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From District to City Scale: The Potential of Water-Sensitive Urban Design (WSUD)

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Abstract: The summer of 2022 was one of the hottest and driest summers that Germany experienced in the 21st century. Water levels in rivers sank dramatically with many dams and reservoirs running dry; as a result, fields could not be irrigated sufficiently, and even power generation and supply were affected. The impact of abnormally high temperatures for extended periods (heatwaves) is not restricted to nature and the economy but is also a considerable public health burden. Experts worldwide agree that these extreme weather events are being driven by climate change and will increase in intensity and frequency in the future. The adverse impact of these extreme weather events multiplies among dense urban environments, e.g., through heat islands. This calls for cities to take action to heat-proof and water-secure their urban developments. Water-Sensitive Urban Design (WSUD) is one such approach to mitigate the aforementioned challenges by leveraging the urban water ecosystem with special attention to the subject of water reclamation, retention, treatment and distribution. This paper introduces and builds upon a prototype of WSUD that centers around an artificial lake as an integrated water resource management system (IWRMS) fed by treated grey water and storm water obtained from two housing blocks flanking the water reservoir. Based on the specifications of this prototype, indicators of site suitability are derived and applied to identify potential locations for replicable projects in the city of Darmstadt. The results confirm the impact WSUD can have: a total of 22 sites with 2527 apartments are found suitable for prototype implementation in Darmstadt. Savings in town water consumption from these 22 sites would add up to 147 million liters. Further benefits include the provision of 24 million liters of irrigation water, storm water retention, adiabatic cooling during heatwave, increased biodiversity and the improvement in livability of the sites and the city.

Keywords: water-sensitive urban design; WSUD; integrated water resource management system; IWRMS; climate adaptive cities; climate resilience

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1. Introduction

Climate change is considered as one of the greatest challenges of the 21st century [1]. Weather conditions in Europe, the United States of America and Asia have increasingly become unusual with both frequency and intensity of heatwaves, droughts and flash floods on the rise [2–4]. These extreme weather conditions have impacted agricultural production, irrigation, energy generation and led to a water supply crisis for cities. This is adversely affecting and even endangering human life. Based on data from the German federal office for statistics during summer months of June to August in 2022, which were characterized by record heat, the number of deaths was significantly higher than the median values from 2018 to 2021 by 9% to 13%. The number of deaths were particularly high in calendar week 29 (18–24 July 2022) at 25%, which was an exceptionally hot week [5]. It is not only extreme heat; even torrential rain and severe flooding are exacting a toll on human life. For instance, the severe flooding catastrophe in the Ahrtal region of Germany in 2021 resulted in devastating damage to houses and infrastructure with a loss of 133 lives [6]. The latest report from The Intergovernmental Panel on Climate Change (IPCC) states that these adverse conditions are not a temporary phenomenon, but the intensity and frequency will increase with "high confidence" [7] (p. 43) in the coming centuries. The 2015 Paris Agreement signed by 196 parties at the 21st UN Climate Change Conference acknowledges that "climate change is a common concern of humankind" [8] (p. 2) and the need for action to limit the increase in global temperature to 1.5 °C. Measures to achieve this objective are directed toward the reduction in greenhouse gas emissions, which are the driving force behind climate change [8] (p. 4). But as recent events show and the IPCC report predicts, climate change is already taking its toll on human life. This calls for tailored ad hoc to medium-term measures to reduce the immediate impact of climate-change-related shocks and stress. The urban settings of cities are more exposed [9] to extremes that culminate in "heat, flooding, water scarcity and droughts" [10] (p. 18). This is due to the dense built environment that characterizes cities and is known to exacerbate the prevailing adverse conditions induced by climate change. The city microclimate, for example, is more prone to heat waves because of the Urban Heat Island (UHI) effect [11]. Studies have also shown that the UHI effect can induce heavy rainfall events [12]. These can subsequently lead to flooding because the sealed (concretized) surfaces lead to heavy runoff, creating a storm water overload that regularly overwhelms the city drainage systems. Droughts also exacerbate the flooding as they damage the urban greenery and dry out the ground, reducing its natural ability to soak in storm water, which adds to heavy runoff when rainfall eventually does set in. In light of these challenges, state agencies have begun to promote climate change mitigation and adaption, e.g., through heat action plans or directives. These include measures referring to the transformation of the built environment such as "conserve and create shaded green spaces and parks, preferably with cooling evaporation areas such as bodies of water [. . .], reduce heat by creating or keeping clear air channels [. . .] or reduce degree of soil sealing in open and public squares [. . .]" [13] (p. 23). Others aim for the protection of vulnerable population groups [13] or water saving incentives [14]. Cities in particular need to take action, a fact which is stressed by studies on urban water scarcity and security [15,16]. After all, an estimated 60% of the world's population will be living in urban environments by 2030 [17] and 80% of Europeans by 2050 [10].

One of the possible adaptation measures that urban settlements can apply is Water-Sensitive Urban Design (WSUD) which incorporates a number of the aspects outlined in the German state heat action plan referenced above [13]. The concept of WSUD originated in the 1990s in Australia [18] and Australian government agencies defined it as "an approach to urban planning and design that aims to integrate the management of the urban water cycle into the urban development process" [19] (p. 1). This paper refers to WSUD as a design principle that, in its essence, reconsiders the management of urban water streams such as storm water (precipitation induced runoff), town water (from tap), greywater (from sinks, showers, bathtubs and laundry) and black water (from toilettes or urinals) and intends to integrate these in landscape, building and infrastructure design by means like "reducing potable water demand, minimizing wastewater generation, optimizing the use of water sources" or "promoting a significant degree of water related self-sufficiency" [20] (p. 1). WSUD represents a mitigative measure in the adaptation process of urban environments toward climate change. This is underlined by a report of the European Environment Agency entitled *Urban adaptation in Europe: how cities and towns respond to climate change* [21].

