
- Sustainable Stormwater Management Principles of Tartu [12].
- State level guidance for climate and energy planning and climate change adaptation in Norway [13].

OPERATIONAL MODELS IN PLANNING NBS TO LEARN FROM

Aarhus

According to the wastewater management plan [14] of city of **Aarhus**, the city applies **a two-level model for the management of urban runoff** (Figure 5). Municipality Government is responsible for compiling urban catchment level stormwater drainage and detention masterplans (RVDP – *Regnvandsdispositionsplaner*) whereas each developer in the city is responsible for compiling a separate runoff management plan (RVHP – regnvandshåndteringsplan) in the sub-catchments the development is taking place. Planning criteria has been agreed, along with acceptable methods in validating the planned solutions. Guidance document available in Danish [8].

RVHPs are a compulsory part of each detailed plan and it consists of runoff analysis before and after the planned development, explanatory note for the technical solutions applied as well as foreseen maintenance guidance.

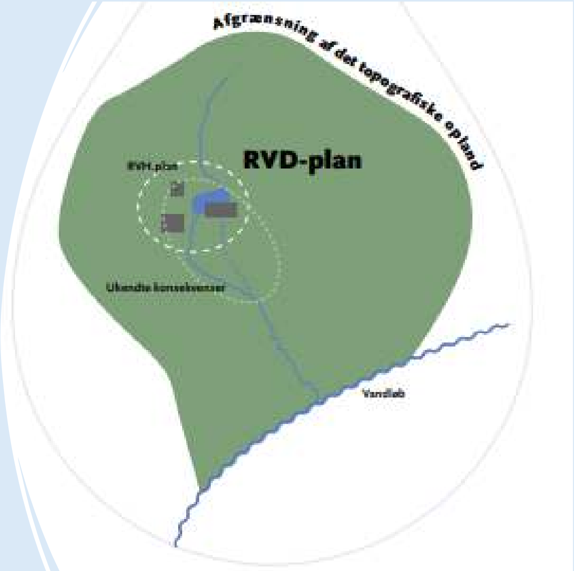


Figure 5 Aarhus plans and manages urban runoff according to 2-level model [7]

Both the two-level management plans as well as the modelling capacity allows to identify locations for NBS implementation and plan the adequate performance for the solutions under different conditions.

Tampere

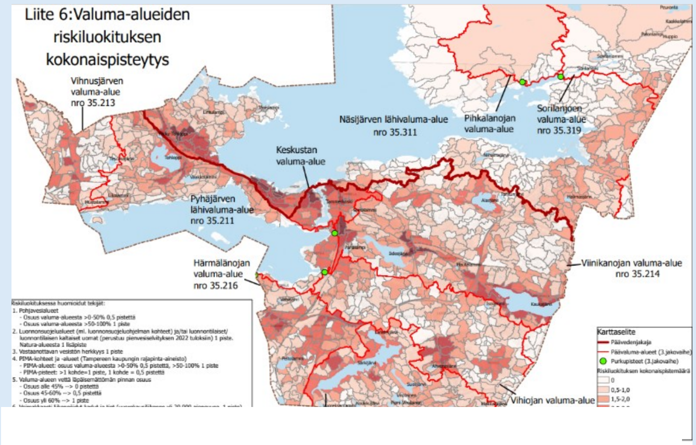


Figure 6 Flood risk of Tampere catchments

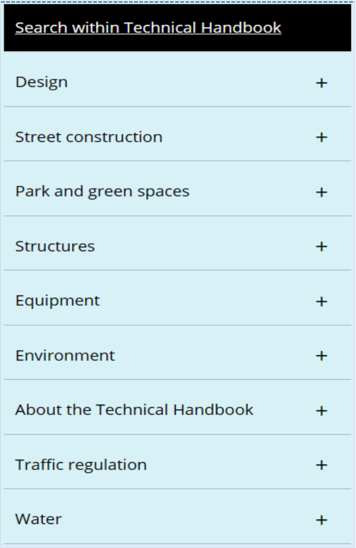
The Stormwater Programme of city of **Tampere** ([11] founds on a **comprehensive flood risk assessment** of urban catchments paired with a Sponge City analysis that has identified water management related challenges that could be responded with green-blue solutions.

Also, Tampere has developed a local classification system for stormwater interventions. According to this, NBS are considered as a priority option.

Malmö

The city of Malmö has set up an online planning support tool **Technical handbook of Malmö (**[10]**.** The technical handbook covers design and planning baselines for different facilities and infrastructures on public land in Malmö. The online format employs cross-referencing between key categories, allowing to integrate green-blue infrastructure guidance to areas like street construction and water management.

Significant sections in the handbook cover contact information to relevant city officials, planning and design requirements and templates, type drwaings as well as more general background information to provide context and justify the relevancy.



Search within Technical Handbook
Design +
Street construction +
Park and green spaces +
Structures +
Equipment +
Environment +
About the Technical Handbook +
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Figure 7 Sections in the Technical Handbook (autotranslated by Chrome)

The main gap cities have brought up in the planning and decision-making processes is the need to engage a broader range of stakeholders in the co-creation and planning of NBS. Planning of NBS for flood mitigation and water quality can be organized as a technical task, engaging only responsible officials and utility operators. However, such an approach does not realize the full potential of NBS, which can be achieved by co-creating with the possible end-users of the created blue-green solutions.

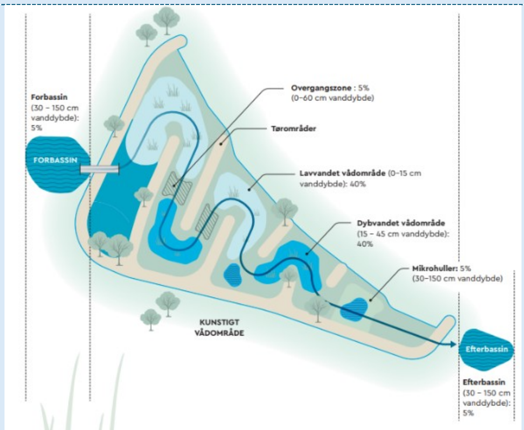
Planning and preparation stage is critical for later delivery of the multi-benefits of the NBS. More specific criteria are however needed to plan and design the solutions with additional amenities beyond hydraulic performance. Solution dependant considerations and criteria for the co-benefits could facilitate planning as well the later stages of implementation of the NBS.

NBS solutions are often preferred, although they are still relatively new and not universally favoured. Therefore, when **designing new NBS**, both the proof of concepts is available from their own pilots as well as knowledge from peer cities in cold-climate regions. Designing NBS involves considering various methods to control flow and to improve the water quality before the runoff reaches the receiving waterbodies. While proof of concepts and type drawings are available then the design stage tailors these to specific sites and integrates the interventions to the existing urban fabric.

Modelling is used to assess the performance of NBS in response to different urban challenges, particularly for larger areas. However, in-house modelling capacity is typically limited, and there is a need for more comprehensive modelling, particularly for small-scale interventions.

OPERATIONAL MODELS IN DESIGNING NBS TO LEARN FROM

Aarhus



Aarhus has developed several thematic design guidelines, among others:

- *Design guide for stormwater pools* [15]*;*
- *Stream restoration by nature-based solutions* [16]*;*

A comprehensive set of guidance is available as national guidance under the Water Sensitive Urban Design of Denmark (WUSD) [17]. WUSD offers approved methods, dimensioning baselines and generic type drawings. Based on this Aarhus has developed a local catalogue of solutions [18].

Figure 8 Aarhus design guide for nature-based stormwater detention systems

Malmö

The Technical Handbook of Malmö [10] includes a set of **type drawings** for a variety of NBS (available also Computer Aided Design (CAD/.dwg) formats.

As a significant resource the handbook clearly outlines the complex system of **roles and responsibilities** of different stakeholders and municipal authorities across the project cycle.

The **guidance provided in the technical handbook is integrated to the regulatory frameworks** and institutionalized processes of the city (Figure 9). The handbook interlinks to Swedish AMA guidance (standardized technical specifications for construction) and VGU (standardized technical specification for road and street construction).

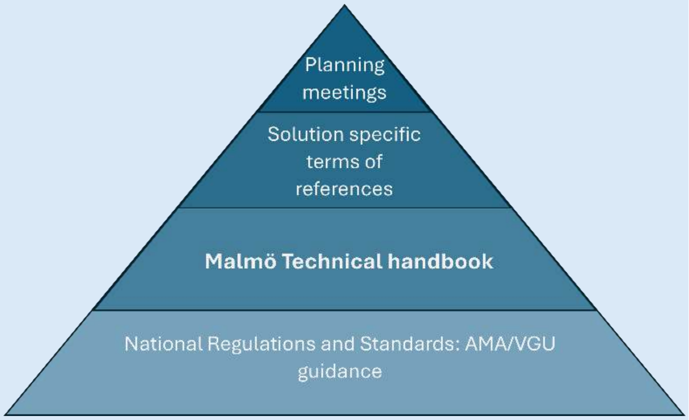


Figure 9 Hierarcy of decision making in planning and desgin

Tampere

Tampere is currently preparing a **Design guideline for nature-based solutions**. This guidance will include decision support for selecting an appropriate solution that consider different boundary conditions and characteristics of the site. The different aspects that are considered in decision making are a) Groundwater levels; b) Soil conditions; c) Space requirements; d) Stormwater quality outcomes and e) Catchment size.

In addition to this, the design guideline will include info-charts about the different archetypical NBS solutions. Guidelines covers the following topics: 1) Utilization of stormwater; 2) Infiltration; 3) Biofiltration; 4) Underground systems; 5) Storage systems; 6) Wetlands; 7) Swales/ditches.

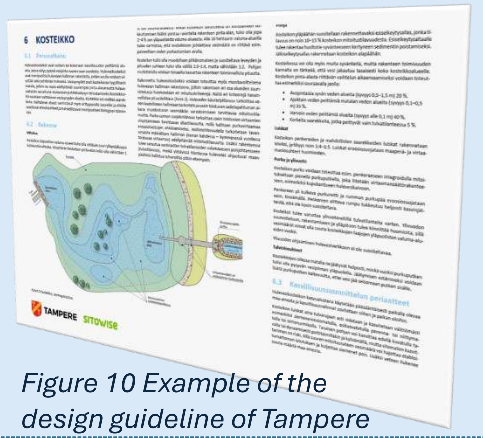
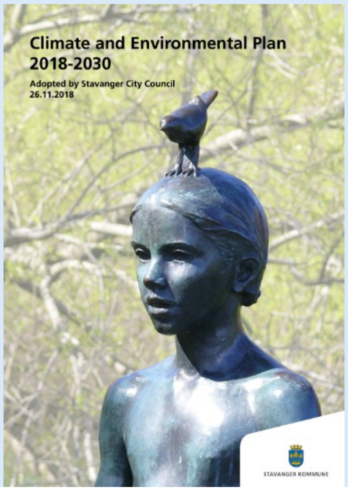


Figure 10 Example of the design guideline of Tampere

Stavannger



Climate and Environmental Plan
2018-2030
Adopted by Stavanger City Council
26.11.2018

STAVANGER KOMMUNE

Stavanger develops a guideline, namely **Climate and Environmental Plan 2018-2030**. This guideline offers a strategic plan to address climate change and improve the city's sustainability. The ambition is to make Stavanger a green, climate-friendly and climate-robust city. The plan aims to protect and conserve areas of natural importance and ensuring the viability of biodiversity in urban areas. The Climate and Environmental Plan for Stavanger also includes a set of strategies for stormwater management. Building blue-green infrastructure for stormwater management is also included in the plan. This strategic plan is the first legal document of Stavanger Municipality that introduced NBS as part of local climate and environmental plan.

In terms of gaps in design of solutions, cities emphasize using the systems in combinations to improve flood resilience across the catchment. Also, more attention needs to be given to monitoring the effects of the NBS and learning and feedback to improve the designs.

The design of NBS considers the maintenance capacity as much as possible; however, most cities admit having significant knowledge gaps and challenges in **ensuring the adequate maintenance of NBS**. Maintenance regimes vary between municipalities and utilities, with some relying on routine maintenance and others responding reactively to failure.

Stakeholder engagement occurs at various planning stages, although there are challenges in engaging residents effectively throughout the project cycle. Residents have become more aware of the ecosystem services provided by NBSs. Justification of the implementation of NBS is required to obtain approval from landowners or utilities, rather than wider communities. Cities aim to justify NBS to stakeholders through public hearings, community engagement, and media outreach.

<table>
<tr><th></th><th>MODELS OF ENGAGEMENT & COCREATION TO LEARN FROM</th></tr>
<tr><td>Aarhus</td><td>

H2020 funded REGREEN project set up Urban Living Labs (ULL) [19]. The ULL prepare innovation and business incubation of startups and SMEs related to NBS, it supports establishment of climate school involving tests of NBS solutions provided by local businesses. Different citizen projects are promoted under ULL.

REGREEN supported the establishment of an ULL advisory board for local politicians from across the political spectrum, civil servants from different administrative sectors and researchers.

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<tr><td>Malmö</td><td>

H2020 funded project CleverCities has supported Malmö in testing different methods in co-creating with communities in designing plans how NBS could solve **health related challenges and how to plan biodiverse and inviting spaces for all** [20]. A co-creation guidance document was developed within the frame of the project [21]. The guidance document includes a toolkit for the implementation of the co-creation process, including 16 steps envisioned in a **complete co-creation pathway to support cities to achieve successful implementation of nature-based solutions**.

The proposed co-creation pathway (Figure 11 Co-creation pathway developed within CleverCities projectFigure 11) includes fundamental co-creation tools, but also recommendations and more optional aspects of for citizen engagement.

H2020 funded project Naturvation helped to test a collaboration format of **Malmö Urban-Regional Innovation Partnership (URIP)** [22]. This collaboration brings together stakeholders from 7 public and private organizations to mainstream the use of nature-based solutions

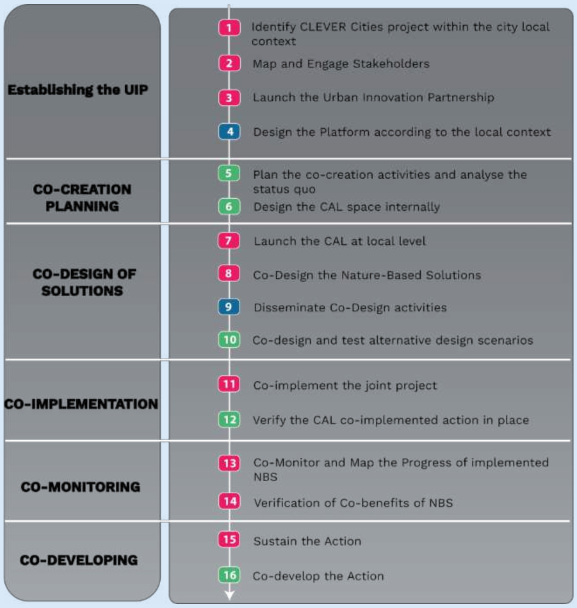

Figure 11 Co-creation pathway developed within CleverCities project

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<tr><td>Tampere</td><td>

With the help of **UNAlab project** [23] Tampere tested the model of granting **Innovation Vouchers** to community NBS projects. Two of the vouchers were used to develop garden areas near residential housing whilst the third voucher funded the creation of a horse park.

In the same project gamification was tested for **engaging local kids in co-creating** their local neighbourhood. The children's visions emphasised places where one can enjoy nature freely. Children of all ages wanted to have benches, campfire sites and other recreational facilities. Paths, bridges and other structures that promote camping and bicycling and pedestrian traffic were also mentioned. The children's designs combined green nature and water treatment elements with the everyday life of the neighbourhood.

Citizen science methods have been applied in public engagement as schoolchildren were involved to the monitoring of water quality in ditches and ponds. Students collected the water samples and identified the invertabrates inhabiting the waterbodies.

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Tartu	Tartu organized a **Climate Assembly (Kliimakogu)** in 2022 [24]. The purpose of the Tartu climate assembly was to involve city residents in discussions on how to make movement and stay in Tartu's street space safer and more attractive. 45 persons from Tartu, chosen by random sampling, participated in the Climate Assembly - a cross-section of Tartu residents, taking into account gender, age, place of residence, occupation and native language. The suggestions of the assembly have been processed by the city government and the actions taken are continuously communicated. Tartu is providing **small grants for private garden owners** to implement actions that support biodiversity [25].
Stavanger	 Stavanger is part of the **UNAlab project** [23]. UNaLab has produced a road map for a climate-adapted city in 2050. It also provided valuable input for the work on the climate change adaptation strategy for Stavanger. The city introduced two projects in UNaLab. First, the development of Mosvatnet park as the blue-green infrastructure that facilitate the multifunctional green spaces. The park provides the place for living organisms, thereby promoting biodiversity. It also functions for stormwater management for the surrounding area of Mosvatnet. Second, a thousand tree of Storhaug. The project has focused on planting and protecting trees in the Storhaug area as part of stormwater management and biodiversity protection. During the two projects, UNaLab used two approaches: co-creation and citizen science. The co-creation was carried out for both projects. The local residents were encouraged and asked to participate in the planning, development, and maintenance stage of Mosvatnet park and the one-thousand trees development. Local students were encouraged to use and monitor the parks and the trees.

The co-creation practices of cities are evolving. The traditional methods of informing residents about urban change are considered insufficient, however there are no established operational models in place for more participatory engagement of residents. Some novel methods however have been tested in the frame of pilot projects as elaborated below.

To conclude, knowledge gaps exist in planning and implementing NBS, particularly regarding the planning criteria and stakeholder engagement. Cities expect the Joint Operational Model of the City Blues project to address these gaps and facilitate collaboration between stakeholders.

Proof of concepts from previous NBS lighthouse projects among City Blues partners

City Blues partner cities have previously participated in several significant R&D projects focusing on NBS. Also, the cities have developed their local practices in establishment of NBS. The most significant lighthouse project that have developed the cities operational models for NBS-based management of urban catchments are listed below.

Aarhus	**Gellerupparken,** 2016, Aarhus Kommune [26] Aarhus has implemented many significant projects showcasing NBS in the city. One of the **landmark projects is a Gellerup park.** The park is designed to provide multiple benefits to the community offering a variety of functions – from playgrounds, a football field, and outdoor fitness, to fruit groves and greenhouses. In the same time the site is operating as a stormwater detention and treatment system. The result is a new form of 'social nature' that measurably has improved the safety, the climate resiliency, the biodiversity and the life quality of the area.  *Figure 12 Gellerup park [25]* Different **river restoration projects** implemented in Aarhus also serve as lighthouses for river basin management in urban and peri-urban settings. One of the landmark pilots was daylighting the Aarhus river in the historical city centre [27]. In addition the city has successfully implemented different deculverting projects as well as restoration of the ecological state of the river by re-meandering and naturalization of the river banks.
Malmö	**GreenClimeAdapt - Green Tools for Urban Climate Adaptation,** 2009-2013, LIFE [28] The GreenClimeAdapt project managed to demonstrate how cities can respond to climate change by adopting measures that helped the City of Malmö to adapt to climate change, making the city more resilient. Key climate challenges for the city concerned increased precipitation and heavy storms that enhance flood risks. The project thus **demonstrated how urban areas can adapt to climate change by implementing innovative green tools such as open storm water systems, green facades, and green roofs**. Project activities were carried out in Augustenborg, a city district with an eco-profile and in Skogholms ängar, an area near Riseberga Creek in the Fosie industrial area.
Tampere	**UNa-Lab Urban Nature Labs,** 2017-2022, H2020 [23], [29] Demonstration of different NBS solutions in Vuores district, where the project supported the development of an **integrated nature-based stormwater management system** with retention ponds, swales, wetlands, and streams. The nature-based water management system already starts from plots where, e.g. green roofs, rain gardens and rainwater harvesting, serve both for water management as well as for recreation. UNaLab URBAN NATURE LABS
Tartu	urban LIFE circles **urbanLIFEcircles,** 2022-2027, LIFE Nature [30] The aim of the urbanLIFEcircles project is to increase biodiversity in the city, create a network of interconnected green areas, mitigate the effects of climate change and create a good living environment for everyone. In the course of the project, best practices will be developed, which other cities can follow as an example in the future. Several demonstration sites are foreseen within the city, mostly concentrating on **improving the ecological quality of urban greenery.**

Stavanger	**UNa-Lab Urban Nature Labs,** 2017-2022, H2020 [23], [29]. Stavanger is the follower city for the UNaLab project. The projject is a demonstration of different NBS solutions in Mosvatnet park, where the project supported the development of an **integrated nature-based stormwater management system** with retention ponds, swales, wetlands, and streams. The nature-based water management system already starts from plots where, e.g. green roofs, rain gardens and rainwater harvesting, serve both for water management as well as for recreation. The other project is about planting and protecting urban trees in the Storhaug area. The project aims to improve stormwater management and biodiversity by planting trees.

