

City Blues pilot in Aarhus

D 2.1 Reports on the implemented watershed pilots

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Table of contents

Table of contents	2
Summary	3
1. Planning of the pilot	5
1.1 General planning	5
KPI's	11
1.2 Detailed planning / Construction design of the pilot	11
Design starting points	11
Design process and timeline	13
Challenges and solutions	14
KPI's	15
Lessons learned:	16
2. Construction phase	16
3. Citizen and stakeholder engagement	17
KPI's	17
4. Risk management	18
Lessons learned:	19
5. Maintenance, monitoring, and retirement plans	21
5.1 Monitoring campaign	22
6. Pilot investments	27
7. Governance model of NBS in Aarhus Municipality	28
7.1 Key Institutional and governance dimensions	28
7.2 Legal building blocks	30

Summary

The City Blues pilot area in Aarhus are located in Nye, a new urban development north of the city. The project focuses on the Ravnbakke and Bueris streams (each about 1.5–1.6 km² with the catchment area) and aims to develop nature-based solutions for stormwater management, biodiversity, and climate adaptation. The pilot projects focuses on watershed-/catchment-based climate adaptation: handling stormwater, erosion, biodiversity, and making water a positive asset in urban development rather than just a risk.

Urban development in Nye (Aarhus N) is a planned and sustainable development of a new district with a focus on nature and community, which is expected to house 15,000-20,000 inhabitants. On 22.06.2016, Aarhus City Council adopted the first local plan for Nye (stage 1). The local plan includes 650 homes of the future city and is the culmination of 10 years of targeted and innovative planning work.

In the new district of Nye near Aarhus, a central, groundbreaking secondary water system has been established that recycles collected rainwater and drainage water for toilet flushing and laundry, which reduces drinking water consumption by approx. 40% and relieves the groundwater. The system directs the rainwater to a treatment plant, where it is treated before being delivered through a separate pipe system to the homes.

The main focus of the City Blues project in Aarhus is to apply nature-based solutions (NBS) in a defined watershed area to make urban water management more resilient, restore streams, improve biodiversity and create attractive living conditions.

The pilot aims to:

- Restore the regulated streams as Bueris Stream and Ravnbakke Stream in the new development area Nye, north of Aarhus.
- It takes a “catchment-based” approach: treating the entire hydrological area (streams, runoff, land use) rather than just individual spots.
- Integrate solutions for flood mitigation, erosion control, water quality improvement *and* enhancing nature and people’s wellbeing via green/blue infrastructure.
- Stakeholder co-creation and planning from early stages is a key component — involving city departments, utilities, developers and local actors.

Collaboration among stakeholders has been active in all phases. Special focus was set on general planning and finding the best solutions during the collaborative meetings. The local resident’s involvement in the process is always informative but in this pilot the involvement of citizens was included in later via social activities and workshops.

In the monitoring phase of the City Blues project in Aarhus (Nye area), efforts focus on tracking how well the implemented nature-based solutions perform environmentally and technically.

City Blues is improving NBS planning in Aarhus by combining science, technology, and community input into a systematic and collaborative framework. It helps the city move from isolated green projects to integrated, catchment-wide, and evidence-based water management embedded in urban development.

In short, City Blues helps Aarhus turn its existing NBS experience into a structured, measurable, and transferable model for sustainable urban water management.

1. Planning of the pilot

1.1 General planning

General planning started with the development of Stage 2 in Nye after the developer started local planning process for the development.

Rainwater management plan has been developed (Regnvandshåndteringsplan (RVHP)- Nye Etape 2.) for Stage 2 in Nye. Rainwater management plan for Stage 2 in Nye, and the related land-zone / discharge / restoration documents indicated that there are several issues that are not clarified for Bueris Stream and Ravnbakke Stream and for the development of rainwater management setup in general for Nye.

Discharge of rainwater from the area proved to be challenging, the challenges explained below.

The planning phase started in May 2024 and finished in June 2025. The construction phase was started after all permissions was approved, in September 2025. Maintenance of the sites continues and there will be complementary planting in 2026.

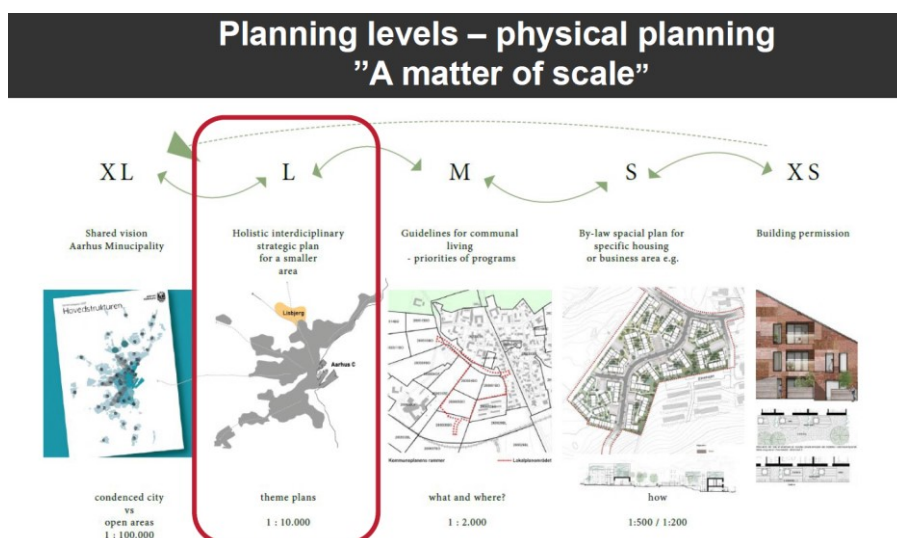
Holistic water management planning

This holistic approach recognizes that effective water governance requires coordination across multiple spatial and organizational levels.

To structure this coordination, planning is divided into five complementary levels from XL (strategic) to XS (building permit) each addressing specific dimensions of the water system while contributing to the municipality's overall climate and sustainability goals.

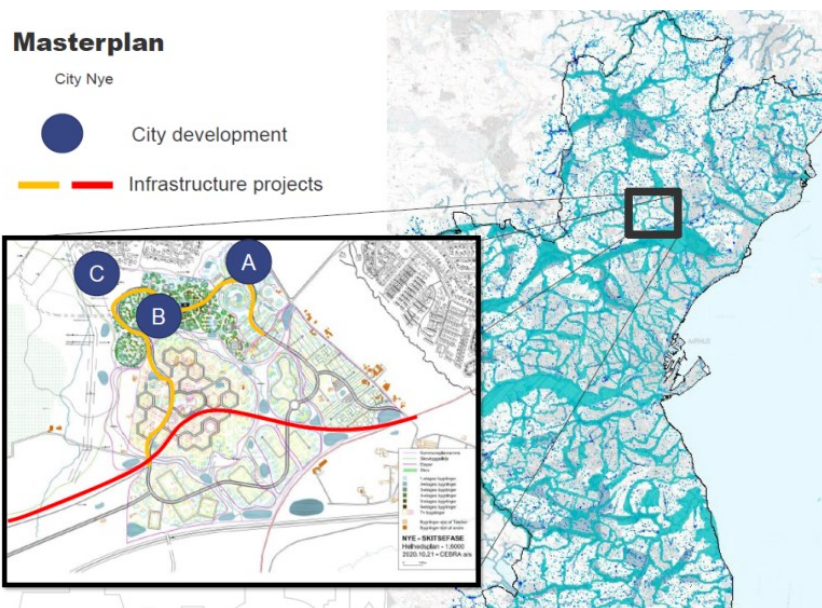
At the XL level, Aarhus sets its long-term vision and policy framework for the entire water cycle. This scale involves city-wide strategies that integrate water management with urban development, climate adaptation, and environmental protection.