In this paper, a prototype of WSUD is introduced that includes a grey-to-service water treatment, storm water catchment and an artificial lake as a reservoir and central element of landscape design of a residential housing development. Building upon the specifications of this WSUD prototype and investigating the case of the city of Darmstadt, the research in this paper is directed toward the following key questions:

1. What indicators describe the suitability of a city site for application of a replicable WSUD?
2. How many potential sites for the application of WSUD exist in the city of Darmstadt?
3. What impact on the city water cycle of Darmstadt would the application of all WSUD have?
4. What relevance would this application have in regard to climate change adaptation?

By addressing these questions, this study conducts a multi-scale assessment method based on a district-scale prototype that is multiplied on a city scale. In consideration of the fact that the IWRMS design of the WSUD prototype is one-of-a-kind in Germany and that this study uses real-world as opposed to simulated data, it contributes to filling a gap in research: the quantification of town water savings through district-based WSUD on a city scale.

In the following section on Materials and Methods, the principles of WSUD are outlined, followed by a detailed description of how they are integrated in the WSUD prototype. Next, the city of Darmstadt is introduced. Federal, state and city assessments on climate change are presented in order to evaluate to what extent Darmstadt is already affected by climate change and what climate projections indicate for the future. The last section names the indicators that are derived from the WSUD prototype in order to assess potential WSUD sites. Based on the number of possible WSUD sites in Darmstadt, a grand total of reclaimed and retained water is calculated in order to estimate the overall impact that citywide application could have on the city water cycle.

2. Materials and Methods

2.1. Water-Sensitive Urban Design

There are multiple definitions for WSUD, but for this paper, it is defined as a design principle that in its essence reconsiders the management of urban water streams such as storm water, town water, grey water and black water and intends to integrate these in landscape, building and infrastructure design. In Germany, WSUD projects referring to the aforementioned definition are rarely found. However, it is worth noting that other design approaches, labeled as "Decentralization" or "Sponge City", can be found in Germany, which are similar to WSUD in objective but differ in scale, design and realization. "Decentralization" or "Sponge City" usually focus on flood protection in the scope of localized storm water management that is mostly designed and realized by engineers and hydrologists with no or little contribution from architects and landscape designers. In the authors' understanding, this is a significant difference and qualifies WSUD as a relatively young new discipline that bridges the gap between urban design and urban water management for building urban climate resilience.

2.2. The WSUD Prototype

A WSUD project, which was designed based on an interdisciplinary understanding and the principles of WSUD [22–24], is under construction in the city of Mannheim at the time of the writing of this paper and expected to be finished by 2024. The project contains 74 residential units distributed in two multi-story family houses and offers a variety of different apartment types from 1.5 to 4.5 rooms with a total living space of 5888 m^2. The two buildings are arranged in such a way that they form a courtyard with a naturally designed but technically controlled waterbody referred to as the WSUD lake from here onwards (Figure 1). The WSUD lake is a technical water reservoir fed by local storm water and surplus service water reclaimed from greywater from the apartments. It is designed to hold 120 m^3 of water on average under normal operating conditions. It also has a provision for extension which enables the holding of an additional 50 m^3 of water, which corresponds to a 100-year storm event. In order to allow unlimited access to the lakefront and to prevent any form of fencing, the level of the lake is limited to a depth of 0.4 m. The WSUD lake maintains a steady water level as it receives 100% of the storm water which is collected from the roofs and the façade of the development and the surplus of an integrated grey-to-service water system of the apartments. Though it is strongly dependent on the season, the storm water inflow accounts for between 60% and 90% of the overall reservoir capacity while service water accounts for the remaining 10% to 40% under normal operation conditions. The grey-to-service water system in the households is designed to collect grey water from showers, sinks and laundry. The grey water is then processed with the help of contemporary water reclamation technology such as ultrafiltration membrane to remove contaminants. This is followed by ultraviolet light exposure (UV) for disinfection, before the majority of it is pumped back to the apartments as service water, while the surplus of service water is spilled in the WSUD lake (Figure 2).

Figure 1. Site plan WSUD prototype.

In order to maintain a steady current and to avoid stagnated areas, the WSUD lake is designed in a length to width ratio of 1:7 as a result of specific flow simulations. This also refers to assessments in the field of environmental engineering, in particular, lake management [25]. Furthermore, the lake water is constantly pumped through a sand filter for treatment purposes. The WSUD lake is used for the irrigation of the surrounding green areas between March and October—the extended summer season. The regular capacity is sufficient to meet the irrigation requirements of the development during the normal dry season, i.e., without any storm water inflow into the WSUD lake. In case of extreme weather events (heat wave or drought) the regular irrigation can be continued until the water level reaches a critical minimum of 25%, after which irrigation needs to be stopped to protect the ecosystem of the WSUD lake. In this situation, the critical minimum of 25% water level of the WSUD lake is maintained by the daily inflow of the surplus of service water which is determined to be sufficient to overcome evaporative losses. In the case of an extreme rain event, the lake extension is activated to hold an additional 50 m^3. Water held in the lake extension is designed to be slowly released through infiltration trenches without triggering flooding. This additional water is not retained for the rest of the year for irrigation or reuse purposes.