City Blues project team assessed the planning, design and implementation of previous lighthouse projects considering the 9 potential benefits (explained in section

Benefits of NBS). The cities were asked to distinguish between primary and co-benefits. In total, 23 lighthouse projects were analysed, and the results are provided in the next figures.

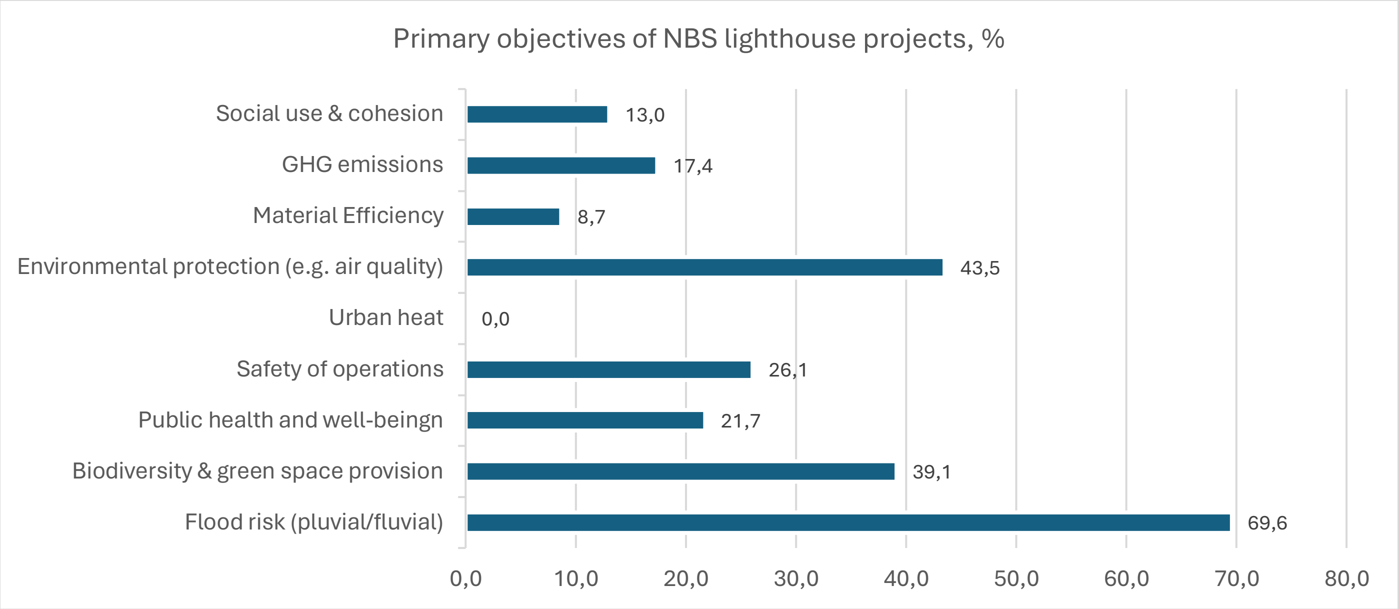


Figure 13 Primary objectives for designing NBS in the cities participating the City Blues project

The analysis revealed that the NBS are mainly designed for flood risk mitigation (69.6 % of cases) and improvement of water quality (43.5 % of cases) closely followed by increase of biodiversity. In case of secondary or co-benefits the distribution was as follows:

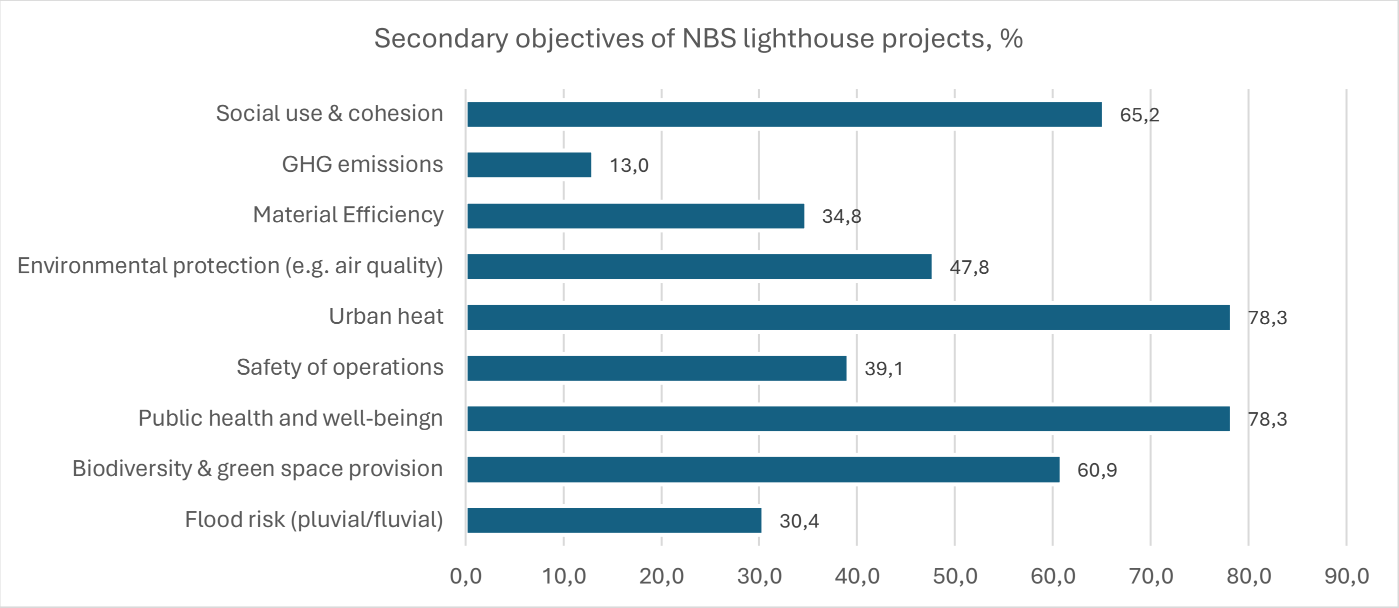


Figure 14 Secondary objectives for designing NBS in the cities participating the City Blues project

Main co-benefits for NBS are foreseen for urban heat reduction and improvement of public health and well-being followed by social use and cohesion and improvement of biodiversity. The analysis show that the primary objectives coincide with the objectives that can be quantified and have standardized design and assessment methods (e.g. calculating flood volumes and reduction potential or estimating improvements of water quality). The estimation of secondary objectives is often qualitative and lacks standardized methods that can be implemented straightforwardly to different NBS. Therefore, a state-of-the-art review was conducted to define the research gaps in planning, designing, operating and maintaining NBS for catchment scale urban water management considering specific climatic condition around the Baltic Sea region.

State of the art of NBS relevant for BSR

The advancement of NBS in the Baltic Sea region is centred on enhancing urban resilience and tackling environmental issues. Research indicates that the implementation of NBS has increased since the 2000s, particularly in Sweden and Denmark, where hybrid solutions like urban wetlands are widely used. Despite this progress, there is a scarcity of tools designed to facilitate the adoption of NBS in urban areas. Challenges in this regard include limited resources, a shortage of expertise, complex institutional arrangements, and difficulties in collaborative governance. To address these challenges, efforts are being made to develop and test new models of implementation and business approaches that can support the widespread adoption of NBS, particularly in urban settings. Although some cities in the region have more experience with NBS implementation than others, it is important to recognize that NBS are still an emerging concept in the Baltic Sea region. Despite policy-level support, broad implementation is impeded by a variety of barriers.

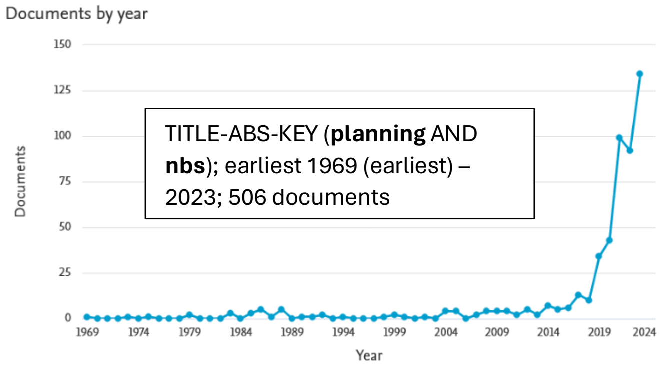
To overcome these barriers the Nordic Council of Ministries (NCM) led a project focusing on mapping the current practices of NBS in the Nordic countries [31]. The mapping included reviews of both academic and grey literature, establishing insights on the status of research on NBS in the Nordic countries and to describe the policy framework for NBS and practical implementation of NBS projects across the Nordic countries. A **catalogue of**

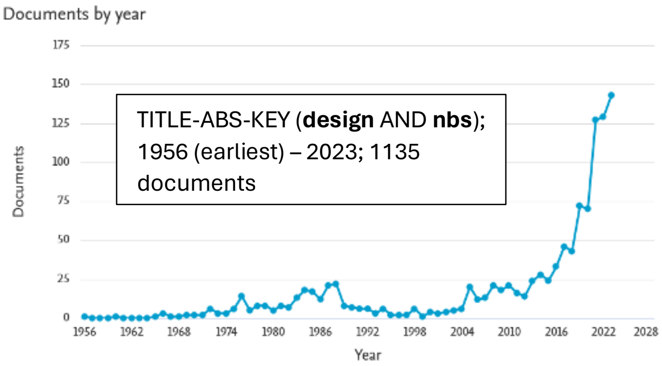
Nordic NBS case projects was established, which contains implemented case projects from each Nordic country, using NBS in all major ecosystems: terrestrial (forests and agricultural land), freshwater, coastal and marine, to show the breadth of NBS used in the Nordic countries.

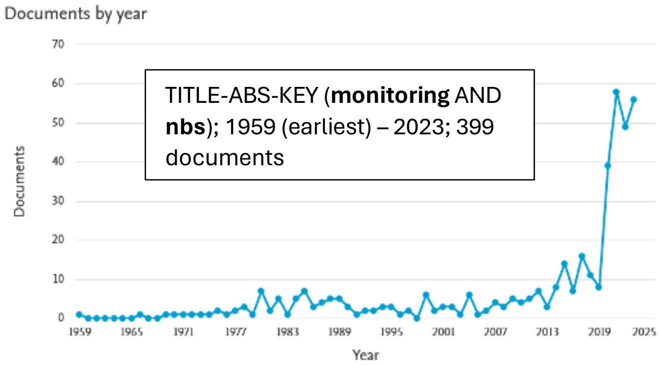
An ongoing **GuideNbs project** supported also by NCM will create an online handbook that is a practical toolbox for adopting nature-based solutions in the Nordic region [32]. The handbook must contain advice for the practical use of NBSs in six specific ecosystems: coastal areas, cultural landscapes, forests, mountains, cities and wetlands.

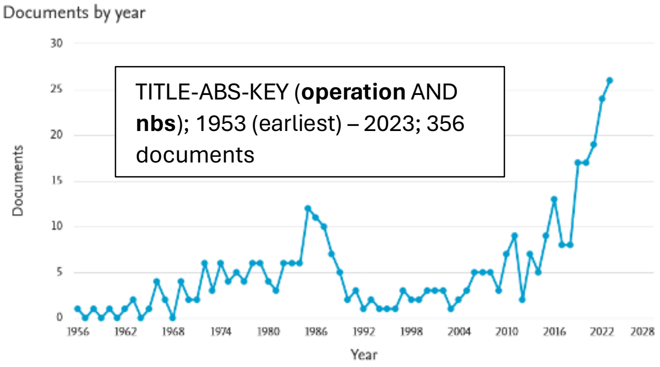
Literature review

A simplified publication database (Scopus) document search with word pairs searched from within the title, abstract and keywords demonstrates the expanding knowledge base regarding NBS. Systematic efforts are therefore needed to determine the relevant information for NBS-based climate change adaptation.









Planning and co-creation

There is a growing recognition of the importance of incorporating participatory approaches in the planning and implementation of NBS to achieve sustainable environmental outcomes. This section provides a state-of-the-art review of the crucial involvement of the community, the significance of tackling environmental injustices, the need for regional adjustment, and the diverse additional advantages that NBS provide, especially in urban areas.

a) What is the role of community engagement in the planning and implementation of NBS?

Community engagement is fundamental in ensuring the successful planning and implementation of NBS. Living Labs serve as a collaborative framework for the establishment of NBS, with a particular emphasis on the significance of community involvement throughout the stages of planning and execution. Lupp et al. (2020) demonstrated the efficacy of Living Labs in facilitating the co-creation of NBSs through the promotion of active engagement from community members [33]. The significance of this engagement lies in its ability to guarantee the contextual relevance and acceptance of NBS by their intended beneficiaries. [34] emphasize the importance of engaging stakeholders in the planning of NBS in areas that are susceptible to flooding. The authors emphasize the importance of participatory approaches to tailor solutions to the unique environmental and social circumstances of such regions.

b) How have participatory methods in NBS planning evolved from traditional approaches?

Participatory methods in NBS planning have evolved from simple implementation to active engagement in urban NBS projects. [35] have documented a notable transition from simple implementation to active engagement in urban NBS projects. This shift highlights the progression of participatory planning towards more cooperative and collective methods, signifying a break from the top-down decision-making process. [36] support this claim by examining the use of serious games in participatory planning, providing novel approaches to involve communities in the NBS planning process. These studies support the use of methods that promote inclusivity and active involvement, which are crucial for the successful implementation of NBS.

c) How does incorporating principles of environmental justice in NBS initiatives affect community equity?

Community participation in NBS planning is crucial for both effective implementation and equity. The integration of environmental justice principles into NBS initiatives is advocated by Herreros-Cantis and McPhearson (2021), who highlight the potential of participatory planning in addressing environmental injustices [37]. This approach guarantees that investments in NBS do not reinforce pre-existing inequalities but rather foster fair and equal environmental advantages across different communities.

d) What is the significance of regional adaptation in the effectiveness of NBS?

Regional adaptation is essential for the effectiveness of NBS in addressing specific environmental challenges. Various studies further underscore the importance of regional adaptation in the planning of NBS. The effectiveness of NBS in addressing multiple environmental issues, such as water conservation and climate change adaptation has been demonstrated by [38] and [39]. These studies emphasize the importance of employing region-specific approaches to effectively tackle the challenges. [40] emphasizes this claim, advocating for the implementation of NBS strategies that are specifically designed to address unique environmental objectives. Furthermore, [41] and [42] have examined the significance of green and blue infrastructure in addressing urban heat and improving air quality. Their research emphasizes several additional advantages that NBS provides, such as urban well-being and improved ecological resilience in colder climates.

e) Research gaps

It becomes evident that there is a broad consensus regarding the importance of participatory approaches in the planning and execution of NBS. [33] and [34] examine the process and advantages associated with community engagement in environmental planning. In contrast, [35] and [36] demonstrate the progress of participation methodologies, incorporating novel approaches such as serious games. [37] provide an important viewpoint to the ongoing debate on environmental justice by establishing a connection between participatory planning and principles of equity and fairness.

To ensure the successful and equitable implementation of NBS, it is vital that we gain a deeper understanding of their long-term implications and how best to tailor participatory approaches. Key research gaps include:

- Long-term impact: A lack of longitudinal studies makes it difficult to fully understand how effective NBS are over time, and whether they adapt well to changing conditions. More research is needed to track the long-term benefits and challenges of implemented NBS projects;
- Context-specific: There's limited research comparing different participatory tools and how well they work in different societies and cultures. More studies are needed to reveal which participation methods are successful given unique social and economic circumstances;
- Quantifying environmental impacts: While there's an emphasis on using NBS to improve environmental justice, methods for measuring the real impact on social equity are underdeveloped. Additional ways to track whether NBS lead to fairer distribution of environmental benefits are necessary;
- Adapting NBS to extreme climates: Most research focuses on typical environments, leaving a lack of guidance on how to best adapt NBS to extremely challenging settings such as arctic or colder regions. More research is needed to optimize NBS in these unique contexts.

Design

This section highlights the state-of-the-art in urban NBS design considerations with relevant interlinkages by defining three main research questions and potential gaps that need to be addressed in City Blue and other ongoing and future research projects.

a) How are NBS planning, design and operation variables interlinked?

Design of NBS needs to be considered bilaterally with technical siting to ensure the achievement of primary and co-benefits. Different analytical methodologies, e.g. [43], for prioritizing siting vegetated NBS for biological diversity, social and public health, and water quality benefits based on where benefits spatially converge or diverge have been proposed and piloted. The implementation of the approaches is often limited to data availability and optimization of multi-benefits as conflicts between the objectives may arise when attempting to use the NSB for multiple purposes [44].

Feedback loops and interlinkages between NBS life cycle stages imply that design cannot be considered as once achieved and concluded set of tasks. [45] argue that key challenges of NBS mainstreaming - design standards, regulatory pathways, socio-economic trends, finance ability, and innovation - need to be considered in an integrative manner, e.g. design standards must align with local policy context. Furthermore, while grey solutions can usually be implemented with relative certainty about the type and timescale of benefits, as NBSs evolve over their life cycle and offer more flexible long-term solutions, changes in the provision of ecosystem services over time, for example, under climate change and other stressors, need to be fully considered, taking into account that benefits might not be reaped when the costs are felt [46].

When designing and planning the operation of NBS considering primary and secondary intended benefits the desired design parameters should be set in concurrence. One key drawback in the today's practice of NBS implementation is that they are designed and constructed in the urban environment mainly as monofunctional solutions (e.g. for improving water quality or decreasing flood risk) with acknowledging the co-benefits as potential added value and not fully considering the interconnections [47], [48]. Urban NBS are integrated solutions and need to be based on a systems approach and further research is needed to assess the possibility of partially or fully preventing trade-offs between different functions and to develop schemes to prioritise between different benefits and solutions [49]. Future research is also needed to provide data on the multifunctional performance of NBS that can inform design standards as currently a standardized design process for hybrid infrastructures that aligns with the regulatory framework and includes a maintenance commitment is lacking [45].

Considering the research conducted on NBS a significant shifting of focus is needed in NBS' implementation. Within the ongoing rapid uptake of NBSs for water quality issues the current focus is on design, placement, construction, and further development of the solutions, while less attention is put on operation, maintenance and rehabilitation needs [50].

b) What are the main NBS design and construction considerations?

In terms of stormwater runoff retention (RR) there are several potential solutions that can be considered based on the local conditions. For example, the main design parameters for green roofs are vegetation types, geometrical properties (i.e., surface coverage area and slope) substrate properties (i.e., type, depth, porosity, density), and drainage layer properties (i.e., type and depth), with important contingent effects indicating that optimal design depends on local climate characteristics (i.e., climatic region, rainfall intensities, antecedent dry days, season) [51]. [51] have found a non-linear negative correlation between RR and rainfall intensity, a linear positive correlation between RR and substrate depth, and an inverse U-shape correlation between RR and green roof surface coverage area. In addition, based on an analysis of referenced 2375 experimental samples they found a RR rate of 62%, while a best practice guideline for green buildings ("Assessment Standard for Green Building GB/ T50378–2019'', China) requires at least 70% of RR rate. [52] found that configurations of green roofs with a combination of flat roof or lowered slope with deeper media and vegetation enhanced RR.