Key objectives include safeguarding groundwater resources, separating stormwater and wastewater systems, managing flood risk, and ensuring sustainable urban growth.



Policies and investments at this level are typically aligned with initiatives such as *Water Vision 2100*, which outlines how Aarhus aims to become a climate-resilient and resource-efficient water city.

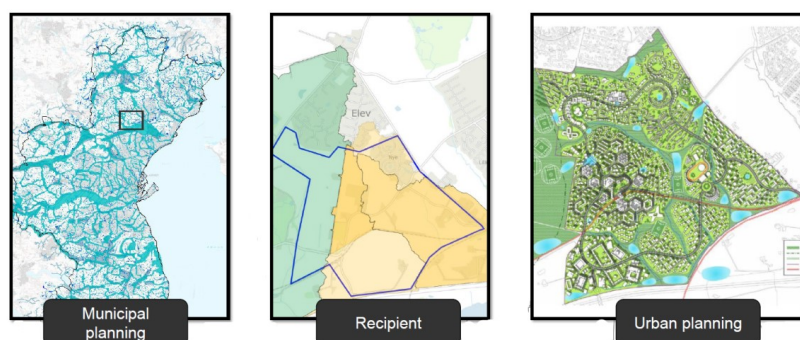
Focus here is on vision, governance, regulation, and investment priorities for the whole municipality.



Aarhus Master plans on Urban Catchment scale purpose are to ensure holistic planning for stormwater coordination with the city, ensure the areal dispositions for stormwater, coordination of municipal disciplines & city development and connection of planning chains.

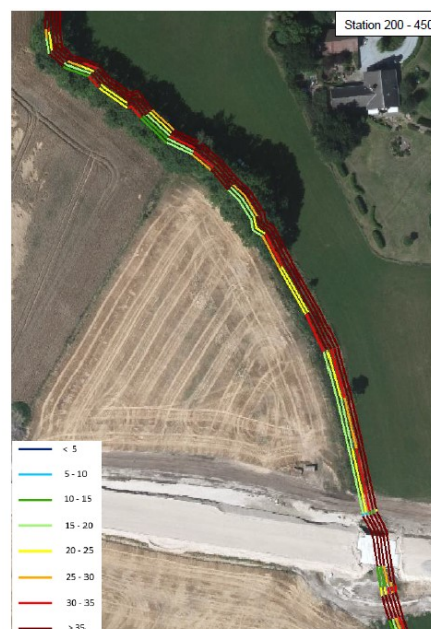
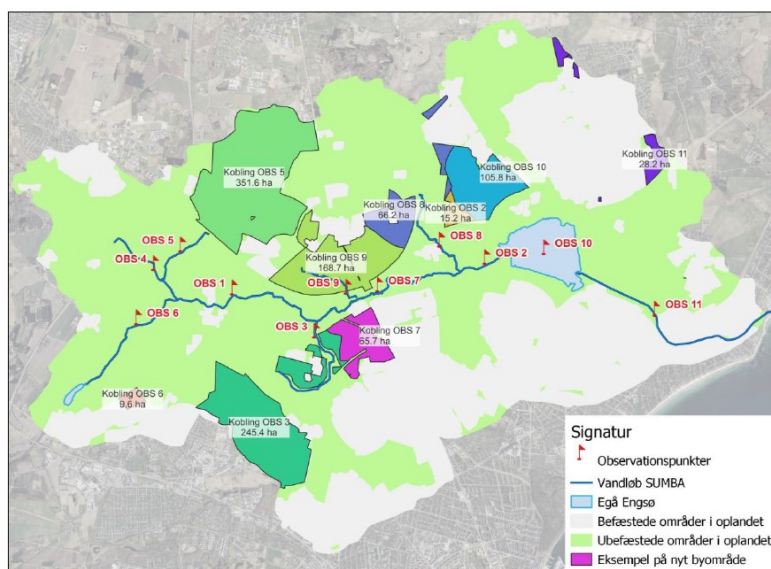
The L level translates strategic visions into spatially defined actions within river catchments, valleys, and coastal zones. Here, planning focuses on balancing natural hydrological processes with urban development, using green-blue infrastructure such as wetlands, retention basins, and infiltration zones. This scale ensures that rainwater, groundwater, and surface water are managed collectively to prevent flooding, improve water quality, and maintain ecological health -> stormwater masterplan. Focus here is on spatial integration of water and land use, stormwater management and retention capacity.

Stormwater Masterplan Framework & Prerequisites



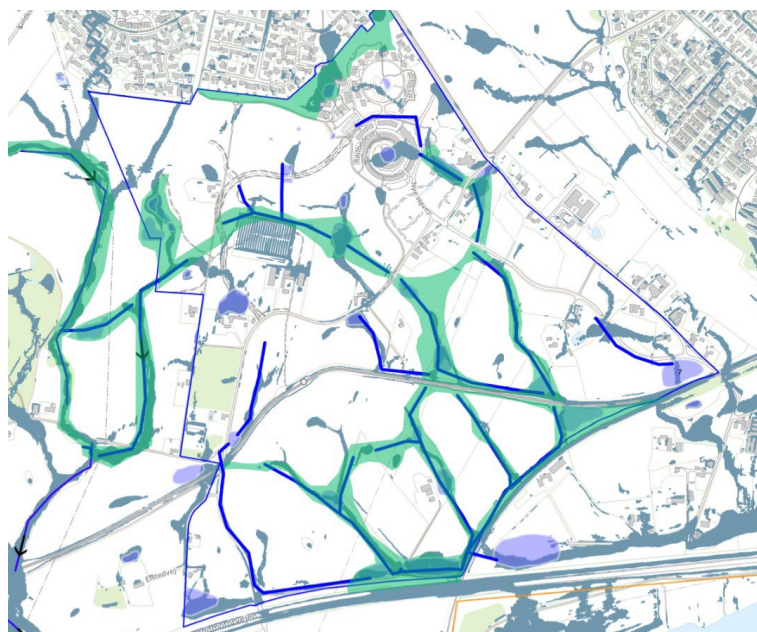
The vulnerability and catchment analyses have been carried out for Egå River and tributaries – Ravnbakke and Bueris streams. The vulnerability analysis for watercourses assesses how vulnerable a watercourse is to, for example, pollution, climate change or changes in water discharge. The analysis often involves both a hazard analysis (where and how flooding occurs) and a vulnerability analysis that looks at both tangible and intangible damage in each area. The results are used to assess the hydraulic capacity of the watercourse and form the basis for risk management plans. It is becoming quite common/widespread in Danish municipalities. Authorities use the analyses to assess whether they can grant permission for discharges without it leading to flooding, assess to ensure that a discharge does not lead to more frequent or larger flooding than natural or catchment based analyse to understand the catchment area of the watercourse, including groundwater and surface water, that is important in order to assess how changes in the catchment area affect the watercourse.

The Nature Department in Aarhus Municipality ensures that local plans manage water responsibly by assessing environmental impacts, requiring rainwater management plans, issuing water-related permits, and safeguarding nature and groundwater resources including effects on watercourses, groundwater, wetlands, and protected nature areas (§3, Natura 2000).