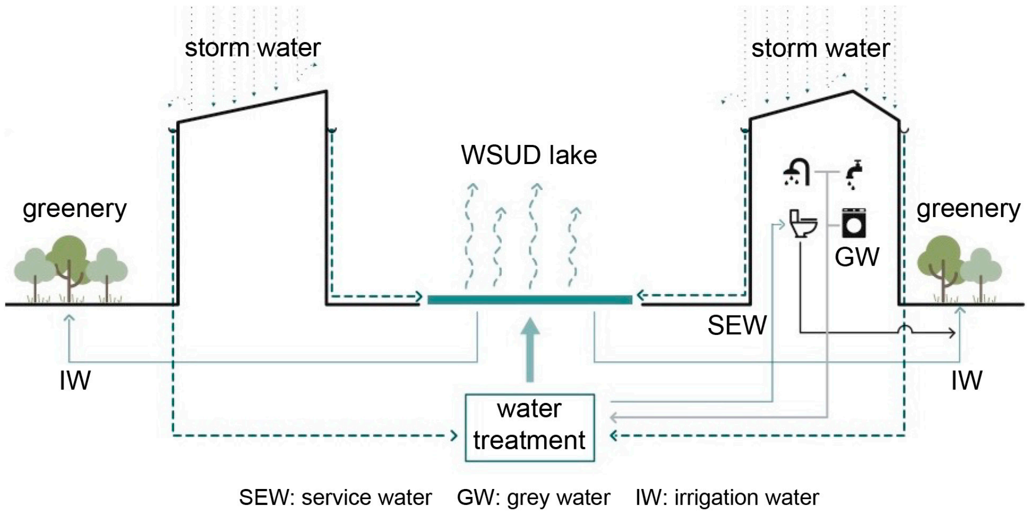


Figure 2. Scheme WSUD prototype.

WSUD by closing the water cycle at the decentralized scale can lead to a significant reduction in town water supply. An estimated reduction of up to 40% can be achieved per household. WSUD also eliminates the burden of irrigating common greens within the development with town water, which is estimated to further lower town water demand from the site by 20%. The estimated payback period for the initial investment in WSUD is about 25 years based on the savings in town water consumption and wastewater fee payments. While the decentralized water management technology itself is not new [26–30], the WSUD prototype stands out by combining treated grey water, i.e., service water and storm water, in the WSUD lake. This approach distinguishes it from other notable WSUD projects in Germany such as the "Hamburg WATER CYCLE" [31] or the "BUGA Heilbronn" [32]. In addition, the way the technology is applied under WSUD and connects to people via design and architecture is unique in this project. WSUD also provides an improvement in quality of life and a reduction in vulnerability to extreme weather, which is not easily captured in the aforementioned technical and financial details. It is critical to acknowledge the importance of design and architecture in unlocking the full potential of technical intervention like decentralized water management. Design can help leverage it to increase biodiversity by creating a constantly green oasis while providing the community with a highly resilient structure which can mitigate the effects of climate change.

2.3. The City of Darmstadt

The city of Darmstadt is a mid-sized university town located in the federal state of Hesse 30 km south of Frankfurt am Main. Darmstadt has a population of 163,435 and an area of 122 km^2 [33], making it the fourth biggest city within the federal state of Hesse. The city is an important center of education, research and science. Darmstadt has major employers in the information and communication, healthcare and manufacturing sectors [34]. Darmstadt is part of the Frankfurt Rhine-Main metropolitan region which includes the cities of Aschaffenburg, Offenbach and Frankfurt am Main. Frankfurt Rhine-Main is one of the eleven metropolitan regions in Germany and is home to a population of 5.8 million people and the location of numerous influential political institutions and corporate headquarters [35]. Climate change adaptation has gained traction within the municipality of Darmstadt with multiple strategies being developed and implemented in the last decade. In 2013, an integrated concept for climate protection was set up [36] which was followed by a 25-point immediate action plan for climate protection in 2020. In 2021, the city of Darmstadt established the office for climate protection and climate adaptation, which meanwhile has grown to a staff of over ten employees.

Exposure to Climate Change

In 2021, the German Environment Agency (UBA) published its report, *The Risks of Climate in Germany*, where it clearly confirms that Germany will be affected by climate change nationwide [37,38]. It also noted that adverse effects such as heatwaves or heavy storm water will not be distributed evenly but impact differs regionally [38]. The overview map in Figure 3 illustrates how different parts of Germany, e.g., the coasts, the northwest and the mountainous regions, are exposed to either a minor, strong or very strong increase in four categories of risk, i.e., average temperature, heat, heavy storm water and drought.

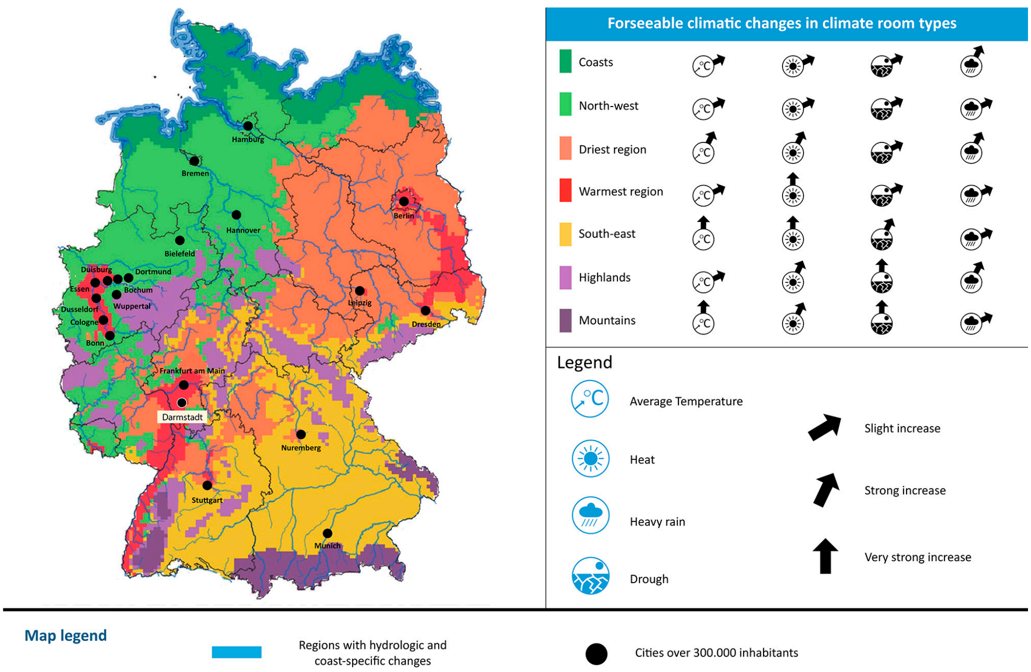


Figure 3. Regional impact of climate change in Germany.