Bioretention systems' design parameters, such as media composition, plant species diversity, and internal saturation zones together with operational parameters (e.g., rainfall intensity) and environmental conditions (temperature) produce high variability in pollutant removal efficiency [52]. Constructed wetlands may be designed as free-floating, submerged and rooted plant-based systems, with surface and subsurface (vertical and horizontal) flows and [52] have overall found that the pollutant removal efficiency of a hybrid system appears to be higher than that of a single-approach system.

Consideration of local climatic conditions and event return periods will determine the as-designed continuity of operations. NBS can significantly reduce hazards associated with small floods in small catchments, but evidence is lacking in terms of major effects on more extreme events [46]. There is growing evidence NBS are more cost-effective than engineered alternatives for less extreme hazard scenarios [53], e.g. coastal defence projects aimed at median wave heights [54], and natural flood management approaches at small floods in small catchments [46], [55]. Furthermore, excessively high values of hydraulic loading rates reduce the removal of contaminants, particularly those more prone to leaching, by NBS, such as constructed wetlands, green walls and green roofs [56].

The local climatic conditions must be considered more thoroughly while planning and implementing NBS as the widely applicable guidelines show large variability in NBS performance across different climatic conditions [57]. Cold climate regions where repeating cycles of frozen ground, snow cover, rain on snow and snowmelt are experienced need supplemental design considerations that address urban winter hydrology [58]. [59] studied the infiltration capacity of NBSs under frequent freeze-thaw cycles and concluded that the soils tend to be more saturated in cold maritime climates than in continental areas, and thus, well-drained and vegetated soils are preferred to avoid media freezing and regular maintenance is required to sustain the functionality. [60] concluded that a combination of inlet-based ion-exchange units, geotextile-based sediment traps and adsorbent amended filters would make robust and flexible engineered NBS for stormwater treatment for high annual average high traffic sites in cold climates. De-icing salts, in addition to freeze-thaw cycles, affect the performance of NBSs in cold climates. [61] for instance studied how salt-enriched stormwater can affect bacterial communities in cold climates and how the presence of soil bacteria improves pollutant removal by green infrastructure.

c) What are key design considerations to control the NBS performance?

Smartening elements, such as (near)real-time control or monitoring assets can alter the performance of NBS. [62] divided the NBS classification into no-tech, low-tech and high-tech green, to highlight that these systems are not interchangeable when a specific level of ecosystem service performance is required. They outlined the evolution of vegetation supporting systems from “volumes of soil and lots of space” (no-tech) to systems that passively detain rainwater for later infiltration or evaporation (low-tech), in turn to sensor-managed and data pre-emptive control driven high-tech NBS and foresee that the debate on whether or not to implement NBS will shift further into what specific NBS to implement, thereby ensuring that the solutions’ potential will be used optimally.

[63] evaluated the challenges and opportunities of applying real-time control (RTC) on NBS by reviewing published experimental and modelling studies. They focused on solutions of different spatial scales (green roof, bioretention and detention basin) and found that RTC improves the performance of bioretention cells in terms of water quality and detention basins in terms of quality and quantity control. Regarding green roofs, studies on RTC of UDS combined with passive green roofs reported peak flow and runoff volume reduction [64]. Meanwhile, [65] reported that while RTC has the potential for improved operation during average flooding events, for extreme scenarios it cannot significantly alleviate risks.

Operation efficiency of NBS is also determined by integration with existing infrastructure. Implementation of NBSs is often seen as a one-to-one replacement of existing piped systems rather than realizing the whole array of available potential and functionality that NBS could serve. According to [46] we should move beyond pitching green solutions against grey and focus on finding synergies. While a rich body of literature identifies and conceptualizes interconnections among different urban infrastructure systems, only a limited fraction of the available studies develops coupled approaches for simulation and assessment, with even connections between assets in the same domain, such as water supply and drainage, considered to a limited extent [66].

Furthermore, there is a lack of studies about the interconnections of existing systems and network of NBS. Multifaceted and integrated solutions combining digital technologies, NBS and decentralisation need further investigation because strategies to achieving urban water infrastructure resilience goals, i.e., system upgrade, decentralisation, digitalisation and nature-based solutions’ implementation are mostly investigated separately but are not sufficient to achieve these goals on their own [67].

d) Research gaps

- A scheme to prioritise between different NBS benefits and limit trade-offs in the planning and design phase is needed.
- A standardized design process for hybrid infrastructures that aligns with the regulatory framework and includes a maintenance commitment is lacking.

- Data (cross-city and -scale comparison) on the multifunctional performance of NBS to inform design standards in lacking.
- Contingent effects of (climate, hydraulics and design) variables affecting NBS performance point to the need to study the correlations to be able to predict the performance in the design phase.
- Further efforts (in design, control, and interlinking) are needed if NBS are intended to mitigate risks and function in weather extremes.

Performance and monitoring

This literature review provides a general overview on NBS measures in terms of their performance, failure mode, needed data and monitoring. The overview is oriented towards quantitative water management.

a) What is the functionality and performance of NBS regarding stormwater retention?

NBS can be planned for many different reasons and therefore can have many different objectives, ranging from flood risk reduction to biodiversity & green space provision to public health and well-being to urban heat island reduction to GHG emission reduction to simply provide recreation areas [68]. This section focuses on NBS regarding quantitative water management, therefore the functionality of NBS can be described as the infiltration, evaporation, and retention of stormwater. The shares of infiltration, evaporation and retention vary in between the different NBS. The functionality of an infiltration swale lays more on the infiltration part, whereas artificial water bodies focus more on the retention part. Depending on the planned functionality different performance criteria's can be used to evaluate the functionality, i.e. performance indicators/parameters [69].

Kumar et al. divide performance indicators for NBS into three main categories; 1) biophysical indicators; 2) socio-economic indicators and 3) sustainability indicators [70]. In the following the focus lays on the biophysical performance indicators regarding stormwater retention. For stormwater retention the main indicators to assess the performance was defined by European Commission guidelines as flood peak height, time of flood peak, runoff in relation to precipitation quantity, infiltration capacity and evapotranspiration [71]. Especially the runoff retention (%) and the peak runoff retention (%) is used to evaluate the performance, i.e. of green roofs [51], bioretention cells [72] and constructed wetlands [73]. Besides these performance indicators, the infiltration rate (mm/h) is a common parameter to evaluate NBS performance, such as biofilters [74] and rain gardens [75]. Nevertheless, [76] states that numerical parameters often are difficult to compare reliably, since NBS often differ in their structure, i.e. layer thickness, size or external factors such as climate and therefore must be used carefully.

b) What are typical failure modes (i.e. damages, dysfunctions) affecting the functionality/ performance of NBS?

Failure modes, damages or dysfunctions can directly affect the functionality of the NBS, which is then ultimately reflected in the performance of the NBS. However, a distinction must be made between indicators, such as standing water on permeable pavement and the actual failure mode, such as clogging of the permeable pavement. In general, failure modes can occur at all points during the lifespan of an NBS.

First failure modes can be caused in the planning and construction phase, by wrongly sizing the NBS or single parts, i.e. outlets of the NBS, as well as the selection of inadequate vegetation [77] [78]. During operation there are various recurring failure modes that affect the performance of NBS. Clogging is one of the common ones, it can occur either to outlet structures, i.e. of stormwater wetlands [79] or more commonly to surfaces of different infiltration measures, such as biofilters [74] or infiltration trenches [80] [81].

The performance of NBS can also be affected through damages that are related to the vegetation of NBS, i.e. vegetation death on green roofs, which is caused due to diseases or excessive human stamping [82]. Tiwary et al. concluded that fully foliated and twiggy green facades show large differences in their performances [83] supported by Funke and Kleidorfer who have outlined a wide variety of further failure modes of NBS, such as erosion, pump failure or debris build-up [84].

c) Which factors influence functionality and performance of NBS?

The failure modes described previously have an effect on the performance of an NBS. Besides that, there are other factors that influence the performance, but do not necessarily have to be a failure mode or dysfunction.

A distinction can be made between external and internal factors that affect the hydrological performance of an NBS. External factors, i.e. climate change and conditions, such as temperature scaling or evapotranspiration change the performance of NBS similarly to rain characteristic, such as depth, frequency, intensity and duration [85]. Of course, the lack of adequate maintenance of NBS is an important external factor that influences the performance of NBS [73].

Internal factors that directly affect NBS are design parameters, i.e. the depth of layers/substrate and vegetation type. Also, NBS geometries, slopes and ages of NBS affect the performances. Another impact on the performance has the Initial Moisture Content (IMC)[86] [85].

d) How to quantify the impact of failure modes on the performance (consequences of damages)?

The impact of these failure modes on NBS performance must be quantified in order to assess their severity. Two main approaches outlined are: 1) modelling the impact of failure modes and 2) measuring the impact of failure modes on the performance of NBS.

Funke and Kleidorfer used the software Stormwater Management Model (SWMM) to investigate different failure modes (erosion, clogging, pump failure, debris build-up) of NBS on their hydrological performance over a period of 60 years [84]. In this work the failure modes were modelled by changed parameters, which were obtained from other research work. For example, swale sedimentation in a bioretention system was represented by reduced berm height and soil conductivity. Results showed that failures and malfunction can have a significant impact on the performance. Siriwardene et al. investigated the clogging behaviour of infiltration systems in a laboratory study, setting up a simple regression model for the prediction of clogging due to stormwater sediments [87].

A mixed approach was conducted by [81], based on the findings of a three-year monitoring campaign, were clogging of infiltration trenches was monitored. A clogging model was fitted and prediction for future performance were made. Nevertheless, modelling of failure modes affecting the hydrological performance is rare, as Funke and Kleidorfer state, a more common approach is the direct monitoring of failure modes [84].

Stormwater infiltration or volume retention measurements are widely used for direct performance measurement of NBS. Le Coustumer et al. investigated the performance of biofilter systems for stormwater management, deep ring infiltration tests were carried out, to assess the infiltration rate (mm/h) [74]. Al-Rubaei et al. [88] used double ring infiltrometers to assess the performance of different infiltrations measures, such as vegetated concrete grid pavers and grassed swales.

The measurement of stormwater volume reduction and peak flow detention/reduction of NBS is performed using depth, velocity and flowmeters. Several different research projects have assessed the performance of green roofs, by relating precipitation (measured by rain gauges) and the outflow of green roofs (measured by flow meters) [51] [89] [90] [91], [92]. The same measuring principle was applied for bioretention cells by [72] and [93]. Nevertheless, the downside of direct measuring of performance parameters are high costs.

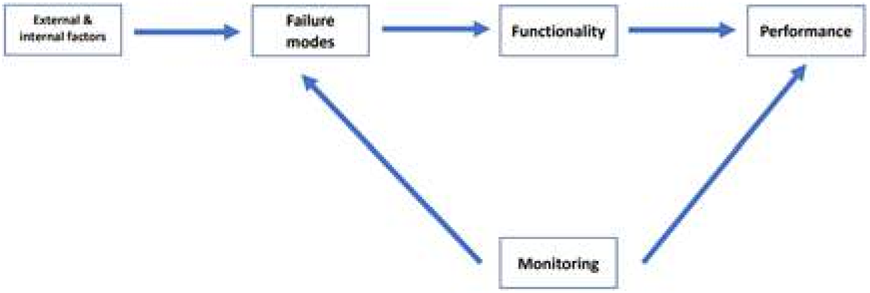


Figure 15 Connection failure modes -> performance

A distinction must be made here, as to what information is used to draw conclusion about the status of the NBS. The easiest way to assess the performance is to use direct performance parameters for evaluation, for example the infiltration rate (mm/h) or the stormwater retention rate (%). However, it is not always possible to measure the performance this explicitly. One reason is the spatial delimitation of NBS, which is often precisely defined for green roofs, but not for many other NBS, such as multifunctional retention areas or large infiltration systems.

In order to evaluate their performance and in general draw conclusions with less effort, assessments of performance can be based on other indicators, such as failure modes (Figure 15). Simpler methods can be used here, such as visual assessment, i.e. the condition of the vegetation or blocked outlets are assessed. With todays technologies, these indicator surveys can be carried out on a larger scale and no longer by humans itself, e.g. using drones, remote sensing or cameras.

A short overview on monitoring methods is given in the following section.

e) Which monitoring approaches can be used?

Different monitoring approaches can be used to obtain first knowledge about the status or performance of an NBS. These can range from very simple methods to novel applications that are just being developed further:

- **Surveys and manual assessment** are simple methods of obtaining information on NBS, including the following: An evaluation form to assess the condition of a variety of NBS was introduced by [77]. The form includes: assessment of lack of maintenance; by-passing of inlets and/or outlets; incorrect flow path; short circuiting of treatment mechanism; erosion, clogged media or underdrains; inappropriate media/material/soil; poor vegetation quality; failing structural components and safety issues. Similar approaches were used by [82] and [94], where the main assessment categories were weather conditions and building/roof data; constructive system, anomalies and causes and maintenance actions. The advantage of the simple visual assessments is that they are inexpensive and can be carried out without technology, but the results do not provide exact quantitative information about the performance of NBS. Another possibility to gather data on NBS, is using citizen science. Pudifoot et al. gathered information with the help of citizen scientist that estimated soil colour, compaction, texture, moisture content and infiltration rates [95]. It was shown that citizens can take actions to improve local green space and support local flood resilience.

- **Ground measurement** is another category to collect data on NBS, which include many different possibilities and sensor types, such as flow meters, water level sensors or cameras. As previously stated, flow meters in combination with rain gauges are commonly used to determine the stormwater volume reduction and peak flow retention, e.g. [51] and [89] applied for green roofs or [72] and [93] for bioretention cells. Infiltration measures with infiltrometers were carried out by [96] and [88] to determine the infiltration capacity. Besides that, pressure transducers in combination with calibrated underwater camera images and time lapse photography can be used to determine the infiltration capacity, as presented for rain gardens [97] and swales [98].
- **Remote sensing (RS) and Earth observations (EO)** are approaches of gathering data from distance, by sensors that are not in physical contact with the object of investigation (RS) and the target of investigation being the earth, therefore EO [71]. Remote sensing data sources are increasing rapidly, as public space agencies satellites i.e. European Sentinel and Landsat are providing large datasets which could be applied to monitor performance of NBS. Water level can be indirectly measured based on remote sensing images of flood extent, combined with digital elevation models [70]. Nevertheless, it is important to mention, that currently, RS by satellites have constrains (large frames) and therefore should be complemented by ground measurements. A possibility to overcome this, are drones, which can gather more detailed information. Here, especially in dense environment, no flight zones and rather expensive equipment are currently limiting their use [71].

f) Research gaps

- As Dabas and Molleti [85] stated, currently there is no specific widely recognized standard or code to determining the hydrological performance of green roofs as a whole system. This could be extended to different NBS.
- The knowledge on green roof (GR) performance is quite good, due to relatively easy monitoring of them, however, other NBS which are not as spatially defined as GR are lacking on monitoring and knowledge on the performance due to failure modes.
- Furthermore, long term monitoring of NBS integrated in municipalities is lacking! No laboratory monitoring!
- Understand how water utilities and municipalities take care of maintenance of NBS. There is a large variety of different NBS maintenance guidance's, but are they, due to resource (financial & time) fulfilled? There is a need for a survey in the BSR region with water utilities & municipalities.
- How can existing monitoring strategies be optimized? Can simple data-driven models be created that give maintenance prediction based on open accessible data, e.g. based on climate, traffic, design & construction data.
- Expand, optimize and systematically use remote sensing and drones as data sources.

Baseline scenarios for the city level pilots

Summary of the exercise

Baseline scenarios for city level pilots in City Blues projects are aimed to serve as elaborated descriptions of targeted challenges and project objectives, which are aimed to facilitate further implementation of the project activities and align the site-based initiatives with development of the operational models.

To prepare the scenarios, cities were introduced to the concept of scenario thinking during a short workshop. In addition, a scenario template was prepared and presented to the cities. Different approaches were applied to develop the scenarios, in some cases cities used the scenario methodology during co-creation workshop to discuss the site level challenges with the stakeholders. In other cases, the scenarios assisted cities in preparing for the stakeholder engagement workshops.

Baseline scenarios for the pilots

Aarhus

Introduction to the pilot site

Aarhus is Denmark's second largest city with approx. 361 544 inhabitants. The Aarhus pilot will focus on two streams within the boundaries of a planned city development on the outskirts of Aarhus: Ravnbakke Stream and Bueris stream. The city Nye is planned for development over the coming 20-30 years with an expected population of 15.000-20.000 citizens. Ravnbakke stream is a 1.2 km long stream on the eastern edge of the development, whereas the approximately 2.5 km long Bueris stream runs through the more central part of the development in an area currently used for agriculture. Both streams were channelised, partly piped and deepened in the late 19th-century to gain agriculture land. Both streams run out in the Egå Engsø – a manmade lake on the river Egå that is approximately 1.1 km from Aarhus Bay. The topographical catchment of Ravnbakke stream is 1.5 km^2 and Bueris stream have topographical catchment of 1.6 km^2.

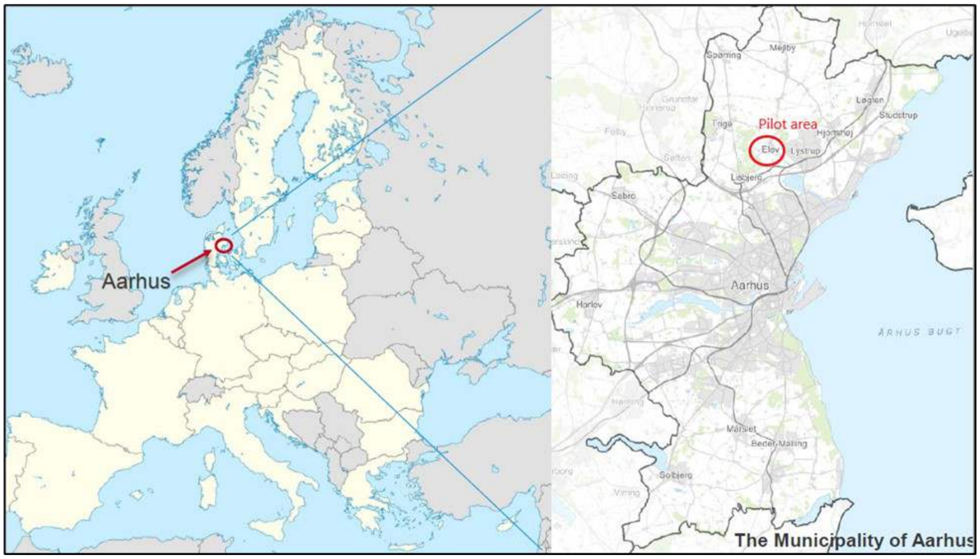


Figure 16 Location of the project site

A minor part of the eastern catchment is owned by Aarhus Municipality whereas the rest is privately owned by the developer. It will be a future residential area in the city. Nature, biodiversity, and water are drivers for urban development and the community at the heart of the resilient district (project area). The nature-based development is a result of the strong collaboration and a common vision.

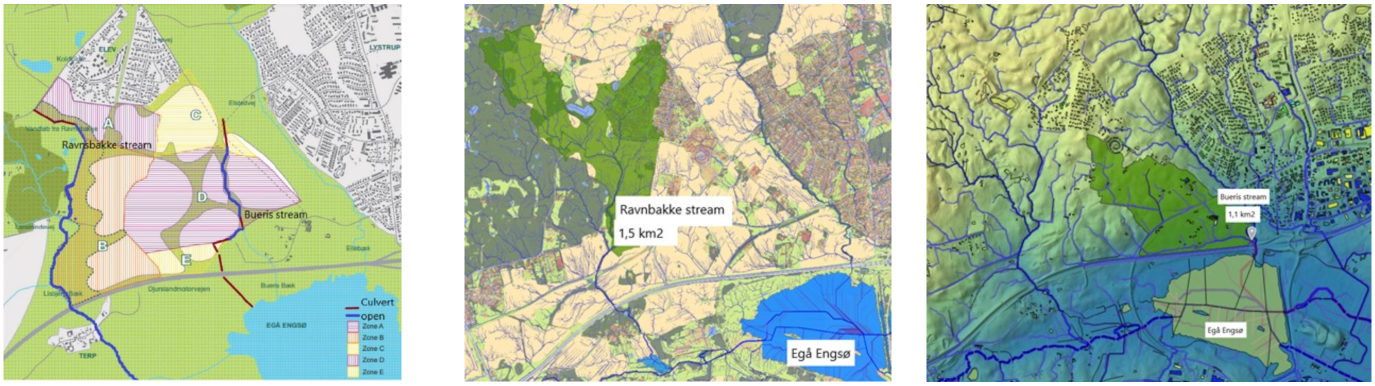


Figure 17 Overview of streams in pilot area, NYE (left). Topographical catchment of Ravnbakke stream (1,5 km^2) (centre) and Bueris Stream (1,1 km2) (right).