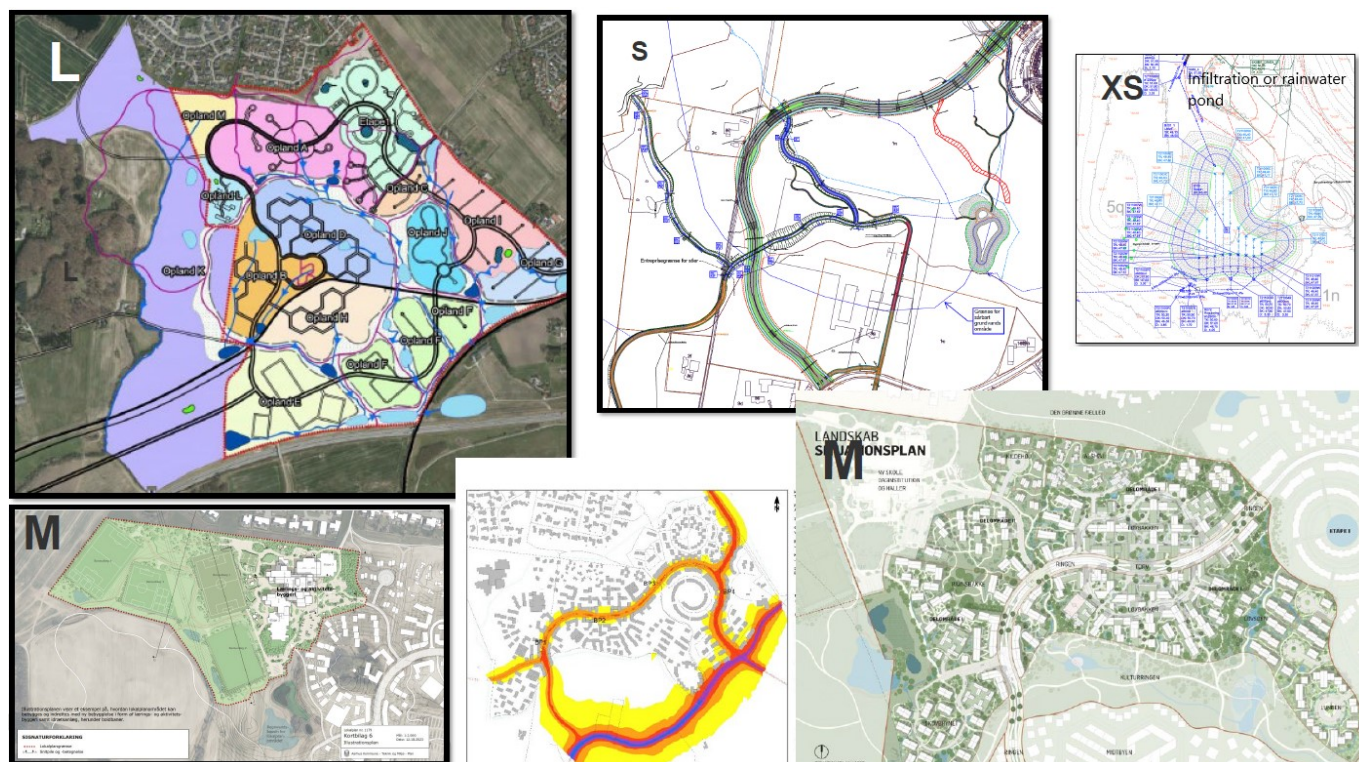
Figur 6 B. Kort med beregnet streampower i en vintersituation, hvor linjen til venstre afspejler baggrundsafstrømningen (referencen 0,88 l/s/ha) og de øvrige linjer fra venstre mod højre udledningsveauer på hhv. 1 l/s/ha, 2 l/s/ha, 3 l/s/ha og 4 l/s/ha.

Figures show the whole catchment based analyse (Egå catchment) with paved areas (grey), unpaved (green), new development area (pink), lake and streams (blue), Bueris and Ravnbakke streams are tributaries. The right figure shows a stream stretch in Bueris stream in vulnerability analyses. The red and dark red markings show very high stream power where the expected erosion and flooding can appear.



In Aarhus flood mapping has become a cornerstone of stormwater management and climate adaptation planning. One critical design parameter is the surface flow flux during extreme rainfall — often evaluated for the 100-year rain event. Locations where the specific flux exceeds 25 L/s per metre of flow path are considered high-risk and require targeted mitigation. We used MIKE 21 (often coupled with MIKE URBAN/MIKE+) as the main 2D model for flood mapping and stormwater management. It underpins the design criteria (including the 25 L/s/m flux threshold) and the city's climate-adaptation planning.

We achieved detailed overarching plan of holistic stormwater management, placement of blue-green corridors to transport stormwater and increase accessibility.



At the **M-level**, planning becomes local and project-based (Nye fase 2). This includes new developments, urban renewal areas, and demonstration projects where the integration of water solutions is part of the urban design.

Measures include rainwater harvesting, permeable pavements, green roofs, and on-site infiltration. Aarhus involves citizens here and local stakeholders at this scale, as seen in this pilot, where citizens/residents are normally informed about the designing local stormwater solutions in existing areas. It is a new residential area so the residents involvement is not really so actual in this projects but more stakeholders, NGO and developer involvement.

The pilot is currently in M-level so that with water stream restoration we can secure the development on S and XS -levels.

The **S-level** focuses on the technical and operational aspects of Aarhus' water system forming water supply and wastewater networks to treatment plants and digital monitoring systems. Aarhus Vand, the city's water utility, plays a key role at this level, ensuring efficient service delivery through leak reduction, energy recovery, and real-time system control. These operational measures directly support the higher-level goals of sustainability and resilience. At the **XS-level**, the focus shifts to individual buildings and households the smallest but equally important unit in the holistic water cycle.

Together, these levels form a coherent, multi-scale planning system that bridges policy, environment, infrastructure, and community engagement ensuring that Aarhus remains at the forefront of water-smart, climate-adaptive urban management.

In this particular case following issues were pointed as outcome of analyses and surveys:

Issues that specifically affect Bueris stream:

1. **Large change in runoff from development increased flows to Bueris stream.**

The documents note that the area is under heavy development (Nye stages) and that this will substantially change runoff patterns and increase loads to Bueris stream. This creates higher peak discharges that the existing narrow channelized and culverted stretch network must accept.

2. **Partly culverted / undersized culverted sections and local collapse.**

Bueris stream currently has sections that are partly piped and some pipes (e.g. Ø200 mm, Ø300–500 mm) are described as under dimensioned for future flows; photos and inspection notes report collapsed culverted reaches causing diffuse leakage and local instability. Those bottlenecks cause backwater, local flooding and groundwater/drain interaction.

3. **Risk to adjacent infrastructure (light rail embankment).**

There are documented problems with high water levels/stagnation adjacent to the light-rail alignment and previous issues of water backing up against the track. The plan highlights the need to avoid future undermining of the rail embankment and flooding.

4. **Agricultural drain inputs and diffuse pollution.**

The catchment currently receives substantial drainage from cultivated fields (many tile-drain outlets were identified). That increases volume and potential pollutant loads (nutrients, sediment) into the stream which complicates ecological targets downstream (Egå River system / Lake Egå Engsø).