Climate projections for the city of Darmstadt predict a very strong increase in heat risk. While a minor increase in the remaining three risk categories is also predicted. Figure 3 also shows that Darmstadt is located in the warmest region of Germany. In addition, the report states that densely populated urban areas such as the "Ruhrgebiet" or the "Rhein-Main-Neckar Region" will be affected significantly more by weather extremes [38].

The findings of UBA have been seconded by climate change studies performed at the state and city levels. The 2017 integrated climate protection plan of the state of Hesse that incorporates climate projections carried out by the Potsdam Institute for Climate Impact Research confirms that the degree and characteristics of climate-change-related effects vary regionally, and the south of the state of Hesse including the region around the city of Darmstadt will be especially affected by high temperatures and long-lasting heat [39]. Studies on climate change carried out or commissioned by the municipality of Darmstadt complement the federal and the state reports by providing data of higher granularity on a district scale. The semi-annual report on statistics in 2020, for example, includes a special issue on climate change in Darmstadt [40]. This report makes use of data provided by a number of temperature metering stations positioned throughout the city. From 1961 to 2019, the annual mean temperature has risen from 10 °C to 11 °C with summer and winter seasons experiencing the greatest increase in monthly average temperatures. The number of summer days with temperatures exceeding 25 °C has increased from an average of 43 days between 1961 and 1990 to 76 days in the time span from 2015 to 2019. The number of hot days characterized by a temperature that exceeds 35 °C has tripled while average frequency of heat waves has increased eight-fold for the same reference time frames. A heat waves is defined as "a multi-day period with extraordinary thermal stress" [40] (p. 11). The climate reports paint a slightly different concern regarding storm water risk to the city of Darmstadt. The number of rainy days per year has not changed significantly, but the mean annual storm water has decreased. From 2015 to 2019 average storm water per year amounted to 639 mm, which is 13% less than from 1961 to 1990. Furthermore, the distribution of storm water has shifted. Spring and summer are getting dryer, whereas the winter season is receiving more storm water. From 2015 to 2019, storm water volume dropped by more than 20 mm in the months of July and August, which is significant. Nevertheless, the Hessian Agency for Nature Conservation, Environment and Geology labels the city of Darmstadt as "increasingly at risk" [40] (p. 18) to heavy storm water events. A 2016 study commissioned by the city of Darmstadt also provides further details on the city microclimate and its exposure to climate-change-related effects [41]. All climate risk and vulnerability studies are unanimous that the city of Darmstadt is already suffering ill-effects of climate change, which are predicted to worsen in the coming future. The risk to the city is predominantly posed by increase in temperature and decrease in storm water during the summer. The city already has a tough baseline, given its location in the hottest region of Germany, and shows pronounced UHI effects in its inner core. The predicted further increases in heat and decreases in storm water will lead to numerous problems in the city. One of the most obvious will be drought, as high heat leads to water evaporation that in turn aggravates drought [40]. Thus, dryness will also pose a major problem in the future.

2.4. Further Data and Sources

To map and assess potential WSUD sites in Darmstadt following data were acquired:

1. For the assessment of potential WSUD sites, a leading municipal housing association provides data on their real estate located in Darmstadt. Altogether, its building stock includes 17,000 units, which is comparable to the size of the housing association realizing the WSUD prototype in Mannheim that maintains 15,000 units. This is an important indicator for transferability from the setting of Mannheim to Darmstadt. And both operate in mid-size cities. The data provided include address, number of buildings per site, number of building levels, number of apartments, total living space, date of erection and status of refurbishment.
2. For the assessment and the mapping of potential WSUD sites, the spatial data of the city of Darmstadt including infrastructure, plots, buildings, topographic and aerial photos are provided by the land surveyors office of the city of Darmstadt.
3. Data on monthly, daily and hourly storm water for Darmstadt are retrieved online from the German Weather Service (DWD) [42,43] and assessed for a ten-year period.

3. Results

3.1. Indicators for WSUD Application

The WSUD prototype presented in the previous section serves as a template for the assessment of potential sites in Darmstadt that are suited for the citywide application of a replicable WSUD. To ensure citywide coverage, the paper is focused on identifying existing building sites with suitability for WSUD application rather than green field developments. The main intention for focusing on the existing building stock is simply that the ratio of existing buildings is much higher than those which are being newly built in Darmstadt. Thus, emphasizing existing sites will, in all probability, lead to the identification of more WSUD applications than focusing on sites that are currently in development. This approach to maximize impact is supported by studies carried out in the context of the German energy transition, which have concluded that the biggest reduction in energy consumption can be achieved by the energy-focused refurbishment of the existing building stock [44]. The energy-focused refurbishment of the building stock in Germany is an ongoing process that is driven by state and federal subsidization as well as legal requirements with the long-term goal of achieving climate neutrality by 2050 [45]. From an economic, strategic and logistic point of view, it will be reasonable to combine WSUD application with energy-focused refurbishment measures, because there is an overlap in the overall climate objectives of both programs. Moreover, "resource efficiency" in a holistic sense [46] (p. 15) as defined by the Sustainable Development Goals (SDG) to "make cities and human settlements inclusive, safe, resilient and sustainable" [46] (p. 15) includes both water and energy. Hence, non-refurbished sites awaiting energy-focused renovation are particularly suited for WSUD application.