The characteristic discharges for the streams in the Egå system have been calculated based on the period 1976 – 2019 on basis of the flow sensor station in Egå Stream (MST no. 23.01, site no. 230091). Based on the time series analyses and catchment weighting of daily mean flow data from this measuring QQ-station, the following catchment characteristic runoff values have been determined for both streams with similar characteristics (Table)

Table 1 Characteristic runoff values of the pilot streams

Characteristic runoff	Flow (l/s/km^2)
Summer median minimum	0.7
Annual average	9.1
Winter median maximum	55

Challenges

The Ravnbakke- and Bueris stream are both small waterbodies which are partly running in culverts and modified due to agricultural activities in previous landscape.

Ravnsbakke Stream

The small stream Ravnsbakke is a protected stream in accordance with the EU Water Framework directive, that is highly susceptible to changes in its hydrology, existing pressures from agriculture and physical limits of the stream. The downstream stretches of Ravnsbakke, and its subsequent parent stream Lisbjerg stream are biologically rich and species diverse, with several red listed and rare invertebrates present. The susceptibility of the stream encompasses risk of fluvial flooding, erosion of stream banks, capacity limitation, pollution from stormwater runoff and agricultural discharge. Additionally, drought and water scarcity may pose additional problems.

Bueris Stream

The stream is highly modified, through culverts and channelization for large stretches of the stream. The stream is not recognized as a waterbody within the EU water framework directive. The biological diversity of the stream is generally poor due to the physical constraints and hydrological flow patterns, e.g. the riparian zone of the stream consists dominantly of agriculture and the stream is highly channelized leaving little space and possibility for the immigration and reestablishment of more biologically diverse and rich habitats.

City development and increased urbanization with the catchments of the two streams, without diligent care for the stream may increase these pressures, along with a changing climate and therefore risk additional pressures upon the stream habitats.

1. Physical constraints: Both streams are currently physically constrained with their boundaries, through channelization, culverting and deepening of their water course with a highly reduced habitat diversity as a consequence.
2. Flooding and erosion: Due to the physical constraints of the streams, they are both susceptible to floodings from stormwater runoff of both the existing and developing city. Frequent flooding and capacity breaking events leads to destabilized banks, increased sedimentation, loss of habitats and degrades the water quality of both streams.
3. Riparian zones & land use: Current land use within the catchments of both streams is either impacted by agrilculture or urbanization, leaving no space for riparian zones of the streams.
4. Drought: Because of both streams' limited sizes, the physical regulations of the catchment, increasing urbanization and climate change they are both vulnerable to drought.

Possible and planned solutions

To counteract the effects born from the current physical limitations and developing city, a plethora of actions and plans are instigated.

1. Wastewater planning – Masterplans of rainwater management: To counteract many of the imposing effects of increasing urbanisation within the catchments of the two small streams, masterplans dispositioning stormwater ponds, stormwater flow paths, purification methods, etc. from the environmental screenings of, among others, the streams are carried out in a watershed approach. These steps counteract the usual effects of urbanisation in; increased runoff, increased temperature and decreased oxygen levels of the recipient. To mention some of the actions, the construction of ponds functioning through infiltration, where sorption and purification processes are performed through the soil matrix, which additionally allows a decreased water temperature of the discharged water.
2. Stream restoration: Both streams have elaborate plans of reverting the negative physical changes from previous decades. The first steps of the restoration are aimed towards removing the culverts and deepened courses of the streams, these actions, in cohesion with remeandering and revegetating the riparian zones are the main aims of stream restoration. The process of designing and implementing the stream restorations are carried out in close cooperation with stakeholders of the catchments. Among others the developers but furthermore also Municipal departments regarding sports facilities in the area.
3. Reactivation of river valley hydrology: To further increase the effects of stream restoration actions, it is attempted to reactivate the floodplains toward their natural hydrology, in creating ponds and retention areas along the course, removal of existing drains and generally increasing the robustness of the river valley.
4. Combined efforts: The watershed-approach on both wastewater and stream restoration will allow the city to work in cohesion with the stakeholders to achieve common goals. Whereas these goals often are not shared between authorities and private stakeholders, the combination of wishes regarding the city development and environmental regards, allow for a greater cooperation between the involved parties. These interactions additionally allow for a greater focus of the developing city upon recreative possibilities and access to the river valleys of the area.

Baseline scenario development for projects starting from DESIGN stage

Baseline scenario 1: Pilot site is designed to be performing under drought conditions with high biodiversity.

What are the consequences of long retention periods upon the NBS? Long detention periods may adversely affect the other capacities of the NBS solutions aimed at purifying water before discharge. Stagnant water may have high temperatures and low concentrations of oxygen.

What are the consequences of drought adaptation within the catchments? Drought adaptation may result in large volumes being retained continuously within the catchment, and the flood capacity of the catchment may be greatly reduced. **How can these adaptations increase biodiversity?**

To increase biodiversity while maintaining drought tolerance of the catchment will require more wet areas where water is retained until it infiltrates to the streams. These retention areas can be used to increase spawning grounds and lake habitats in close connection with streams.

What are the potential consequences hereof? The increased retention to increase drought tolerance, may reduce the possible access possibilities within the water valley of the streams. Thus decreasing the overall experience of the expected citizens within the area. Extraction for secondary water usage, eg. Toilet flush, may be highly limited from the design towards a drought tolerant system.

What will the implementation of the solution demand from the community: residents, landowners, utilities? Drought-tolerant solutions are innovative and may require increased area disposition requirements and increased maintenance in both ponds, swales and stream design to allow for continuous water supply to streams.

ALTERNATIVE DESIGN AXIS: HIGH biodiversity

Baseline scenario 2: Pilot site is designed to be performing under flood conditions aiming maintain high biodiversity.

What are the consequences of large flood retentions upon the NBS? NBS solutions designed towards flood and high biodiversity may pose large requirements of the NBS solutions, in ponds, sandtraps and larger slopes to detain the flooding. Alternatively they are required to be very large or allow for a higher continuous discharge.

What are the consequences of flood adaptation within the catchments? High performing catchments in regards to flood control can incur reduced possibility coping through droughts as the catchments need to empty between events of flooding and therefore have a reduced capacity to maintain flow of the stream.

How can these adaptations increase biodiversity? Flood adaptations may potentiate biodiversity through the large area dispositions they require. The floodprone areas may not be used beyond attributing to blue-green connections and the green experience of the area.

What are the potential consequences hereof? Flood resilient cities require increasing areas to maintain their capabilities when accounting for climate change. These requirements may affect the disposition of development and herein the possibility of achieving a more resilient city. If the flood prone areas are used for the citizens of the area, there may also arise conflicts when floods occur and the connections are broken/unavailable. Extraction for secondary water usage is not limited from flood protection.

What will the implementation of the solution demand from the community: residents, landowners, utilities? Flood tolerance towards the large rain events expected may, similarly to drought, require large area dispositions and possibly more focus on reestablishment of flood prevention measures.

Drought STRONG AXIS: METEO-HYDROLOGICAL PERFORMANCE **Flood**

Baseline scenario 3: Pilot site is designed to be performing under drought conditions being also pleasing and safe for single visitors.

What are the consequences of long retention periods upon the NBS? In the condition, that they are also pleasing and safe for visitors drought tolerant NBS solutions may need to be designed more similar to lakes retaining the water, whereas the natural construction would be more similar to a wetland/floodplain structure.

What are the consequences of drought adaptation within the catchments + pleasing conditions? These constructions may require more terrain regulation to ensure safe passage through raised pathways and bridge like passageways.

How can these adaptations be pleasing and safe? Passageways and pond/lake constructions require intensive manipulations of the terrain, while they function as permanent connections for citizens and stakeholders throughout a catchment designed to be pleasing.

What are the potential consequences hereof? The generally increase terrain regulation and focus on aesthetics will highly reduced the possibilities of obtained very rich biodiverse areas.

What will the implementation of the solution demand from the community: residents, landowners, utilities? It must be expected that the drought tolerant and accessible solutions incur greater costs to, whereas their possible areal requirements may be reduced in comparison with a biodiverse focused project as the terrain regulation are increased.

Lower biodiversity

Baseline scenario 4: Pilot site is designed to be performing under flood conditions being also pleasing and safe for single visitors.

What are the consequences of large flood retentions upon the NBS?

What are the consequences of flood adaptation within the catchments?

How can these adaptations increase biodiversity?

What are the potential consequences hereof?

What will the implementation of the solution demand from the community: residents, landowners, utilities?

Stakeholder workshops

The city development and different stakeholders of the pilot site are previously engaged in cooperation and coordination of projects, both in relation to municipal and local planning, infrastructure, and wastewater planning. Meetings will therefore progress continuously throughout the project period.

To divide meetings from workshops of the current project, several separate workshops have been carried out and planned.

1. Municipal magistrates of Culture & Citizens service, Children & Young and Technical services took part in an internal workshop focussing on the ongoing development of a school on the edge of Ravnbakke stream floodplain, where both school and 4 separate football fields are being planned.

   Magistrate of children & Young, School department, responsible for the building of the school were engaged to talk about the stormwater management and direction of this. They are required to manage a 100-year return event from the school area, without it damaging building mass or the environment.

   Magistrate of culture and citizens service, department of Sport were engaged in relation to management of tile drainage of the football fields. Traditional tile drainage of football fields is very intensive and may result in high discharged volumes. They were engaged to reduce this influence on Ravnsbakke Stream.

   In coordination between the three departments several areas for stormwater management, tile drainage retention and flow paths were localized. In addition football fields could be placed, so the stream restoration of Ravnbakke could successfully be carried out, with a minimum of 10 m distance to the brink of the stream. On one occasion, one field could not meet general requirement from the sports department if it was not allowed a steeper slope towards the stream.

   The discussions led to a coordinated plan, where retention basins' for tile drainage were placed at the end of stormwater flow paths, and both flood and drought risks of the stream were significantly reduced. Additionally, the joined discussions and shared visions for the area led to better possibilities for the stream restoration, in which more areas within the flood plain can be used for meandering, revegetation of the riparian zones and possible mimics of oxbow lakes.

2. Techical department and utility company.

3. Workshop with external developer for both Ravnbakke Stream and Bueris Stream has been postponed on basis of developers wishes. It is planned for 24th of April.

Malmö

Introduction of the pilot site

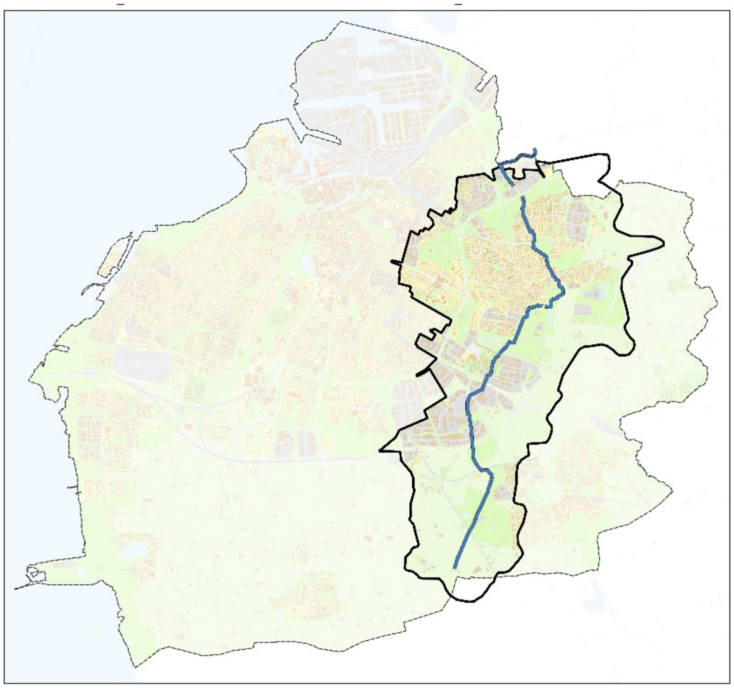


Figure 18 Map over Malmö with the catchment area of Riseberga stream

Malmö is Sweden's third largest city and has over 360 000 inhabitants. It is a dense city situated on flat and low-lying land next to the sea which makes it vulnerable to all types of flooding.

The Malmö pilot will focus on Riseberga stream which is a 12 km long stream running through the eastern part of the city. The stream was straightened and deepened in the late 19th-century to gain agriculture land but as Malmö has grown more than two thirds of the catchment area has been developed with a mix of residential and industrial uses.

Challenges

The land use in the catchment area of Riseberga stream differs depending on whether you are upstream or downstream from the outer highway that surrounds the city of Malmö. Downstream it's an urban landscape with industrial and residential areas, infrastructure, and parks where the utilisation company is responsible for storm water management. Upstream, south of the highway, agriculture is the main land use and landowners, of which the city of Malmö is the biggest one, are responsible for the maintenance of the stream. There is no part of the stream that hasn't been altered.

Figure 19 hotos from different stretches of the stream

Drainage companies with legal permits

In the southern parts of Sweden as much as 90% of the wetlands have been drained to gain arable land and Malmö and the Riseberga catchment area is no exception. When the stream's hydro morphology was altered, and its surroundings drained it was regulated through a permit and an agriculture drainage company was developed. Landowners that benefit from the drainage are part of the organization and have the right and obligation to withhold what is stated in the permit. Such a permit usually states how deep the stream is allowed to be, how steep the slopes are supposed to be and what flow capacity it can handle. To be able to restore the stream or increase its capacity, a new permit pursuant to the Swedish environmental code is needed. Such a new legal permit can take more than a year to apply for.

Water quality

The riseberga stream is not a waterbody according to the EU water framework directive (wfd) but it's a part of Sege stream river basin that has its outlet to the main recipient Öresund, the strait between Denmark and Sweden. Both Sege å and Öresund lies under the wfd and are not achieving good status which makes it important to also consider the quality in Riseberga stream to be able to reach the environmental quality standards for water. The status in Riseberga stream is unsatisfactory mainly because of changes in hydromorphology and high levels of nutrients and other pollutants originated from stormwater and agricultural land use. Another challenge that affects the water quality is erosion of streambanks that lead to sediment transport and turbid water. Discharge from the wastewater treatment system due to overflow occurs a couple of times per year and also has a negative impact on the stream's water quality.

Flooding

When the stream was straightened and deepened it was to gain arable land and the capacity was designed to manage drainage water from agriculture land use. Since then, the city has expanded around the stream, and more than 30 percent of Malmö's storm water now flows to Riseberga. Constructing roads and buildings significantly changes the hydraulic properties of an area and urban runoff runs faster with less infiltration, leading to higher volumes, than drainage water from agriculture land. This has led to problems with flooding and erosion in several stretches. Together with climate change the flood risk will increase further with consequences for both residents, the city and the ecology of the stream.

Figure 20 Maps over the urban development of a section of the catchment area from year 1812, 1940, 1960 and 2022

Recreation and biodiversity

The catchment area of Riseberga consists of agricultural and urban land with few bigger nature areas. The stream itself is more of a straight, narrow and steep ditch than a natural flowing stream but despite altered hydromorphology and high levels of nutrients there are still biological values within the stream with spawning trout (Salmo trutta) and with a relatively high abundance of Stone loach (Barbatula barbatula). Some terrestrial areas in the catchment area also have a rich biodiversity and recreational value but they are underutilised and for most stretches there is a great potential for improvement.

Future visions

In Malmö's comprehensive plan that was approved in 2023, Riseberga identified as an important part of the city's green and blue infrastructure, but the quality and accessibility vary greatly along the stream. There is no clear vision or direction for the development, and coordination and implementation of water management on a catchment level is lacking. Today there is no part responsible for such work and instead there is a risk that measures are being suboptimal regarding a sustainable management of water resources.

Primary and secondary objectives of the intervention

The Malmö pilot is all about gathering different stakeholders, mainly within the city, to form a common and holistic vision about the future of Riseberga stream and create a development plan. There is a need for a catchment area approach that includes nature-based solutions to secure a sustainable management of water resources with co-benefits as biodiversity and recreation. Such a planning document will in turn become an important supporting document for Malmös next comprehensive plan. The main objectives will then be anchored within the organisation and amongst the decision makers which is necessary for a long-term implementation.

The primary objective for the planning document is to handle flood risk and erosion since the urban sprawl means more impervious surfaces that increases the water flow in the stream. This affects the stream itself and its biodiversity but also residents and businesses along the stream. Older documents report of flooding events and erosion and suggests measures whereof very few have been implemented. Measures that have been conducted have mostly been to alleviate the acute problem and not to solve the underlying issue.

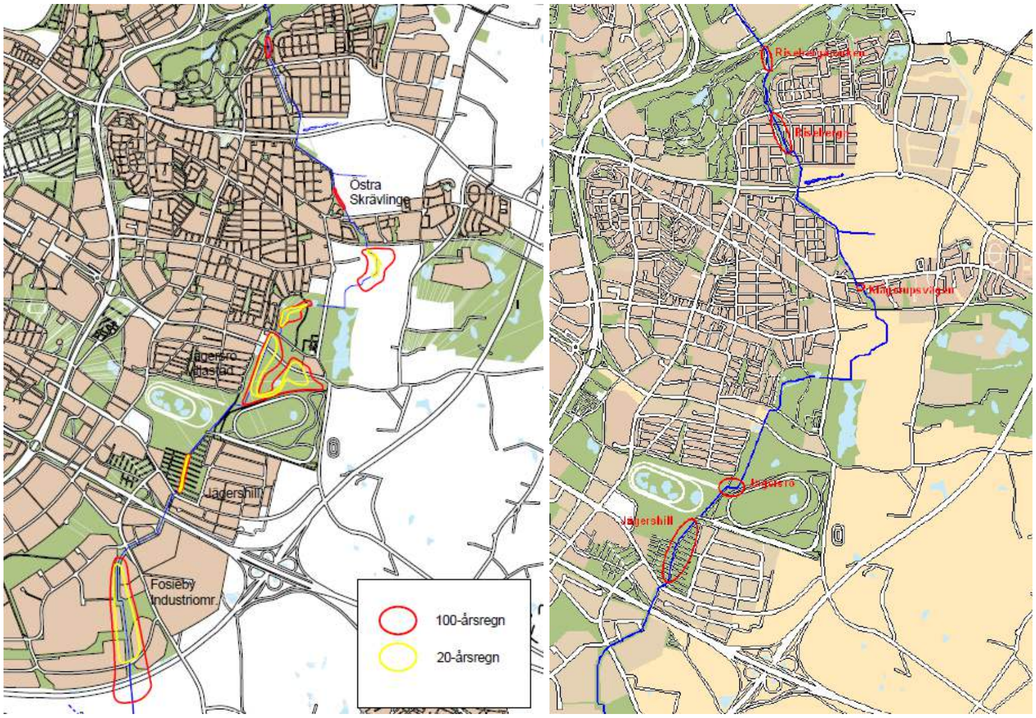
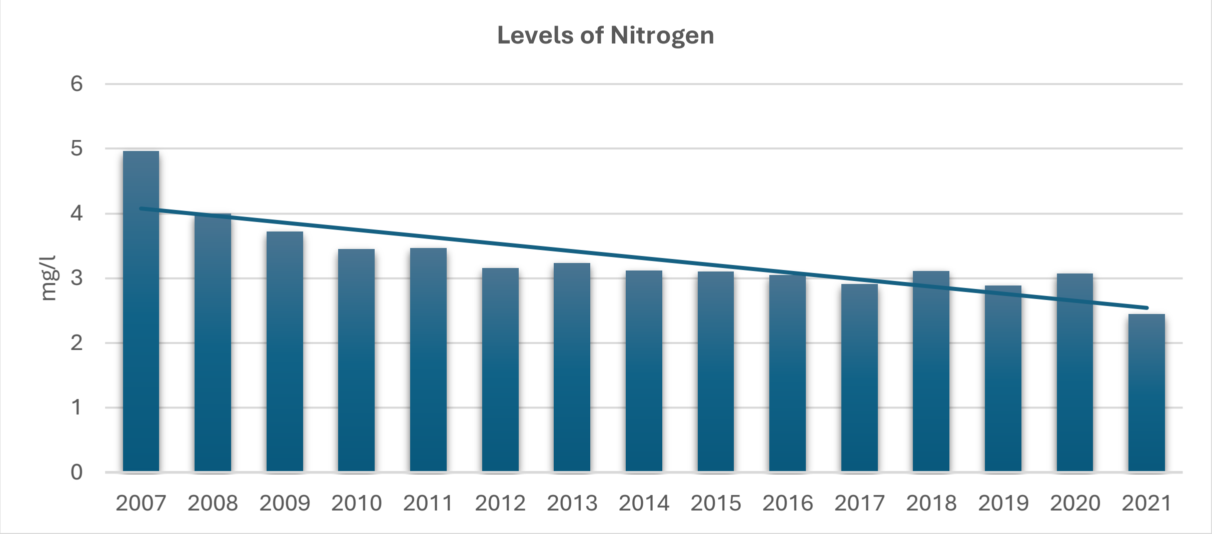


Figure 21 Map of flood risk with 100-year and 20-year rains in today's climate (left) and existing erosion along Riseberga stream (right)

Drainage, urbanisation, and climate change have increased the pressure on the stream with flooding and erosion as a consequence. Higher flows and increased urban runoff also affect water quality which is our secondary objective for the planning document. Except for urban runoff there is a vast amount of agriculture drainage water with high levels of nutrients reaching the stream and even if there is a positive trend in nutrient retention the levels are still too high and gives an unsatisfactory ecological status.