Issues that specifically affect Ravnbakke Stream:

1. High ecological goals — sensitive recipient.

Ravnbakke Stream is having high ecological goals (Danish Stream Fauna Index -DVFI 7 and high quality measured by fyto-benthos) according to Danish Water Management Plans. Any discharge must therefore meet high water-quality and temperature/oxygen demands; these constraints allowed discharge rates and treatment. The plan stresses careful measures to avoid degrading the recipient.

2. Design reliance on filtration ponds in OSD (drinking-water protection) areas.

The chosen concept (infiltration pond with filter-soil + oxygenation steps) sits inside/adjacent to areas with drinking water protection area (OSD). That triggers requirements (e.g., tight pond bottom, prevention of uncontrolled infiltration to groundwater) and complicates ponds design/operation. The plan indicates this as a constraint and a potential issue if not executed exactly as required.

3. Local topography and excavation depth — disturbance risk and large soil moving works.

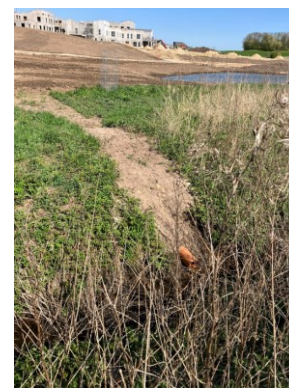
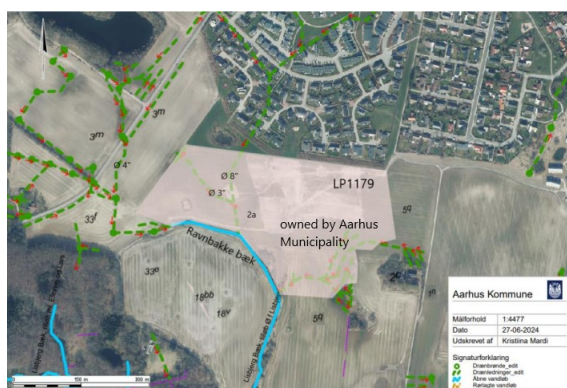
Filtration ponds require significant excavation (1–2 m in places) and modification of terrain; the plan notes risk of disturbing soils, affecting nearby land uses, and generating construction-period runoff/erosion if not properly managed.

4. Need for tight operational controls and maintenance to protect the high-status stream.

Because the filtration pond will temporarily store and then discharge to a high-status stream, the documents stress low allowable release rates and installation of pre-treatment (sedimentation pond, filter-soil) and oxygenation features — all of which require robust maintenance commitments (and monitoring) or else the stream could be harmed.

5. Large population of Giant Hogweed

The removal of Giant hogweed during the river restoration involves a strategy combining physical removal - excavation (Aarhus Municipality is not using chemical treatment), all while taking extreme safety precautions due to its toxic sap. In some cases, digging out the plant and its root can be part of the process, particularly on development sites. Care must be taken to remove the top layer of soil, as seeds are concentrated there. The top layer soil can be buried up to 2 m deep hole or covered by up to 2 m seed-free soil.



Figures show overview of Ravnbakke stream, giant hogweed populations along the stream and drained newly established public school in Nye. There is a filtration pond on right photo that harvest the drainage water from the school's football fields that ensures slow and continuous drainage and rainwater outflow to the stream to prevent stream to dry out in summer.

KPI's

Key Performance Indicators (KPIs) were defined for the Aarhus pilot within the City Blues project.

These KPIs are part of a shared framework Joint Operational Model (JOM), which all partner cities use to measure and compare the effectiveness of their nature-based solutions (NBS). Aarhus' KPIs were developed specifically for the Nye catchment area (Ravnbakke and Bueris streams) to track how well the project meets environmental, technical, and social goals.

Normally Aarhus Municipality is not used to define KPI's in development process. Aarhus was chosen for the City Blues project because it already has strong experience developing nature-based solutions (NBS) for stormwater, biodiversity, and urban planning. The city's existing projects like in Nye provide a solid foundation for testing new methods. Through City Blues, Aarhus is now:

- Systematizing its NBS work using catchment-based planning and KPIs,
- Monitoring environmental and social effects more precisely, and
- Sharing knowledge with other cities in the Baltic Sea Region.

1.2 Detailed planning / Construction design of the pilot

Design starting points

After pointing out issues in the rainwater management plan for the area Aarhus Municipality's working group (authority for water bodies, authority for rainwater management, planners and nature authority) carried out several meetings with the developer, developers' consultants and main stakeholder as Aarhus Water utility (Aarhus Vand A/S).

Surveys

The streams were inspected several times, and the stream survey was carried out for both streams. In Denmark municipalities use a unique software product (VASP), which has been used by stream/river professionals for more than 30 years. Streams and rivers management includes many things to ensure their protection, the drainage of agricultural areas, the improvement of physical habitat by restoration, the handling of floods, etc. This work often includes stream channel calculations to assess the consequences of water levels and risk of flooding. The basis for calculations requires relevant data, i.e. description of cross-sections from surveys, hydrometric data (statistical data for runoff), etc. VASP has a unique design and structure to organize/collect all kinds of relevant data in a database. Moreover, VASP has extensive possibilities to visualize results on longitudinal and cross-sectional profiles as well as a GIS platform to convey results in an easily understandable way.

SCALGO Live a web-based platform for surface water planning that uses advanced algorithms to perform large-scale hydrological analyses was used to construction design for streams. Scalgo allows to explore terrain, analyze flood risk, and design sustainable water-related solutions with high-resolution elevation data and instant simulations, even for entire countries. The platform is used by engineers, urban planners, and landscape architects for projects like city and infrastructure planning, nature restoration, and coastal management.

The conceptual design for river restoration was developed by Aarhus Municipality's stream/river professionals.

River restoration design and stream quality

Designing a river restoration project in Denmark involves a structured and science-based approach aimed at improving the ecological, hydrological, and geomorphological functions of rivers while balancing agricultural, flood control, and recreational needs we carry out the preliminary investigation. River restoration aims to re-establish natural river processes, improve habitats, enhance water quality, and meet the EU Water Framework Directive goals for good ecological status.

The design process typically includes five phases: preliminary investigation, concept design, detailed design, implementation, and monitoring.

Preliminary investigations for Bueris and Ravnbakke streams was carried out during 2023-2024 by Aarhus Municipality.

The preliminary investigation is the foundation of the project, and it gives the Understand existing conditions as hydrology, morphology, physical conditions and ecology. It Identify constraints and opportunities – land use, infrastructure, and environmental protection areas and landowners involved.

The investigation is based on baseline data for future monitoring but normally it is needed to collect supplementary data due to lack of data or data is old, and to give a better overview og ecological and chemical water quality status in the water bodies.

The preliminary investigation also assesses feasibility and costs to ensure sustainable and practical solutions. The overview of landowners and stakeholders involved gives the possibility to engage stakeholders, developers, landowners, municipalities, and local communities early in the process.

The investigation report forms the basis and information for permits under Watercourses Act.

The Bueris stream is not yet been included under the Water Framework directive (Danish Water Management Plan 2021-2027) but is defined as waterbody with good potential.

