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Stormwater management using play areas: potential, limitations and design considerations

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PREFACE

This master's thesis concludes my two-year program in Water and Environmental Technologies at NMBU. I am grateful for the opportunity to learn from exceptional researchers and collaborate with motivated fellow students who have made this short but intense period of study both educational and fulfilling.

This research has been a truly enlightening experience, combining my professional interests with personal motivation. As a mother, I have always been curious about how children perceive the world around them, and how we can create places where people of all ages can thrive together. I also believe that understanding the role of water in this equation is crucial.

I hope that this study contributes to a better understanding of how to build more resilient and just cities, in line with the vision of the TOWARDS collaboration project that this research is a part of. My goal is to help creating cities that are not only functional and efficient, but also promote the health and well-being of all their residents. I believe that this challenge requires collaboration across disciplines, sectors, and communities and hope that this thesis inspires further dialogue.

This thesis is an attempt to think outside the box and explore unconventional approaches to urban water management. I am extremely grateful to my supervisor, Kim Aleksander Haukeland Paus, for his guidance and support throughout the process, that were invaluable in shaping the direction and scope of this study. I would also like to thank the TOWARDS team for inspiration and everyone who generously provided information and insights, in particular Tone Helland and Svein Rune Ussberg from Lillestrøm municipality, Ståle Dokken from Kilden kindergarten and Kjerstin Faanes from Øya kindergarten.

Finally, I would like to thank my husband for his unwavering support throughout these past two years, and to my son for inspiring and motivating me to manage my time effectively. This thesis, and the whole study, would not have been possible without their love and encouragement.

ABSTRACT

The study investigates how urban play areas can be involved into addressing stormwater issues by designing them as multifunctional spaces. The study begins by examining current practices in a range of projects and outlining common design trends and functionalities, along with useful classifications for different types of play areas.

Further, the study delves into relevant regulations and research concerning the recreational use of runoff and proposes key principles for the practical application of stormwater functions to play areas, with a focus on health and safety concerns. The study also provides more detailed checklists for each type of play area to reflect their specific needs and potential design solutions.

Finally, the proposed principles are applied to a case study of Lillestrøm city and a detailed analysis of Volla school and park. It is found that schools in Lillestrøm have the greatest potential for contributing to stormwater solutions due to their total area and proximity to major runoff lines. The analysis of Volla school and park demonstrates how the multifunctional principle can be applied to enhance playability and reduce surface runoff generated by the site.

Although it was challenging to quantify the benefits of the multifunctional design approach, the study suggests that joining the functionality of climate adaptation methods and play spaces in Norwegian cities can bring additional values. It recommends further research on the cost-effectiveness of multipurpose spaces, gaining more information on how such spaces function in changing weather and the universal design of stormwater facilities.

Overall, the research provides useful insights for city planners and landscape architects on how to allocate sufficient space for stormwater management in cities while also creating enjoyable and sustainable play spaces.

SAMMENDRAG

Studien undersøker hvordan urbane lekeområder kan brukes til å håndtere problemene med overvann ved å utforme dem som multifunksjonelle områder. Studien begynner med å undersøke nåværende praksis i ulike prosjekter, og beskriver vanlige design-trender og funksjoner, sammen med nyttige klassifiseringer for forskjellige typer lekeområder.

Videre går studien inn på relevante regler og forskning som omhandler rekreasjonsbruk av overvann, og foreslår nøkkelprinsipper for praktisk anvendelse av overvannsfunksjoner på lekeområder, med fokus på helse- og sikkerhetsaspekter. Det også foreslås mer detaljerte sjekklister for hver type lekeområde for å gjenspeile deres spesifikke behov og mulige designløsninger.

Til slutt blir de foreslåtte prinsippene brukt på en case-studie av Lillestrøm by og en detaljert analyse av Volla skole og park. Case-studien fant at skolene i Lillestrøm har størst potensial for å bidra til overvannsløsninger på grunn av deres areal bidrag og nærhet til større overvannslinjer. Analysen av Volla skole og park demonstrerer hvordan den multifunksjonelle prinsippet kan brukes for å øke lekemulighetene og redusere overflateavrenning fra området.

Selv om det var utfordrende å kvantifisere fordelene med den multifunksjonelle design-tilnærmingen, antyder studien at å kombinere funksjonaliteten til klimatilpasningsmetoder og lekeområder i norske byer kan bringe nyttige verdier. Det anbefales ytterligere forskning på kostnadseffektiviteten til flerbruksområder, få mer informasjon om hvordan slike områder fungerer i endrende værforhold og universell utforming av overvannstiltak.

Generelt gir studien nyttige innsikter for byplanleggere og landskapsarkitekter om hvordan man kan tildele tilstrekkelig plass for overvannshåndtering i byer samtidig som man skaper hyggelige og bærekraftige lekeområder.

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Chapter 1. INTRODUCTION & SCOPE

Image credit: DNNK/ Brøndbyøster afterschool

Introduction

Climate changes around the globe are calling for new adaptation strategies for both extreme weather events and more frequent daily rains. Most severe consequences are seen in densely populated cities, and in this context, public spaces need to be adapted or redesigned to maintain their functions and prevent flood damage. The transition to open and nature-based solutions has been widely acknowledged in water industry as more environmentally sustainable and cost-effective strategy of climate adaptation than traditional "grey" infrastructure (State of Green, 2022).

The Copenhagen cloudbursts of 2011 and 2015 have demonstrated that current practices are inadequate to cope with the effects of climate change. The severity of these events has led to a transformation of the city's cloudburst management strategy and approach to the stormwater problem (*The City of Copenhagen. Cloudburst Management Plan*, 2012). Similarly, the city of Amsterdam has launched a program called "Rainproof Amsterdam," which involves the implementation of a network strategy to mobilize all stakeholders who can contribute to the city's climate adaptation efforts. The program emphasizes the effectiveness of capturing rainwater at the point of precipitation as the most efficient method of stormwater management (Amsterdam Rainproof / Saskia Naafs, 2023). The city of London's environmental strategy incorporates the implementation of sustainable drainage systems (SuDS) to manage surface water runoff and address challenges posed by heat waves and urban heat islands, contributing to overall climate resilience (*London Environment Strategy*, 2018).

Incorporating open stormwater management systems in urban setting is important but challenging task due to limited space and conflicting interests. Areas like schools and kindergarten yards are no exception to it. Norwegian regulations oblige educational institutions to manage stormwater locally, preferably with infiltration or drainage via open waterways and ponds, and maintain water's natural cycle (Norwegian Building Authority, 2017 ,§15-8). This, however, can be a complicated task for new developments as the scarcity of space in Norwegian kindergartens and schools is already a concern, and especially pressing in urban areas, as reported by Thoren A. - K. H. et al. (2019) in their study on outdoor areas in schools and kindergartens. Another study on school yards in the Stavanger region (Olesen, 2019) identified a reduction in yard area as well as the need for better stormwater management, and emphasized importance of preservation of "school forests" in this context. While keeping natural environments at school and kindergarten yards would be a logical response to the issue, current trends in play area design appear to prioritize different aspects.

Current trends and challenges with design of play areas

The ongoing urbanization process, conflicting priorities and space scarcity has had an impact on the contents of play areas. Children are now offered more structured spaces with elaborate equipment. The KFC approach, which stands for Kit, Fence, Carpet (Woolley & Lowe, 2013) has become the dominant design method for play areas worldwide, including in Norway, where it is commonly used for schools, kindergartens, and public spaces. The Kit is defined by fixed play equipment with pre-set range of activities that are believed to be fun, entertaining and engaging. The reasoning behind is, among other, decline in physical activity levels, which is a global trend. The importance of schools and kindergartens in encouraging positive physical activity behaviors in children, contributing to the development of a healthy lifestyle in the long run, is widely acknowledged and supported by numerous studies including Fairclough et al. (2012), van Sluijs et al. (2021), and Telama (2009). But while vibrant designs and sophisticated equipment may look appealing at first, they tend to become boring with time due to limited functionality.

The fall protection, provided by Carpet, is typically made of artificial turf or rubber mulch. The widespread use of such surfaces in playground designs has dominated due to maintenance, safety and universal design reasons. These surfaces are often made from a combination of plastic and recycled car tires. And while individual components are believed to be innocuous, there are emerging concerns regarding the release of microplastics and other chemicals from these surfaces. Studies suggest that this may lead to cocktail effects, with potential health implications from hand-to-mouth transfer and inhalation(Koutnik et al. (2023), Schulze et al. (2020)).

In contrast, several recent studies have shown that natural spaces invite children to more physical activities and increase variation of self-organized play by providing natural materials such as sticks, corns, leaves and stones (Thoren A. -K. H. et al., 2019). They allow for more imaginative play and positive impact on cognitive development is more pronounced (Nebelong (2021b), Dankiw et al. (2020), Torkar and Rejc (2017)). In addition to promoting physical activity, there is an emerging interest towards utilizing school yards as outdoor learning environments, with water as one of the essential elements. Research has linked nature-based outdoor classrooms to positive learning and development outcomes (Samuel F. D. Jr. et al., 2014), with children becoming more engaged, creative, and patient in natural learning environments (Samuel et al., 2019). Lastly, several projects have shown how the problem of urban heat island effect can be successfully solved by creating natural environments at school yards, addressing both climatic and stormwater challenges through a single solution (*Cooling schools. Experiences from C40's Cool Cities Network* , Flax et al. (2020)).

Norway has a strong record of adapting innovative strategies in stormwater management and promoting water reuse, but there has been a lack of emphasis on multifunctional design. Given that children are naturally drawn to playing with rainwater, there is a potential in combining this innate curiosity with safe and effective design strategies suitable for Nordic climate. The present study therefore aims to bridge the gap between the international experience and national practices by identifying important aspects of creating multifunctional and climate-resilient play areas. The research was conducted as part of TOWARDS master partnership, which aims to explore the socially just and sustainable transformation of the Lillestrøm city.

Drawing on the above, the problem statement has been formulated as follows:

Problem statement

The objective of the research is to investigate the feasibility and potential of multifunctional approach in design of play areas to address stormwater problem in Norwegian climate.

To find the solution to the problem statement the study was divided into three chapters that build on each other, with aim to answer the following research questions:

Research question 1

What variation in design and materials can be identified from existing sites? Which solutions are most used and suitable to have play and recreation as additional functions?

The first part of the study examines existing sites, presenting a selection of projects that integrate stormwater management into play areas. The aim of this chapter is to assess the practical implementation and experience of these projects, as well as identify which solutions can be feasible for the Norwegian context. There were selected projects where integration of stormwater management elements in play was a deliberate decision. Projects with limited variations of SuDS were excluded, and projects designed for broader audiences, for example public squares, were deemed too generic. The geographical location of example sites was evaluated, with an emphasis on areas with climates comparable to Norway. A range of natural playgrounds was also considered, but the impact on stormwater management at such spaces was difficult to quantify as it was not a primary consideration in the design process. To identify relevant projects and reports, a web search was conducted based on findings of the Oslo municipality's summary on stormwater management solutions (Braskerud et al., 2017) and a fact sheet on multifunctional play areas by SLA and Orbicon (Gabriel & Fiil, 2016).

Research question 2

What do current regulations say about using stormwater in recreation, and what differences are there between Norway and other countries' practice? Which criteria can be suggested for the design process to ensure satisfactory quality, safety and health risks of multifunctional installations?

The second part of the study conducludes a review with aim to examine current regulations and establish a framework for potential design solutions. The review includes both Norwegian and international laws, standards, guidelines, and research related to stormwater and play. Although there are currently no explicit regulations for this type of design application in Norway or globally, various regulations were utilized from different perspectives and complemented with relevant research on specific topics. Databases and documents were identified and translated using web search, Google Scholar and ChatGPT engines.

Research question 3

How can the multifunctional approach be applied in a real urban setting to enhance stormwater management and contribute to a playful cityscape?

The third part of the study is focusing on practical applications of the findings and suggestions discovered in first two chapters to the real setting. An analysis of Lillestrøm city was conducted to find out the potential area contribution of outdoor play spaces in overall stormwater planning, using QGIS. The design recommendations presented in the previous chapter were implemented as a feasibility study on Volla school and park, located centrally in the city. SCALGO Live was used for analysis of runoff patterns and catchment area.

Scope limitations and definitions

The study is focusing on outdoor areas that are explicitly designed for recreational and sports activities, primarily targeting children. These areas include municipal and private kindergartens and schools, and areas like public and private parks and playgrounds, sport centers, and afterschool clubs. The scope of potential projects is limited to a reasonable site area, thereby making such places as smaller private playgrounds insignificant contributors. Henceforth, all relevant areas are denoted as "play areas."

The target age group is children from the age when they start attending kindergarten, which is approximately 10 months old for Norwegian kindergartens, and up to the age of 16, which is when Norwegian children graduate from secondary school (*ungdomsskole* in Norwegian). While the upper limit for age is not as strictly defined for sport facilities and afterschool clubs, the study focuses on the age group of children who are most actively growing and can benefit from various water-based activities to develop other essential skills.

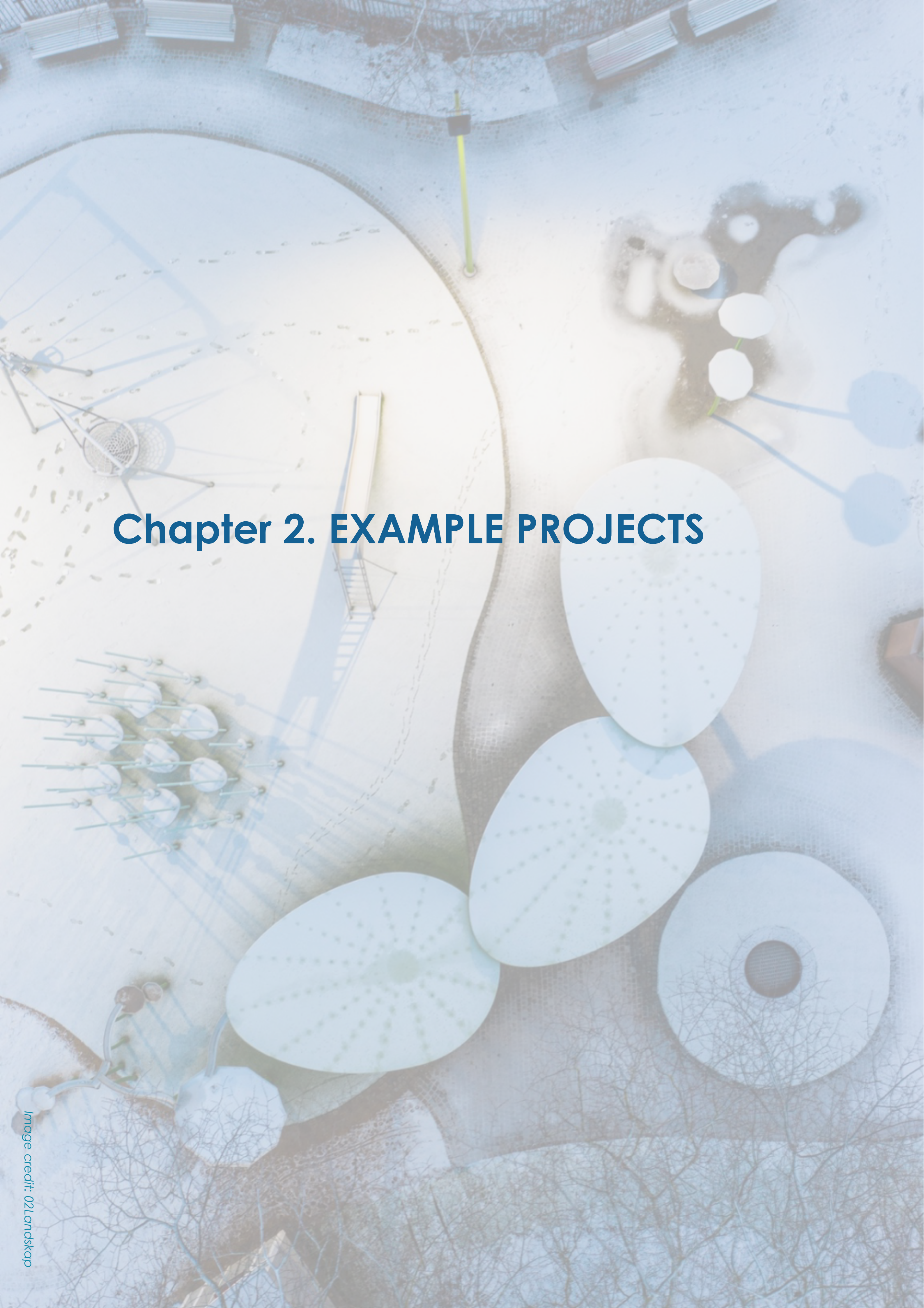
Finally, the study's primary aim is to research how play areas can be turned into or combined with open, sustainable and nature-based stormwater management methods. It is however acknowledged that sole use of open stormwater solutions is often impractical in real-life projects, so the study also takes into consideration semi-natural stormwater management systems, where nature-based solutions are complemented with grey infrastructure.