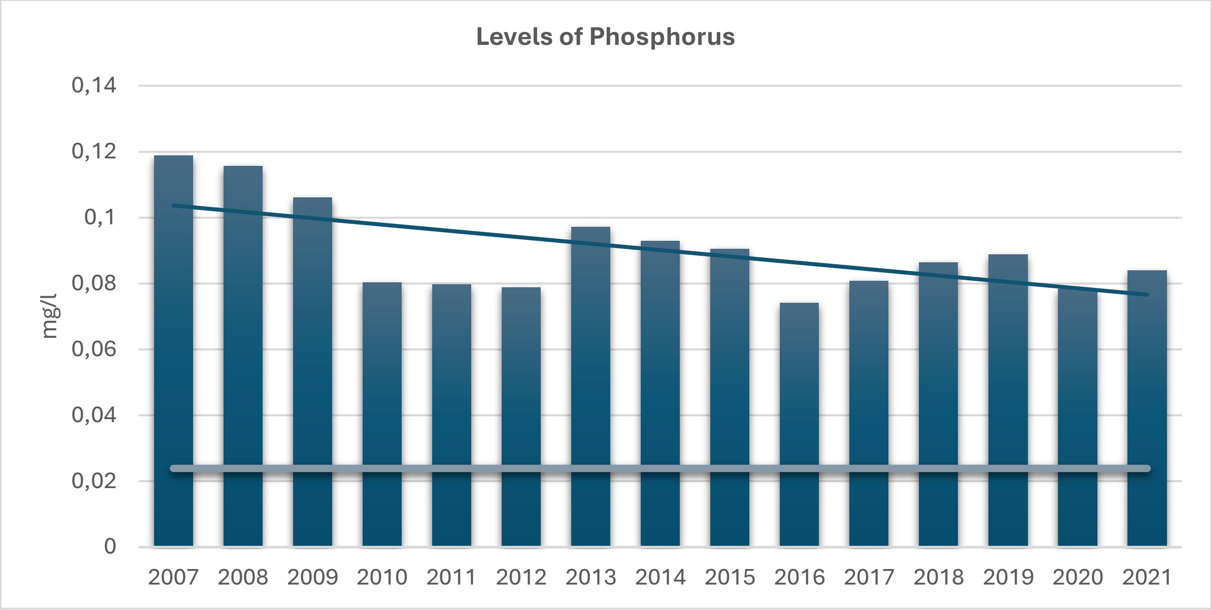


Figure 22 Levels of nitrogen and phosphorus in Riseberga stream. For phosphorus the lower line is showing the reference value.

A planning document must take both objectives into account and make sure that recreation and biodiversity is a central part of the suggested solutions. A holistic approach is necessary as well as cocreation with relevant stakeholders to secure and facilitate an implementation phase.

Short description of the baseline scenarios of Malmö Pilot including the tables with axes of uncertainties

– How should Riseberga stream be developed in the next 20 years to come.

The Malmö pilot isn't going to implement any measures but instead compile a planning document with a catchment area approach focusing on nature-based solutions. The baseline scenarios were made to see the consequences if we choose not to consider all objectives with specific questions to figure out the differences. The questions were discussed during workshops and the results are shown in the table below.

Baseline scenario 1: The catchment is not planned to be flood tolerant but to have high water quality.

Under which conditions is it acceptable to disregard the flood risk?
If the city only looks to the legal requirements it could come to a scenario where measures are taken to manage water quality alone.
What solutions would that result in?
This scenario would most likely result in downstream, large-scale, retention ponds for wastewater treatment.
Will flooding affect the water quality?
Urban runoff has an increased pollution load and even if there is retention ponds a flooding situation can still affect water quality negatively.
What will the implementation of the solution demand from the community: residents, landowners, utilities?
This will be facilities constructed for treatment mainly under the utility companies' responsibility and the cost will be covered by the utility tax from residents.
For managing nutrients leaking from agriculture land use there must be a voluntary interest from private landowners to implement measures. The cost can partly be covered by national funding.
What are the challenges and the co-benefits?
There is a big incentive to this scenario since there is a legal requirement for water quality according to the water framework directive.
The co-benefits are on the other hand not as many since retention ponds made with the sole intention of treating storm water aren't necessarily accessible for citizens or constructed in way to enhance biodiversity.

high

ALTERNATIVE DESIGN AXIS: WATER QUALITY

Baseline scenario 2: The catchment is planned to be flood tolerant with high water quality.

Under which conditions can both water quality and quantity be regarded??
This will be the scenario if the city wants to have a holistic approach and prevent future risks of flooding and erosion at the same time as improving water quality.
What solutions would that result in?
To handle both water quality and quantity its necessary with different type of solutions. It will need ponds/wetlands but also restoring floodplains to increase capacity and directing water to dedicated flooding areas.
Will flooding affect the water quality?
When the flooding is controlled e.g., in restored floodplains or detention ponds, it doesn't affect water quality negatively it will rather have a positive effect as it stores water temporarily making it possible for particles to settle.
What will the implementation of the solution demand from the community: residents, landowners, utilities?
This scenario demands action from all stakeholders, the utility company, the city of Malmö as well as of private landowners. The cost will be divided between stakeholders and national funding can be applied for regarding flood risk management.
What are the challenges and the co-benefits?
This approach will need several different solutions e.g., retention and dentention ponds as well as stream restoration. It will come with a higher cost and a new legal permit is needed.
The benefits are a resilient system that can handle a changing climate and growing city as well as giving citizens recreation areas with higher quality and increased biodiversity.

High flood risk **STRONG AXIS: METEO-HYDROLOGICAL PERFORMANCE** **Low flood risk**

Alternative scenario 3: **The catchment is not planned to be flood tolerant or improve water quality**

Under which conditions is it acceptable to disregard both flood risk and water quality?
This is how the current situation look like. Today there are problems with flooding, erosion and poor water quality and there are not enough efforts done to help the situation.
Its only when it comes to planning new development areas that flood risk management and environmental quality standards are legal requirements that can't be neglected.
What solutions would that result in?
If everything was to stay the same that would result in no preventive actions taken except in new development areas.
Will flooding affect the water quality?
In this scenario flood risk will increase with urban sprawl and climate change and will also have a negative impact on water quality directly through excessive runoff and erosion but also indirectly through owerflows from wastewater.
What will the implementation of the solution demand from the community, residents, landowners, utilities?
This will not generate any preventive solutions but instead affect all stakeholders in the event of a flood incident.
What are the challenges and the co-benefits?
Not working preventive means no initial investment cost but instead defer cost until a flood event.
Biodiversity will take the cost of poor water quality and the recreational values of the stream, and its surroundings, will stay low.

Low

Alternative scenario 4: **The catchment is flood tolerant, however water quality considerations are not a priority**

Under which conditions is it acceptable to disregard the water quality?
Riseberga stream is not classified according to the water framework directive which could mean that the city chooses not to prioritise water quality. With urban sprawl and climate change, flooding will on the other hand be a more acute problem that citizens demand action.
What solutions would that result in?
Solutions only regarding floodrisk can result in detentions ponds above ground or bigger pipes and reservoirs underground. It can also include restoring floodplains to increase its capacity.
Will flooding affect the water quality?
Even if only flood risk is considered those measures will also have a positive effect on water quality, especially if they are nature-based. Nevertheless, it will not be enough to be able to reach good status without specific measures directed for increased water quality.
What will the implementation of the solution demand from the community: residents, landowners, utilities?
In this scenario it will mainly be the city who implement measures on its own land. National funding can be applied for.
What are the challenges and the co-benefits?
In this scenario it is not possible to meet up with the legal requirements of the water framework directive.
Underground solutions are space effective but are usually more expensive and doesn't generate any co-benefits.
Nature-based solutions on the other hand can generate positive co-benefits for biodiversity and recreation but measures affecting the hydro morphology of the stream will require a new legal permit.

Stakeholder workshops

There are different processes already going on within the city that are affecting the stream and it's important that they are compatible and set for a common goal. To start we had three different workshops with the most relevant groups of stakeholders to align our visions and needs. This was mere a first discussion and there will be several meetings throughout the project period, and more stakeholders will be involved, to coordinate this work and to find a common understanding that can be visualised in a planning document.

We chose to meet with two groups of stakeholders in this early phase of the process, one that operates within the urban area (utilisation company area) of the catchment and one that operate outside on private land, so that different needs came in to light. We discussed current and future problems in the catchment area, visioned the streams potential if measures were implemented and talked about what those measures would imply and where responsibility for the implementation lies.

It was three interesting workshops that gave valuable input to the continuing process. One conclusion that came as a result from all workshops was the need for further analysis to be able to deepen the discussions and continue the co-creation process.

WS 1- City departments and utilisation company (22/3-2024):

This workshop focused on water quality and more specific storm water treatment within the utilisation company area. A total of 11 persons from different departments in the city together with the utilisation company participated.

Since one third of Malmö's storm water is discharged into Riseberga stream the city and the utilisation company holds a great responsibility to secure water quality. Even though water quality is only one aspect that needs to be considered its one where there are legal requirements pushing the utility company and the city to act. Suitable surfaces for storm water treatment with nature-based solutions have been identified throughout the catchment area. In a dense city like Malmö there are several different claims connected to an area and its necessary to integrate this process in a holistic approach on how to develop Riseberga stream. By having a workshop with relevant departments from the city together with the utilisation company, conflicting interests and possible co-benefits were discussed in an early phase to be able to prioritize. For some areas different interests can be managed together, it can for example be possible to combine an existing park for recreation or an area reserved for nature conservation with a pond for storm water treatment. But for other areas coexistence is not possible. The efficiency of a certain area is also important in prioritizing different alternatives. It's more cost efficient and easier to maintain fewer but bigger retention ponds than several smaller ones. To be able to make a final priority more analyses of cost and technical feasibility must be made but even so this first discussion gave a lot of input to the Malmö pilot and to the utility company's continuous work.

WS 2 - Water council (25/3-2024):

This workshop focused on the part of the catchment area that lies outside of the utilisation company area and that is managed by private landowners.

Riseberga stream is part of Sege åns river basin where there is a water council with the responsibility for environmental monitoring. The council also work with private landowners, implementing measures to improve water quality, enhance biodiversity and reduce flood risk. The council board consists of politicians from the municipalities covered in the catchment area, representatives from the farmers' association, environmental organisations, utilisation companies and bigger industries. There are also four employees which were the ones participating in this workshop.

The water council is an important stakeholder with a lot of knowledge and experience and has the potential to help implement the measures that the Malmö pilot concludes. They recognised the challenges that Riseberga stream are facing from other areas and came up with ideas on methods and analyses than can be useful in the continuous process. They have not approached private landowners in the catchment of Riseberga in their work so far but when we have a more substantial idea on what can be done there are all the reasons to collaborate more in the future.

WS 3 - Development group of Jägersro (3/4-2024):
This workshop focused on a development area called Jägersro (Projekt Jägersro – Stadsdelen för det bästa livet (projektjagersro.se)). A company called SMT, consisting of three housing corporations (Skanska, MKB and Tornet), was formed for the process of developing this new sustainable urban district. Representatives from SMT together with city officers responsible for the planning process, participated in this workshop.

In the years to come Jägerso will undergo urban development and a spatial planning process has been initiated. Today it's a horse racetrack but for the next 15-20 years to come it's planned to become a residential area with about 4000 new housings. The planning process is still in an early phase so it's a perfect time to explore how to make the most of the stream's potential as an integrated part of the areas blue and green space at the same time as it manages flood risk and water quality.

During the workshop we discussed the present situation with erosion and flooding and what role the stream has in future development. All participants agree that the stream with its flowing water is an asset and a unique selling point that should be emphasised. The stream and its surroundings can be developed so it attracts people as well as it contributes to the main objectives for the whole catchment area. The area could be a showcase of how to make the most of the stream's potential with nature-based solutions and an important contribution to the green infrastructure in the east parts of Malmö. With complementing perspectives there are several possibilities for further collaboration with the stakeholders involved in the development of Jägersro. Potential solutions can also cohere with other environmental objectives in the city as for example the ambition to improve the tree coverage and implement the rule of 3-30-300.

How Baseline-scenarios assisted the process

Baseline scenarios is for us a new way of working with a project and has helped us sort already existing information about the pilot area, understand where we still need more knowledge and how we can use the information to help us move forward.

We slightly adjusted the scenario template with questions that better fitted our purposes and could be used in our workshops. We focused on our primary and secondary objectives to get four scenarios and added recreation and biodiversity as a question of which scenario gives the most co-benefits. By working with scenarios, we gained new knowledge about what analyses is needed to be able to move forward with a planning document. It also made it clear that we have more work to do inhouse to create a common understanding and vison before residents and private landowners are involved.

The scenarios form a useful base for discussion and make it easier to envision different alternatives and the consequences of different choices. It's a simple way of showing what a more holistic approach would implicate compared to the work being done so far. Moving forward we can see that they will be helpful in decision making and we will continue to use them in our stakeholder dialogues.

Stavanger

Description of the pilot site

Stavanger City is situated along the southwest coast of Norway. The city has around 130,000 residents, while the greater Stavanger has over 350,000 inhabitants, making it the third-largest urban area in Norway. Stavanger is renowned for its historic status and long history as one of the country's most important centres for the Norwegian oil industry. In conjunction with the effects of climate change, the city's rapid urbanisation has been reflected in increased rainfall and more intense thunderstorms throughout the years. The consequence is an increase in stormwater runoff, which has stressed urban drainage systems and prompted the development of novel stormwater management strategies. The pilot site is Mosvatnet park (around 3 km round). It is situated 2 km from Stavanger city centre and serves as a focal point for community engagement and recreational activities. Over the years, it has become a cherished space for residents seeking both exercise and leisure opportunities. The park's diverse amenities, including a pond, playground, walking paths, and camping grounds, cater to a wide range of interests and preferences, making it a beloved destination for individuals and families alike.

At the heart of Mosvatnet Park lies its central feature: the pond. More than just a scenic water body, the pond is crucial in the park's infrastructure and environmental management. Designed to capture rainwater runoff, the pond acts as a natural reservoir, mitigating the impact of heavy precipitation events and preventing flooding in surrounding areas.

However, Mosvatnet Park project's innovative aspect lies in integrating the pond into the city's drainage system. By strategically positioning the pond within the park, the Stavanger municipality aims to leverage its capacity to collect and store rainwater, effectively incorporating it into the broader network of drainage pipes and channels. This approach enhances the park's functionality and contributes to sustainable water management practices within the urban landscape.

Furthermore, using the pond as part of the drainage system serves as a model for future urban planning and development initiatives. Mosvatnet Park's pilot project sets a precedent for creating resilient, ecologically sensitive communities by demonstrating the feasibility and benefits of integrating natural elements into urban infrastructure.

Challenges

The urban expansion in Stavanger, including the development of infrastructure, housing, and densification of open spaces, particularly in areas like Mosvatnet, Paradis, Stavanger Sentrum, and Mariero, has limited the natural infiltration of rainwater, contributing to the overload of the drainage system. The issue is additionally aggravated by the increasing sea levels that have been recorded in recent decades. The management of this amplified stormwater runoff presents a challenge for Stavanger Municipality (SM), as it must simultaneously accommodate new construction projects and prevent flooding within the boundaries of the city's current drainage system. SM aims to establish a new stream to direct stormwater from the residential area to Mosvatnet pond. The stormwater will no longer flow through the drainage pipes. Instead, it will follow through the channel which later flow out to the sea. The use of the pond to collect stormwater is considered as nature-based solutions that that not only to improve the drainage system, but it also improves biological diversity and becomes and an attractive element for Mosvatnet park.

Illustrasjon: Egil Bjørøen, Stavanger kommune

Mosvatnet park (MP) is increasingly recognized as crucial habitats for biodiversity and for delivering multiple benefits to humans. Here are some ways in which ponds serve as nature-based solutions:

1. Climate Mitigation and Adaptation. MP can help mitigate climate change by storing carbon and help adapt to climate change by providing a buffer against floods.
2. Habitat for Biodiversity. Ponds can create and maintain habitats for a wide range of species, supporting a larger proportion of rare, endemic, and threatened freshwater species.

3. Water Purification. Ponds can help purify water by filtering out pollutants.
4. Flood Mitigation. Ponds can help control floods by storing excess rainwater.
5. Cultural Benefits. Ponds can provide recreational possibilities and contribute to the aesthetic value of landscapes.

Water management permits and policies

In accordance with the Water Resources Act, the Building Technical Regulations (Tek 17), and the National Planning Guidelines for Climate and Energy Planning and Climate Adaptation, Stavanger strictly enforces regulations related to stormwater management. These regulations are significant because they focus on decreasing impermeable surfaces, facilitating local stormwater infiltration, and ensuring that stormwater discharge does not result in disruption or flooding during planning events. There is no concept for planning NBS at the local and national levels. However, there are some guidelines for the national level regarding NBS. There is also a recent initiative by Stavanger Municipality to include NBS as part of local stormwater management. The project focuses on several cases: urban tree development, biodiversity protection, and green space management.

Primary and secondary objectives of the intervention

The primary objective of stormwater management initiatives in Stavanger is to mitigate the hazards linked to flooding and increased stormwater runoff that are consequences of climate change and urbanization. This requires the identification and implementation of NBS capable of managing stormwater locally in an efficient manner, thus relieving the impact on the municipal drainage system. The secondary aim is to guarantee that these initiatives additionally enhance the recreational value, biodiversity, and overall sustainability of the urban environment. The case of Mosvatnet park will look at how stormwater management can connect with biodiversity protection and outdoor recreation.

Two solutions for managing stormwater through Mosvatnet park are proposed. First, instead of flowing directly to the channel, stormwater can be transported to a detention pond (Mosvatnet). The pond will hold the water until pollutants settle to the bottom. The water is then released slowly into the channel, reducing flooding and pollution in the rest of the system. Second, porous pavement, such as interlocking tiles or bricks surrounding the Mosvatnet park and the residential area, allows stormwater runoff to infiltrate the pavement and enter the soil. This removes fine grain pollutants and provides erosion control.