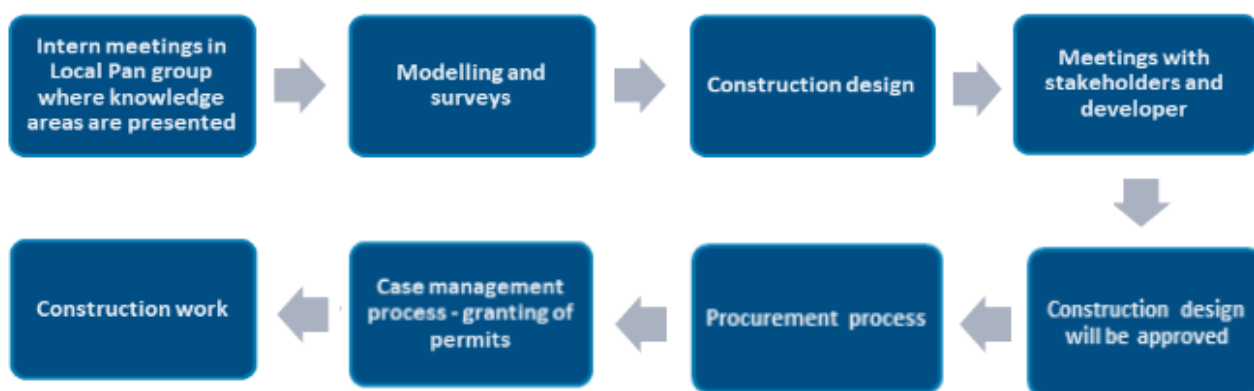
The Ravnbakke stream is defined Danish Water Management Plan 2021-2027 and has been set with goal: good ecological and chemical quality. The stream already has a very good quality on downstream stretches and expected to achieve the goal after restoration and re-opening.

The example of the permit granted to Bueris steam sees here: [Tilladelse til vandløbsrestaurering i Bueris Bæk](#), this document includes also detailed project description for restoration work.

The example of the permit granted to Ravnsbakke steam sees here: [Tilladelse efter vandløbsloven til restaurering af Ravnsbakke Bæk](#), this document includes also detailed project description for restoration work.

Design process and timeline

The planning for Construction work for Bueris and Ravnsbakke stream took place between December 2023 and May 2025. Modelling results were finished in March and the modelling process started already during general planning of Løvholmen local plan.



Update from december 2024 – Concept design for restoration of Bueris Bæk



Challenges and solutions

Challenge	Solution
Bottle-neck area under the Djursland highway – Ø300 mm pipe in Bueris Stream. Case-management process where both BaneDanmark (the owner of the railway infrastructure in Denmark) and Danish Road Directorate have been heard expressed their worries of flooding risks from the future development.	Ongoing work in Bueris stream includes increasing hydraulic capacity under infrastructure (notably the Djursland Highway crossing) and adjustments to connected drainage so the stream can safely receive more controlled runoff from Nye. These upgrades are needed so restored stretches are not overwhelmed during high flows. There has been set up meetings and collaboration with BaneDanmark (the owner of the railway infrastructure in Denmark) regarding construction work and issues regarding construction nearby their restricted safety zones. There has been set up meetings with the developer to find the solutions to eventually design the extra retention area for storm water (buffer area) eventually before Djursland Highway to delay water before the road underpass.
Big colonies of Gigant Hogweed (invasive species) were detected along the Ravnbakke stream.	We organised a separate site visit in the field, and we worked out a plan how we handle the species during the construction work. In the guidelines for the construction phase, special attention is paid to ensuring that vegetation was suppressed and prevented from spreading.

Drought Risk- Urban development can significantly alter natural hydrological cycles, increasing the risk of both flooding and drought. During dry spells, the same modifications that accelerate runoff and reduce infiltration such as paved surfaces and compacted soils but also limit groundwater recharge. As a result, water levels in nearby streams can drop rapidly. This is particularly concerning in small catchments like those of the Ravnbakke and Bueris streams, which cover just 1.5 and 1.6 square kilometres respectively. Their limited size and storage capacity make them especially vulnerable to extremes, with prolonged dry periods leading to reduced streamflow, degraded water quality, and stress on aquatic habitats. Addressing these challenges requires integrated urban water management that balances development with the preservation of natural infiltration and storage processes.

There is designed the filtration pond to collect the rainwater from roofs, paved surfaces. The infiltration ensures continuous water supply to the waterstream and discharge via an aeration ladder - discharge occurs trickling over stone-covered outlets to watercourses. The drainage water from the new school and drainage water from the football fields are collected in small filtration ponds so that we can secure continuous water flow to Ravnbakke stream. In this way we believe that we can always secure some water flow in the stream so that we can achieve the goal – good ecological status in Ravnbakke stream.

In Nye, surface water from roofs, roads and green areas is collected and treated in a central “secondary water” system for reuse (e.g., toilet flush, laundry) — reducing groundwater extraction. This helps relieve pressure on groundwater and on local flows, potentially benefiting the stream.

By reducing groundwater extraction (via reuse of rainwater) there is less competition for base-flow sources feeding the stream, meaning more water remains to sustain it.

Capturing and managing surface water and designing the outflow to feed the stream from rainwater basins can help sustain flow during drier periods or at least maintain ecological connectivity.

The plan includes infrastructure to regulate outflow into the stream (e.g., basins, controlled discharge) which means even when rainfall is low, what system there is can be managed to support the stream rather than having uncontrolled drainage or none.

The issue is still not completely solved yet, because we try this first time and future monitoring will give clear picture if the issue is solved or it needs more modelling or research to be done.

KPI's

- The construction design is completed within the specified time frame.
- Recommendations for future NBS

Lessons learned:

- The sites are always unique, each with their own specific challenges, and the work is shaped accordingly.
- The stakeholder and landowner involvement relevant during the public hearing process important and time-consuming. Many of details can be solved here and particularly when you have the detail project. We already have good experience of carrying out comprehensive NBS-solutions and we know to proceed in this process plan.
- Be aware of unexpected issues that can appear and prepare time for that. We have learned that the preliminary investigation and good baseline based on good data material for NBS solutions is very valuable.

2. Construction phase

The construction of the pilot project are ongoing and the description will come later after the construction phase is finished in the end of February 2026.

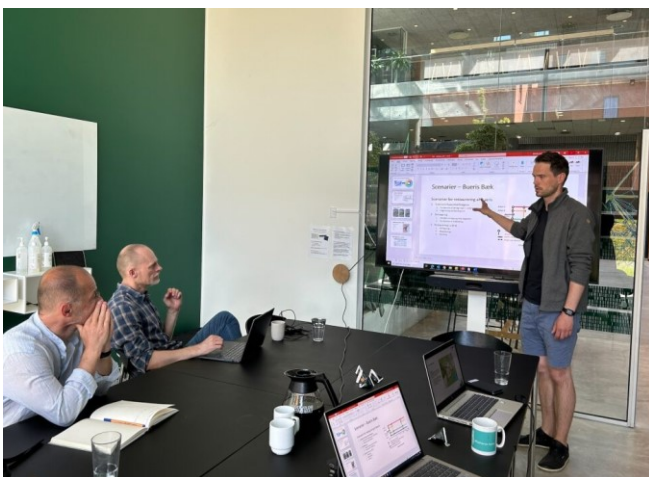
3. Citizen and stakeholder engagement

In this project there are not many stakeholders involved. Developer, Aarhus Water Utility (Aarhus Vand A/S), BaneDanmark (the owner of the railway infrastructure in Denmark) and Danish Road Directorate are the main stakeholders.