Indicators (financial and O and M viability) for site section derived from the prototype specifications are (Table 1):

Table 1. Indicators for WSUD site assessment.

Reference to Prototype	
Indicator	**Specification**
Building use	Residential
Ownership	Housing association
Operation	Housing association
Number of units and/or grand total of living space	$\geq$70 and or $\geq$5900 m^2
Reference to existing site application	
State of refurbishment (one of the three specifications must apply)	Building stock that was erected at least 40 years ago and that has never been renovated
	Building stock that was renovated at least 40 years ago
	Building stock that by the year 2030 will have been unrenovated for 40 years
Available open space	Must be sufficient to position the WSUD lake

1. Building use, ownership and operation

These indicators refer to the usage of the buildings in the prototype which are 100% residential and the building cluster being owned and operated by a city housing association. The building stock assessed in this study comply with both indicators.

2. Number of units and/or grand total of living space

The WSUD prototype is connected to a total of 74 apartment units located in the two buildings flanking the courtyard. Altogether, these provide 5888 m^2 of living space.

Both figures are indicators of financial feasibility. This is a necessity for the housing association executing the prototype, otherwise the project would not have been approved by the executive board. With this number of units, or rather living space, involved, the payback for additional costs of the WSUD prototype is estimated to be within 25 years from the savings in town water use for household and irrigation purposes and by a reduction in wastewater fee payments.

Indicators (logistical viability) for site selection derived from existing site surveys are outline below (Table 1):

1. State of refurbishment

WSUD application in existing building sites would require extensive civil work which includes landscaping, concrete work and the installation of the water treatment unit that additionally requires separate piping in the buildings for grey water and service water [47]. In order to mount this system, the installation shafts in the buildings need to be opened. This is an expensive undertaking, but costs can be rationalized if they are aligned with other refurbishment measures or incorporated within the scope of a full renovation. This can be achieved by clubbing WSUD applications with federal- and state-mandated and subsidized energy-focused refurbishments. Therefore, to ensure the city-scale implementation of WSUD, it is deemed important to link site selection with the refurbishment status of the potential sites. But the timespan when a building is due for renovation can only be defined as an approximation because the lifespan of building materials depends on numerous factors [48] that can lead to disparities between the expected and the actual lifespan, and even though a building might be in a state of neglect, it may not mean that the building operator will take immediate action. In this paper, a 40-year timespan is defined as the age for refurbishment based on the average lifespan of different piping materials [49] when they have reached a state of "major damage that cannot be repaired due to technical or financial reasons" [49] (p. 12). Based on the aforementioned rationale, indicators of state of refurbishment are assessed in three ways: (1) building stock that was erected at least 40 years ago and that has never been renovated, (2) building stock that was renovated at least 40 years ago and (3) building stock that by the year 2030 will have been unrenovated for 40 years.

2. Available open space

The site must have sufficient open space for the WSUD lake to be positioned.

3.2. Shortlisted Sites for WSUD Application

A total of 496 sites were examined in Darmstadt (Figure 4) against the indicators as described in Table 1. In the initial assessment, 19 sites met all the indicators. In the follow-up assessment, three additional sites were shortlisted despite not meeting all the stated indicators. These three sites, namely #3, #7 and #9, fell short of the minimum threshold indicator "number of units and/or grand total of living space" by only less than 9%, which the authors feel is not a significant enough shortfall to disregard their potential for inclusion in the study. Finally, a grand total of 22 sites were shortlisted for assessing the city-scale WSUD application. These sites account for 4.4% of all sites examined in the city of Darmstadt. Since most of the shortlisted sites are significantly large housing developments, they together represent 19% of all apartment units and 20% of total living space examined in the city with a population of about 6300 tenants.

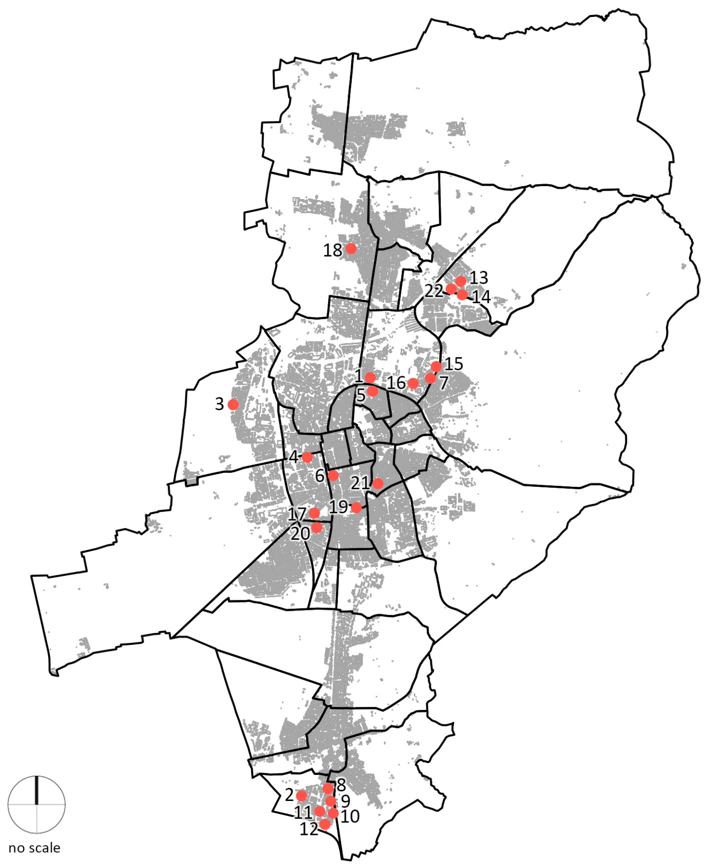


Figure 4. Distribution of 22 sites in Darmstadt.