Short description of the baseline scenarios

A) Baseline for balancing the technical goals with ecosystem values for Stavanger’s Mosvatnet park

Baseline scenario 1: Balancing everyday rainfall with ecological enrichment

- There is a noticeable expansion of the water body, accompanied by the softening of its edges by native shoreline vegetation. Water is directed by swales, while flooding is prevented by permeable pathways. Growing trees provide dispersed shade, which encourages species of birds and insects.
- The strategic utilization of wood and rocks enhances the complexity of the habitat. Even in the presence of intense rainfall, most of the park remains accessible, focusing on enhancing the visitor's experience rather than maximizing ecological functionality.

High

ALTERNATIVE AXIS: ECOSYSTEM FOCUS

Baseline scenario 2: Ambitious NBS, creating a flood resilient ecological sanctuary

- The pond undergoes a transformation into an evolving wetland complex, effectively cleaning runoff and serving as habitats for many types of species. Walkways are flanked with rain gardens and wetlands, providing a display of cyclical beauty.
- Local plant species form a dense and varied layer of vegetation, while wood and rocks generate a wide range of habitats. During severe storms, certain areas of the park may experience temporary flooding due to the natural process of water retention.

Less intensive **STRONG AXIS: Rainwater Management Strategies** **More intensive**

Alternative scenario 1: Modest enhancements, while prioritizing park accessibility

- The drainage upgrades continue to target walkways and areas with high levels of activity. Rain gardens contribute to the aesthetic value of the surroundings, while the primary focus remains on preserving the established park aesthetics.
- The current vegetation is properly cared for, and any invasive species are eliminated. Nevertheless, the potential for enhancing biodiversity through the introduction of novel plant species and habitat characteristics is limited.

Minimal

Alternative scenario 2: Engineering efficiency and prioritizing drainage over habitat

- Increasing the size of the underground storage structure enhances flood control, while causing minimal alterations to the park landscape. The body of water may experience a slight expansion while maintaining its well-kept perimeter.
- Vegetation includes robust and regular plants. Controlling invasive species is crucial for maintaining the condition of existing vegetation, while introducing new species can only contribute to biodiversity.

B) Baseline scenarios for balancing the functional aspect with structural transformation

Baseline scenario 3: Complete redesign with elevated pathways and adaptive activities - The design of the park is drastically changed with parts redesigned for retaining water. High walkways traverse through the reshaped landscape. Play facilities are adjusted to allow for occasional flooding, highlighting elements with a water concept.	ALTERNATIVE AXIS: STRUCTURAL TRANSFORMATION Large	**Baseline scenario 4**: Strong NBS with a focus on ecology and education - A portion of the park is being turned into retention basins or seasonal wetlands to help with flood mitigation and biodiversity. Access is possible on boardwalk paths in most weather conditions. Walking, informal sports in the surroundings become the new priorities for leisure time activities. The shifting landscape is explained by signposts. Closures on occasion could be utilized for educational and research activities.
Maintain current use	**STRONG AXIS: FUNCTIONALITY**	**Evolving use**
Alternative scenario 3: Everyday enhancements, limited disruption. - The water body is being minimally expanded, and native plants are being added to its shoreline. High-use areas' drainage is improved by new permeable pathways. Rain gardens enhance aesthetics. For most of the year, the park strives to keep its regular use.	Small	**Alternative scenario 4**: Targeted NBS, nature observations enhanced. - Within the park, a biodiverse wetland with a platform for bird observation is established. Certain areas are improved by native plants and rain gardens. While there may occasionally be brief closures, the goal of improving the visitor experience in between rainstorms never changes.

Selected baseline scenarios for Stavanger pilot

The *phased ecological enhancement scenario* provides a workable and affordable means to improve the ecological value and operational efficiency of Mosvatnet Park. It is a good fit for a pilot project because it places a high priority on feasible interventions with significant potential impact. It can be put into action gradually, allowing for modifications in response to community input and financial constraints.

Baseline Scenario 1 (Balancing everyday rainfall with ecological enrichment): this is likely a component of a phased scenario that can be put into practice but might be too ambitious in its initial form, as it involves more significant pond expansion.

Baseline Scenario 2 (Ambitious NBS, creating a flood resilient ecological sanctuary): offers a comprehensive transformation but requires significant investment in creating a complex wetland system, extensive native plantings, and potentially elevated walkways throughout the park.

Baseline Scenario 3 (Complete redesign with elevated pathways and adaptive activities): a major overhaul of the park's layout and user experience, requiring substantial investment in elevated pathways, redesigned play areas, and potentially significant earthworks.

Baseline Scenario 4 (Strong NBS with a focus on ecology and education): involves large-scale interventions like converting park areas into retention basins and extensive boardwalk construction, making it a high-cost option.

As a conclusion, the most likely candidates from the tables to be the basis of the *phased ecological enhancement scenario* are a combination of elements from ecosystem table - Alternative Scenario 2 (Engineering efficiency and prioritizing drainage over habitat) and from the functionality table, Alternative Scenario 3 (Everyday enhancements, limited disruption).

The most likely key elements to be selected from **Alternative Scenario 2** are: small, biodiverse wetland; bird observation platform; native plantings in selected areas; emphasis on enhancing visitor experience between rainfall events. The most likely key elements to be selected from **Alternative Scenario 3** are: modest pond enlargement; improved drainage in high-use areas - likely with rain gardens; prioritizing keeping the park accessible for most of the year.

Engagement of stakeholders and co-creation

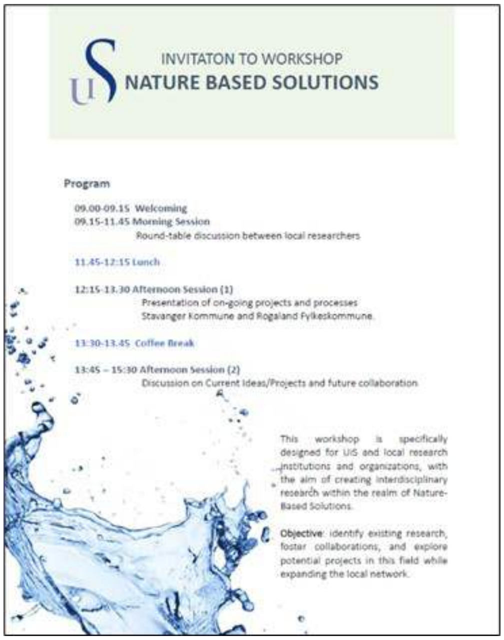
Stavanger proactively engages a diverse array of stakeholders, including surrounding municipal and county authorities, private sector developers, residents, and landowners, in the planning and implementation of NBS. The objective of this cooperative strategy is to synchronize NBS with the community's requirements and regulatory benchmarks, thereby guaranteeing that all suggested solutions are viable, efficient, and supported by all participants.

Challenges and future vision

Stavanger, although progressing in the investigation and implementation of NBS for stormwater management, recognizes a need for more understanding of the efficient planning and execution of such solutions. Stavanger has the opportunity to develop a more structured operational model for NBS through the CITY BLUES project by adapting lessons learned from other cities to local conditions. The objective of the municipality is to develop an adaptable and resilient urban environment that not only effectively handles stormwater but also improves the standard of living of its inhabitants by means of increased recreational prospects and biodiversity.

Workshops

Three workshops were carried out to explore the adoption NBS for stormwater management in Stavanger. **The first workshop** was conducted on 11 December 2023 in Victoria Hotel, Stavanger. The overarching objective of the workshop was to leverage the collective expertise and resources of participating entities to identify existing challenges and interest on NBS, cultivate partnerships, and chart a course for potential collaborative projects within this burgeoning field. The workshop involves key stakeholders including Rogaland County Council, NORCE, UiS, and Stavanger Municipality. The meeting captured the potential of NBS on stormwater management in Rogaland and Stavanger.



INVITATON TO WORKSHOP

NATURE BASED SOLUTIONS

Program

09.00-09.15 Welcoming
09.15-11.45 Morning Session
Round-table discussion between local researchers

11.45-12:15 Lunch

12:15-13.30 Afternoon Session (1)
Presentation of on-going projects and processes
Stavanger Kommune and Rogaland Fylkeskommune.

13:30-13.45 Coffee Break

13:45 – 15:30 Afternoon Session (2)
Discussion on Current Ideas/Projects and future collaboration

This workshop is specifically designed for UiS and local research institutions and organizations, with the aim of creating interdisciplinary research within the realm of Nature-Based Solutions.

Objective: identify existing research, foster collaborations, and explore potential projects in this field while expanding the local network.

The second workshop was conducted online, organised by Rogaland County Municipality (*Rogaland fylkeskommune* in Norwegian) on 21 February 2024. The meeting involved many municipalities within Rogaland County Municipality, including Stavanger Municipality. The workshop was iniatiated by Rogaland County Municipality to solve cross-border challenges affected by climate change. The meeting further explored nature-based solutions as part of intervention for climate change mitigation and adaptation. The workshop also dicussed the case of Stavanger in managing Mosvatnet park as part NBS. The workshop share knowledge faced by different municipalities in dealing with the concept of NBS and its application to the development of blue-green infrastructure.

The third workshop was conducted online on 20 March 2024. The workshop was part of the regular meeting arranged by Rogaland County Municipality. The workshop elaborated specific cases that deal with climate adaptation actions at the local level. The workshop shared Best Management Practices (BMPs) in dealing with NBS for water and stormwater management. BMPs included structural, vegetative or managerial practices used to treat, prevent or reduce water pollution and flooding.

Conclusions

In summary, Stavanger is transforming its stormwater management strategy, which places significant importance on innovation, engagement of stakeholders, and the development of environmentally sustainable alternatives. The municipality can turn obstacles into prospects for improving environmental quality and urban resilience, thereby establishing a model for other municipalities facing comparable challenges.

Tampere

Introduction of the pilot site

In Tampere nature-based solutions are planned for storm water retention and treatment in Lake Iides (in Finnish *Iidesjärvi*) that is part of Viinikanoja catchment area. The pilot area is called *Varsanpuisto–Huhmarpelto*. It is in Takahuhti district about 5 km east from the city center (see Figure 23).

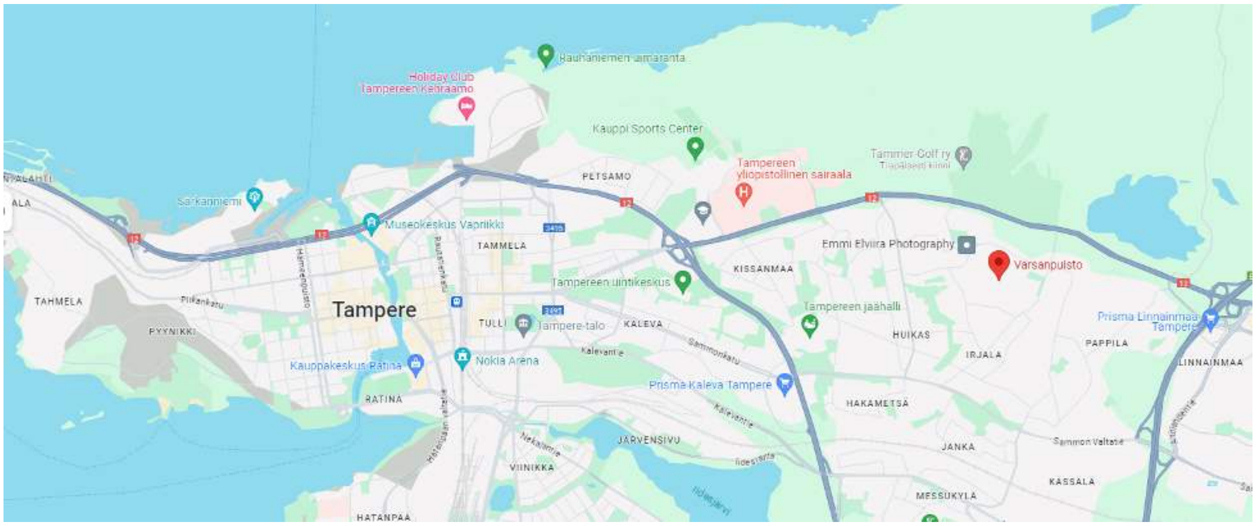


Figure 23 The site location Varsanpuisto marked with red sign (Source: maps.app.goo.gl/7TFJmJpjLtAmSNRu7)

Flooding has been observed along the Vuohenoja stream in Kissanmaa and Iidesranta districts (see Figure 24, marked with light blue dashed line). To prevent flooding, alluvial meadows are planned in the area (see Figure 2, marked with red line), where water will be impounded during heavy rainfall. The aim is to keep the retention volume as high as possible. Use of local plants and seeds is foreseen.

The flow of the Vuohenoja stream is automatically monitored from 1/2023 onwards. The results can be used to design and monitor the pilot.

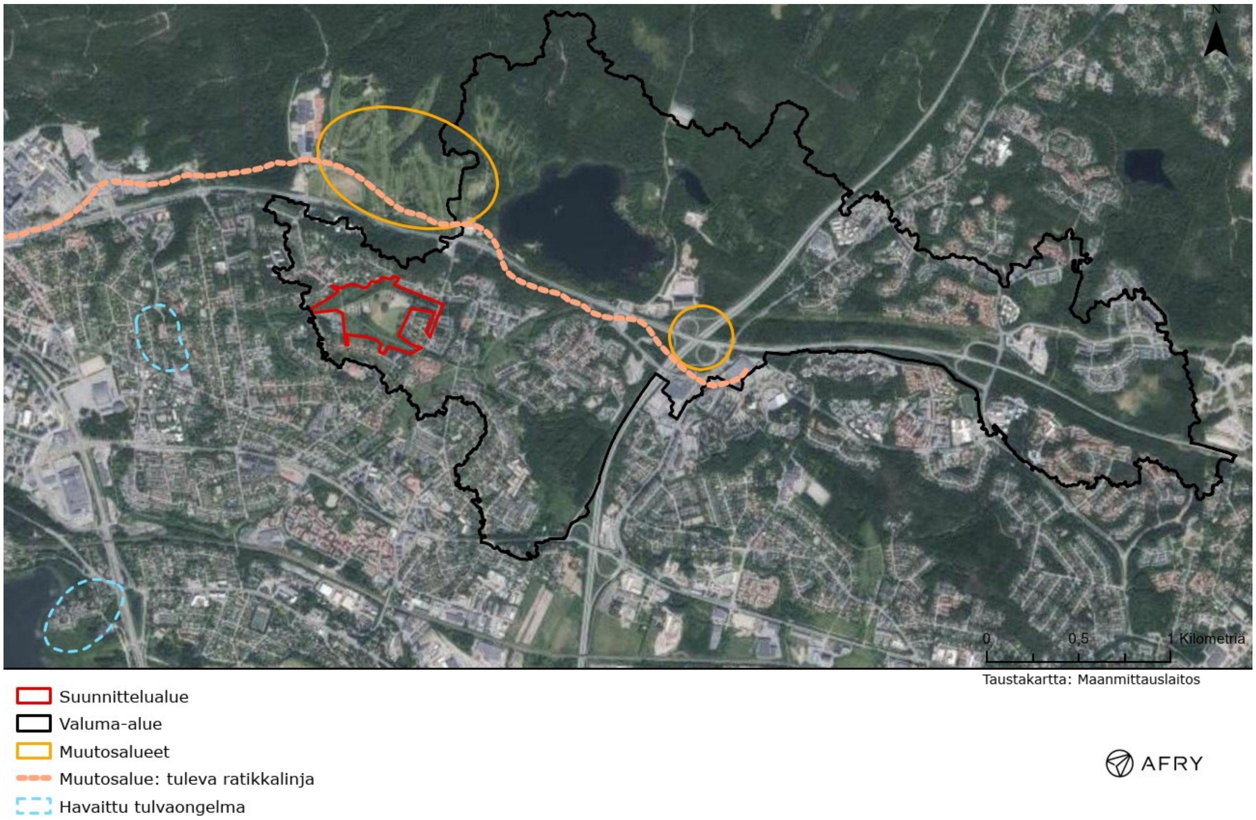


Figure 24 Planning area, catchment area, modification areas and identified flooding problem. Planning area is marked red on the map, the catchment area is marked with black line. In yellow are the areas where construction and the extension of the tramway will tak

The area has traditionally been an open landscape of fields. The aim is to take cultural history into account, and to keep the landscape open. In recent years it has been used as a landscape field, but not all plants have thrived due to excessive moisture. Landscape fields and agricultural plots give the area a distinctive character. The area is a popular outdoor recreation area where, for example, children ride sledges and do cross country skiing in winter. Outdoor trails are used for cycling, walking, and jogging. The planning area includes a garden plot area where there have been drainage problems. (Figure 25) Planning must be done in such a way that we do not increase flooding on agricultural land or on walking paths.

The vegetation is typical of the area and there are no trees of landscape value or rare or protected plant species. Bats have been observed in the area and their habitats should be considered in the design. Brown trout have been stocked in the Vuohenoja stream to support their habitat and reproduction. Trout are highly endangered in Finland, so it is imperative to take them into account in the design. The project will support trout reintroduction by taking into account fish passage in dams and other riverbed structures (e.g. bridge replacement) and through the construction of a spawning lane.

Several invasive alien species are found in the City Blues pilot area. They include Garden lupin, Himalayan balsam, Giant hogweed, Canadian waterweed, Spanish slug, and Signal crayfish.

Figure 25 Photos from the site.

Timetable and phases of the City Blues Tampere pilot

General design phase, February 2024–April 2024

- Field survey 22/2/2024
- Planning process kick-off meeting 5/3/2024
- Resident workshop 19/3/2024
- Master plan draft completed by 30/4/2024
- Official public viewing of the master plan in May 2024
- Refining the plan on the basis of feedback received, May 2024
- Approval of the Master Plan by the City Board May/June 2024

Detailed design phase, May 2024–September 2024

Implementation phase (2024–2025)

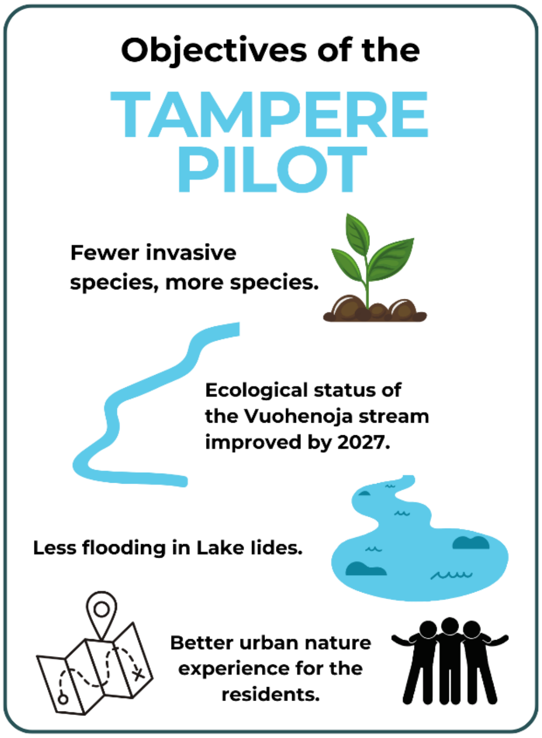
- Tender for implementation, autumn 2024
- Earthworks in January-March 2025
- Planting and seeding, spring 2025
- Voluntary works by residents and stakeholders (e.g. plantations, watercourse restoration), summer 2025
- Supplementary seeding, if necessary, summer 2026

Monitoring phase 2025–2026

- Impacts on stormwater conditions are assessed by stormwater management modelling before and after the pilot.
- Biodiversity observation assessment and/or repeat the nature survey after the measures

- Brown trout is monitored using electrofishing.
- If we want to monitor the improvement in safety and pleasantness, we can do a resident survey.

Primary and secondary objectives of the intervention



The primary objective of the pilot is to prevent flooding and improve stormwater management near Lake Iides and in Vuohenoja stream.

Original secondary objectives are:

- to improve the ecological status and water quality of the Vuohenoja stream and lake Iides
- to increase biodiversity
- to prevent the occurrence of invasive alien species
- to improve the recreational values of the area and to support public health and well-being.

As a result of the scenario building, we also want to add the objective of making the site drought and heat resistant as secondary object.

The aim is to carry out some of the restoration work together with residents and provide opportunities for volunteering and thus to support social cohesion.