Citizens will be included later in this process when the recreational ideas are shared, and blue-green connections will be developed. There has been planned for citizens' involvement and activities. The citizens engagement will take place after the construction work and there is a plan for when Aarhus Municipality will arrange the river restoration day. Citizens will be informed of the preliminary recreational plan and ideas for their residential area and they have possibility to supplement or improve the plan with their ideas. Together with the citizens Aarhus Municipality will establish spawning areas for trout and new habitats for macroinvertebrates in Ravnbakke Stream.

KPI's

- The works have been implemented in accordance with the plan and/or agreement.
- Stakeholder feedback during construction



4. Risk management

Aarhus pilot focuses on construction rather than planning. Normally we are not or we are not use to carry out risk management in construction phase.

Aarhus has a long history of modelling various climate related hazards as coastal flooding due to sea-level rise and storm events as well as pluvial flooding from heavy rainfall and cloudburst.

In City Blues Aarhus Municipality tried to carry out the risks or issues in rainwater management plan that was obvious for further development.

General issues for local plan (level- L) for Løvholmen (Nye, Stage 2) rainwater management plan (RVHP):

1. **Capacity / dimensioning vs future climate and full build-out uncertainty.**

The RVHP and application repeatedly reference design storms (T05, T10, etc.) and set discharge limits for rainwater harvesting ponds (example: T05 outlet 1.6 l/s ha, T10 4.7 l/s ha for one pond). The documents also note that future stages of development and climate uncertainty make it challenging for existing culverted stretches in streams and proposed rainwater harvesting ponds will suffice without adaptive measures.

2. **Complex ownership & operation model (private drainage system + private rainwater guild¹).**

Several documents state that parts of the drainage are to be privately operated by the developer (e.g., Tækker Group). That creates a governance risk: if private maintenance fails, the municipal recipient and downstream landowners could experience impacts. The plan flags the need for clear maintenance obligations.

3. **Potential conflict with drinking-water protection and natureprotection areas / buffer requirements.**

Some basin placements and works lie near protected areas or within zones subject to nature protection/forestry buffer rules; this triggers specific mitigation/permit needs and limits certain design choices (e.g., infiltration vs. sealed ponds). The plan highlights the necessity of additional permits and restrictions.

4. **Construction-phase risks (sediment, temporary discharges and soil works).**

Large amounts of excavation and temporary construction areas are planned — the documents note the need for construction-period sediment/erosion control and temporary handling of runoff to avoid harming streams.

¹ **Establishment of joint private rainwater guild** - this is typically done in connection with new subdivisions and in areas where there is to be a separation of wastewater and rainwater. Instead of the water utility being responsible for the operation and maintenance of, for example, a rainwater pond, it is the private landowners who are responsible for bearing the costs of this. Shared private rainwater systems are operated, like common private wastewater systems, by rainwater guilds. The establishment of a rainwater guild can be done at the request of a private person, or it can be decided by the municipal council for newly subdivided areas where a wastewater supply has not yet been established.

5. Hydraulic bottlenecks where existing culverts/passages under infrastructure are limited.

Several crossings (under Grenåbanen – light rail, Djurslands Highway, etc.) and existing culverts are pointed out as critical bottlenecks that either are undersized or in poor condition — these are pinch points for flooding and for ecological improvements. Streams in general are small, narrow and under the risk of erosion.

Lessons learned:

We have learned that risk management analysis ensures that this pilot area is safe, reliable, and adaptable addressing uncertainties related to water quantity, quality, system performance, and social acceptance.

For further we have learned that it is useful to :

- **Define risk categories:**

Category	Description	Examples in Nye context
Hydrological risks	Extreme rainfall, droughts, groundwater rise	Overflow of retention ponds, local flooding, reduced infiltration capacity
Technical risks	System design, construction, or maintenance failures	Clogging of infiltration basins, malfunction of sensors, sediment buildup
Environmental risks	Impacts on water quality and ecosystems	Nutrient loading in ponds, algal blooms, contamination from urban runoff
Socio-economic risks	Public perception, user behaviour, investment gaps	Residents' resistance to open water, funding delays, unclear responsibilities
Regulatory/institutional risks	Misalignment between stakeholders or regulations	Gaps between municipal, utility, and developer plans
Operational risks	Day-to-day management issues	Insufficient maintenance, unclear ownership, lack of emergency protocols

Category	Description	Typical Risks in Stream Restoration
Hydrological Risks	Changes in water levels, flow velocity, flood patterns	Unintended flooding of nearby land, erosion, sediment transport imbalance
Geomorphological Risks	Instability of new riverbanks or bed structure	Bank collapse, sediment deposition in wrong areas
Ecological Risks	Failure to achieve habitat or biodiversity goals	Poor establishment of vegetation, loss of fish or macroinvertebrate habitats
Water Quality Risks	Pollution or nutrient release during or after works	Disturbance of contaminated sediments, nutrient leaching from adjacent fields
Technical/Construction Risks	Design or execution errors during restoration	Poor compaction, incorrect slopes, structural failure of weirs or culverts
Socio-economic Risks	Landowner opposition, conflicts, public dissatisfaction	Reduced land usability, loss of private land, visual impacts
Regulatory/Institutional Risks	Coordination or compliance gaps	Delays due to permits, unclear maintenance responsibilities
Operational Risks	Long-term maintenance and monitoring failures	Vegetation overgrowth, lack of inspections, silting of restored channels

- **Use Risk Management Process**

Use stakeholder workshops (Aarhus Vand, Aarhus Municipality, developers, citizens). Map physical risks using hydrological modelling (e.g., rainfall-runoff simulations). Identify social and institutional risks through interviews and past project reviews. Prioritize risks with high impact on safety, function, or long-term viability (e.g., pond overflow, infiltration failure).

Develop preventive and adaptive strategies:

Risk	Mitigation Strategy
Flooding due to heavy rain	Design overflow routes, increase retention volume, use flexible pond operation
Sediment clogging	Implement maintenance plan, design pre-settlement basins
Water quality degradation	Add vegetation zones, filter strips, and regular water-quality monitoring
Public resistance	Co-design processes, information campaigns, visible co-benefits (recreation, biodiversity)
Regulatory gaps	Clarify roles between Aarhus Vand, municipality, and developers early in planning

For the restoration to be successful, it must be not only sustainable but also safe, robust, and accepted by the community.

By combining technical design, stakeholder engagement, and continuous monitoring, Aarhus can transform Nye into a model district for climate-adaptive urban water management by setting the standard for future developments across the municipality.

A structured risk management plan for the restoration of Bueris and Ravnbakke streams safeguards both natural and human systems. By integrating hydrological modelling, ecological monitoring, and stakeholder participation, Aarhus can ensure in the future that restoration achieves its ecological, hydraulic, and social objectives, which turning these streams into resilient, multifunctional corridors that enhance biodiversity, manage floods, and enrich local landscapes.

5. Maintenance, monitoring, and retirement plans

The maintenance of NBS in Aarhus is generally integrated in the standard routines for managing green areas, water courses that are administratively under the municipal maintenance task or rain or stormwater solutions

that are Aarhus Water utility (Aarhus Vand A/S) responsibility. Many NBS solutions established on the private land are managed by private owners unless otherwise agreed. The table below shows some examples:

Type of NBS	Typical Owner	Responsible for Maintenance	Notes
Public rain gardens / bioswales	Municipality	Dept.of Nature and Environment	Aesthetic + vegetation maintenance
Stormwater basins / infiltration systems	Water utility	Utility (e.g., Aarhus Vand)	Hydraulic function
Green roofs / private rain gardens	Private owner	Private owner	Maintenance by owner
Restored streams / wetlands in climate adaption projects	Shared (municipality + utility)	Shared by agreement	Often part of “climate adaptation” projects
Streams/ivers	Private	Private or Municipality	According to admin. agreement

Municipalities are typically responsible for publicly owned nature-based solutions, such as green corridors, parks, and wetlands in public spaces, urban trees and bioswales along roads or in public squares. Governed by the *Environmental Protection Act (Miljøbeskyttelsesloven)* and the *Water Sector Act (Vandsektorloven)* maintenance duties often fall under the municipal Technical and Environmental Administration. Municipalities also coordinate with utilities on combined rainwater and wastewater separation projects.