Due to differences in interpretation of several terms concerning stormwater management, the following list presents the definitions of most used concepts in a way they are applied in the study. The definitions were formulated with help of CIRIA SuDS manual (Woods Ballard et al., 2015).

Resilience – the ability to recover quickly from an event or series of events.

Nature-based solutions (NbS), sustainable drainage systems (SUDS) – a set of stormwater management measures that facilitate the natural water cycle, create and sustain better places for people and nature, by managing and using rainwater close to where it falls.

Multifunctional approach - planning and design, aiming to serve multiple purposes; in the context of the study - providing space for recreation and simultaneously managing stormwater runoff.



Chapter 2. EXAMPLE PROJECTS

Image credit: 02Landskap

Øya kindergarten, Trondheim, Norway

Key facts	
Site area	8000 m²
Year	2016
Solution type	Open gutters and retention basin
Return period, catchment and/or handled area	Ca 840 m³ upstream area (calculated using SCALGO Live) Handles everyday rain
Outlet	Overflow to sewers
Materials	Natural stones and concrete
Permanent water level	No
Maksimum water depth	20 cm
Activities involving stormwater	Open gutters make water visible; water play area

The design concept for the outdoor play area of the new Øya Kindergarten is centered around the theme of water, echoing the nearby river Nidelva. The stormwater management system has been implemented in the form of "streams," play gutters that can be filled with water using a hand pump and provides play opportunities near or in it. These streams converge to form a "river," which flows through the playground to a retention basin, functioning as play space, before water is discharged into the sewer system.

The kindergarten has encountered difficulties in use of the retention basin, with feedbacks indicating that the openings in the overflow cover are large enough for toys to fall into it. Although it has not been reported that the lock has become obstructed during snowmelt or freezing cycles, the basin is frequently filled with water.

Figure 1 Playground of the Øya kindergarten

Kilden kindergarten, Oslo, Norway

Key facts	
Site area	7342 m²
Year	2015-2018
Solution type	Open gutters, rain garden, infiltration at sandboxes and rain gardens
Return period, catchment and/or handled area	20 years, runoff from 0,6 ha impermeable area (runoff from 0,237ha to open NbS)
Outlet	Infiltration and open retention, overflow to sewers
Materials	Sand, impermeable surfaces and natural vegetation
Permanent water level	No
Maksimum water depth	Less than 10 cm
Activities involving stormwater	Possibility to use water in play when there is runoff to sandboxes

The newly constructed Kilden kindergarten is a project characterized by its ambitious environmental goals and has been certified to the BREEAM Excellent building standard. Stormwater in the area had to be managed locally, as overflow volumes that can be sent to the city network are limited by local regulations. A part of runoff that runs to western part of the yard, typically used by smallest children, runs openly via play areas and to sandboxes. Overflow is sent to a rain garden. At eastern part, the runoff flows to rain gardens and a swale.

The kindergarten's experience with open stormwater management on their property has been generally positive. However, improvements were needed in the sandboxes, which required shifting to a coarser fraction to enhance infiltration. Additionally, the accumulation of larger stones at the lowest point of the rain garden on the terrain raised safety concerns. Moreover, given the high percentage of impermeable surfaces, it was noted that taller trees were essential for the small children's area when temperatures increased during summer months. While new trees were planted, they have not yet grown tall enough to provide adequate shade.

Figure 2 Kilden kindergarten, overview

KF school (Kristen Friskole), Stavanger, Norway

Key facts	
Site area	4800 m²
Year	2021
Solution type	Open gutters, infiltration in open retention ditches, underground retention units
Return period, catchment and/or handled area	1400 m² roof surface
Outlet	Infiltration, underground retention storage, overflow to sewers
Materials	Combination of rubber surfaces, asphalt, natural vegetation and stones
Permanent water level	No
Maksimum water depth	10 cm – water play, ca 40 cm in retention ponds
Activities involving stormwater	Open gutters make water visible; water play area

The school is situated in the city of Stavanger and covers an area of 5700 m². The school yard is divided into three distinct zones, and rainwater has been embedded to the design as a key feature. The objective of the project was to make rainwater visible to raise awareness about its significance and use it for watering the plants. Half of the roof runoff is channeled through open waterways to retention ponds, while a complex of two underground storage units is utilized to collect the remaining roof runoff and overflow from the retention ponds during periods of heavy rainfall (LINK Arkitektur).

The design incorporates a blend of rubber surfaces, asphalt and nature-based solutions. A dedicated water play area has been created to manage roof runoff, which is channeled through open gutters and a series of ramps to a rain garden, as can be seen at Figure 3.

Figure 3 KF school, overview, rain garden and water play

Åsveien school, Trondheim, Norway

Key facts	
Site area	25000 m²
Year	2015
Solution type	Open gutters and swales, rain garden, water play retention basin, underground storage
Return period, catchment and/or handled area	Runoff from the whole area, including surface and roof runoff 91 m^3 volume required before overflow; 33 m^3 is used for open solutions and 58 m^3 for underground storage
Outlet	Underground storage and overflow to sewers
Materials	Natural stones, concrete, natural vegetation
Permanent water level	No
Maksimum water depth	10 cm
Activities involving stormwater	Dedicaied play area

The project for Åsveien school was developed with a focus on reducing greenhouse gas emissions during construction and promoting energy savings. The requirement for local stormwater management has led to the design of open retention areas and a rain garden, which serve as aesthetically pleasing, playful, and ecological elements.

The stormwater management system consists of a combination of swales, a rain garden, and a water play puddle, which collect water from the surrounding area and roofs. During the winter months, all runoff is directed to an underground storage unit, providing an increased level of security against potential disruptions. However, this also prevents the opportunity to gain valuable experience during cold weather conditions.

The water puddle is highly popular among children and is regarded as an attractive and high-quality feature in the surrounding neighborhood. The maximum water level in the puddle is 10 cm, with overflow directed to the underground storage.

The rain garden has been constructed with nine distinct levels, reflecting the topographical variations, and features a fall of 3 meters over a total length of 66 meters. It consists of a "dry" asphalted section and a planted section, to collect and infiltrate the runoff. The overflow from the rain garden is also directed to the underground storage facility.

Since its opening, the rain garden has never reached full capacity. The water play puddle has accumulated significant runoff volumes during heavy rainfalls, but little water has been observed during warm weather conditions. The school reports that there have been no difficulties adapting to the open water elements, as children are appropriately dressed for the weather conditions exactly when the water accumulates to its highest levels (Sigurgeirsson, 2016).

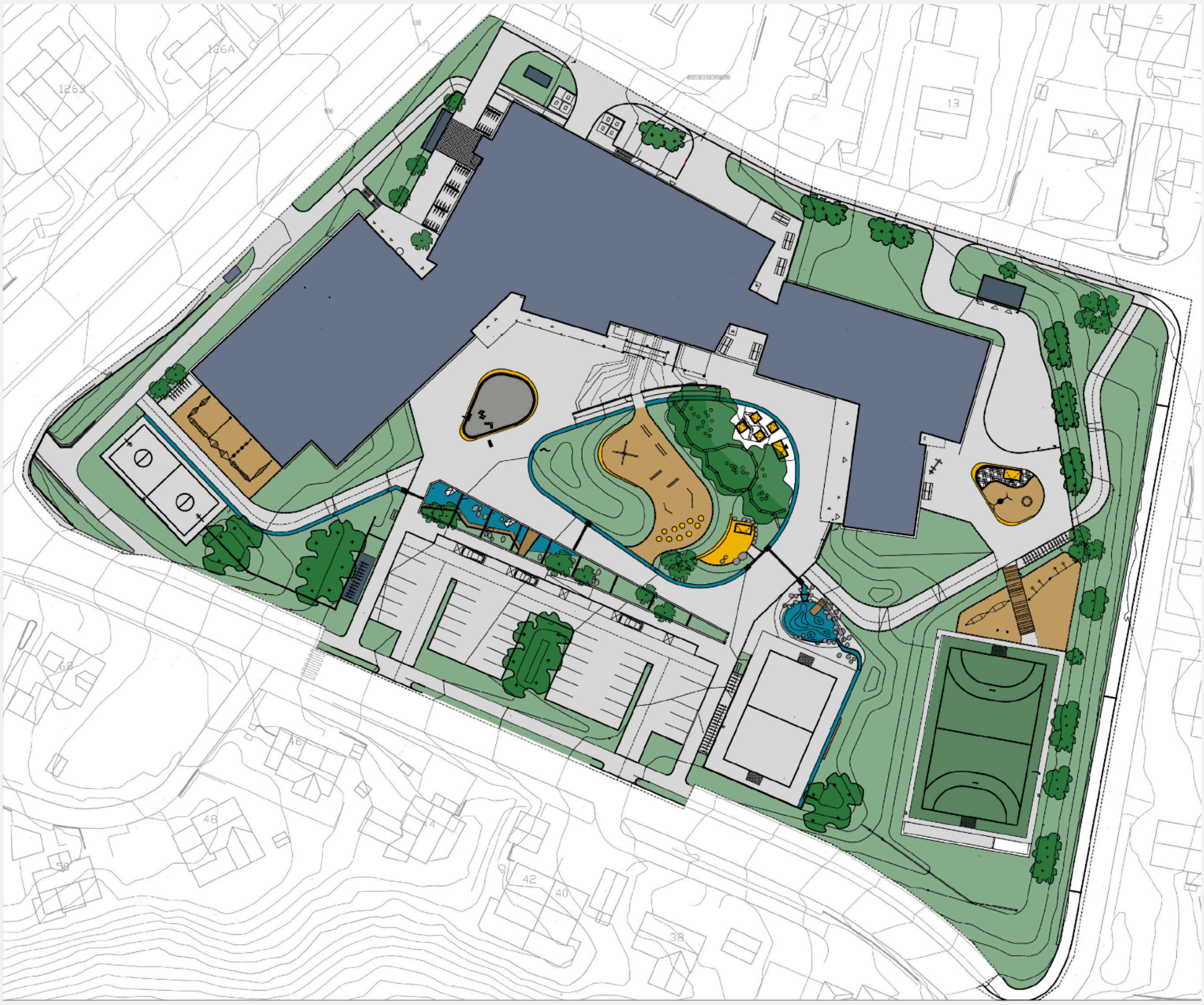


Figure 4 Åsveien school yard, project drawing

Figure 5 Retention basin and rain garden as play spaces

Brøndbyvester school green and gray schoolyards, Brøndby, Denmark

The school yard at Brøndbyvester school has been renovated in 2012 with the objective of managing stormwater through open solutions, reducing the amount of water directed to the sewer system, and incorporating water as a recreational feature. The schoolyard is divided into two distinct areas: the "grey schoolyard," which has a conventional design with predominantly hard surfaces, and the "green schoolyard," which has a more park-like feel and is extensively covered with vegetation.

Grey schoolyard

Key facts	
Site area	1600 m^2
Year	2012
Solution type	Open basin (amphitheater), open gutters, puddle, permeable surfaces leading to underground infiltration wells (total capacity 73m^3)
Return period, catchment and/or handled area	Partial disconnection of 2-year rain runoff from 3000 m^2 roof area
Outlet	Overflow to sewers from storage unit
Materials	Permeable and colored asphalt
Permanent water level	No
Maksimum water depth	0,9m in amphitheater, 15cm in puddle
Activities involving stormwater	Splash games, skating at winter

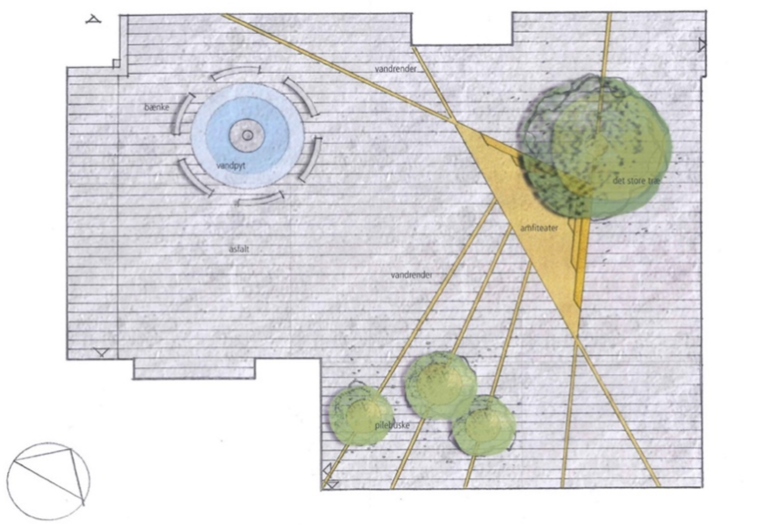


Figure 6 Grey schoolyard, overview

The roof runoff in the gray yard is channeled through orange-colored gutters to an amphitheater. This amphitheater serves as a retention basin and is partially covered with permeable asphalt that enables evaporation and let water infiltrate down to underground storage units. Water on another side of the yard is collected in a shallow puddle and infiltrated into a second underground dry well. The combined capacity of both storage solutions is estimated to accommodate everyday rains and retain some of the water on the surface for recreational purposes. In the event of heavy rainfall, overflow from the underground wells, puddle, and amphitheater is directed to the sewer system.

Green schoolyard

Key facts	
Site area	1200 m²
Year	2012
Solution type	Open gutters, open canal and underground infiltration wells (total capacity 78m³)
Return period, catchment and/or handled area	Partial disconnection of 5-year rain runoff from 920 m² roof area
Outlet	Infiltration, storage, and overflow to sewers for more intense rainfalls
Materials	Green areas (trees, grass), natural stones, concrete and rubber pavement
Permanent water level	No
Maksimum water depth	Ca 20 cm
Activities involving stormwater	Learning about plants, insects, recreation

Figure 7 The Green school yard

The green yard is predominantly covered with vegetation and features an open canal where water is retained permanently. The canal is divided into two parts by a threshold, with the dry part having an overflow to an underground infiltration well designed to handle larger amounts of water. The wet part handles smaller rains and serves as an outdoor classroom, with the help of willow and dogwood bushes that promote biodiversity. In the event of heavy rains, excess water is redirected to the public sewer system. A schematic representation of the water flows in the yard can be found in Figure 8.

The area is open to residents outside school hours and is often used as a park, with water being a central recreational attraction.

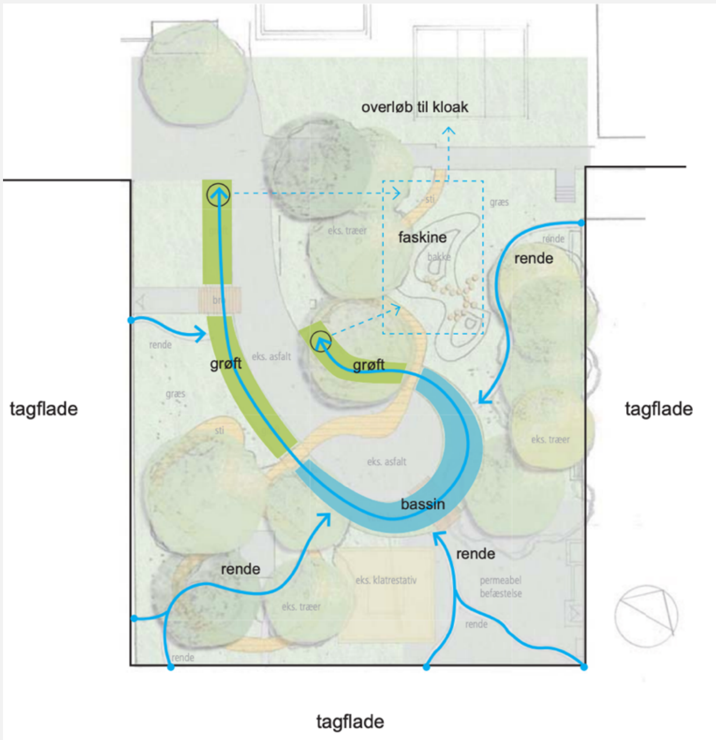


Figure 8 Overview and scheme of runoff collection at the green yard

Brøndbyøster afterschool, Brøndby, Denmark

Key facts	
Site area	1200 m^2
Year	2013
Solution type	Open gutters, rain garden, natural infiltration (total capacity 53m^3)
Return period, catchment and/or handled area	Capacity enough to fully handle 5-years rain, runoff from 2070 m^2 roof area
Outlet	Infiltration and overflow to adjacent football fields
Materials	Colored asphalt, stones, grass and local plants
Permanent water level	No
Maksimum water depth	20 cm
Activities involving stormwater	Exploring nature in rain gardens during wet weather, open gutters make rainwater accessible

Figure 9 Rain garden as a playground

In another example project in Brøndby, stormwater management is organized entirely on the surface with no discharge to public sewers. The central elements of the water management system are two rain gardens located at the school yard, which serve as recreational spaces for children. These gardens are designed with large stones, local trees and bushes, and can be used in both wet and dry weather conditions. The rain gutters for roof runoff are emphasized with red asphalt, enhancing the visual experience of the overall design concept.