3.3. WSUD Lake Dimensioning and Water Balance

In order to assess the overall impact of citywide WSUD prototype implementation, a WSUD lake is dimensioned for each of the 22 shortlisted sites. Based on the dimensions and the water balance of each WSUD lake, a grand total of reused service water, gained irrigation water and retained storm water has been calculated. The lake design and dimensioning calculations refer to specifications and average values applied in the prototype, such as averages of town water consumption per capita, averages of the amount of grey water and black water per capita or averages of the number of tenants for each unit. The lake balancing method refers to standards used in hydrology studies [50]. Climatology data on storm water in Darmstadt from 2011 to 2021 has been sourced from DWD. Data on urban morphologies (Table A1) are used to calculate unsealed space, i.e., the greenery, based on average ratios. Further values include standard irrigation rates (Table A2). Water inflow includes storm water and the surplus of service water from the households; water outtake refers to evaporation and the water provided for irrigation purposes. It must be noted that water inflow by runoff from greenery and water outtake in the form of infiltration from the lake bank and bottom are not taken into consideration because the prototype design specifications do not do so. Furthermore, calculations in this study are performed based on monthly water inflow and outtake in the WSUD lake in order to achieve a monthly water balance. This is the appropriate granularity to meet the objectives of this paper, but the application of approximations, standard values and monthly as opposed to daily or hourly balancing lead to limitations. The precise calculation of roofs and greenery and the application of exact figures on town water consumption or irrigation demands would refine the results. The conduction of hourly simulations would lead to an even better understanding of the inflow and outflow of water and could consider the holiday season with reduced water consumption per capita, which results in less service water inflow. This could further improve the lake design. The calculations consist of two preliminary steps leading to the main calculation for the monthly lake water balance. For conciseness, this section focuses on the description of the main calculation. The preliminary steps are only presented in brief but are outlined in Appendix A of this paper. Table 2 lists all variables and parameters included in the dimensioning and balancing of the WSUD lakes.

Table 2. WSUD lake variables and parameters.

Description		**Additional Notes**
Variables		
Total number of units [-]	**U**	-
Σ base area of buildings [m^2]	$\mathbf{A}_{\text{base}}$	Proxy for calculation of SW inflow
Σ open space of site [m^2]	$\mathbf{A}_{\text{open space}}$	Includes sealed (concretized) and unsealed area
Σ unsealed open space of site (greenery) [m^2]	$\mathbf{A}_{\text{greenery}}$	Is calculated based on average ratios
Σ irrigated open space of site [m^2]	$\mathbf{A}_{\text{irrigation}}$	Is calculated by subtraction of lake area
∑ litres of irrigation water (IW) [l]	$(\sum_{\text{liters IW pre}})$	Total liters IW from pre-dimensioning
∑ litres of irrigation water (IW) [l]	$(\sum_{\text{liters IW lake}})$	Total liters IW referring to lake
∑ litres of irrigation water (IW) [l]	$(\sum_{\text{liters IW}})$	Total liters IW
Σ greywater [L/per day]	**GW**	Total GW based on number of units
Σ reused greywater as service water [L/per day]	$\mathbf{SEW}_{\text{reuse}}$	Total GW that is reused
Σ surplus service water [L/per day]	$\mathbf{SEW}_{\text{surplus}}$	Is GW minus $\text{SEW}_{\text{reuse}}$
Area lake pre-dimension	$\mathbf{L}_{\text{areapre}}$	Pre-dimension of main water body
Area lake retention	$\mathbf{L}_{\text{arearetention}}$	Area of lake extension for SW retention
Area lake	$\mathbf{L}_{\text{area}}$	Area of main water body
Width of lake [m]	$\mathbf{L}_{\text{width}}$	-
Length of lake [m]	$\mathbf{L}_{\text{length}}$	-
Parameters		
Depth of main water body [m]	$\mathbf{L}_{\text{depth main water body}}$	Is 0.,4 m according to the prototype
Depth of lake extension for SW retention [m]	$\mathbf{L}_{\text{depth retention}}$	Is 0.2 m
Ratio lake width to lake length [-]	$\mathbf{L}_{\text{ratio}}$	Is 1:7 according to the prototype
Ø Σ greywater [L/per resident and day]	**ØGW**	Average value
Ø Σ reused GW as SEW [L/per resident and day]	$\mathbf{ØSEW}_{\text{reuse}}$	Average value
Ø Σ surplus SEW [L/per resident and day]	$\mathbf{ØSEW}_{\text{surplus}}$	Is ØGW minus $\text{ØSEW}_{\text{reuse}}$
Ø Σ surplus SEW [L/per resident and mth]	$\mathbf{ØSEW}_{\text{surplusmth}}$	Monthly SEW surplus
Ratios unsealed to sealed open space [%]	$\mathbf{R}_{\text{open space}}$	Are taken from a study on urban morphologies
Duration of irrigation [-]	$\mathbf{IR}_{\text{duration}}$	Is defined as 15 days
Ø daily irrigation demand [mm]	$\mathbf{ØIR}_{\text{day}}$	Average values
Ø monthly irrigation demand [mm]	$\mathbf{ØIR}_{\text{mth}}$	Average values
Daily storm water maximum [mm]	$\mathbf{SW}_{\text{max}}$	Based on SW data from 2011–2021
Ø monthly storm water [mm]	$\mathbf{ØSW}_{\text{mth}}$	Based on SW data from 2011–2021
Ø monthly evaporation [mm]	$\mathbf{ØEV}_{\text{mth}}$	Average values