If a nature-based solution is built on private land (e.g., green roofs, private rain gardens, retention basins on residential developments), the landowner or homeowners’ association is responsible for maintenance.

Private developers as Tækker Group in Nye maintain NBS during construction and early operation phases, then hand over responsibility to the municipality (municipality owned /public), to a homeowners’ association, and water utility (if part of the public drainage network).

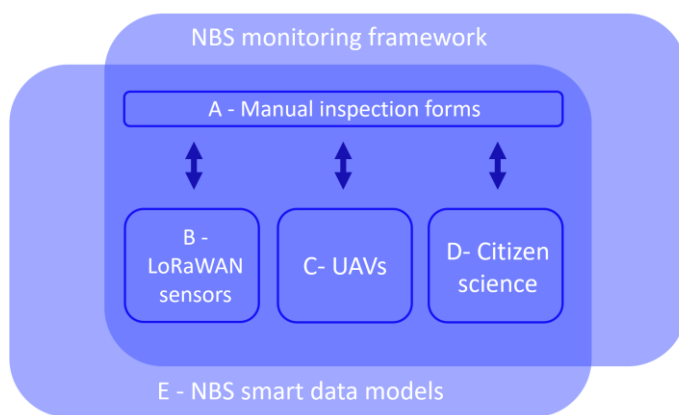
As a part of the City Blues the maintenance plan for NBS solutions will be developed.

5.1 Monitoring campaign

With the growing implementation of NBS, effective and adequate maintenance is becoming increasingly critical for municipalities in order to ensure the long-term functionality of distributed NBS systems, while keeping costs manageable. This is relatively uncharted territory for many municipalities, as their efforts have primarily focused on planning and deployment. Within the project, the consortium will develop and test a series of approaches for NBS monitoring and condition assessment. While condition assessment is well defined for linear assets, it remains a somewhat vague concept for NBS. In this case study, condition assessment involves evaluating the performance, functionality, and failure modes of NBS. The results can be used to define appropriate maintenance measures.

As a part of the pilot, Aarhus Municipality has collaborated with the City Blues partner KWB (Kompetenzzentrum Wasser Berlin) and Aarhus Vand to test the innovative monitoring approaches at selected study sites.

Ultimately, this study aims to enhance condition assessment and optimize maintenance planning for NBS on a citywide scale. Figure below provides an overview of the planned monitoring approaches. The manual inspection forms are intended to serve as a standard approach and act as the reference, for comparison with the other monitoring approaches (LoRaWAN sensors, Citizens Science). The different approaches are planned to be embedded in two overarching frameworks. The NBS Smart Data Model plays an overarching role, integrating the data into a unified framework. The monitoring framework aims to provide clear guidance on these approaches, allowing interested municipalities to implement them effectively within their own contexts.



Graphical abstract of WP2 - in City Blues

In Aarhus a monitoring campaign that includes manual inspection forms and LoRaWAN sensors will be conducted. In the monitoring campaign we would like to include the research questions, pilot areas, monitoring approaches and data management.

The research questions are as follows:

LoRaWAN sensors:

- How effective are LoRaWAN sensors in detecting specific failure modes of NBS compared to manual inspection?
- Can LoRaWAN sensors detect clogging of infiltration measures at an early stage?
- Can LoRaWAN sensors detect clogging of in- and outflows of basins/artificial water bodies?
- Can the surrounding infiltration measures be extrapolated from a single monitored infiltration measure?

Study approach (detailed) ->

- Build a SWMM model (surface runoff, stormwater system) based on open data
- Calibrate model with given data (weather station, water level)
- Model the amount of stormwater flowing into the infiltration/retention basin
- Calculate time for infiltration per rain event
- Build soil hydraulic model
- Compare to LoRaWAN measurement

In Aarhus, two different pilot sites have been identified for a possible measurement programme. In both areas, infiltration and retention systems are operated by the City of Aarhus and the utility company Aarhus Vand to manage rainwater and protect receiving surface waters (streams).

In Trige, the functionality of two identical filtration pond will be monitored using LoRaWAN sensors. The aim is to detect malfunctions at an early stage and trigger maintenance measures. These study sites are not located in Nye -City Blues pilot sites but close to the Nye where similar conditions appear and same type of NBS are currently established in Nye so it was not possible to use local ponds in this monitoring program.

LoRaWAN sensors – Pilot area Aarhus

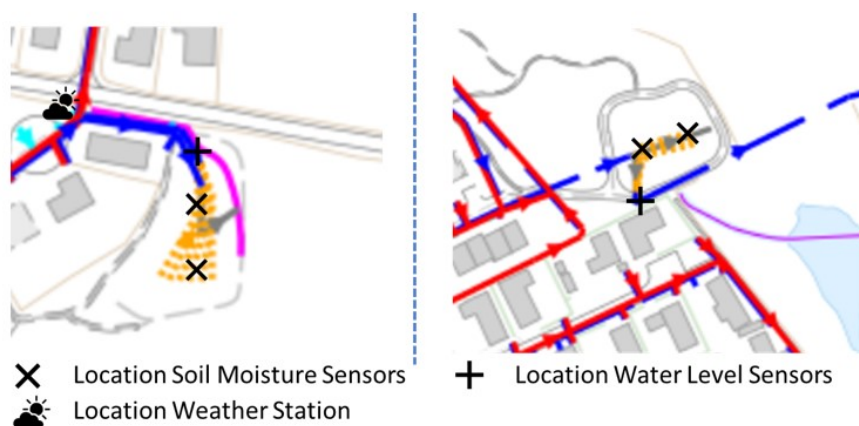


In each filtration pond 2 LoRaWAN sensors are installed – one close to the inflow and the other one approx. 20 m in the opposite end of the pond. Sensors in each sites are installed 10 cm and 30 cm depth to detect the soil moisture.

The water level sensor is installed in the outlet/overflow well.

The weather station is installed on the site to registrate precipitation in the pilot area. This provides an accurate measurement of total precipitation, air temperature,

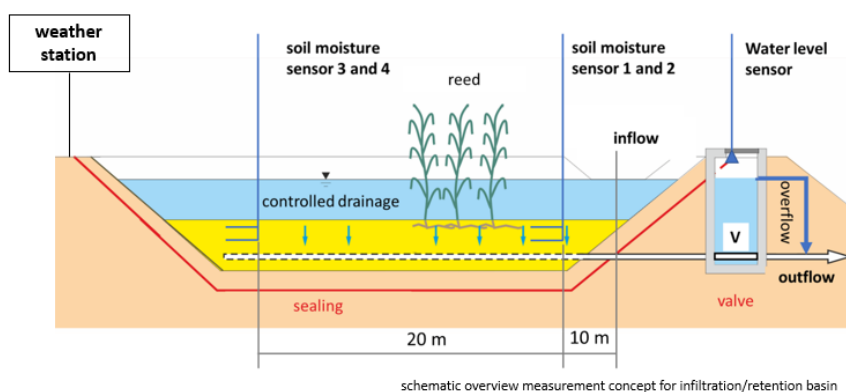
LoRaWAN sensors – Test site: Aarhus



relative humidity, solar radiation, precipitation

Sensors are providing data automatically every 20 min.