Figure 10 Overview of the site and runoff patterns

Lindebjerg school ("Klimaskole"), Roskilde, Denmark

Key facts	
Site area	4500 m²
Year	2012-2015
Solution type	Permeable surfaces, rain garden, underground infiltration unit, retention dam (play basin)
Return period, catchment and/or handled area	100-years rain with 6 hours duration, runoff from ca 1300 m² roof area for project I and II; 20-years rain for the multiplay area alone
Outlet	Infiltration and overflow to sewers
Materials	Permeable concrete, asphalt, grass and local plants
Permanent water level	No
Maksimum water depth	12 cm
Activities involving stormwater	Play in the "fjord" and with water pump; climate adaptation in school curriculum, with school yard as live lab

The ambitious aim of the "Klimaskole" project at Lindebjerg school was to make the institution more environmentally sustainable, and a part of this were two demo-projects for open stormwater management. The school yard has previously experienced floods, and the implementation of measures to separate part of the roof runoff from the public sewers has not only improved overall water balance, but also enabled the integration of water into educational and recreational activities.

The first demo-project consists of a retention basin designed as a play area with a maximum depth of 12 cm, which mimics the landscape of the surrounding fjords - Isefjord and Roskilde Fjord. In case of overflow, the water is directed to an underground infiltration well, which can be emptied manually with a hand pump at the rain garden. Overflow from the rain garden flows through a trench, and together with runoff from approximately 200 square meters of roof area is captured by the second demo-project, a multifunctional retention basin constructed as a pump track with parkour elements. From there water infiltrates into the ground through permeable rubber covering the multiplay park.

Adopting the principle "rainwater is too valuable to be confined to pipes," the school encourages water activities and has integrated climate adaptation education into its curriculum. Older students are trained as climate ambassadors, taking responsibility for the school yard and contributing to decision-making regarding new initiatives at the school. Children have also been involved in the selection of plants and construction of the trench (Ministry of Environment of Denmark, 2015).

School staff have reported two safety concerns following the completion of the project. The first one was regarding the quality of the water pumped out from the storage by the hand pump, which did not meet the safety standards. The issue was addressed by increased supervision of children by teachers to restrict mouth contact and consumption of water. The second concern was related to the water level in the trench rising excessively at certain times, which was resolved by installing a pump that helped emptying the trench when needed by the personnel (Ministry of Environment of Denmark, 2015).

Figure 11 Play basin

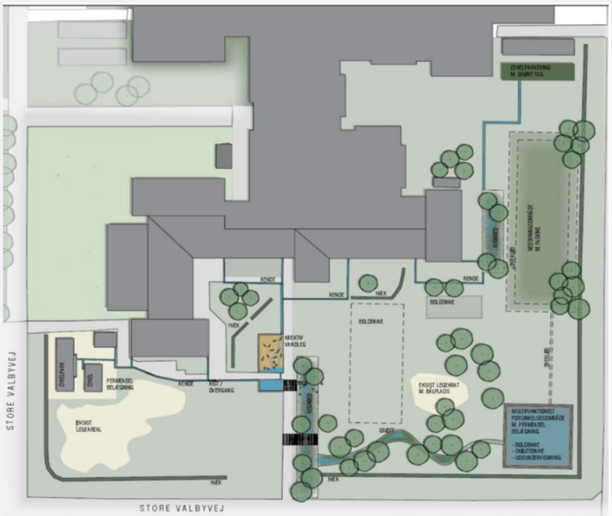


Figure 12 Overview of the school yard

Figure 13 Multiplay area

Figure 14 Hand pump

Gladsaxe Sports Center, Copenhagen, Denmark

Key facts	
Site area	23 ha
Year	2013-2015
Solution type	Series of open retention basins and waterways, total capacity of 7600 m^3
Return period, catchment and/or handled area	Catchment area is the while sport center together with adjacent Marielyst quarter with return period of 10-years rain to heavy cloudbursts
Outlet	Open stream, biofilter/rain garden and sewers
Materials	Impermeable rubber and concrete
Permanent water level	No
Maksimum water depth	From 20 cm to 1,8 m
Activities involving stormwater	Water is additional element in play areas, possible to play with while retention time is below 24 hours

The Gladsaxe Sports Center, which was previously a conventional sports facility with primarily flat playing surfaces for sports such as football and volleyball, has undergone renovation in response to severe flooding in 2011. The renovation aimed to mitigate the excess runoff that was contributing to stormwater problems in downstream residential areas, improve the capability to handle heavy rain events and increase the active usage of the facility by attracting a wider range of users beyond the members of the sports clubs.

The Sports Center was transformed into a multi-functional park that could handle large volumes of rainwater. There were designed and constructed a series of retention basins and waterways that can be used for various sport activities like BMX, tennis, football, and free play. Rainwater is viewed as a playful element rather than a hindrance and all outdoor facilities contribute to runoff retention, with a total capacity of up to 7600 m^3.

When the residence time exceeds 24-hours, the runoff is directed to a biofilter for treatment due to health concerns. The water can undergo additional treatment with UV light if necessary and is then recirculated back to the park. The source of feed water for the "geysers" has been changed from surface runoff to drinking water for the same reason. Additionally, all runoff between November 1st and April 1st is directed to the public sewer system due to contamination with de-icing agents.

Despite the fact that the design does not involve new permeable surfaces and consist of impermeable basins, the Gladsaxe municipality has observed that flood frequency downstream has decreased and recreational value for the entire area has improved. The project owners also reported a 20% reduction in construction costs compared to traditional solutions such as pipe networks and storage units (VANDPLUS, 2015).

Figure 15 Retention basins as a playground

Figure 17 Tennis pitch and the area before and after climate adaptation

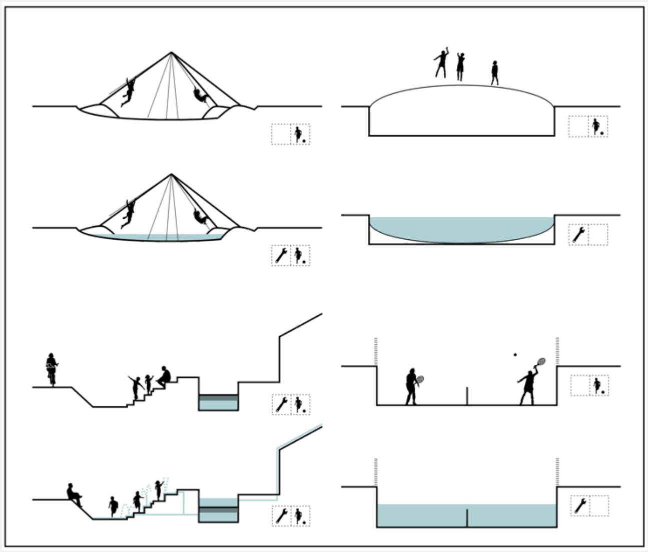


Figure 16 Multifunction of play areas

Selsmosen water park, Copenhagen, Denmark

Key facts	
Site area	25000 m^2
Year	2008-2012
Solution type	Extension of existing water reservoir
Return period, catchment and/or handled area	Catchment area of 67 ha, protection against extreme cloudbursts
Outlet	Natural infiltration and discharge to local river network; pump-controlled water level
Materials	Wood, concrete with no-slip surfaces
Permanent water level	Yes
Maksimum water depth	30 cm in water activity area
Activities involving stormwater	Active play with and near water with help of installed equipment

Selsmosen park () is an existing stormwater retention reservoir that was partly redesigned and extended by 12000 m^2 after a severe flood in 2007. The municipality made a conscious decision to enhance the area by adding recreational features and transforming the technical lake into an aesthetically pleasing "blue park," rather than solely increasing its capacity and sacrificing green spaces. The park's central location among residential neighborhoods, a local theater, and a train station presented both challenges and opportunities. The redesign project not only added a variety of recreational activities to the area but also established new routes to the train station.

The newly extended lake has two artificial islands that are connected by wooden bridges. The west bank has been designated for various activities, while the area between the football pitch and the southern island has been transformed into a water play area with various activities. A variety of tools and elements like water cannons, pumps, an artificial canal, stepping stones, bridges for climbing and pontoon bridges, and a "boat" have been installed. The water level in the play area is maintained at 30 cm for safety purposes, except during extreme cloudbursts. Water at the play area is circulated by an automatic water mill installed beneath one of the bridges and can be manipulated by the public.

Figure 18 Plan view of Selsmosen park

Figure 19 Water activities at Selsmosen

Rabalder park, Roskilde, Denmark

Key facts	
Site area	40000 m^2
Year	2012
Solution type	Open water channel (445m), retention basin (Bowlen), natural infiltration
Return period, catchment and/or handled area	Capacity to manage 23000 m^3 of water for return period of 10 years, catchment area of 250000 m^2
Outlet	Retention dams (Søen and Engen), natural infiltration in surrounding meadow
Materials	Natural vegetation, concrete, asphalt
Permanent water level	Partly (in Søen, depending on amount of rain), not permanent on other parts of the park
Maksimum water depth	Varies in Søen, depending on amount of rain; smaximum depth of about 2 meters
Activities involving stormwater	Primarily recreational

Rabalder Park was established in the municipality of Musicon on a former gravel excavation site that had subsequently been converted into a landfill. Due to pollution from a previous concrete goods factory, gas leaks from the landfill, and the absence of stormwater infrastructure, the municipality needed to incorporate open stormwater solutions during the area's redevelopment and adaptation to changing climate (Andersen, 2022). The project resulted in construction of a modern skate park with surrounding green recreational area that is intended to accommodate a diverse range of users.

A 445-meter-long asphalt canal, that functions as a skating track at dry weather conveys runoff throughout the site to three basins – Søen, Engen and Bowlen. The Søen and Engen are semi-natural ponds; they collect the initial runoff, with the Søen often containing standing water. The Bowlen is a skating bowl and is intended to fill during the heaviest cloudbursts, which occur approximately once every 10 years, however, this has not been seen since the park's opening.

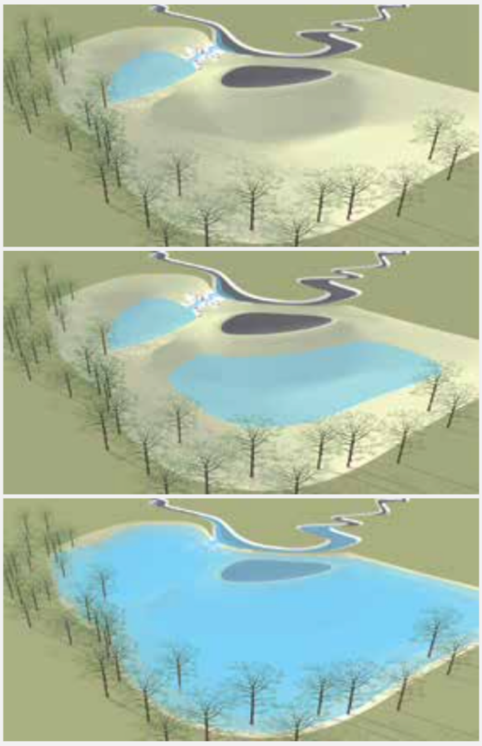


Figure 20 Water management at Rabalder park during different rain events

To ensure ease of maintenance and proper functionality, the park was designed to be as simple as possible. Following heavy rainfall, the park is cleaned to prevent any potential issues. Although this incurs additional costs, the municipality notes that combining the expenses of the recreational park and stormwater management has been beneficial. If the park had been constructed solely for recreational purposes, the cost would have been considerably higher.

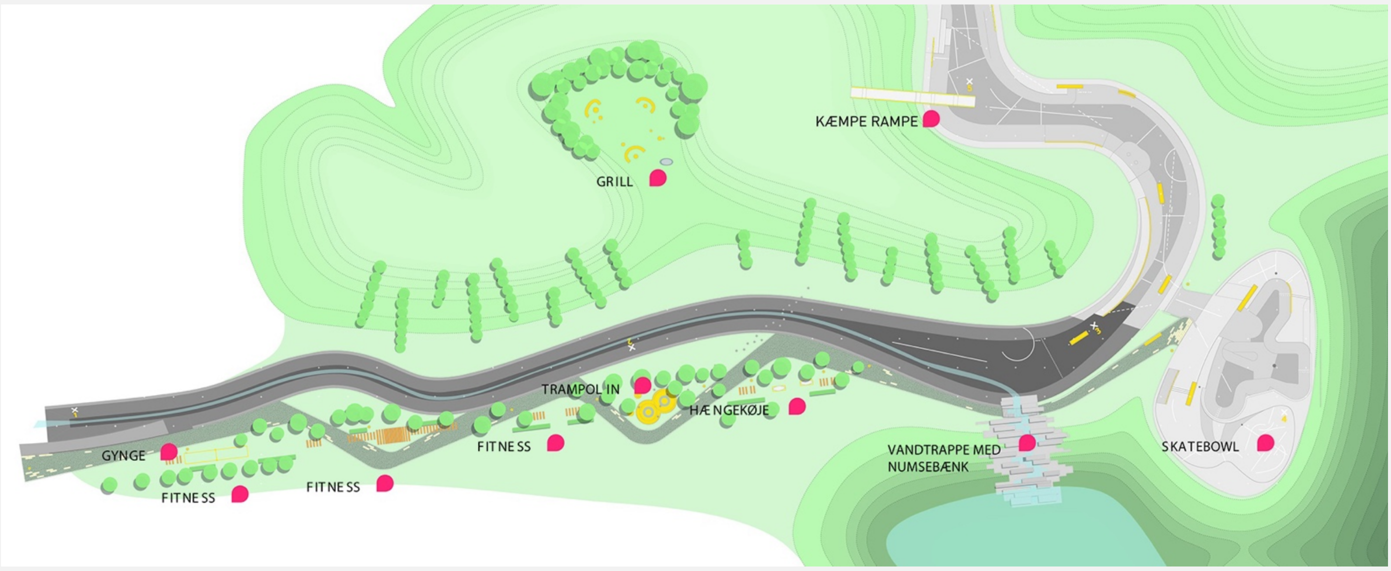


Figure 21 Overview of the park

Figure 22 Søen, Engen and Bowlen (top left) and design details of the skating track

The Rain Playground (Regnlekplatsen), Gothenburg, Sweden

Key facts	
Site area	390 m^2
Year	2018-2019
Solution type	Retention in shallow basins
Return period, catchment and/or handled area	Everyday rain that falls on the playground
Outlet	Runoff to adjacent pond
Materials	Concrete, steel, sand (outlet)
Permanent water level	No
Maksimum water depth	20 cm
Activities involving stormwater	Play with water flowing through funnels, play-puddles

Figure 23 Play with rainwater

The city of Gothenburg has in 2021 filled 400 years and local citizens wanted to celebrate this by "getting closer to water and turning rain into resource", according to Ecocycling and Water (2018). Given that it rains approximately every third day in Gothenburg, residents wanted a playground specifically designed for rainy days with features that make it even more enjoyable to play in such conditions. This resulted in constructing a "Rain playground" in the Renström park.

In summer and autumn of 2017, children and adults were able to contribute ideas for the design of a playground. The final solution incorporates architectural elements such as leaf-shaped roofs that serve to provide shade and protect from rain. The roofs collect and guide the rainwater through smaller funnels and gutters, directing it back to the surface. Shallow depressions near the playground serve as small retention basins that can be walked or cycled through. Overflow runs to a little beach that lines a bank of the adjacent pond.

Figure 24 Plan view of the rain playground and the recreational space around it

Other examples of climate adapted play areas

Brooklyn public school 261, New York, US

The project represents an impressive climate adaptation of a typical American school yard. Before and after pictures can be seen in Figure 25. The green playground includes features such as green roofs on storage structures, rain gardens and barrels for collecting rainfall, synthetic turf playing fields, and asphalt surfaces that are sloped towards green areas to redirect stormwater runoff and minimize its impact. As a result, local sewers are relieved of 1890 m^3 runoff every year, as well as flooding in downstream Gowanus Canal, known for frequent overflows, is reduced.

Figure 25 Brooklyn public school 261

The New York case of transforming and adapting schoolyards for the benefit of both schools and local communities is supported by other campaigns in the United States, such as the *Boston Schoolyard Initiative* and *Space To Grow Chicago* . Similar campaigns in Europe, such as *Amsterdam Impulse Schoolyards* (Disch, 2018), and *Paris OASIS Schoolyard Programme* also supplement this movement towards climate adaptation and transformation of schoolyards.

Herron playground, Philadelphia, US

The city-owned playground is located in a neighborhood where surface runoff is discharged to combined sewer system. Green stormwater infrastructure was installed as a part of playground renovation, with aim to relieve public network of excessive runoff from the nearby streets and the playground. Existing basketball court was resurfaced with permeable asphalt that drains to the underground infiltration well. A rain garden and newly planted trees improve the runoff quality, enhance the appearance, and decrease the heat island effect. Total area managed is about 1200 m^2.

Figure 26 Herron playground

Ikiminami primary school, Fukuoka, Japan

In response to the significant reduction of natural habitats and green spaces in Fukuoka City, a biotope project was launched to aid in the restoration of nature. The ten-year project aimed to establish a school garden where children could also play and study biology and ecology. The authors of the project emphasized the crucial role of student involvement throughout various stages of the initiative, which contributed significantly to its success, in contrast to other unsuccessful attempts that did not prioritize student participation (Ito, 2013).