This is the first time in Tampere that local plants are used to create a meadow in a wet environment.

The objectives are not contradictory but mutually supportive. They are based on the city's strategies and programs.

Short description of the baseline scenarios of Tampere Pilot including the tables with axes of uncertainties

We looked at three different aspects in scenario building (a–c). First, we observed what happens if we concentrate on biodiversity and on drought/flooding. Secondly, we considered how the safety and pleasantness of the area would affect drought/flooding. The third aspect was how we can combine the prevention of invasive species with the use of local and native species. The axes of uncertainties contain our reflections and different scenarios.

Heat waves increase with climate change. Global warming will strongly increase water evaporation in summer, which will increase drought even if precipitation remains unchanged or even increases slightly. We realized that we needed to design the site so that it could cope with both floods and droughts. We also discovered that the prevention of invasive species must be the starting point for planning. We also want to support the potential of local species in the area and increase the diversity of the area. At the same time, of course, we want to make the area more pleasant and safe for users.

When making the scenarios, we gathered information on how the invasive species of the area and valuable species trout would cope in a drought or flood situation. Information was collected from climate change adaptation and environmental protection professionals in the City of Tampere and the Finnish Natural Resources Institute. Invasive alien species and endangered species in the area and their resistance to drought or flooding is shown in table 1.

Table 2 Invasive and valuable species in the area and their resistance to drought or flooding

Invasive alien species	Resistance to drought or flooding
Himalayan balsam	Likes damp, so can cope with flooding. Surviving drought depends on the length of the dry period and the soil. Even if it is dry, the plant always tends to reproduce. In addition, the soil has a seed bank, so even if the plant suffers one summer, the seeds of Himalayan balsam will remain reproductive for about 5 years.
Giant hogweed	Grows also on banks and alongside streams, so it can survive in wet conditions. It also grows in dry places, and there needs to be drought for quite a long time to have negative effects on the species. The seed bank lasts for about 7 years.
Garden lupin	With its root system, it tolerates dry sites well and also thrives alongside ditches and tolerates moisture. In the city's stormwater basins and NBS solutions, Garden lupin is abundant. Their seed bank lasts for decades.
Canadian waterweed	Is an aquatic plant and does not grow on dry land. It spreads with floods, i.e. the species benefits from flooding.
Signal crayfish	If there is a long hot season, so that the water temperature rises enough, it will harm Signal crayfish.
Spanish slug	Suffers from drought, at least in the sense that if the vegetation is cut short it will not find shelter from drying out. Survives well in wet conditions.
Endangered species	Resistance to drought or flooding
Brown trout	Brown trout spawn in October and hatch in spring. When the trout's roe is developing, it should not be left under the sediment in an oxygen-deprived state, otherwise the roe will not develop. Water quality typically deteriorates during floods. Trout prefer cool waters and require acidic water. Trout can suffer from flooding because there is often erosion and sediment loading, especially during the spawning season. Increased winter rainfall and earlier spring floods can make spawning more difficult.

Next, we present our scenarios in three tables with axes of uncertainties. In all cases, we design a long-lasting solution with regular maintenance. We develop maintenance guidelines for NBS solutions to ensure that solutions are managed appropriately.

Tampere scenarios 1-2: Biodiversity vs. rainfall and weather

ALTERNATIVE DESIGN AXIS: BIODIVERSITY

Rich

Baseline scenario 1: **The pilot site is designed to be drought tolerant and rich in biodiversity.**

In this scenario, we focus on preventing drought and improving biodiversity. Climate change leads to longer periods of drought, and rising temperatures increase drought periods in southern Finland. The risk of plant diseases and pests increases. Drought negatively affects tree growth, increases their susceptibility to insect pests and fungal diseases and increases the risk of forest fires. To adapt we use a greater diversity of species.

Southern species and invasive alien species increase and spread further north. Several invasive species are found on the site. Invasive species like Himalayan balsam causes erosion along streams. This can also have a negative impact on the spawning success of trout and other fish in the stream. We remove invasive species.

When there is a prolonged period of drought, fish passage in the ditch becomes more difficult. Salmonids like brown trout prefer cool waters and require oxygenated water. Heat is prevented by planting shade trees on the south side of the channel.

Certain species of algae benefit when the water is not flowing, when there is calm and when the temperature rises.

New plants are chosen to withstand prolonged drought. We use a wide variety of species and seeds and seedlings from local plants. The trees are noble deciduous trees that tolerate drought. Felled trees are left on the site to decay, as decaying wood also contributes to biodiversity.

We maintain and irrigate the area during dry summers.

Baseline scenario 2: **The pilot site is designed to be flood tolerant and rich in biodiversity.**

In this scenario, we focus on preventing flooding and improving biodiversity. Current average annual precipitation in Tampere is 660 mm. It will increase 20–30% by 2070-2100. In Finland we will see heavy summer rainfall, and summer precipitation will increase. There is also more rain in winter. Spring floods turning into winter floods as snow falls as water.

Different precipitation amounts are modelled for specific rainfall events. In addition, adequate detention volumes are considered, where detention basins are placed, how many and where dams are needed, and how replaced culverts need to be sized.

Alluvial meadows are designed so that water only temporarily rises during rainfall events and snowmelt. The flood will rise in an area covered by vegetation. Separate erosion barriers are built in the stream using rocks and decaying wood. This supports trout's habitat, too.

New plants are selected to withstand wet conditions. We use of a diverse mix of trees. The new tree species are moisture-resistant deciduous trees. A wide variety of species and seeds of local plants are used. Felled trees are left on the site to decay and to improve biodiversity.

Floods spread seeds of invasive species like Canadian waterweed to new areas. We remove invasive species and combat them on a broad scale, also upstream.

Heavy rainfall causes soil erosion and damages vegetation. Heavy rains can be particularly damaging just after sowing. Replanting may be necessary if the vegetation is not established and is washed away. We take this into consideration in maintenance.

Drought **STRONG AXIS: METEO-HYDROLOGICAL PERFORMANCE** **Flood**

Alternative scenario 1: **The pilot site is drought tolerant; however, the biodiversity considerations are not a priority and there is no attempt to increase the number of species in the area.**

In this scenario, we focus on preventing drought. We do not add any new plantations on the excavated land, but let the area grow what nature provides from the seed bank.

This scenario could happen if the space is so confined (as it is in the core city) that there is no room for above-ground NBS structures and flooding would be controlled by an underground solution. *In the City Blues pilot area, this is a completely unrealistic scenario.*

Removing invasive species costs money and results in greenhouse gas emissions if they must be exported elsewhere. If the restoration budget is very low, invasive species are not removed during the earth works, nor will we take them into account when dumping excavated soil.

It is not always possible to afford the best solution for budgetary reasons, for example by not being able to buy seeds or plants of local species that are much more costly than domestic seeds or plants. For local species, it is necessary to manually weed the area for at least two years which adds costs.

Alternative scenario 2: **The pilot site is flood tolerant; however, the biodiversity considerations are not a priority and there is no attempt to increase the number of species in the area.**

In this scenario, we focus on preventing flooding. Instead, we do not add any new plantations on the excavated land, but let the area grow what nature provides from the seed bank.

This scenario could happen if the space is so confined (as it is in the core city) that there is no room for above-ground NBS structures and flooding would be controlled by an underground solution. *In the City Blues pilot area, this is a completely unrealistic scenario.*

Removing invasive species costs money and results in greenhouse gas emissions if they must be exported elsewhere. If our restoration budget is very low, we will not remove invasive species during the works, nor will we take them into account when dumping excavated soil.

It is not always possible to afford the best solution for budgetary reasons, for example by not being able to buy seeds or plants of local species that are much more costly than domestic seeds or plants. For local species, it is necessary to manually weed the area for at least two years which adds costs.

Poor

Tampere scenarios 3-4: Safety and pleasantness of the area vs. rainfall and weather

ALTERNATIVE DESIGN AXIS: SAFETY AND PLEASANTNESS

Safe and pleasant

Baseline scenario 3: **The pilot site is designed to be performing under drought conditions and aiming to be safe and pleasant for the users.**

In this scenario, we design the area to cope with drought and to be safe and pleasant for users. The area looks good during the dry season, since we use drought-tolerant plants and establish dry meadows.

The principle of an open landscape is important in design but can create heat island effect. We plant many trees and create shady resting places, for example by the water.

To avoid the stagnant pond effect and odor nuisance, troughs and slopes are designed to allow water flow at all times. Shading vegetation is planted near the pond.

The need to water plants and trees can increase in drought conditions. A stormwater pond provides irrigation water, so we don't need to use tap water for irrigation.

Maintaining green spaces in the heat can pose a risk to the workers. Dressing smartly, drinking plenty of fluids, seeking shade and other health and safety measures help to prevent the dangers of heat.

Mites thrive in dry conditions and spread dangerous diseases. We include in the maintenance manual that mowing near the pathways is necessary to avoid causing a mite problem for users and pet owners.

The new bridge is safe to cross by bike and on foot. The pathways are resurfaced because the previous surface was too soft and caused cycling hazards. We improve signs in the area and add information on which paths are not maintained in winter. The outdoor lighting is in good condition.

Residents often seek green spaces and shadow during hot weather, which can increase nuisance use and littering in the site. The area is well looked after, with lots of people and people of all ages using the space. Several litter bins are added to the site.

Baseline scenario 4: **The pilot site is designed to be performing under flood conditions and aiming to be safe and pleasant for the users.**

In this scenario, we focus on flooding performance and on safety and pleasantness. Flooding is modelled (e.g. a heavy rainfall that happens once every 100 years) to find out, what happens to the solutions like spiral pond.

NBS are planned to prevent water damages in buildings and structures nearby. We design a solution that prevents water from frequently rising onto park corridors and paths, and community gardens in the area. The surface material of the paths prevents them from becoming muddy during heavy rainfall. The new bridge design takes flooding into account.

In winter, ice is not allowed to form on paths and we sand paths in slippery weather. We improve signs in the area and add information on which paths are not winter-maintainable.

Wet meadows and appropriate plant species are planted to make the area pleasant and beautiful. We will add benches and bins to the area.

Wet meadows may have a high mosquito population, which can add to the unattractiveness. The area is designed to be open landscape, so that the breeze can pass through many places, which will draw mosquitoes further away.

We can think about whether it would be possible to use animals like sheep as grazers in the area after the project. They are usually nice for the residents, especially children.

The outdoor lighting is in good condition.

Drought — **STRONG AXIS: METEO-HYDROLOGICAL PERFORMANCE** — **Flood**

Alternative scenario 3: **The pilot site is designed to be performing under drought conditions. However not safety nor pleasantness of the area is a priority.**

In this scenario, we design the area only to cope with drought. *This scenario is unrealistic because we cannot create an unattractive or unsafe city.*

The vegetation we encourage is monotonous, so that in the dry season plants can die off on a large scale leaving the landscape ugly looking.

We allow open landscape create heat effect. Trees are planted only near the riverbed, not south of the paths.

In the summer season, a prolonged period (more than 1 month) without rainfall and a simultaneous heatwave, which increases evaporation, reduces the flow in the riverbed. Then, the pond becomes a stagnant pond, which leads to an increase in algae, resulting in odour nuisance. We are not trying to prevent this by design.

To make the area as uninviting as possible, we will pave the areas with asphalt and add a parking lot.

Unsafe and unpleasant

Alternative scenario 4: **The pilot site is designed to be performing under flood conditions. However not safety nor pleasantness of the area is a priority.**

In this scenario, we focus only on flooding performance of the solutions. *This scenario is unrealistic because we cannot create an unattractive or unsafe city.*

If we don't care about safety or pleasantness, water is often raised in the area, and we don't care if it rises to the pathways or river crossings.

We don't care if ponds form in the area that are dangerous for small children during heavy flooding.

We will not put more benches or bins in the area, nor will we plant new plants to replace those that have been removed.

To make the area as uninviting as possible, we will pave the areas with asphalt and add a parking lot.

Tampere scenarios 5-6: Combating invasive species vs. diversity of local and native species

Baseline scenario 5: **The pilot site is designed to eradicate invasive species and to introduce more local and native species.**

In this scenario, we get rid of invasive species and use local seeds and plants. We gather information and professional views to support eradication, organize meetings and field visits.

Invasive species are removed during construction, and invasive soils are removed or encapsulated and covered with clean soil. The restoration work is planned so that the eradication of invasive species does not destroy other species. There remains also local desirable species.

No matter how well invasive species are considered, they can grow back into the area from the banks of the river. We agree with maintenance that upstream weeding is done prior to construction of our site.

Himalayan balsam causes erosion along streams and reduces water quality. This is tackled when invasive species are eradicated.

The reintroduction of trout into the riverbed started before City Blues with meadow planting. The project will support trout reintroduction by taking into account fish passage in dams and other riverbed structures (e.g. bridge replacement) and through the construction of a spawning lane.

Plant selection will take pollinators into account as it is important to improve the situation. Planting decaying wood will support decaying wood-dependent species.

Sheep grazing would support biodiversity. During the project, it is not possible but could be considered whether it would be possible to use the animals as grazers to support biodiversity in the future. We will already take into account in the design that we do not make too steep places where grazers would not be able to access e.g. water.

ALTERNATIVE DESIGN AXIS: DIVERSITY OF SPECIES

Rich

Alternative scenario 6: **The pilot site is planned to be rich in diversity of native species, however there is no attempt to control and eradicate invasive species.**

This scenario is unrealistic, as the city cannot make the situation worse for invasive species.

By force of circumstances, despite all precautions, seeds of Himalayan balsam, for example, may return to the area from upstream with the water. It may also be difficult to eradicate Canadian waterweed from the Vuohenoja stream.

No measures are planned against the signal crayfish: it is present upstream and downstream and cannot be eradicated by our actions.

No invasive species **STRONG AXIS: PRESENCE OF INVASIVE SPECIES** **Plenty of invasive species**

Alternative scenario 5: **The pilot site is designed to eradicate invasive species; however, diversification of species is not a priority.**

We will carefully remove invasive species using the measures described above, but in this scenario we will not try to increase the number of species.

If we don't try to increase the number of species, we don't plant, but let whatever happens to grow there from the seed bank grow, because we can't spend years manually weeding for cost reasons.

Or alternatively, we save on costs by planting with native but not local species.

The city of Tampere has the expertise in invasive species and biodiversity, but a small municipality may not have the expertise. If Tampere did not have the expertise, we might have to choose this scenario or buy the expertise from consultans.

Poor

Alternative scenario 6**: In designing the pilot site there is no attempt to control and eradicate invasive species. Diversification of species is not a priority.**

This scenario is unrealistic, as the city cannot make the situation worse for invasive species or create a species-poor environment.

However, if this were done, one would only think about flooding and let the seed bank take care of the plants in the area. This could happen if the budget was very limited and could only afford to do flood prevention and stormwater management. Or if there was no expertise to think about it in terms of species.

Selected baseline scenarios for Tampere pilot

We have chosen the following three scenarios as our final baseline scenarios:

- **Baseline scenario 1**: The pilot site is designed to be drought and flood tolerant and rich in biodiversity.
- **Baseline scenario 3:** The pilot site is designed to be performing under drought and flood conditions and aiming to be safe and pleasant for the users.
- **Baseline scenario 3:** The pilot site is designed to eradicate invasive species and to introduce more local and native species.

Alternative scenario

We also identified an alternative scenario where **we do not take any measures in the area**. Then there would be a lot of invasive species in the area. Presumably, in the future, the number of invasive species in the area would increase even more.

There are currently no rare or valuable species in the area. The landscape field has also been too wet, and plants do not thrive in the field. There would be few native desirable species in the area in the future if this scenario were to be realised.

However, the alternative scenario is not an option because we are going to implement the City Blues pilot.

Overview of the co-creation process in three workshops

Our co-creation process included three events that are also part of the planning and design process. First, we held a kick-off workshop to get both the planning of the area and co-creation of the baseline scenarios off to a good start. This workshop was held online, and the target group were professionals from different design fields.

Secondly, we organised a residents' workshop to share and get feedback on the plans, as well as new local knowledge and empirical information to support planning and scenario building. In the workshop, we gathered views on all the things that should be considered when designing a site. At the same time, we gathered an understanding of which themes we should look at in the scenarios and what kind of stories and facts we should write in them.

Thirdly, we went through the scenarios generated based on the first two events with the city's stormwater team and finalised the work.

The co-creation process has involved stakeholder engagement with:

- Residents
- Local resident and private housing associations
- City Blues associated organisations: Wild Zone, Sospro, KVVY
- 4H association (they rent plots of land for farming in the area)
- From the City of Tampere, stormwater experts, invasive species expert, landscape designer, tree expert, geology expert and green area management expert
- From the planning company AFRY Finland, a flood expert, a landscape architect, a traffic planner, a modelling expert

Overall, 47 people participated in three workshops to develop the scenarios.

Design process kick-off meeting (5 March 2024)

A total of 13 experts attended the first planning meeting of the area. Their expertise included stormwater management, landscape design, geotechnical engineering, management and maintenance of green areas, biodiversity, use of vegetation and trees and project management.

There were eight experts from the city organisation, three from the company in change of the designing, AFRY Finland Oy and two from the City Blues associated partner Wild Zone which will provide seeds and seedlings of local plant species for the area and guide the planning and restoration of the area. Altogether, there were 13 attendees in the workshop. Their roles and organisations are listed in the Table 3.

Table 3 Participants' roles and organisations.

Role / expertise	**Organisation**
Project manager	City of Tampere, green areas and stormwater
Landscape design	City of Tampere, green areas and stormwater
Stormwater management	City of Tampere, green areas and stormwater
Maintenance of green areas	City of Tampere, maintenance of green areas
Urban trees	City of Tampere, green areas and stormwater
Geotechnical planning	City of Tampere, planning of municipal engineering
Stormwater management, limnology	City of Tampere, green areas and stormwater
Biodiversity, citizen engagement	City of Tampere, climate and environmental policy
Biodiversity, use of native species	Wild Zone
Biodiversity, use of native species	Wild Zone
Project manager, stormwater management	AFRY Finland
Landscape design	AFRY Finland
Stormwater management	AFRY Finland

The 2-hour workshop was held online 5th of March at 12-14 (Figure 26 The design process kick-off meeting was held as an online meeting where e.g. photos were shared.). The agenda included a presentation of the target area, objectives for the design and preliminary ideas for the design. The necessary follow-up measures were also agreed.

The baseline scenarios were not presented at the workshop, as the creation of the scenarios only started after the meeting. The meeting provided good input on which topics to work on. The issue of invasive species came up strongly at the meeting and the consensus emerged from the discussion that special attention should be paid to the eradication of invasive species from the area during planning and implementation. The meeting agreed to organise a field visit in the summer to observe invasive species.

Another issue that came up was the need to replace current bridge that was in a bad shape. Therefore, a separate meeting was held to discuss the replacement of the bridge, so that all the objectives of the pilot could be taken into account. The bridge replacement will be paid for from the city budget but will be done at the same time as the earthworks for the project.