LoRaWAN sensors & weather station



Manual inspection:

The manual digital inspection forms pursue two main objectives: firstly, to test and assess a standardized low-cost/low-tech solution in the municipalities for assessing the condition of NBS. Secondly, they are intended to serve as a reference for monitoring using LoRa WAN-Sensors.

Beside using LoRaWAN sensors will Aarhus Municipality together with Aarhus Vand use the citizens science approach to detect malfunctioning/clogging but also inspect the biodiversity and vegetation coverage in NBS established in Nye.

Our focus is also to observe and carry out manual monitoring regularly.

KWB will have provided a tablet which can use the QField app, where specific inspection forms will be provided per NBS type (infiltration-, retention- system). The inspection forms provided are composed of a literature review, input from other researchers (NTNU, TU Delft) and the inspection forms previously used in the City Blues partner municipalities. The manual inspection forms are filled out every two weeks during 6 monitoring month or if any heavy rain weather event occurs in order to have a reference (in terms of duration of inspection and detected failure modes & maintenance needs).

Monitoring campaign is still ongoing, and more information will be added here after monitoring campaign is ended.



KWB team, Aarhus Municipality team and Aarhus Vand



planning the monitoring campaign



Visiting and preparing the potential monitoring sites



Infiltration pond in Trige



Installation of
Weather station and
sensors



6. Pilot investments

The City Blues pilot was mainly financed by European Union through Interreg Baltic Sea Region program. The Aarhus pilot include the construction work.

In total, 200 000 euros is reserved for construction of NBS by City Blues project and 12 000 euros comes from the city's budget. The cost of planning hours comes from the salary of the municipal team and is funded by the city.

Reports, data collection and analyses, monitoring is funded through the City Blues project. It will confirm that the analyses, information collected, documented, and partnerships developed through City Blues have provided a sufficient foundation for investment and long-term action.

7. Governance model of NBS in Aarhus Municipality

7.1 Key Institutional and governance dimensions

A robust governance model for catchment-based NbS in Aarhus would combine a catchment-scale spatial unit, multi-stakeholder governance bodies, clear regulatory/institutional/incentive frameworks, operational working groups and action plans, and project-level interventions all embedded in a monitoring & adaptive feedback loop. Because Aarhus already has many of the institutional and technical pieces, the governance model needs to emphasise coordination, stakeholder engagement, multifunctionality, and long-term maintenance/governance.

Aarhus's catchment-based governance model for nature-based solutions illustrates how cities can turn water management challenges into opportunities for ecosystem restoration and community well-being. By aligning municipal planning, utility operations, landowner collaboration, and adaptive science, Aarhus is creating a living governance framework—one that manages water, enhances nature, and strengthens local democracy.

As climate pressures increase, such integrated, catchment-scale governance will be essential for ensuring that nature-based solutions deliver their full ecological and social potential.

1. Institutional actors and roles

- Aarhus Municipality has a central role: it leads urban planning, sets guidelines for green/blue infrastructure, integrates NBS into broader plans (e.g., stormwater, land use).
- The municipal water utility (Aarhus Vand) is a key partner when water circulation, stormwater and separation of rainwater/sewage are involved.
- Research institutions (e.g., Aarhus University) are involved in modelling, evaluation, stakeholder-governance frameworks and act as knowledge brokers.
- Private landowners, citizens, community organizations — governance emphasizes engagement and co-creation with stakeholders for successful NBS.
- Funding/finance: Some NBS are supported by EU-funded research & innovation programs (e.g., Horizon, Interreg) and national/municipal budgets.

2. Policy integration and planning instruments

- NBS are integrated into municipal strategies and planning frameworks. For instance, Aarhus decided to separate rainwater from sewage by 2085 and commit to using NBS as a preferred technology.
- Specific planning requirements for new development areas: e.g., identifying blue-green corridors, reserving space for retention ponds and green infrastructure ahead of building.
- Co-creation and participatory planning: Workshops and involvement of local stakeholders in scenario development (e.g., for the new suburb “Nye”) with municipal departments and the utility.

- Use of modelling and simulation tools: Aarhus uses simulation models to evaluate the effect of NBS on urban hydrology, groundwater and infrastructure risk.

3. Governance mechanisms & stages of implementation

- Early pilot projects in less complex contexts (outer areas) to learn how NBS works, before moving to denser urban centres.
- Use of “Urban Living Labs” in projects (e.g., Interreg REGREEN) where Aarhus acts as a living laboratory for co-creation of NBS governance.
- Monitoring, evaluation and value capture: There is attention to multiple benefits (biodiversity, recreation, health, value of property) and not just traditional engineering metrics.

4. Stakeholder engagement & co-governance

- The “A GREENER AARHUS” strategy emphasizes co-creation in green projects, involving children, youth, elderly, associations and organizations.
- Workshops and stakeholder processes for NBS: For example, a hybrid workshop in 2025 invited municipal/urban experts about stakeholder engagement in NBS for stormwater or
- To ensure the 300 ha “New Nature” area in Aarhus is co-created, co-managed, and co-benefited by all relevant actors — integrating ecological, social, and economic perspectives (Interreg Biodiverse Cities) including stakeholder mapping & analysis, co-creation & engagement, Implementation partnerships, stewardship & long-term engagement, stewardship & long-term engagement
- Land-owner cooperation: In afforestation efforts, Aarhus Municipality works with private landowners, organizations, companies and citizens.

5. Financing and business models

- The governance model acknowledges that NBS often produce multiple added values (biodiversity, recreation, property value) and thus business models need to capture those.
- Funding may come from municipal budgets, EU/Interreg/Horizon programs, utility contributions and private land-owner cooperation. Example: The “City Blues” project for stormwater management.

6. Challenges & governance constraints

- In dense built-up areas there is limited space, making retrofitting NBS more difficult than greenfield sites.
- Coordination across departments is needed: e.g., water, land-use planning, environment, utilities — negotiating shared objectives and processes.
- Ensuring long-term maintenance and governance of green/blue infrastructure: Who is responsible? How is funding secured?
- Integrating evaluation of non-traditional values (recreation, health) into decision-making frameworks and cost-benefit analyses

7.2 Legal building blocks

Aarhus Municipality's governance of NBS is legally grounded in Danish planning, water, and environmental legislation, but its effectiveness depends on coordination across laws, sectors, and partners. Legislation both enables local autonomy and imposes structural constraints that Aarhus manages through integrated planning and partnerships.

Aarhus operates within Danish national laws that give municipalities power to plan and implement local environmental and climate actions. The most important frameworks are:

- The Planning Act – gives Aarhus authority to use spatial planning (local plans, zoning) to integrate NBS.
- The Environmental and Water Acts (FrameWater Directive)– regulate water management, stormwater, and wastewater responsibilities.
- Municipal Climate and Adaptation Plans – translate national climate policy into local strategies that prioritize blue-green and nature-based infrastructure.

Overall, legislation both enables local action on NBS and limits flexibility due to strict funding and permitting rules.