Figure 27 Establishing of the school biotope, Ikinami primary school

Summary

Research question 1

What variation in design and materials can be identified from existing sites? Which solutions are most used and suitable to have play and recreation as additional functions?

The scope of the example projects selected is diverse and encloses a range of applications spanning from 2012 to 2021. The following categorization of projects can be identified: kindergarten yards, school yards, and public play spaces including both sport facilities and playgrounds. The design variations are discussed below.

Solution types

The majority of the projects implemented various forms of impermeable retention basins. This appears to be a logical decision as such elements offer ample opportunities for design variations and landscape architectural concepts. Open basins were designed as skate bowls, play puddles and courts, making them suitable for a variety of activities, even with water present on the surface. The potential of using retention basins as a solution to add play function was therefore significant, particularly when combined with permeable surfaces, such as asphalt as demonstrated in the Herron playground case.

Rain gardens have also been employed in several projects, however only the Brøndby afterschool project has incorporated them directly into the play area. Together with other similar solutions like swales, ditches, or infiltration trenches, that combine retention and infiltration functions, vegetated depressions ranked the second most used solution type.

In selected cases, additional hydraulic capacity was frequently supplied by a range of underground solutions, with or without infiltration. At Lindebjerg school, the stored water could be pumped out and reused for play purposes. This, however, raised safety concerns, which will be addressed in subsequent chapters.

Natural or semi-natural ponds and wetlands were uncommon and are possibly perceived as a challenging option for incorporating play functions, presumably due to water treatment and safety requirements. An interesting case from Selsmosen Park nonetheless highlights creativity in discovering new play opportunities within existing site and point out to importance of assessing the risks and potentials of every project individually.

It should be noted that green roofs and roof gardens were not mentioned as options for incorporating play functions. However, these solutions may still be considered as appropriate for certain sites.

Design parameters

Most of the solutions analyzed prioritized addressing daily and moderate rain events (*trinn 1* and *trinn 2* rains in Norwegian classification). Five of them additionally focused on providing protection against severe cloudbursts or have considered the site's functionality during these events. There was a significant variation in the dimensioning return period among the sites, even for those located in the same region, making it difficult to do any classifications or assumptions.

A few sites were designed with a permanent water level. Water play area at Selsmosen was organized with continuous water flow; the rest of the area was designed as park not inviting to play. An artificial pond at Rabalder Park had variable water level depending on precipitation volumes, but lacked specific play features, indicating that direct interaction with water was also not intended. However, at Brøndby green yard access to the permanent water table in the channel is not restricted, as well as students of Ikiminami primary school have free access to the semi-natural pond at the school biotope. This suggests that permanent water table is more often used in combination with educational activities than for recreation.

In the rest of the projects, the maximum water level in retention features was typically restricted to 20 cm or less, irrespective of the targeted age group of the children, and was mainly influenced by the overall design of the area. A few Danish projects additionally mention the need to restrict the retention time of collected rainwater to 24 hours due to health regulations. Lastly, some projects mentioned health concerns about using sprays of rainwater. The reasoning behind these policies will be explored further in the subsequent section.

Materials

As expected to see in projects prioritizing nature-based approach, a wide range of solutions using natural vegetation were observed. There was mostly used grass and shorter plants, while new trees were planted in about half of the cases.

Hard surfaces such as asphalt, concrete, and impermeable pavements were also used frequently. Bigger stones can also be named among popular materials, both for architectural and play purposes.

Only a few projects in the study incorporate permeable surfaces in their design. The use of such materials could significantly improve accessibility and meet the requirements of both universal design and stormwater regulations.

Sand, a popular play material, was surprisingly underutilized in the analyzed projects, with only two projects, Kilden kindergarten and The Rain Playground, adding it to their play areas. The reasons for this are unclear, but it is worth noting that Kilden kindergarten encountered problems with water standing in the sandbox due to the fine sand not allowing infiltration. Consequently, coarser sand was used instead. This highlights the importance of analyzing the infiltration capabilities of a specific site to fully maximize the advantages of incorporating sand in designs.

Activities

The way rainwater is used in play spaces varied greatly depending on the intended purpose of the area. In school settings, the educational aspect was more prominent compared to the recreational aspect, particularly when areas are utilized as outdoor classrooms. In playgrounds, particularly those designed for younger children, interactive playful elements were more prioritized. The diversity in forms and functions presents challenges for comparison but showcases ample opportunities to create unique and creative concepts.

The range of water-related activities depend considerably on the level of engagement of the site owners. This is particularly evident at school projects, such as Lindebjerg school, that integrate climate adaptation strategies into their daily routines.

It should be noted that playability and attractiveness of a play features is a good instrument in controlling the access and establishing limitations on the intended user group. Play elements that are visually appealing or have easy access encourage users to play in designated areas, as seen in Selsmosen where all play features are located in shallow waters, so visitors are unlikely to play near deeper waters. Conversely, planting tall vegetation can restrict unwanted access and protect areas that can be considered dangerous.

Limitations and uncertainties

The following limitations and uncertainties are acknowledged when interpreting the results and conclusions of the case study:

- The cases used in the study may not be representative of the entire population of multifunctional projects for playgrounds, leading to potential selection bias.

- Data collection methods and access to project documents may have been limited, leading to potential data quality issues and incompleteness of information.

- Insufficient evaluations of the projects' functionality, particularly in varying weather conditions (such as spring and fall), could potentially impact the overall assessment of the suitability of NbS for playgrounds. The conducted surveys were limited to two projects. More practical information on climatic impact on functioning NbS in recreational activities is needed.

Chapter 3. REGULATIONS & RESEARCH

Image credit: Marie Konstantinovitch/ City of Paris

Overview of current practice

In Europe, several countries have developed strategies for climate adaptation and guidelines to support the practical implementation of sustainable and nature-based solutions. These efforts aim to assist the industry and to gather best practices for managing the impacts of climate change. In England, the SuDS manual (Woods Ballard et al., 2015) provides guidance on designing, constructing, and maintaining sustainable drainage systems for managing surface water runoff in urban areas. Similarly, the Sustainable Stormwater Management Guideline in Sweden offers recommendations for planning, designing, and implementing sustainable stormwater management practices (Svenskt Vatten, 2011). Denmark has developed extensive knowledge and expertise in addressing various challenges associated with stormwater management in Nordic countries, with numerous projects implemented to tackle surface runoff issues.

Regarding the combination of surface runoff and recreational activities, The Danish Nature Agency conducted a study, that evaluated the potential health risks involved by employing a literature review and modelling approach (Clauson-Kaas et al., 2011). Due to the report's extensive research and its significant relevance to the study's subject matter, including climate conditions, it was regarded as a critical input document for the chapter. The report's principal findings, supported by research on specific topics and guidelines developed in various countries, as well as Norwegian practice, helped identify the most important aspects of using surface runoff in recreation. This, in turn, explained the reasoning behind the design solutions presented in the example project study.

Origin of the runoff and source control

Clauson-Kaas et al. (2011) propose a classification of urban runoff into three types: roof water, surface runoff from public spaces such as parks and squares, and street runoff, which is mainly associated with traffic pollution. The authors indicate that the risk of exposure to microbiological or chemical hazards from runoff originating from roofs is generally low and typically complies with regulatory standards for swimming pools and bathing waters. Th SuDS Manual by Woods Ballard et al. (2015, p. 767) support this claim. However, certain factors such as the use of roofing materials like zinc and lead, or the presence of a large bird population on the roof, can result in runoff containing harmful substances and infectious agents. The report suggests that green roofs can improve water quality and reduce peak contamination, i.e. the first flush effect. Galster and Helmreich (2022) support this claim, proving that runoff from analyzed metal roofs has higher concentrations of Cu and Zn during the first flush, underscoring the importance of decentralized sustainable urban drainage systems in treating stormwater runoff at the source to safeguard natural water bodies. While a recent pilot study in Luleå, Sweden (Müller et al., 2019) has raised concerns about the release of organic components from building materials into rainwater runoff, their impact on using the runoff for recreational purposes has not been investigated.

Roof runoff generally complies with regulatory standards for swimming pools and bathing waters.

According to Clauson-Kaas et al. (2011), the quality of runoff from parks and public spaces is largely influenced by the maintenance practices in place. In Denmark, it is generally considered safe for recreational purposes as long as measures are taken to monitor and remove large amounts of litter or limit the presence of birds, such as pigeons. However, pet and bird droppings are confirmed sources of nutrients, primarily nitrogen and phosphorus, and fecal microorganisms in urban stormwater, as noted by Müller et al. (2020). These sources can be of concern in areas with large bird populations and opportunities for bacterial survival, such as interstitial water and urban beaches, as well as in urban green areas frequented by pets and wildlife. It should be noted that pet waste is a major source of phosphorus, which is a limiting nutrient for the growth of algae and cyanobacteria in freshwater systems (Correll, 1999).

Müller et al. (2020) emphasize the importance of air deposition as a potential source of stormwater pollution, contributing significant quantities of total suspended solids (TSS), nitrogen (N), phosphorus (P), and metals associated with traffic and local industrial emissions. Such pollutants may not originate from within the catchment area, indicating that constructing recreational facilities using runoff at institutions and public spaces located near busy roads or industrial sites may not be feasible without incorporating measures like first flush treatment. Other nonpoint source pollution may not be fully assessed and also influence the water quality.

Health risks

Rainwater storage and usage within 24 hours does not pose any additional health risks.

In compliance with Norwegian regulations on playground equipment safety, hazardous substances or products that are classified as dangerous to human health are prohibited from being contained, released or formed by playground equipment (Norwegian Ministry of Justice and Public Security, 2014). In the context of water playgrounds, Clauson-Kaas et al. (2011 identify direct contact with water as the highest risk factor for humans, especially infants in diapers due to the potential for fecal contamination, further recommending that testing of rainwater intended for recreational use should include analysis for Campylobacter. The study also proposes, based on a literature review, that rainwater storage and usage within 24 hours does not pose any additional health risks, as long as there is a maximum of one user per 1 m^3 of water per day. Woods

Ballard et al. (2015, p. 768) support this recommendation and advise treating harvested roof runoff at least once if it is stored for longer periods, although they do not specify a time frame for that.

Deeper retention basins should be placed in areas with better access to sunlight.

Clauson-Kaas et al. (2011) additionally suggest that deeper retention basins should be placed in areas with better access to sunlight as solar UV radiation can effectively inactivate pathogens. Sinton et al. (2002) supports this recommendation by demonstrating a connection between the inactivation of microorganisms, including fecal coliforms, in freshwater samples and the amount of solar radiation received. Another review carried out by McGuigan et al. (2012) describes the principle of solar disinfection for treating freshwater to safe drinking quality and additionally recommends consuming solar-disinfected water within 24 hours to avoid post-exposure re-growth. On another side, UV radiation intensities in Northern Europe are expected to be lower than in Africa or Asia, so the inactivation effect cannot be considered as sufficient treatment and only used as a supplement to other measures.

In Denmark, active growth of microorganisms in warm bathing waters has been a concern, with guidelines issued by the Danish Health Authority advising against the use of rainwater in temporary wading ponds due to the transfer of microorganisms from children and the surrounding environment to the water. The guidelines particularly emphasize the growth and spread of Legionella spp., which can cause mild flu-like cases (Pontiac disease) or severe pneumonia (Legionnaire's disease) through the inhalation of contaminated water mists (Danish Health Authority, 2009). Although Legionella bacteria can be found in natural environments with rainwater and natural soil as alternative sources, especially under favorable conditions (van Heijnsbergen et al., 2014), their multiplication is limited to temperatures between 25 and 42°C, with optimal growth occurring at 35°C (Fields, 2007). However, Clauson-Kaas et al. (2011) assess that based on previous negative findings of Legionella spp. in collected rainwater and the high temperatures required for the growth of the bacterium, Legionella does not pose a significant health risk during recreational activities in harvested surface runoff. Nevertheless, it should be noted that temperature rise following climate change may cause more intense local heating of retained rainwater, possibly posing a safety hazard. Further research is needed in this area.

Design and safety concerns

Drowning

Drowning is a significant cause of death for children under the age of 15 globally, with higher mortality rates in low- and middle-income countries (World Health Organisation, 2014). Children under five years old are at a higher risk, and the severity of the risk is linked to the child's physical abilities, previous medical conditions and adult supervision. According to Peden et al. (2020) , drowning can occur quickly, even in shallow water of just 15 cm depth, and poses a potentially fatal risk, especially for children aged 16-31 months. Statistics indicate that 90% of drowning cases are the result of a fall into water. The lack of awareness about water dangers and a lack of swimming education are some of the factors contributing to this mortality, as mentioned by the World Health Organisation (2014), with early swimming education being important strategy to prevent drowning incidents, including children with mental disabilities(Alaniz et al., 2017).

Children under five years old are at a higher risk of drowning, many drowning cases are the result of a fall into water.

In Norway, Norwegian Building Authority (2017) stipulates in §8-3, 4th paragraph, that outdoor recreational pools, wells or similar features must be secured with railings, covers, or other protective measures to prevent fall injuries. Smaller dams, without the total area specified, do not require railings if they are secured against drowning; the regulation deems a maximum depth of 20cm to be sufficient security. Another guideline by Norwegian Water Resources and Energy Directorate proposes the limit values for depth (D), velocity (V) and the product of the two (DV) on flooded area institutions like kindergartens and primary schools be minimal (DV = 0) (Norwegian Water Resources and Energy Directorate (NVE), 2022). This guideline implies that smaller children are at risk regardless of water depth and velocity, though it applies to areas with uncontrolled stormwater flow.

20cm depth is deemed to be sufficient maximum depth, according to TEK17

Infiltration

According to Norwegian TEK17 regulations, stormwater shall be infiltrated or managed locally as much as possible to relieve networks and behold water balance (Norwegian Building Authority, 2017§15-8). Sand infiltration is a common method used to manage stormwater and is also used in playgrounds, especially for kindergarten-age children. According to World Health Organization's guidelines on safe recreational water environments (World Health Organisation, 2003), primary risk encountered upon beaches is from animal excreta, particularly from dogs, and preventive measures such as fencing and warnings can help avoid contamination.

Vegetation

When designing rain gardens, it is important to comply with safety regulations that restrict the use of poisonous plants. Native plants are often preferable due to their growth rate and ability to prevent erosion, which is a common issue at play areas. However, the shorter growing season in Scandinavia may impact productivity and the time required to establish a stable plant cover. It istherefore important to preserve existing vegetation, including trees that provide weather protection and contribute to managing stormwater, and minimize changes to the terrain (Building Research Design Guides (Byggforskserien), 2022). This is also an effective strategy to address the wear and tear of green areas in play areas, along with providing ample green areas for children to play on to help distribute the load.

Established vegetation should be preserved and changes to the terrain minimized.

Heights and fall protection

According to TEK17 §8-3, 3d paragraph, elevation differences must be marked to prevent falling injuries, and terrain differences over 0.5m combined with hard surfaces like concrete, asphalt, or stones must be secured with railings, dense vegetation, or similar. The Norwegian Building Research Design Guides on the design of outdoor areas for play and activity (Building Research Design Guides (Byggforskserien), 2022) state that if the fall height of playground equipment is over 60 cm, it shall have a shock-absorbing surface, which can be achieved using rubber surfaces or other solutions. However, the design guide emphasizes that promoting children's health and well-being should not be compromised by overly strict safety regulations, which may require exploring a wider range of solutions.

Universal design

Figure 28 Example of an accessible water playground in Scotland

Public play areas provide many benefits for children with impairments, including outdoor play, social interaction, and inclusive experiences. However, there is no agreement on the practical applicability of universal design for play areas, and terms like universal design, inclusive design, and accessible design are often used interchangeably (Moore et al., 2022). The basic principles of universal design include equitable and flexible use, simple and intuitive use, high tolerance for error, and low physical effort. Norwegian regulations (Norwegian Building Authority, 2017, §5-6) require that outdoor recreational areas offer various activities and be usable by different groups of people, prioritizing flat terrain. The principles of universal design also require sufficient lighting, good contrast between elements, enough space and surface for wheelchair users, and the use of allergy-friendly plants and vegetation (Standard Norway, 2011).

In their study on inclusive playground designs, Courtney and Keith (2017) found that a playground containing loose elements including a sandbox, water table, and wooden planks created more opportunities for cooperative play. Although there is no specific guidance on combining recreational water features and universal design, it may be beneficial to organize surface runoff into architectural features. This can be helpful for children with mental impairments, who may find free runoff scary or see it as an obstacle. Additionally, water features provide opportunities for inclusive play due to their universal play characteristics. However, relevant research on the topic is quite limited.

Summary and key takeaways

Research question 2

What do current regulations say about using stormwater in recreation, and what differences are there between Norway and other countries' practice? Which criteria can be suggested for the design process to ensure satisfactory quality, safety and health risks of multifunctional installations?

In Norway, there is a strong emphasis on sustainable climate adaptation and use of stormwater as a resource, but the utilization of surface runoff in recreation is currently not at specific focus. Regulations are generally comparable to those in other Northern European countries, with some localized differences in strategy formulation. There are no apparent barriers to the use of rainwater for recreational purposes, and previous project illustrations suggest that such solutions can function effectively in Norway.