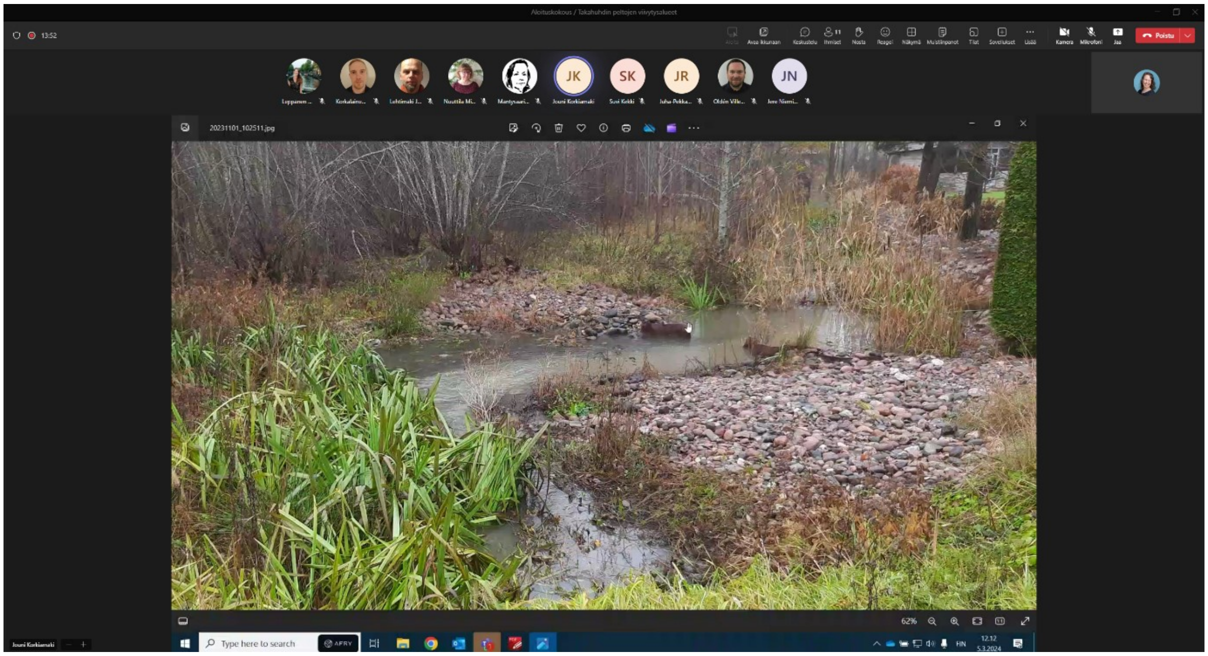


Figure 26 The design process kick-off meeting was held as an online meeting where e.g. photos were shared.

Residents' workshop (19 March 2024)

We organised a workshop to inform the residents and other users of the Varsanpuisto-Huhmarpelto area about coming changes and to gain ideas and wishes from the users. The event was advertised well in advance and 29 people attended, including the organisers and speakers. Some of the participants represented, for example, a residents' association.

A child protection unit run by Sospro Oy is located in the pilot area. We agreed with the Sospro Oy that they would collect comments from the young residents separately, as the association's representative or their young clients could not attend. They will be taken into account in the design process.

After presentations, the participants discussed as a group and marked their observations on the map. The topics were:

- Are there any areas missing on the map where invasive species have been seen?
- Have you noticed any problem areas, such as erosion damage?
- How would you like the vegetation to be placed?
- Where could soil excavated during restoration be placed in the area?
- How else would you like to see the site developed and what other comments would you like to bring to the attention of planners?

Figure 27 Photos from the residents' workshop.

We received 138 comments for the development of the area, as well as experience-based information about the area. For example, we found out that the area is often used by schools and kindergartens in the neighbourhood. One idea was that the area could be signposted with information about the planted species.

Figure 28 Example of a map of the planning area on which participants collected comments.

We also got observations on invasive species and other species, and information on, for example, where there have been flooding problems. Butterfly and bee-friendly species were hoped for the area. Residents also asked for more benches and trash bins.

Comments were sorted into categories: general comments, stormwater, landscape/nature, mobility, landfill and requested items to be added such as benches/dumpsters. The comments were discussed on 21 March between the area planners and city representatives. At the meeting, it was agreed which comments would be taken into account as such, which would be taken forward to other city units, which comments could not be taken into account or implemented, and the reasons for doing so.

The results of the workshop formed a good starting point for further planning and development of our baseline scenarios. Residents have a sense of place and a knowledge of the history of the area. The workshop provided great input for scenario building. Our idea of using native species in planting was highly supported. We also made new observations of invasive species in the area, for example.

Workshop in City's stormwater team meeting (27th March 2024)

Third workshop was an internal event with stormwater experts of the city. Before workshop, we created draft scenarios based on two previous workshops. These were sent to the City’s stormwater team members in advance so that they could familiarise themselves with them beforehand and form an opinion. We discussed the scenarios and comments with the city's stormwater team in a hybrid meeting via MS Teams 27 March from 8.30 to 10.00 a.m.

Five participants were Pekka Heinonen, Juho Korkalainen, Salla Leppänen, Kimmo Mäkinen and Anna Vilhula, all from City’s green areas and stormwater unit. After the workshop the scenarios were finalised. Individual comments and clarifications were taken into account in the scenario texts. The chosen scenarios were considered viable.

Short summary of the learnings how the baseline scenarios assisted the design and planning process

With experts from many different fields contributing to the discussions and developing the baseline scenarios, we were able to consider the issues in depth from several angles. For example, in the process of making the scenarios, we identified the importance of taking into account invasive species in all phases of designing and implementing the solutions. The scenario work made it possible to find out how invasive species will react in the event of severe floods or droughts. We gained new perspectives to support our planning and learned new things at the same time. The results will also be shared with those experts planning the area.

During the process, we became clearer about our own pilot site design objective, as we needed to choose which would be the 3-4 most important objectives. We found that in Tampere both drought and flooding will cause problems in the future. The initial focus of the design was on flood prevention, but this review has allowed us to place a stronger emphasis on drought preparedness in the design process.

It was also good that the residents' meeting was held before the mandatory consultation at the master planning stage. We now have valuable perspectives and local knowledge and observations from residents in good time for planning. Residents also provided good information for writing scenarios.

Residents asked for signposts in the area. An information sign will be erected in the area. The sign can inform users of the changes that have been made to the area and the reasons why. At the same time, the city can explain what it is doing to adapt to climate change and how nature-based solutions can be used to prevent flooding.

During the process, it also came up that climate change is already happening, and warming is already happening in Tampere, too. Solutions are therefore urgent, because the intensity of rainfall will increase in the future, so when it rains, it rains a lot at a time. This will easily cause flooding. It is therefore important to try to prevent flooding through new restoration and nature-based solutions as soon as possible.

Tartu

Introduction to the pilot site

Out of the areas in Tartu historically exposed to pluvial flood risk, the junction of Riga street and Tln-Luhamaa railroad is the most vulnerable, as floods which occur there disrupt public services (ie availability of rescue services, disconnecting public transport etc).

Figure 29 Riga junction before the investment (left). Inundation in Karlova district – the catchment through which the current system is directed (right).

As the junction was not only vulnerable to extreme rain but also exposed to floods in medium precipitation events, then recently the junction was reconstructed, by adding a system combining 715 m derivation pipe and a pumping station allowing to drain the junction. However, the current system that combines pumping into a pipe servicing residential areas has high energy demand (~5 kW pumps) and pumping the large volume of flood from the Riga junction to the upstream stormwater collectors of residential catchment increases significantly the risk of the private properties (Karlova district of historical wooden detached houses and small apartment buildings) being flooded. The current system with the flood derivation pipe and pumping would not succeed to perform in the precipitation events that have been recently occurring in Western Europe (2021) or Italy (2022) and occurrance of which is considered possible according to the climate scenarios of Estonia.

As a next step to solve the problem, a new drain collector is built in 2025 from Kesk-Kaar along the left bank of Sadamaraudtee will be constructed all the way to Tähe street where it will connect to existing rainwater system. The Tartu Water Utility has foreseen that as a next step another stormwater collector would be built in the Sadamaraudtee green corridor. While the first two collector pipes were needed due to elevation (flooded area being located in a lowpoint) then downward from Tähe street is possible to create an open channel that would have other amenities in the green corridor.

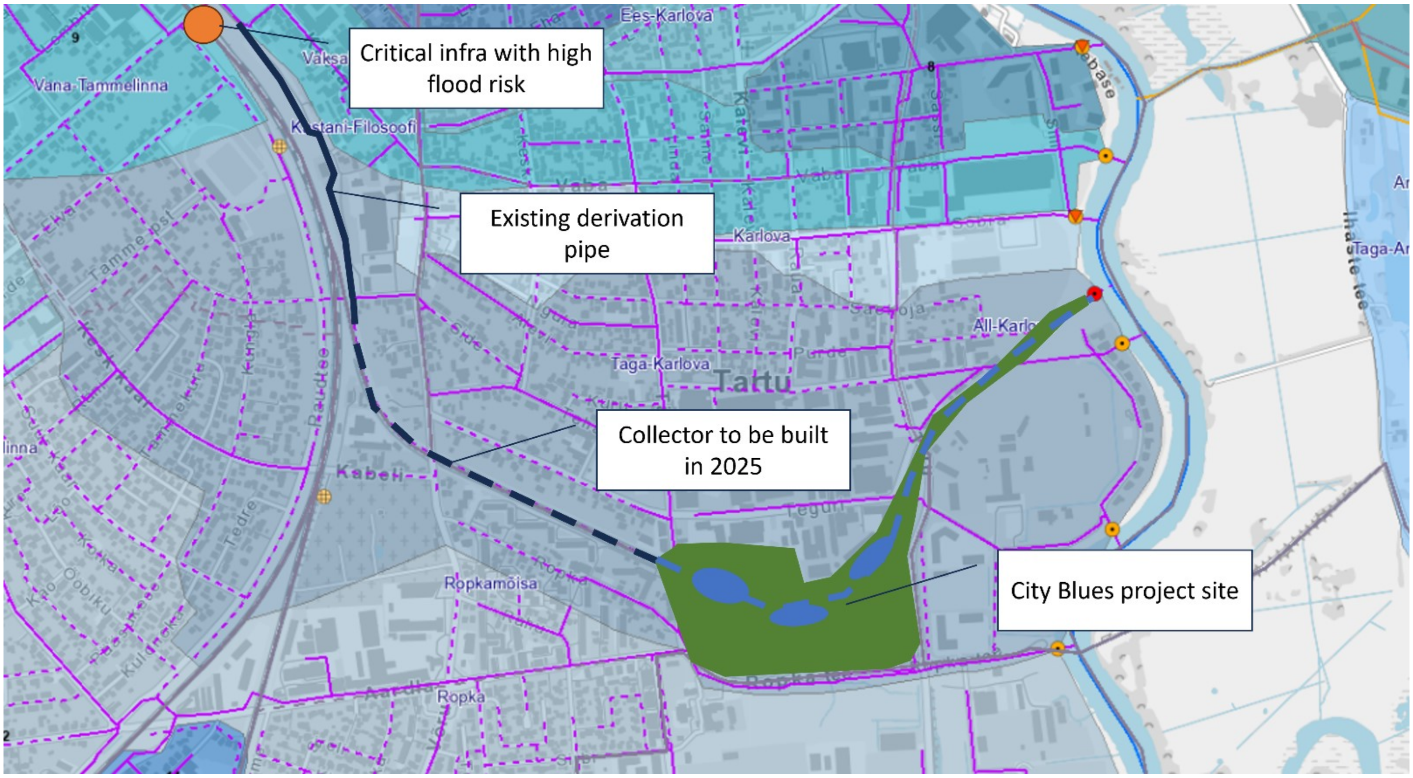


Figure 30 Catchment scale interventions plan Tartu pilot site

Primary and secondary objectives of the intervention

The primary aim is to develop a solution in which the flood derivation pipe is connected to a cascade of nature-based solutions in a green corridor left from abandoned railroad. Along with a system of flood detention system, the distributed system of NBS would also perform as a corridor for biodiversity, when the established NBS would be planted with native species.

The abandoned railroad corridor is also a demonstration site of complementary project urbanLIFEcircles, launched in Sept 2022, in which the restoration of the ecological corridor is aimed in.

Main objective: Significant improvement in ability to cope with heavy rainfall

- Floods (with ponding depth exceeding 15 cm) avoided in the critical junction (100% improvement)
- Reduction of flood risk of private homes (~100 properties)
- Critical infrastructure protected: (6 bus lanes servicing half of city of Tartu from the total of 13 lanes pass through the railroad bridge). This junction is the closest crossing of railroad for the Tartu hospital (alternatives 1,5 km and 3,1 km.

Supporting objective 2: Reduction of experienced temperature during a heatwave

- Public pedestrian corridor in the abandoned railroad corridor has healthy multi-layered native vegetation supporting the pleasant microclimate (peak daily temperatures >2 °C lower from the Riga junction);
- Detention of stormwater for supporting the microclimate during heatwaves;

Objective 3: NBS that are resilient to Boreal urban operational conditions

- The Abandoned railroad flood cascade will support the green corridor of biodiversity of Tartu (co-creation of solutions with freshly launched urbanLIFEcircles project).
- Flood cascade is designed to reduce pollutant stress to Emajõgi (smart quality based control combined with NBS performance capacity: cascading the plant communities with ability to bind different pollutants and cope under different stressors).
- Flood control system which supports urban biodiversity, integration of control parameters for maintaining favourable conditions for amphibians and large invertabrates in the stormwater detention ponds.

Objective 4: Achieving a community involvement in co-creation

- Carrying out community dialogue for co-creating the solution: blending the interests of green corridor improvement and stormwater control and detention and upkeep of the pedestrian moving corridor;
- Participatory processes withr ~100 property owners

Objective 5: Public feeling of being protected against severe climate events: co-creation and awareness efforts on site and at events.

Objective 6: Reduce the carbon footprint of resilience

- The current high-energy demand solution replaced with resilience solution that captures CO_2 > 15 tCO_2e annually [99]

Short description of the baseline scenarios

C) Baseline for balancing the technical goals for Tartu's NBS and performance of UDS

Baseline scenario 1: The area is to be designed with extreme storm and rain water scenarios in mind when at the same time remaining a cycling and walking corridor in the city

- The technical planning and rainwater scenario building have to have the main focus with the area managing bulk of water coming from the planned drain pipe
- Design has to ensure that area is accessible and safe even during most severe rain scenarios.
- The scenario can mean that the area would be severely flooded many times throughout the year. And accessibility of the Sadamaraudee corridor can become risky.
- The scenario may be the most expensive one and project funds may not be enough to achieve all goals

High

ALTERNATIVE XIS: ACCESSIBILITY

Low

Baseline scenario 2: The NBS is planned to serve as a supporting solution to the

- The technical planning of the solutions can take into account the more severe rain events of the year as it is working as a supplementary solution to main rainwater system.
- The man focus is on accessibility and ensuring that Sadamaraudtee corridor remains open throughout the year and can be used as a walking-cycling lane and provide access to the adjacent functions.
- In this scenario the main purpose should be on providing a quality public space and the area to function as a demo and learning site for local people but also city planners and engineers
- It is a possibility that the area should not be accessible on all times of the year. It is to demonstrate that not all technical systems or areas have to function perfectly in extreme weather situations.

Main solution **STRONG AXIS: Solutions's role in rainwater management** **Supplementary solution**

Alternative scenario 3: The are would be designed as a technical solution with no cobenefits in mind.

1) The scenario is based in engineering and technology
2) It would be an good exercise for rainwater retention planning and solution demonstration
3) The scenario would have no redeeming co-benefits

Alternative scenario 4: the area has

1) The solution is low in ambition
2) The realization if the scenario should be avoided at all cost
3) Realization of the scenario would not be a success and would probably give a bad reputation to the term NBS in Estonia

D) Baseline scenarios for balancing hydrological performance with biodiversity

Baseline scenario 1: The area is designed to be biodiverse and drought resilient.

- The most extreme scenario is to have no rainfall in Tartu for around 6-8 months straight (example from may-june 2023).
- To be prepared for the scenario the plantation should be native and drought resilient.
- As droughts usually come with heat and may include short but heavy raindfalls, the plants should be able to withstand the sharp change.
- The area would need regular maintenance as to avoid invasive and quick growing species that might overtake native species when water conditions improve.
- To overcome droughts the area should be able to retain water from short but heavy rainfalls.

Rich

ALTERNATIVE DESIGN AXIS: BIODIVERSITY

Baseline scenario 2: The area is designed to be rich in biodiversity, withstand floods and to retain water and moisture around the year.

- The area is currently not regularly flooded so the construction of the area should create the flooding scenarios to support rainwater management system
- The collection of plants chosen for the area should consist of native wetland cultures.
- The plantation and design of the area should take into account the melting of snow from the streets and all the pollutants from streets and/or find ways to prevent the pollutants reaching the flood area
- The solution can be susceptible to drought or heat waves that are becoming more common in Tartu. The solution has to find a way to retain water and moisture throughout the year.
- This scenario is currently the preferred one, but retaining moisture through the year can be a challenge with Tartu Water Management hinting at artificial irrigation in drought periods

Drought STRONG AXIS: METEO-HYDROLOGICAL PERFORMANCE **Flood**

Baseline scenario 3: area is drought resistant with no emphasis on biodiversity.

- The scenario can be achieved with minimal to little investment and redesign.
- It would be very engineering based and would provide no additional learnings.
- The scenario should be avoided as it provides few to no co-benefits.

Poor

Baseline scenario 4: area is designed to be flood resistant with little emphasis on biodiversity.

- The scenario would be very similar to BLS3 as the solutions would be mostly technical for the NBS to work as part of water management system.
- The scenario would include no planting as the area would be allowed to regrow as it would naturally.
- The risk is of invasive species finding the area and becoming a risk to the neighbouring parks and green areas.

E) Baseline scenario: balancing human attractions with biodiversity

Baseline scenario 1: The area is designed to be with diverse set of attractions for humans with little room or space for greenery and biodiversity. - In this scenario main emphasis would be on creating a NBS with human co-benefits in focus and nature on lower priority. - Plantation would be left on its own devices to populate the pilot area. - Main focus would be on water retention solution that would provide as many leisure activities as possible to the area. - The scenario would probably mean losing some of the wild nature and underdeveloped charm of the Sadamaraudee corridor.	High priority ALTERNATIVE DESIGN AXIS: Human attractions	**Baseline scenario 2**: The area is designed with human attractions in mind with the biodiversity being the attraction - The scenario would aim to create a diverse landscape with rich plantation to attract people with natural beauty - Existing materials (old railroad elements, olde concrete, leftover wood) would be used for designing a wild looking environment - The NBS with flooding and water in mind would be the attraction to visit while - The collection of plants chosen for the area should consist of native wetland cultures. - The plantation and design of the area should take into account the melting of snow from the streets and all the pollutants from streets and/or find ways to prevent the pollutants reaching the flood area
Poor	**STRONG AXIS: Biodiversity**	**Rich**
Baseline scenario 3: The scenario would only focus on water functionality of the pilot area. - The scenario where there is no attention on co-benefits to surrounding citizens or to biodiversity should be avoided at all cost.	Low priority	**Baseline scenario 4**: The priority of the pilot area is to serve water management goals and to boos biodiversity throughout the process - The scenario can be a testbed for water scenarios and urban wetland plantation - The risk is here to create confusion and lose local citizens support when the scenario does not provide any human co-benefits - When going this rout the solutions should make sure that no current functions are lost during the change

Stakeholder workshops

For co-creating the Baseline Scenarios for the Tartu pilot 3 workshops were held:

Biodiversity workshop – 28th of February 2024

Online workshop organized in cooperation with project urbanLIFEcircles partners and with KINO landscape architects to discuss and explore biodiversity goals for the City Blues pilot area. Main ideas floated:

- Creation of urban wetland testbed to determine best native plants suitable for urban flood areas
- Adding trees and bushes to certain areas of the Sadamaraudtee to add different levels of shade to the area

- Possibilities to redirect rainwater from adjacent areas to the Radamaraudtee ditch and plantation and solutions to use to filter the water.

Human centric function workshop – 13th of March 2024

Workshop on location with local citizens and KINO landscape architects to redetermine existing functions, strengths and weaknesses of the current solutions from the human perspective. Also to determine missing functions and possibilities to strengthen the unique location. Main ideas that were determined:

- The railway corridor lacks seating arrangements in certain sections
- Thre are certain sections that lack shade and are in bad need of mid to high greenery
- The corridor is full of material (wood, concrete, old railway elements etc) that can be used to create unique locations along the rout and create new destinations
- There are certain forms in the landscape along the railway that with simple solutions can be turned into unique destinations along the railway

Water management centric workshop – 28th of March 2024

Workshop took place with Tartu Veevärk the Tartu water management company. Learnings are as follows:

- The water management has secured financing to construct drain pipe along the railway rout’s left bank from Väike-Kaar to Tähe street.
- The construction and installation will take place during 2025.
- The City Blues NBS will be situated between Tähe and Turu streets.
- Connection and function to the pipe will be determined according to extreme weather and climate scenarios
- Section between Võru and Tähe street will mainly focus on human centric aspects of the NBS

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