3.3.1. Preliminary Steps

Preliminary steps define the size of the main water body of the WSUD lake that is to be used for irrigation purposes and an extension area intended to temporarily retain storm water from extreme rainfall events. The irrigation capacity refers to the amount of water that is necessary to fully irrigate the standard greenery of each site for a period of 15 days. Retention, on the other hand, is based on the amount of storm water that would add to the lake level in the case of a 100-year heavy storm water event. The calculations incorporate average values on urban typologies [51] (Table A1) and irrigation rates [52] (Table A2). Retention capacity refers to the maximum daily storm water event for Darmstadt (Table A3). The dimensions of the lakes are restricted to a depth of 0.4 m and a width to length ratio of 1:7, as outlined in the description of the prototype.

3.3.2. Monthly Water Balance

The preliminary steps are the basis for the monthly lake water balance (Figure 5). Water inflow through storm water refers to monthly averages (Table 3). Because site data do not include information on the nature of the roofs, SW_{mth} is multiplied with the base area (A_{base}) of the buildings to approximate the total of storm water inflow. Additionally, inflow includes the surplus of service water per month ($SEW_{surplus}$) based on average consumption values applied in the design of the prototype and multiplied with the number of units (U). Lake outtake includes irrigation water and evaporation. The German weather service (DWD) provides data on evaporation for a lake depth of two meters. The deviation in the depth of the prototype is negligible because lake depth is not taken into account for the calculation of evaporation [53]. The total amount of irrigation water withdrawn from the lake is calculated by multiplying monthly irrigation averages ($ØIR_{mth}$) with the irrigation area ($A_{irrigation}$) of the site.

$$\mathbf{A}_{\text{base}} \times \mathbf{ØSW}_{\text{mth}} = \sum \text{litres from SW inflow} \tag{1}$$

$$\mathbf{U} \times \mathbf{ØSEW}_{\text{surplusmth}} = \sum \text{litres from SEW surplus} \tag{2}$$

$$\mathbf{A}_{\text{irrigation}} \times \mathbf{ØIR}_{\text{mth}} = \sum \text{litres of irrigation} \tag{3}$$

$$\mathbf{L}_{\text{area}} \times \mathbf{ØEV}_{\text{mth}} = \sum \text{litres of evaporation} \tag{4}$$

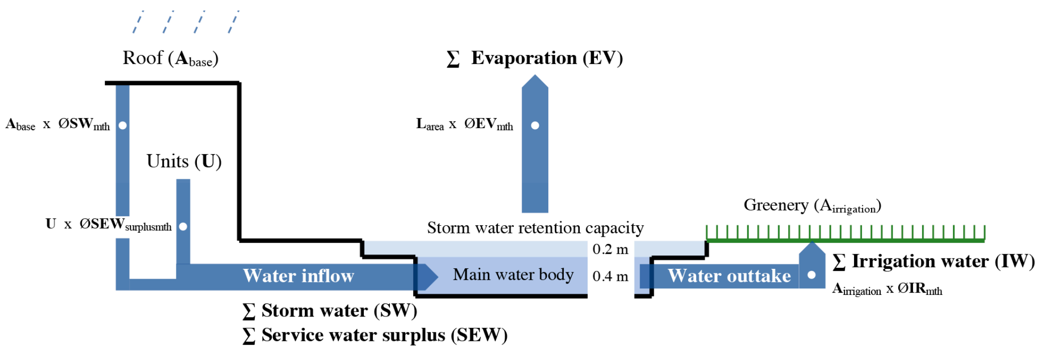


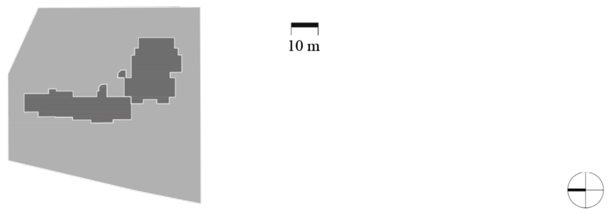
Figure 5. Scheme monthly lake water balance.

Table 3. Monthly storm water average Darmstadt.

Month	Ø Σ SW [MM] per Month 2011–2021	Month	Ø Σ SW [MM] per Month 2011–2021
January	62	July	59
February	41	August	66
March	39	September	49
April	38	October	52
May	68	November	50
June	62	December	68

As an example, Figure 6 shows the lake water balance sheets for sites 03 and 04 alongside the corresponding site plan. Irrigation rates are reduced in gradations of $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ and $\frac{1}{8}$ referring to the greenery that is watered. As stated in the description of the prototype, lake levels must not fall below a capacity of 25%. Apart from this requirement lake levels must reach 100% when the irrigation phase begins in April.