The utilization of rainwater as a prominent element in play areas raises concerns regarding the potential risk of drowning. National regulations establish a safety limit of a maximum 20cm depth, which is supported by the example project review results of discussed in this study. It was challenging to find the reasoning behind this. Research and drowning statistics have demonstrated that this depth limit may still pose a risk for smaller children, as well as giving a certain safe depth limit is impossible and may be unethical. As a result, it is suggested to restrict the maximum water depth to minimal (a few centimeters) in areas where children under the age of five years are present and prioritize the designs minimizing tripping hazards. For older children, the 20cm depth limit is deemed adequate with the information available. It is imperative to emphasize the importance of active supervision in any activity involving water.

The examination of typical sources of contamination to rainwater and the challenges in mitigating nonpoint source pollution in urban environments indicate that a practical guideline of a 24-hour residence time for use of harvested runoff appears to be a reasonable conclusion for most scenarios. Clauson-Kaas et al. (2011) additionally suggests maximum water volume of 1m^3 per person, however this may not be feasible in practice. To effectively manage the risk of contamination, it is necessary to assess it on a case-by-case basis, taking into account characteristics and circumstances of the area.

The selection of appropriate solutions can help to minimize risks to some extent, and possibility of harm should be weighted with benefits of provision, as Woods Ballard et al. (2015) state. The installation of compliant barriers such as fencing to help minimizing bacterial contamination from pet droppings and wildlife is an example. Water treatment may be introduced in areas where it is necessary or feasible, and can enable incorporating rainwater fountains, which is typically not advisable due to risks of aeration and spreading of legionella and other organisms. The inactivation effect of solar UV light and area planning accommodating for it, mentioned along possible measures, cannot be considered a requirement in the Norwegian climate, due to the naturally low intensities and therefore limited efficiency. Nevertheless, this aspect should be taken into consideration wherever it is feasible to do so.

Designing universally accessible recreational water features can be challenging due to the lack of research and documented practice. However, no limiting factors have been identified, and universal design requirements can be possibly met through a range of NbS, for instance permeable surfaces.

Based on the literature review, it can be concluded that rainwater infiltration in sandboxes is a safe option for stormwater management as long as the frequency of water accumulation is minimal and subsoil infiltration rates are sufficient.

To summarize the analysis provided above, the following considerations to aid application of multifunctional approach in Norway are suggested:

- When doing the site analysis, the most important factor to consider would be the runoff origin and possible pollution sources, including air deposition, as it can be of critical importance for whether stormwater can at all be incorporated in play. Roof runoff is typically safe to get into direct contact with, given the roof material is not emitting dangerous substances, and bird presence is limited.

- Input parameters to consider would be site location, surface and roof cover type and composition, proximity to industrial sites and busy roads. These factors influence whether runoff needs to be treated.

- The solutions need to be selected based on local functional requirements and site specifics. Robust overflow control and arranging safe water flows for torrential rain events are important to limit possible health and safety impacts due to higher flow and velocity rates.

- Maximum water depth in retention ponds should be kept minimal where smallest children are present and design has to focus on tripping hazard risks; 20 cm maximum depth at spaces dedicated for children of school age.

- Maximum 24 hours residence time is proposed to limit possible health risks, avoid algae bloom and growth of other waterborne microorganisms.

- Take advantage of sun UV disinfection effect and place for example retention ponds in sun-exposed areas. Sprinkling of rainwater should be avoided unless the runoff is treated or residence time is controlled by continuous flow.

- Even though adult supervision is important safety factor, the personnel can't be held responsible for the technical solutions, they need to be dimensioned to the best knowledge to date when it comes to health and safety risks.

- Established vegetation and terrain forms should be preserved to the maximum extent.

Additionally, as different types of play areas have certain specifics, it is deemed necessary to specify the following consideration for each of the groups.

Stormwater management at kindergarten playgrounds

Specifics

- Design must correspond with the target age group - minimal water depth recommended for these areas
- Retention basins should be avoided due to higher safety risks and possibility of fecal contamination (children in diaper age); if used - water quality monitoring and supervision by adults are to be considered
- Priority should be given to solution involving infiltration, like sand boxes, rain gardens and similar, with good control over infiltration rates
- Rainwater harvesting for later use in gardening is also a good option
- Thorough planning for torrential rains to limit areas with high depth and velocity
- Focus on keeping open gullies clean (sand and leaves can block and force water flow in different direction)
- General awareness of the stormwater features important to ensure their functionality during operation

Span of possible solutions

As it was highlighted earlier, natural landscapes have an important role in motoric and cognitive development of the youngest children. Additionally, Thoren A. -K. H. et al. (2019) has in their report about outdoor areas at kindergarten and schools given an overview of progression and movement capabilities of children in different age groups, with examples of environments that can be suitable for certain age. For the stormwater management context in Norwegian kindergartens, elements like sand, shallow gutters, "mini-forests" with raingarden function for smaller children, and slightly more variative terrain with taller plants for older children are the possible solutions. Permeable surfaces or maintaining sufficient terrain slope are a good alternatives in keeping excesses of water away from surface, with possibility to either infiltration or storage and further transport. Particular attention needs to be given to manhole and overflow pipe lock type in terms of openings to prevent toys falling into them and feet getting stuck in between bars.

Bank of ideass

Figure 29 Different playground designs for smaller children: top left - Øya kindergarten, top right - hallow play puddles at Regnlekplatsen, bottom left – natural materials as fall protection, bottom right – Paris Oasis project yard

Figure 30 Sand and permeable surfaces at Nardo and Solbakken kindergartens, Trondheim

Stormwater management at school yards

Specifics

- More focus on learning and wide possibilities to include water as a play element and in curriculum activities with a school yard as a live lab
- Several smaller multifunctional areas instead of few large and popular to avoid queueing
- Use vegetation that is diverse and representative for education purposes (different types of leaves, seeds, models of reproduction, edible species etc.)
- Retention basins to be designed allowing maximum 20 cm water depth
- Timely removal of sediments to avoid release and blockage
- Differentiate "wet" and "dry" areas so children who do not want to engage in water activities have other play options
- If parcel garden is chosen, consider operation nuances like watering system and harvesting, allocating a dedicated teacher to maintain the garden during the working hours, also holiday periods

Span of possible solutions

Ability of natural landscape to enhance natural curiosity can be combined with the whole variety of stormwater management facilities. According to (Building Research Design Guides (Byggforskserien), 2022), children in school age need bigger challenges when it comes to strength, balance, coordination, speed and endurance. Activities like obstacle courses can be designed including water challenges (ex. a bridge over water), given the eventual fall into water will not introduce additional hazard; use of natural materials can give flexibility and customization. For the areas like basketball or football pitches and cycling parks, practical implications of permeable surfaces should be considered. Larger areas can be designed as retention ditches with controlled drainage and overflow, freezing water can be exiting addition at wintertime. At the same time, children above 10 years old need to have the opportunity to retreat and relax, so such elements as rain gardens can be suitable for this purpose.

It is important to note that engagement and inclusion of the students, as well as forming of the school's identity when redesigning school yards can be dramatically improved by participation of school children and residents in design process. The approach was successfully piloted by, for example, Klimaskolen (The Danish Nature Agency, 2015) and Colene Hoose Elementary School project (Nebelong, 2021a), resulting in greater benefit of the whole neighborhood. Such approach can also allow for better public awareness and increased feeling of ownership, that can potentially reduce misuse and vandalism.

Bank of ideas

Figure 31 Outdoor classrooms

Figure 32 Gabions and rain gardens forming a playscape

Figure 33 Wear and tear protection without using impermeable surfaces

Figure 34 Using water as exciting and accessible element

Figure 35 School biotope at Ikiminami primary school, Fukuoka, Japan

Figure 36 Challenging physical environments

Stormwater management at public recreational play and sport areas

Specifics

- Used by wider variety of users and not restricted to specific age groups – need to find solutions suitable to broader audience and all age groups or create separate dedicated spaces
- Higher risks of contamination due to openness to public and typically lack of fencing – high focus on hydraulic retention time
- Pollution control from wildlife and pet presence – warnings to dog owners, mapping of wildlife and bird presence

- Robust and easy maintenance designs to prevent garbage collection and vandalism
- Information boards about water safety can be evaluated, depending on the design solutions chosen

Span of possible solutions

Incorporating water features into public spaces for play has the potential to increase awareness about water, ecology, and enhance the identity of the area, creating a popular destination for the public. To cater to a wider audience, design solutions with more emphasis on architecture could be used in combination with specific play areas for different age groups or activities, such as a playground for younger children, an obstacle course, or a skatepark. These areas should be designed not just for children, but to encourage interaction between different groups, with water as the starting point and motivation. Involving local residents in the design process can promote inclusivity and reduce malicious behavior, as demonstrated by the Heiner Metzger square project in Ulm, Germany (DREISEITLconsulting, 2005). Additionally, the sound of water can contribute to a pleasant soundscape. Since water is generally appealing to most people, incorporating water features can create a more inclusive design for everyone to enjoy.

The analysis of public play areas and especially sport facilities have demonstrated that introducing different forms of rainwater retention is often an acceptable solution. The larger investment potential and lack of design restrictions, as required for educational institutions, present opportunities for more innovative solutions that may not be feasible at other places, like advanced rainwater harvesting or treatment techniques in areas where surface runoff is not appropriate for direct use. An example of this is the Gladsaxe sport park, where a biofilter is introduced for stormwater treatment, the solution not necessarily viable for a school or a kindergarten. The introduction of wetlands can also be feasible, and in some instances, existing water bodies can be enhanced with play areas, such as in the case of Selsmosen park.

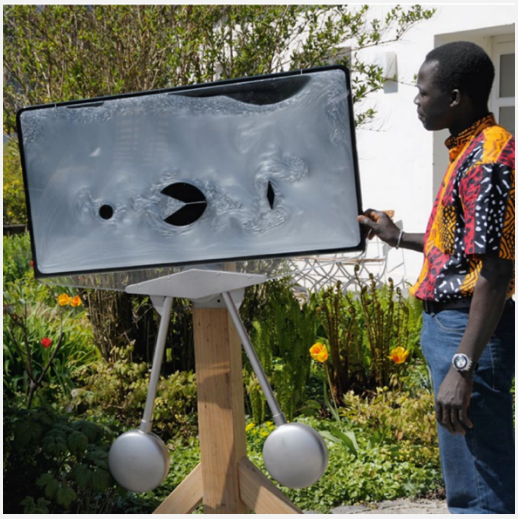



Figure 37 Activities and experience: top left - pattern board filled with water, top right - soundscape at Heiner Metzger square, bottom left – engagement of teenagers, bottom right – rain garden with enhanced retention and infiltration

Figure 38 Zoning for different age groups in the Reduta park, Poland

Figure 39 Design of water features can promote acceptable risks

Chapter 4. THE CASE STUDY - LILLESTRØM

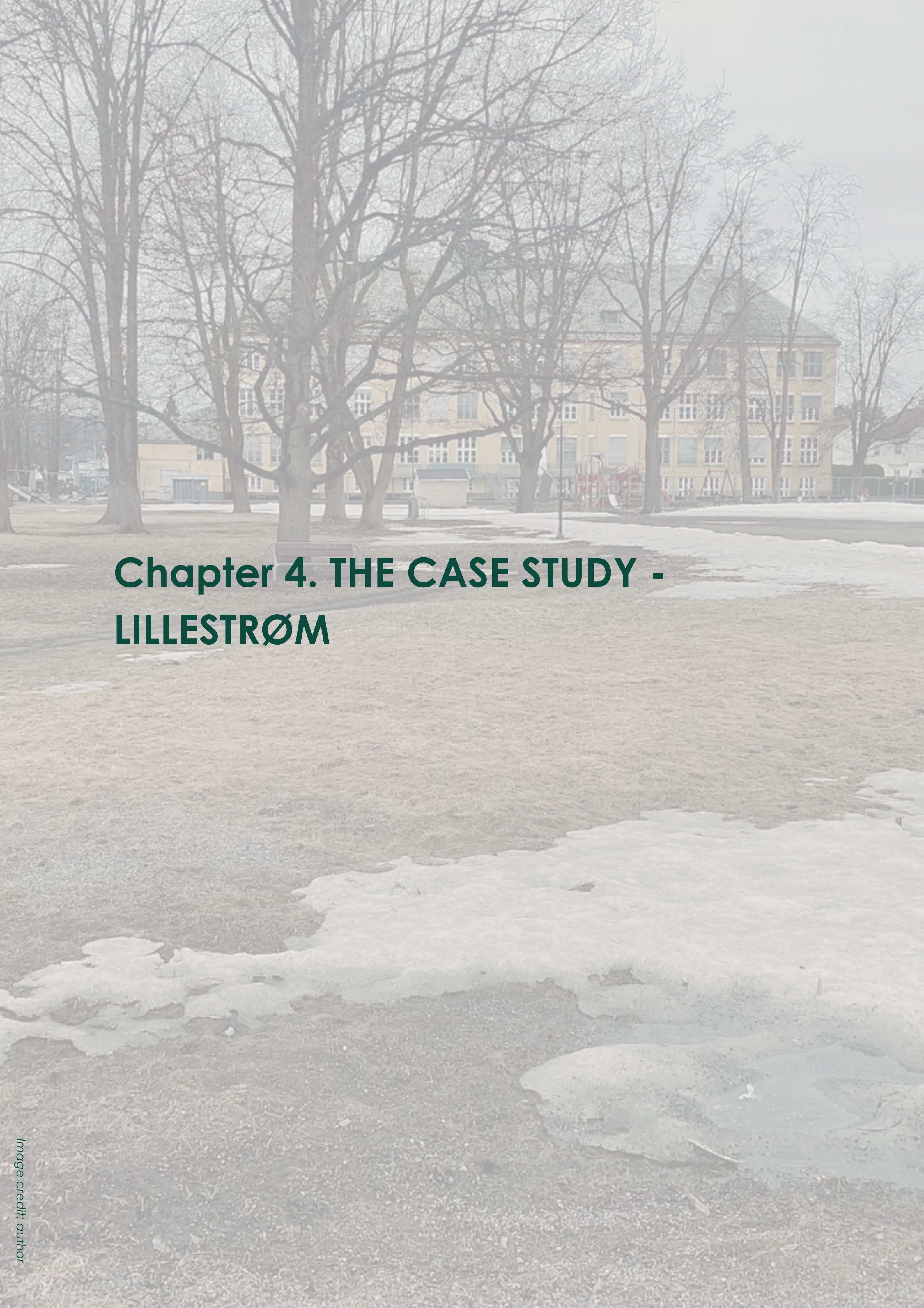


Image credit: author

Figure 40 The Lillestrøm city

The city of Lillestrøm and its development plans

The city of Lillestrøm is a quickly developing city, strategically located between Oslo and Gardermoen airport. This location, combined with a diverse housing market and attractive job opportunities, provides Lillestrøm with a competitive edge over other cities in the region. In order to keep up with this development, urban spaces need to be developed in tandem with residential and business areas.

To guide this process, Lillestrøm has released a plan outlining their strategy for urban development. One of the key concepts presented in this plan is the "Vision blue-green city" (Figure 41). This concept presents different strategies, including a strategy for increasing the amount of green space in the city by creating a "Green Belt" (“Grønne ringen”) around the city and connecting existing and future urban parks to form a network with attractive features. The ultimate goal of this plan is to increase the total amount of green space in Lillestrøm to 49% of the city's area.

Figure 41 The strategies of the concept “Vision blue-green city”: The green network with the Green Belt and robust stormwater management system

Lillestrøm is located on a delta plain between the Nitelva and Leira rivers, with a flat moorland landscape and a slight incline from the south up towards Kjeller district. Historically, the city has had large residential

Figure 42 The largest public cityscapes in Lillestrøm - Kirkeparken, Rådhusparken, Kulturparken and Sørumsparken

areas built with detached houses and gardens. However, the latest trends involve rapid urbanization and shrinkage of green spaces, that together with more frequent intense rain events leads to increased surface runoff. The existing pipe network is built to convey both stormwater and wastewater (*fellessystem*) and is already at capacity with large overflow discharges (Opheimsbakken, 2017). This forced the authorities to develop a strategy for robust stormwater management as a part of the city's "Vision blue-green city". The strategy involves prioritizing open stormwater solutions, exploring the potential of incorporating previously enclosed natural streams into the cityscape as pedestrian and cycling connections, make use of open water bodies like dams and ponds, while also improving the overall quality and quantity of water in the city.

Analysis of Lillestrøm's play areas

According to the municipality's status report issued in 2021 (The city of Lillestrøm, 2021), only 35% of the city is covered by vegetation. Private gardens make up the majority of these areas, while public green areas and parks account for only 7% in total. These figures fall short of the UN's recommendations for urban areas. Additionally, residents have expressed a need for more public spaces, as well as to improve the existing areas which often lack desired recreational content and qualities.

The report also reveals that only 42% of residents have a public green area within a 200-meter radius of their house, while the aim it that all residents have this opportunity. To achieve this goal, the municipality is planning to create more smaller green spaces in addition to the existing ones. An important aspect of this effort is the utilization of areas such as schools and kindergartens to establish smaller "pocket" parks and provide recreational qualities within close proximity.

In fact, location of the schools and kindergartens is very well aligned with the municipality's strategy for the blue-green network. For example, Lillehagen and Norlandia Furulund kindergartens, Skedsmo VGS, Kjellervolla primary and Vigernes schools are located within the planned "Green circle". Furthermore, Volla school and park, as well as Lillestrøm kirkepark and Lillestrøm VGS are situated on the planned "kunnskapsaksen" and the green link through the area. Additionally, all city's schools and both Lillehagen and Norlandia Furulund kindergartens are located on or near major runoff lines, as can be seen from Figure 43, so their yards have the potential to contribute to better stormwater management in the respective neighborhoods. The total reported green areas available at these institutions to date are 1,7 hectares, excluding the newly climate adapted Souphie Radich's school. Accounting for the fact that some parts of school yards are not reported as green areas and including school roofs that may also be greened, the gross potential of schools and kindergartens can increase to 13.1 hectares, which is approximately 2,5% of the total city's area.

Existing public parks and playgrounds cover approximately 8,7 ha, excluding the city's levee (the Flomvollen). The available open sports facilities in central Lillestrøm are limited to 1.4 hectares, with only tennis fields between Elvegata and Buegata and a football field at Øyeren plass offering some potential for climate adaptation solutions. It notal, play areas cove 23,2 ha, or 4,5% of total city's area. Lillestrøm's schools have the greatest potential in terms of multifunctionality of all play areas. They are located on or near major runoff lines, as seen at Figure 43, and the total area is largest. To look closer on the effect of multifunctional approach at specific site and demonstrate the practical application of proposed guidelines, Volla school and park was chosen for further detailed analysis. This decision was made based on the municipality's preferences and the opportunity to support ongoing renovation projects.

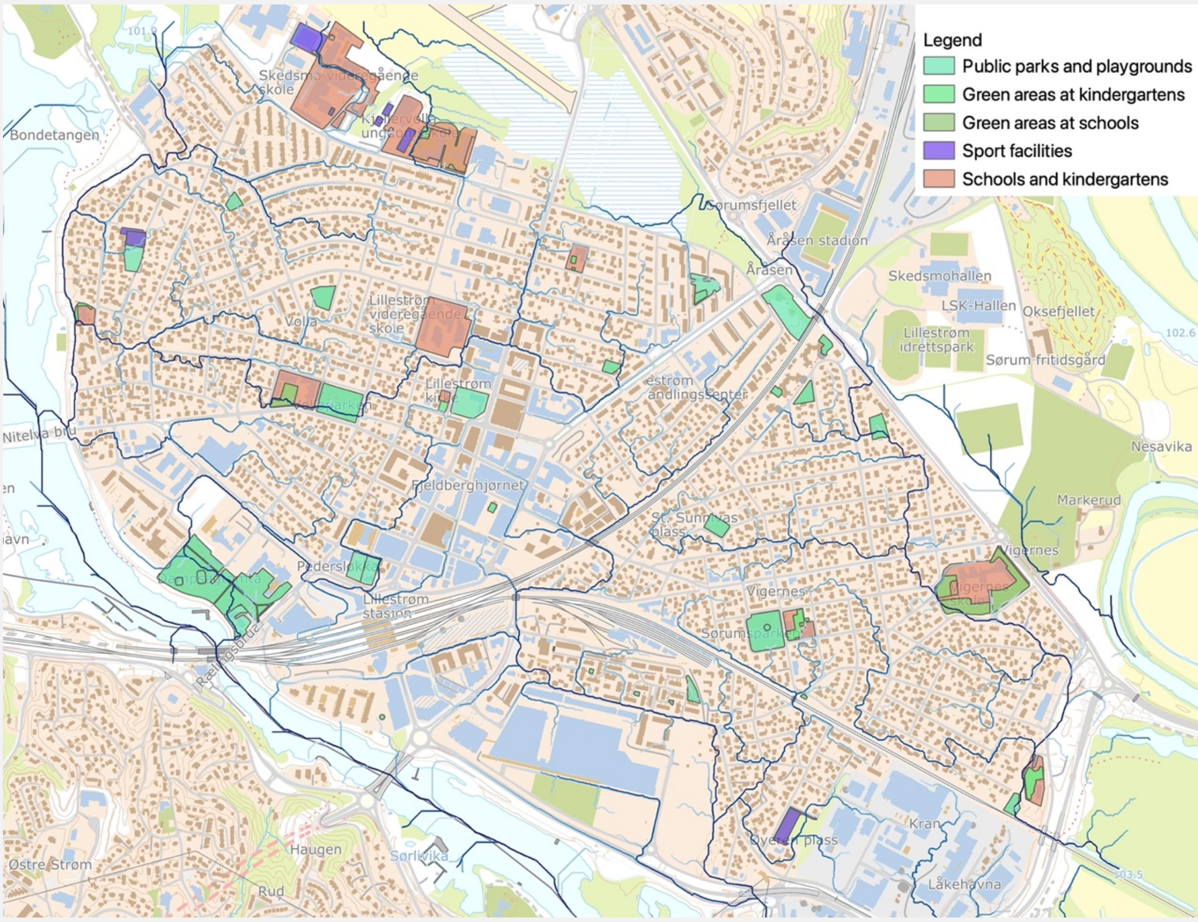


Figure 43 Overview of play areas and runoff patterns at Lillestrøm, GIS analysis

Volla district, school and park

Volla is so called *hagebyen* – a residential district with primarily private houses, few blocks and gardens located in a grid of streets. It is known for its popularity among families with children, who appreciate proximity to schools and kindergartens. However, the few available meeting places are not interconnected and lack content. An example of such place is Volla park.

Figure 44 Volla school

Figure 45 Volla park

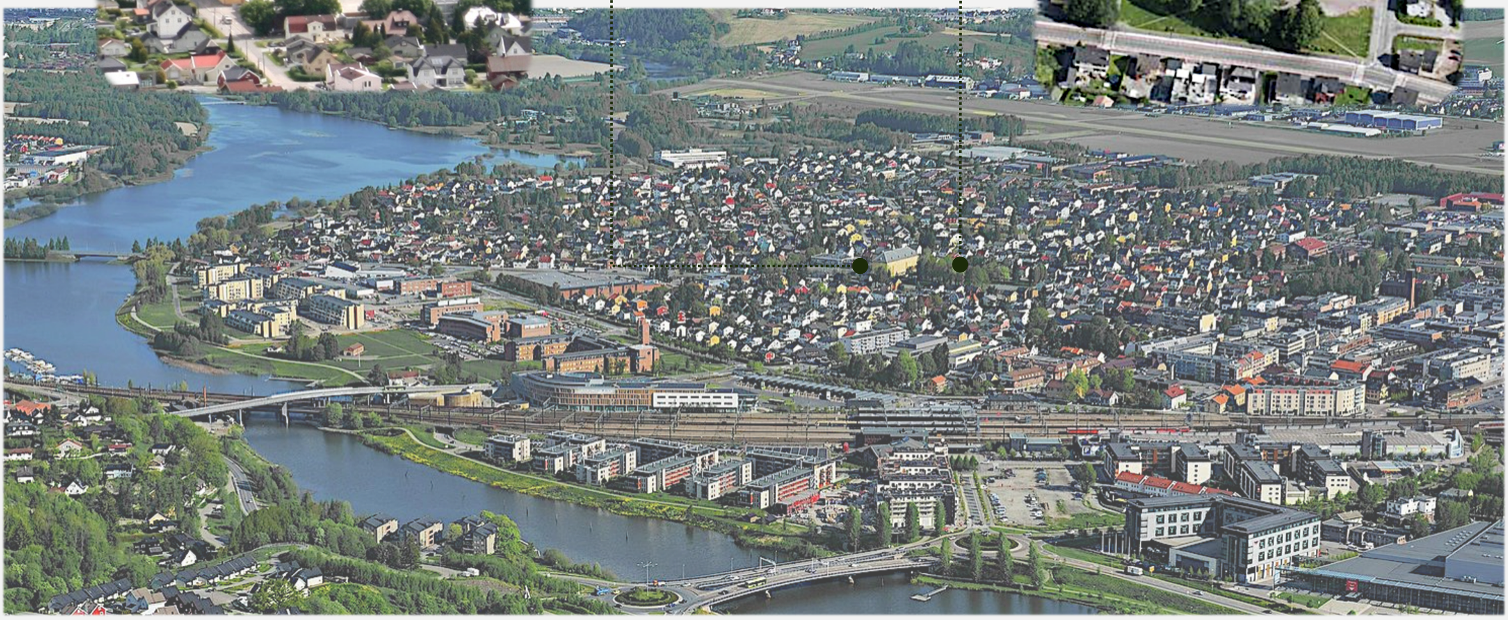


Figure 46 Central Lillestrøm overlooking the train station and Volla district

Volla Park, one of the largest parks in Lillestrøm, has been an integral part of the city's landscape for almost a century. The park currently has limited amenities during the summer season, comprising only a gravel playfield, grass lawn, and small playground. Water accumulation is also evident in rainy conditions. However, in winter, the gravel field is transformed into a bustling skating rink that attracts many local residents. The municipality acknowledges that the park is underutilized, except for the ice rink, and has the potential to provide more recreational activities, inclusive spaces, and meeting areas. In addition, the park's vegetation needs to be enriched with a wider variety of plants. During school times, the neighboring Volla school uses the park as an additional outdoor play area.

Figure 47 The Volla park and school seen from north-east

Volla primary school, established in 1922, is Lillestrøm's oldest school with over 400 pupils up to 7th grade. The school's venerable building is adjacent to an indoor swimming pool, which is also used by the students. The municipality has initiated a rehabilitation project aimed to increase the room capacity of the main school building and reconstruction of a side wing, as the current capacity is partly being fulfilled by a temporary pavilion. The project also includes updating the school yard. The city plans to strengthen the school's role as an important community and neighborhood center for residents of Volla and the center west in the future.

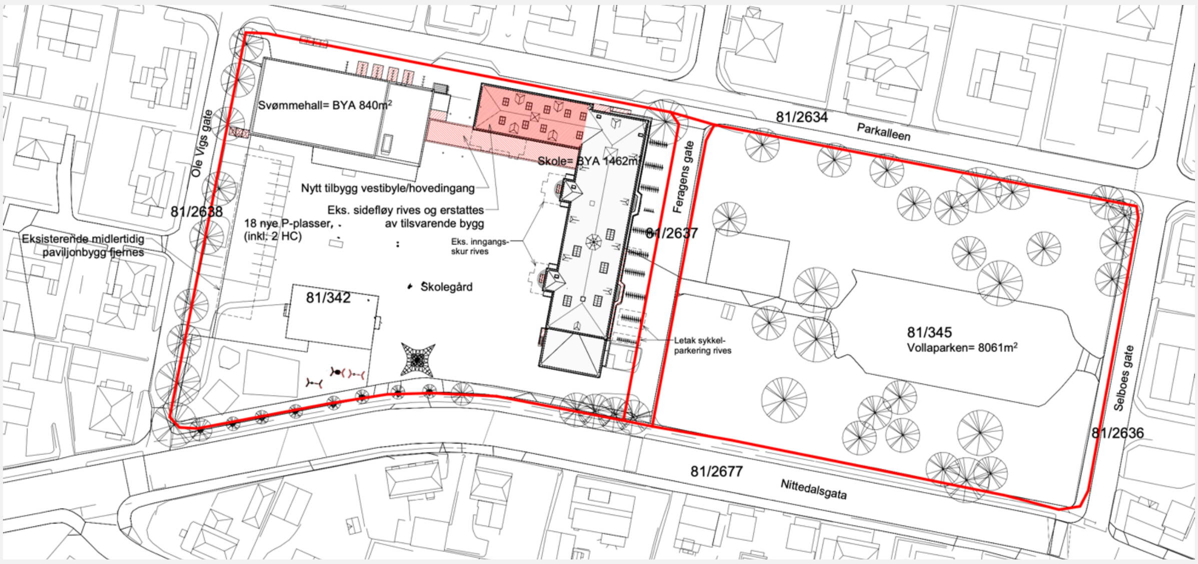


Figure 48 Volla school and park, project drawing

Ongoing rehabilitation projects

The Volla school rehabilitation project is currently in its early phase. Figure 49 shows the latest landscape plan. The temporary pavilion is to be replaced with parking lots. The current stormwater plan (Gjessing, 2021) calculates a runoff of 103 l/s from the school and proposes to convey it by 400mm pipes to an underground storage system of 365 m^3 with overflow to the municipal network. Infiltration trenches are also proposed to collect the runoff from the permeable surfaces in the parking area and lead it to a sand trap, however use of porous materials is missing from the landscape plan.

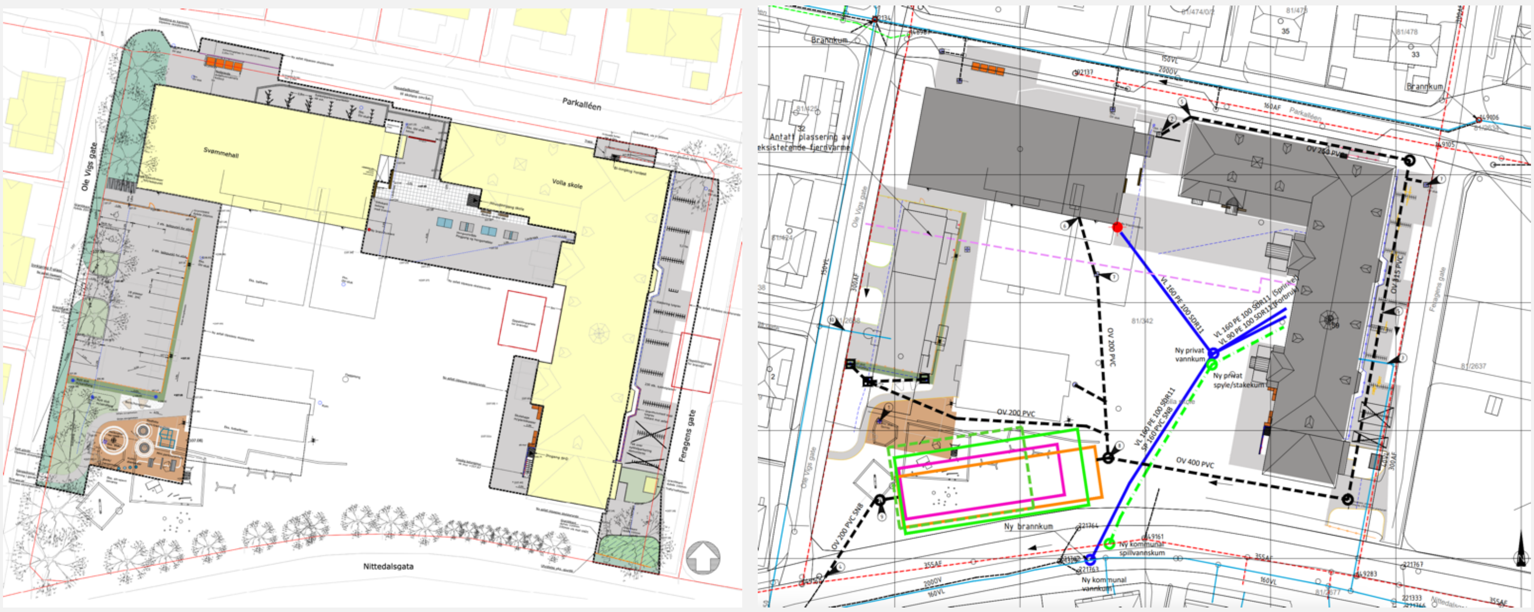


Figure 49 Landscape and stormwater plans, Volla school

In the park rehabilitation project, here are no planned changes in elevation for the existing ice rinks, and the runoff is intended to be spread throughout the area and managed using open solutions such as rain gardens and swales.

For larger rainfall events (*trinn 2* rains), estimated overflow volumes of 0,5 l/s are planned to be directed to the municipal network at the northwest and southeast of the park (SOLA, 2023).

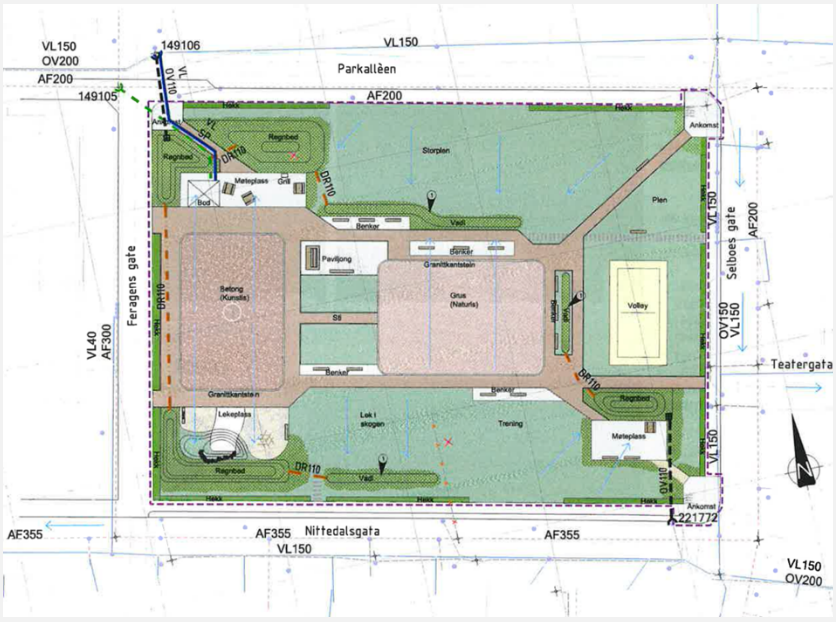


Figure 50 Stormwater and landscape plan, Volla park

Volla site - detailed analysis

Background information and existing situation

The present study considers the school and the park as a single entity for the purpose of analysis, due to their proximity and frequent user interaction.

The geotechnical survey of the area, conducted in 2020, revealed that the soil composition primarily comprises of silt and clay. The top layer is composed of peat with a thickness of approximately 1 meter, followed by silty clay and a sand layer at a depth ranging from 5 to 10 meters. The soil has weak characteristics, but the risk of quick clay is absent, as reported by Gjessing (2021).

The school yard is predominantly covered by impermeable surfaces, with roughly one-third of the total area reserved for play. A portion of the playground is situated on natural soil, and the field outlet area is located at its outer corner. On the western side of the yard, large trees provide a natural boundary. Newly planted trees line the southern edge facing the street outside the school fence.

Figure 51 Playground at the field outlet

The park area is situated approximately 0.5 meters below the level of the surrounding streets, except for Feragens street, as illustrated in Figure 52. The topography of the area is generally flat, with minimal variations in terrain. During the inspection, there were observed snow piles resulting from cleaning snow from the ice, which caused flooding in the surrounding area upon melting. The existing trees are the most noticeable features of the park.

Figure 52 Volla park seen from north-east

Runoff origin

Based on the analysis conducted using SCALGO Live (Figure 53), the catchment area of 0,37 km2 drains to the lowest point in the western corner of the school yard. The park receives the runoff and directs it towards the school yard, as shown on Figure 54.

Figure 53 Catchment area for the site

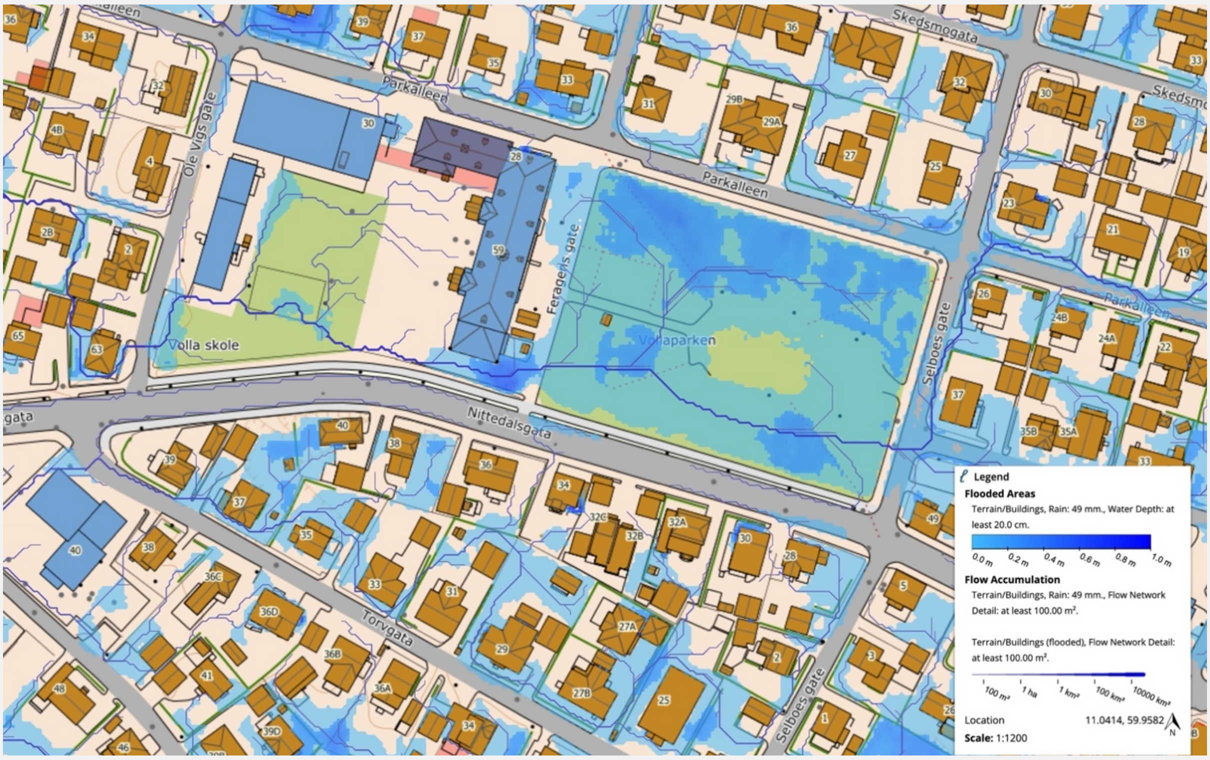


Figure 54 Runoff lines and flooded areas

The entire study area is situated adjacent to Nittedalsgata, which is a moderately trafficked road with an annual average daily traffic (AADT) volume of 4700 vehicles, as reported by The Norwegian Public Roads Administration (Statens Vegvesen) . A sampling station located at the eastern edge of Volla park monitors concentrations of PM2.5, PM10, and NO_2 in the area. In 2021, the yearly average concentrations for all parameters were reported to be below the respective threshold values by the Norwegian Environment Agency . There are no major industrial sites situated in close proximity to the study area or within the watershed.

Figure 55 Catchment area, Volla park inflow

The catchment area that drains to the park (Figure 55) primarily comprises private houses with gardens, along with a few areas containing block houses and two heavily trafficked roads – Storgata (AADT 10,000 vpd) and Alexander Kiellands street (AADT 10,200 vpd). As a result, any water flowing into the park must be treated before it can be used for recreational purposes. A small portion of the runoff streams from Nittedalsgata to the eastern corner of the park. The central part of the park is dominated by an existing gravel pitch that is slightly elevated above the surrounding grass. This results in snow and runoff being retained in the area, leading to the formation of several ponds around the rink The runoff harvested within the park can be considered generally safe for recreational use, although the current slope may pose a challenge for meeting the required 24-hour residence time. The overall slope of the area is from east to west, with the outlet situated in the western corner that drains to a low point located near the southern façade of the school. This location can be clearly seen in historical photos, as presented in Figure 56.

Figure 56 Overflow from the park to the school yard at Feragens street

Most of existing trees in the park are situated in the southern part, resulting in shade being cast over the western and north-eastern sections of the park. The central area around the existing gravel rink is more exposed to direct sunlight.

In addition to the park runoff, a portion of stormwater at the school is collected by surface and roof runoff. The school roof, as well as the new wing which is planned to have a similar roof covering of slate, partly drains to the inner yard and partly towards Parkalleen and Feragens street which separates the school from the park. The pool roof, which is assumed to be covered in bitumen, drains through internal drains to an underground pipe network. Some smaller portions of the runoff flow towards Parkalleen and Ole Vigs street. The Google street view photo indicates the presence of local depressions in the middle of the yard which collect water (Figure 57).

The school yard has very limited vegetation, consisting of only a few trees planted along Ole Vigs street and one large tree located in the western corner close to the park overflow. Due to its south-west orientation, the yard receives ample sunlight during the daytime, resulting in minimal shading.

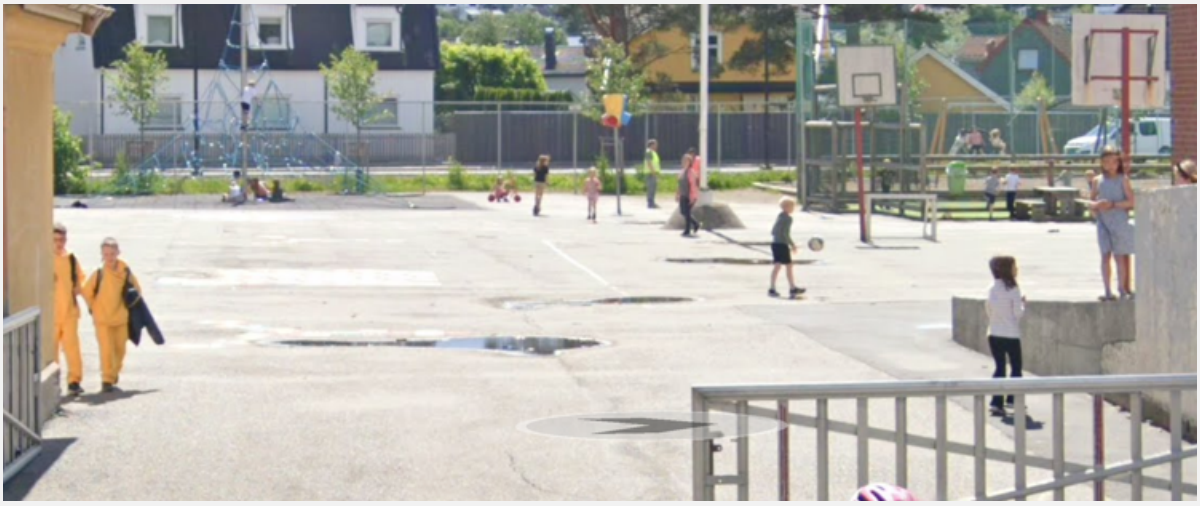


Figure 57 Depressions filled with water in the middle of the school yard

Currently, there is no designated flood path in the area. The primary drainage route that runs through both the park and the school is expected to be the main flow direction in the event of a flood, as shown in Figure 53.

Solutions

Given the minimal slope of the entire area, it would be more practical to propose infiltration-based solutions rather than retention and storage systems to have better control over maximum retention time. However, the infiltration rate is likely to be relatively low due to the soil's composition. Therefore, it is recommended to design for infiltration of smaller rainfall events while also planning for safe transport of larger events to storage and retention systems that can provide overflow to the public network. The proposed concept for the site can be seen in Figure 58.

Figure 58 The proposed design concept

In order to limit pollution transfer from the catchment area, it is necessary to implement measures in Volla park. It is therefore proposed to construct a wetland at the east side of the park. This wetland will receive and treat incoming rainwater, including runoff from Nittedalsgata.

The current topography of the gravel rink determines how water flows through the park. To capture runoff from the southern part of the park and act as an overflow for the wetland, the gravel rink can be modified and lowered to create a shallow retention pond with a maximum depth of 20cm. The excess water is discharged through a swale that leads to the park outlet via a playground relocated further south, as proposed by SOLA (2023). The new playground location can be made more engaging with the addition of an obstacle course and small bridges over the swale. The swale can also be used to store snow produced when cleaning the ice rink during winter, and a bridge can be constructed for it to cross the street, as illustrated in Figure 59. In addition, a sand volleyball pitch is proposed to be built in the western part of the park next to Feragens street, which can help intercept some of the runoff from that area.

Figure 59 Example of a shallow swale crossing

It is recommended to install three rain gardens for the school. The first rain garden should be placed near the southern corner of the school, around the existing tree to follow the existing terrain variations and making use of the tree's infiltration contribution. This rain garden will assist in managing existing water accumulations in a safe and effective manner. To avoid frequent water accumulation on top of the vegetation, it may also be feasible to direct the overflow to the municipal network.

The second rain garden is recommended at the center of the school yard that will also collect roof runoff by directing open rain gullies to it. This placement is strategic for addressing current issues with standing water. Planting one or several trees will contribute to overall stormwater management and provide shading on warmer days. The rain garden can also be enhanced with architectural water features, benches, or other design elements to create an appealing and functional space.

The third rain garden is proposed located near the field outlet to retain runoff before discharging the excess to the municipal network.

It is suggested to lower the existing football pitch to allow for retention of runoff from other areas of the school yard, the pool roof and rain garden overflow. This water can slowly drain to the public network via a drainage system. Overflow is conveyed via infiltration trench or swale located between the playground and parking. The playground should maintain a sand surface, with lowered edges to allow runoff to enter and infiltrate the ground.

Finally, it is recommended to maintain the proposed permeable surface for the future car park to minimize the amount of runoff generated from that area. It is also suggested to investigate the potential installation of green roofs at the pool and new wing to further limit runoff volumes.

The floodway, which is anticipated to originate from the north-east side of the park, will pass through the park and discharge runoff from the upstream catchment area as well as within the park. The floodway will run through the planned rain garden located at Feragens street on the southern side towards the playground and retention pond.

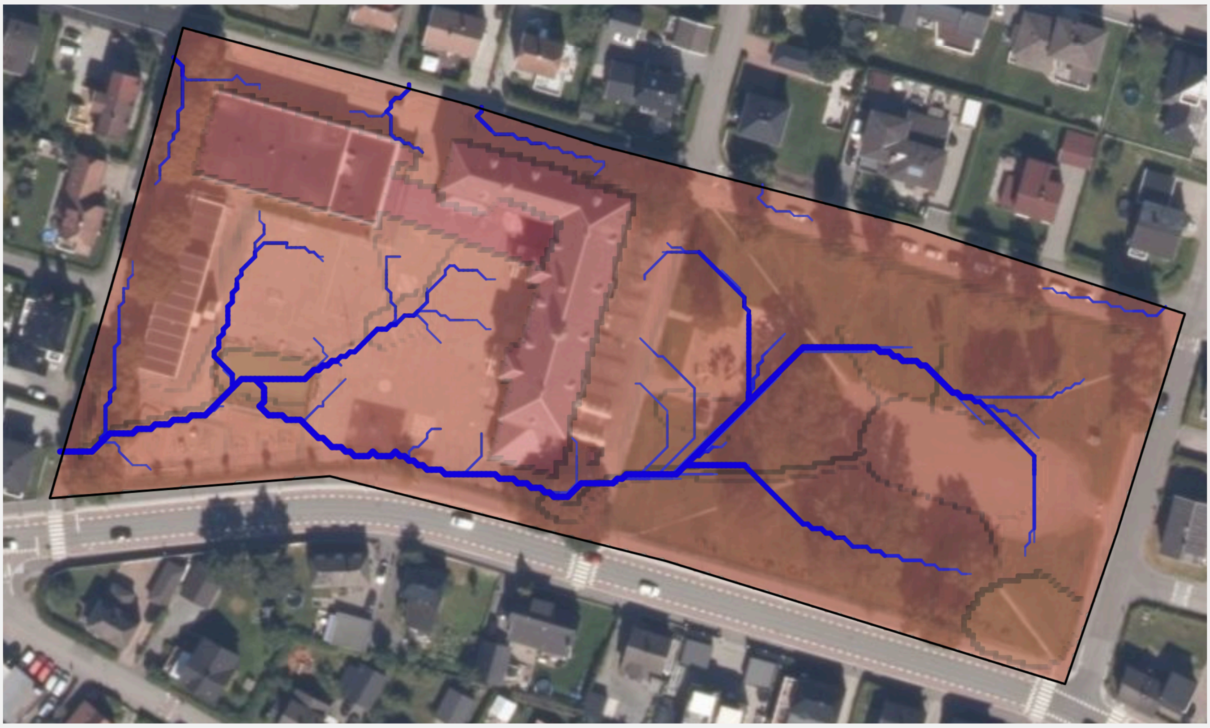


Figure 60 Calculated floodway

Summary

Research question 3

How can the multifunctional approach be applied in a real urban setting to enhance stormwater management and contribute to a playful cityscape?

The comprehensive analysis of Lillestrøm city indicates that play areas cover in total 23,2 ha, or 4,5% of the city, that could be utilized to enhance stormwater management. It is evident that schools in Lillestrøm have the most potential for implementing the multifunctional approach, as they can contribute the largest area to stormwater management and are located close to major runoff lines. Furthermore, the multifunctional approach aligns well with the city's future development plans concerning blue-green infrastructure and desired improvements in recreational amenities. The strategy gave important input to the analysis as it provided direction on the municipality and residents' preferences. At the same time, it is believed that the lack of a clear strategy does not hinder recreational reuse of runoff, but could provide additional inspiration to city planners.

The feasibility analysis of Volla school and park showcases the practical implementation of the multifunctional approach and highlights possibilities for the site. Due to time constraints, detailed calculations were not included, and the applicability is limited to demonstrating the potential benefits of the multifunctional approach in stormwater planning. The site's topography and soil composition restrict the range of solutions available, requiring thorough planning and design to meet proposed water quality and safety parameters. Certain features, such as parcel gardens or outdoor classrooms, were not proposed as they were deemed less critical to the overall stormwater concept and would require further collaboration with the school and architects.

Although detailed calculations were not performed, it is believed that evaluating the school and park as a single site produces better results for the area in terms of consistent stormwater management. The proximity and usage patterns of the entire area offer significant potential to create an enjoyable urban space with a distinct identity. The impact on overall stormwater management, along with enhancements in playfulness or play value, is evaluated as follows.

Effect on stormwater management

Treating the school and park as a single site provides several advantages, including resolving existing issues with water accumulation and transfer between the areas, and limiting inflow to the entire site by halting it at the wetland. This approach is positively quantified by metrics such as the blue-green factor, which emphasizes the significance of interconnecting existing and planned blue-green networks by awarding 0.05 points for each connection made (Standard Norway, 2020). Additionally, this approach enables the treatment of inflow, leading to a reduction in the overall transfer of pollution to the Nitelva.

The proposed design offers a notable improvement by including a safe floodway for extreme rainfall events, which is lacking in both the current situation and other ongoing projects. This aligns with the priorities of the Lillestrøm authorities, who already recognize the importance of planning for such events. It should be noted that SCALGO Live assessment implies certain limitations, such as the exclusion of the municipal network, infiltration rate, and variations in local topography, which may have affected the results. Nonetheless, these factors were considered less important for the study's purposes, as the focus was on the application of the multifunctional approach rather than detailed dimensioning.

Reduction in the percentage of impermeable surfaces at the school leads to overall reduction in generated runoff and reduction in temperature at the school yard during warmer days. The possibility to reuse school roof runoff and improved infiltration at the park helps reduce total runoff volumes from the site. These enhancements are anticipated to impact the overall blue-green factor of the area and are expected to lower the inflow to the public network, compared to the current situation.

Play value evaluation

Measuring the extent to which the proposed design contributes to a more playful cityscape is challenging, as it is difficult to quantify such benefits. Various studies have demonstrated the importance of play for children's development, however, there is limited methodology available for comparing different outdoor play settings objectively, particularly with regards to evaluating water features. Woolley and Lowe (2013) study on the relationship between design approach and play value of outdoor play spaces attempts to address this issue. The study defines play value as play opportunities and introduces a three-dimensional toolkit to identify the play value of a space (see attachments for further details on the toolkit). While the toolkit cannot be fully applied to the proposed design due to its level of maturity and detail, it provides a useful direction for identifying which features are considered more valuable for overall play experiences.

Dimension 1 of the toolkit concludes that play environments which facilitate various types of activities are more valuable. This implies that the play areas should not only cater to gross motor skills but also stimulate children's creativity, social interaction and engagement. The proposed design solution is anticipated to obtain an additional score for constructive play in comparison to the current situation, owing to the availability of natural play elements such as sand and water.

Dimension 2 of the toolkit assesses the prevalence and existence of key specific physical elements at play area. It cannot be fully applied to the proposed concept as it has not been developed in enough detail for a thorough evaluation. However, certain parameters such as vegetation, access to loose and natural materials, water and sand, and range of surfacing materials can be used to assess the design's potential for play value. The proposed design is likely to score higher as play value increases with more variety in vegetation types, objects to manipulate, and a broader range of surfacing materials that stimulate imagination. This aspect is particularly important for the school as it accommodates children of a relatively young age who benefit greatly from having various stimuli available to them.

Dimension 3 of the toolkit focuses on the environmental characteristics of the area, with a greater emphasis on spaces that provide a variety of experiences, challenges, and learning opportunities for people of all age groups. The proposed design is expected to score higher in this dimension as it incorporates water features, rain gardens, swales, obstacle courses, and a sand volleyball court, which offer opportunities for learning, challenges, and physical activity. In addition, the absence of random water puddles at the schoolyard and park is expected to enhance the overall impression of the area. As previously discussed, water is a versatile material that is suitable for people of all ages and abilities, thereby promoting inclusivity.

The proposed design can also be evaluated using Shackell et al. (2008) 10 principles for designing successful play spaces (Figure 61). According to these principles, the proposed design is expected to be more successful because it is custom designed for the specific site, incorporates a wide range of natural materials and play experiences that include elements of risk and challenge (such as jumping over water), and is sustainable and adaptable by limiting the use of rigid materials like concrete and asphalt and allowing for water reuse. Overall, the proposed design appears to be well-suited for promoting successful play experiences.

The 10 principles for designing successful play spaces

Successful play spaces...

- are 'bespoke'
- are well located
- make use of natural elements
- provide a wide range of play experiences
- are accessible to both disabled and non-disabled children
- meet community needs
- allow children of different ages to play together
- build in opportunities to experience risk and challenge
- are sustainable and appropriately maintained
- allow for change and evolution.

Figure 61 The 10 principles of successful play areas after Shackell et al. (2008)

Currently, it is difficult to objectively demonstrate clear benefits of applying the multifunctional concept to the Volla site. This is mainly due to the difficulty in quantifying the additional advantages that multi-use can provide, and the design is not yet fully developed. Despite this, certain additional values such as an increase in the blue-green factor and runoff treatment can still be observed. These benefits could potentially provide insight for strategic planning purposes.

Chapter 5. CONCLUSION

Image credit: author

Norwegian cities are facing stormwater challenges following urbanization and work to find space for resilient, open solutions that help adapting to the changing climate. One way to solve this is reuse of rainwater recreationally at public play spaces. This study aimed to explore the potential of this multifunctional approach to designing play areas that can address stormwater problems in Norway while providing recreational opportunities for children.

To explore this approach, the research classified play areas into three categories, based on a selection of example projects: kindergarten yards, school yards, and public play areas, including playgrounds and sport facilities. Comparison of design parameters and materials has shown that water depth is typically restricted to maximum 20 cm, as well as use of permeable surfaces and sand was overlooked. Review of the current regulations and applicable research identified the key design parameters and practices that can ensure the safe application of this approach based on the latest knowledge. Based on the literature, the roof runoff can be considered generally safe for recreational purposes, but the residence time of the harvested water should not exceed 24 hours. It is proposed to differentiate the maximum depth limitations based on the age of children, as children under the age of 5 are more vulnerable to drowning risks. Separate checklists were formulated for each type of play areas to reflect the specifics of each one and help frame potential design solutions.

The case analysis of the Lillestrøm city demonstrated that play areas provide additional 23,2 ha for stormwater management. The placement of existing sites, and especially schools, aligns well with existing runoff patterns, which can support effective allocation of space for stormwater management in a city. Detailed analysis of Volla site has showed which part of the runoff can be reused recreationally to reduce total inflow to public sewer network.

One of the most important takeaways from the study is the inclusion of the public, especially children, in the design process. This approach is widely recognized as very successful in boosting overall satisfaction and inclusiveness, helping to create enjoyable cityscapes.

Overall, the multifunctional approach is a very viable strategy for Norway that creates additional benefits without compromising the primary stormwater function. However, to support such projects, further work is needed on quantifying the values of multipurpose spaces, for example documenting cost differences in a systematic manner. The research also pointed out that detailed statistics on how multifunctional sites function in changing weather, especially in spring/autumn seasons, were hard to find, and such a study would be an important contribution that could influence the possible span of designs. The aspects of universal design of recreational water features also need further investigation.

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Attachment 1. Dataset description and GIS analysis

Dataset: Arealbruk 2022 by SSB (SSB-arealtype i UTM32 Euref89 for Lillestrøm kommune)

With reference to metadata published at geonorge.no, the following dataset features (main classes, *Hovedklass*) were identified as relevant for the analysis:

- *GroenneOmr* (green areas) - Objects that are defined as parks, playgrounds or graveyards in FKBarealbruk and N50-arealdekke datasets.
- *IdretstOmr* (sports facilities) - Objects where built area is dominated by sports facilities (SSB building type 651-659). Additionally, areas defined as sports facilities (idretts- og sportsområder) in FKB-arealbruk, N50-arealdekke or based on idrettsanleggsregisteret.no.
- *UndervisnBhage* (schools and kindergartens) - Objects where built area is dominated by kindergarten or school buildings (SSB building type 611-629)

Relevant sub-classes (*Underklass*) include:

- *GroenneOmr*,
- *IdrettsOmr*,
- *BarneUngdSkole* (primary schools),
- *Barnehage* (kindergartens),
- *VideregSkole* (secondary schools)
- *AnnetUndervisn* (further areas related to schools)
- Sub-class *UniversitetMm* was filtered out as these are related to a different target age group and activities.

The dataset extent and verification

Green areas exclude urban forest, the green areas of the Flomvollen levee (not mapped by the dataset), graveyards and only consist of green areas freely accessible to public. It shall be noted that the actual stretch of the green areas can be mapped incorrectly and inconsistently due to reporting limitations (for example, need to follow property boundaries).

Data in the dataset used for analysis were adjusted to best suit the analysis as follows:

- Souphie Radich's School excluded from the analysis as it has been newly climate adapted.
- Class *GroenneOmr* that are located within school or kindergarten areas in the dataset are reassigned to new *Hovedklass GroenneOmrSk* or *GroenneOmrBh* respectively.
- Removed polygons assigned to institutions and areas that were irrelevant for the study or not up to date: removed Klosteret- avdeling rus og avhengighet – not relevant for study, a polygon next to Norges Varemesse – not a green area to the date; Skedsmo VGS Flylinjen – not a traditional school building but one

of the school's departments, renting location in an office building; sport area near train station – indoor training center, not relevant for the scope.

- Removed areas within the Flomvollen (a training area at Bondetangen and Strandpromenaden Krokettklubb) to aid consistency.
- Assigned area around A.C. Svarstadsgata playground to *Hovedklass GroenneOmr* (was *IdrettsOmr* before) to reflect actual situation.
- Added/reassigned relevant missing areas: Kulturparken (*Hovedklass* changed to *GroenneOmr* from *KulturReligion*), Sølepytten kindergarten (*Hovedklass* changed to *UndervisnBhage* from *KulturReligion* and extended to include the play area), green area next to Lillestrøm tennis club courts at Buegata (*Hovedklass* assignet as *GroenneOmr*), Lillestrøm kirkepark (*Hovedklass* changed to *GroenneOmr* from *KulturReligion* to reflect actual situation) and Ole Bulls square (added with *Hovedklass GroenneOmr)*.

GIS analysis

The analysis of existing areas was done using QGIS software and datasets *SSB-arealtype i UTM32 Euref89 for Lillestrøm kommune* (2022) in combination with fkb4 WMS (see attachments for further details). The SSB dataset was overlayed with the city borders (relevant school base districts - *grunnkretser* in the central Lillestrøm) and filtered to include relevant polygons. The precision and quality of the results depended on the original data precision of the SSB dataset. Area statistics on the result dataset is presented at Table 1:

Table 1 Statistics on the areas, using "Statistics by categories" function

	HOVEDKLASS	sum	count	unique
1	GroenneOmrBh	2670,39	5	5
2	GroenneOmrSk	14396,0500...	7	7
3	IdrettsOmr	14000,5999...	12	12
4	UndervisnBhage	114141,3700...	16	16
5	GroenneOmr	86992,29	37	37

Runoff lines for the area were exported from SCALGO Live.

Attachment 2. Play value of outdoor play spaces, assessment tool (Woolley & Lowe, 2013)

According to Woolley and Lowe (2013), play value of an area can be assessed using three dimensions: play type, physical elements and environmental characteristics of the site.

Dimension 1 - The play type is assessed by observation and adult's perspective on whether the play space allowed for each of the five play categories: constructive, functional, fantasy, social and games with rules. The description of these categories is the following:

Table 2 Dimension 1 Play types

Category	Constructive play	Functional play	Fantasy play	Social play	Games with rules
Description	Involves manipulation and control of the environment	Develops fine and gross motor skills, integrating, muscles, nerves and brain functions	Exploration of new role and situations through the experimentation of language, concepts, drams and emotion in a risk-free environment	Interaction with others, develops notion of social rules and responsibility by sharing and cooperating	Develop an awareness of how to react in social situations which are controlled by rules and boundaries

Dimension 2 - The physical elements uses indicative scoring to assess prevalence and existence of 12 key specific physical elements drawn from the review and interpretation of the literature. The scoring guide is presented by Table 3:

Table 3 Dimension 2 Physical elements and indicative scoring

Element within the space	Criteria	Scoring 0 - 5
Range of fixed play equipment	Number of pieces of equipment: climbing apparatus, spring mounted, slides, balancing beams, swings, see-saws, multi play structures	0= none 1= one 2= two-three 3= four-five 4= six- seven 5= contains all of above
Moveable equipment	Dependent upon the number of pieces of moveable equipment	0= none 1= one 2= two pieces 3= three pieces 4= four pieces 5= five + pieces
Open space allowing for individual, group and team movement/ activities	Dependent upon open space being available for free movement for individual, group and team activities	0= none; 1= limited, physical barriers limit free movement for individual, group or team activities; 2= free movement for one of the above; 3= free movement for two of the above;

		4= some free movement for all of the above; 5= no physical barriers, free movement for all of the above
Different sizes and types of spaces	Dependent upon access to very small/private, small, medium, large, sheltered, exposed spaces	0= none; 1= one; 2= two; 3= three; 4= four; 5= all these types of spaces
Vegetation/ trees	Dependent upon the variety of vegetation: visual stimulation and opportunities for interaction	0= none; 1= minimal; 2= limited types; 3= several different types in part of site, visually stimulating or encourages interaction; 4= several different types across site, visually stimulating or encourages interaction; 5= several different types across whole or part of site, visually stimulating and encourages interaction
Landform	Changes in landform which is stimulating, engaging and challenging	0= no changes; 1= predominantly flat, minimal of the above; 2= some changes, minimal of the above; 3= several changes, one of the above; 4= several changes, two of the above; 5=several changes, all of the above
Loose materials	Access to, quantity of, and opportunity to move loose materials across the site	0= none; 1= little access; 2= very small quantities and very small, defined location; 3= small quantities or small defined location; 4= useable and movable; 5= useable and movable across the whole of the site
Natural materials such as stones, water, sand, bark, moss, leaves, mud, logs, fruit, sticks	Access to, number of and availability of natural materials across the site	0= no access; 1= one type, across entire site or in areas of the site; 2= 2-3 types in confined locations; 3= 2-3 types across entire site; 4= 4+ types in confined locations within site; 5= 4+ types across entire site
Water and sand	Access to and opportunity to engage and manipulate water and sand	0= access to neither; 1= access to either sand or water, no opportunities to engage or manipulate; 2= access to either with opportunities to engage or manipulate; 3= access to both with opportunities to engage or manipulate;

		4= access to both with opportunities to engage and manipulate; 5= access to both in more than one form allowing opportunities to engage and manipulate
Obvious physical boundaries such as fencing	Existence of clear and rigid boundary and visual stimulation and engagement	0= whole/part of site defined by physical boundary, neither visually stimulating or engaging; 1= whole of site defined by physical boundary, visually stimulating or engaging; 2= whole of site defined by physical boundary, visually stimulating and engaging; 3= part of site defined by physical boundary, visually stimulating or engaging; 4= part of site defined by physical boundary, visually stimulating and engaging; 5= whole site is free from rigid physical boundaries
Seating opportunities: opportunities for social interaction	Quantity and location of seating opportunities	0= none; 1= some, not within play area; 2= limited within play area, located around the edge; 3= limited within the play area, isolated & sporadic; 4= some throughout the site, does not encourage children to interact; 5= large amount throughout the play area
Range of surfacing materials: including grass, sand, bark, gravel, rubber	The number of surfacing materials and whether they are engaging and stimulating	0= none; 1= one, not engaging or stimulating; 2= one or two types, engaging or stimulating; 3= one or two types, engaging and stimulating; 4= more than 2 types, engaging and stimulating; 5= 3+ types, engaging and stimulating

Dimension 3 - The environmental characteristics of the space uses the five environmental characteristics of enticing, stimulating, challenging, learning opportunities and provision for all age groups. The scoring guide is presented by Table 4:

Table 4 Dimension 3 Environmental characteristics and indicative scoring

Environmental characteristic	Criteria	Scoring 0-5
Is the area enticing?	Does it have inviting entrance, no rigid site boundaries, informal oversight, accessible to adults and children, contains seating	0= no evidence, 1= contains one of the above, 2= contains two of the above, 3= contains three of the above, 4= contains four of the above, 5= contains all of the above

Is the area stimulating by creating a range of experiences, containing natural elements and allowing for movement?	Allows for personal movement, movement of materials, use of senses, natural elements, access to a range of materials	0= no evidence, 1= contains one of the above, 2= contains two of the above, 3= contains three of the above, 4= contains four of the above, 5= contains all of the above.
Is the area challenging?	Does it contain opportunities for swinging, sliding, balancing, rocking, jumping, climbing	0= no evidence, 1= contains one of the above, 2= contains two of the above, 3= contains three of the above, 4= contains four of the above, 5= contains all of the above.
Are there learning opportunities?	Opportunities for access to natural elements and for manipulation or experimentation	0= no evidence 1= limited opportunities to interact with materials or the natural environment and does not allow for any kind of manipulation or experimentation, 2= access to a few types of materials, but limited access to the natural environment, and allows for either manipulation or experimentation, 3= Access to a few types of materials, some access to the natural environment, and allows for either manipulation or experimentation on one area of the site 4= Access to a large range of materials, the natural environment and allows for manipulation and experimentation in more than one area of the site 5= Access to a large range of materials and the natural environment and allows for manipulation and experimentation across the whole site without restrictions
Is the area available for all age groups	Provides for under 3 year olds, 3-6 year olds, 6-9 year olds, 9-12 year olds, 12+	0= no evidence, 1= caters for one age group, 2= caters for two age groups, 3= caters for three age groups, 4= caters for four age groups, 5= caters for all age groups

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