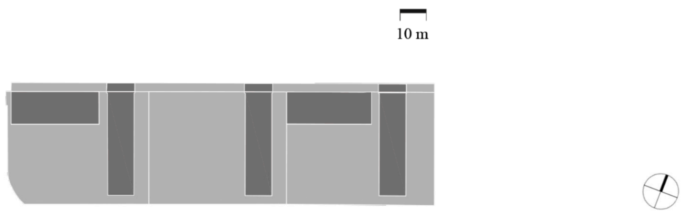
Number of site	**03**	
Base area of buildings [m^2]	888	Color matches site plan
Grand total of open space [m^2]	4242	Color matches site plan
Grand total of greenery [m^2]	3478	
Area of main water body [m^2]	256	
Capacity of main water body [m^3]	102	
Capacity of extension [m^3]	52	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	33%	25%	25%	50%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	54,744	36,138	34,211	33,713	60,446	55,304	52,817	58,430	43,829	46,094	44,353	60,615
Irrigation outtake [L/mth]	0	0	0	64,442	161,105	74,431	80,553	80,553	80,553	0	0	0
Service water inflow[L/mth]	58,522	58,522	60,472	58,522	60,472	58,522	60,472	60,472	58,522	60,472	58,522	60,472
Total litre [L]	102,000	102,000	102,000	102,000	32,604	40,484	36,582	42,648	45,742	102,000	102,000	102,000
Evaporation [L/mth]	1025	3075	7174	18,960	29,209	31,515	36,639	32,283	18,704	8968	2818	1537
Lake level	100%	100%	100%	100%	32%	40%	36%	42%	45%	100%	100%	100%

Number of site	**04**	
Base area of buildings [m^2]	1490	Color matches site plan
Grand total of open space [m^2]	7078	Color matches site plan
Grand total of greenery [m^2]	6299	
Area of main water body [m^2]	459	
Capacity of main water body [m^3]	184	
Capacity of extension [m^3]	87	



Site plan

Irrigation rate	0%	0%	0%	100%	75%	33%	25%	25%	50%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	91,858	60,637	57,404	56,569	101,425	92,797	88,624	98,042	73,543	77,343	74,422	101,708
Irrigation outtake [L/mth]	0	0	0	116,800	219,000	134,904	146,000	146,000	146,000	0	0	0
Service water inflow[L/mth]	93,269	93,269	96,378	93,269	96,378	93,269	96,378	96,378	93,269	96,378	93,269	96,378
Total litre [L]	184,000	184,000	184,000	183,052	109,498	104,169	77,495	68,046	55,331	184,000	184,000	184,000
Evaporation [L/mth]	1837	5511	12,860	33,986	52,357	56,490	65,676	57,868	33,527	16,074	5052	2756
Lake level	100%	100%	100%	99%	60%	57%	42%	37%	30%	100%	100%	100%

Figure 6. Example site sheet 03 and 04.

The remaining 21 site sheets (Figures A1–A10) can be found in the Appendix B of this paper alongside data on monthly storm water in Darmstadt (Table A4) and site assessment (Table A5).

3.4. Impact on the City Water Cycle

Based on the final calculations, altogether (a) 123 million liters of town water could be saved by WSUD prototype application per year from the 22 sites. This refers to the reuse of service water in toilets and washing machines in the households. Irrigation water provided by the lake would account for (b) 24 million liters per year. Two million liters is the total storm water retention capacity. Thus, the total savings in town water add up to 147 million liters (a + b) per year, which corresponds to the consumption of 3200 inhabitants. Under normal circumstances, this water would need to be retrieved from groundwater. However, it must be noted that despite all the designing and engineering permutations and combinations, only four sites can maintain full irrigation throughout the entire year with WSUD application. These four sites have a relatively higher ratio of built-up area to open space ranging between 0.35 and 0.51. This means they have much higher storm water runoff and less greenery to irrigate compared to other sites. In these cases, the supply of storm water and surplus of service water exceed the irrigation demands from April to September. The remaining 18 sites must lower irrigation levels between May and September ranging from 25% to 75%, otherwise the lake level would fall below the critical 25%. This is due to their ratio of built-up area to open space being low, and they range between 0.09 and 0.21. The reduced amount of irrigation water can either be distributed evenly or can be allocated to priority irrigation spots.

3.5. Further Limitations and Obstacles

Apart from the indicators listed in Table 1 applied for WSUD site assessment, there are a few caveats that need to be named and considered. These do not affect the application but may have implications on the WSUD lake design. These caveats would need further investigation and consideration in case a WSUD project is ultimately executed on site. The first caveat refers to the area that needs to be provided for the fire brigade so it can access the site in case of a fire. Length, width and position of this area are based on set requirements but to a limited extent are negotiated with the local fire brigade and tailored according to the site [54]. Nevertheless, this area cannot overlap with the WSUD lake; therefore, lake design has to be adjusted to accommodate this. The second caveat relates to the existing trees on a site. It can be a challenge to preserve old and full-grown trees while positioning the WSUD lake on the site. It is important to point out that trees are beneficial for climate resilience in an urban context [55] and should be preserved; therefore, WSUD lake design has to be adjusted to accommodate such trees. As noted earlier, splitting the lake into more than one basin is possible and could help address both aforementioned caveats.

Other noteworthy obstacles were witnessed in the planning process of the WSUD prototype. Generally speaking, storm water management and in particular the infiltration into the soil has to be approved by the environmental agency. The management of grey and service water, on the other hand, has to be approved by the health agency. Since the IWRMS combines storm, grey and service water, there was no clear responsibility. Only a special permit signed by both units enabled the continuation of planning and realization. In addition, the housing association in Mannheim insisted on a proof-of-concept ensuring that lake levels do not fall below the critical minimum in summertime. These examples demonstrate two challenges: it was new for the city administration to handle a project that did not comply with water management standards, and on the client side, there was recurring insecurity in the prototype's flawless operation.

4. Conclusions and Discussion

Climate change is already impacting weather patterns across the world, and the scientific consensus is that it will only get worse. Urban environments, due to their inherent form, are aggravating the impact of climate change on their residents, increasing the urgency to implement adaptation measures. Assessments carried out for Germany and the city of Darmstadt in particular underline this necessity. The WSUD prototype presented in this paper could be one of numerous interconnected measures taken in order to mitigate the impact of climate change. The assessment carried out in this paper provides evidence that WSUD can help the city during drought by reducing dependency on town water for local irrigation and household use. It also helps provide thermal relief during heatwave due to the adiabatic cooling effect of the WSUD lake on the development sites. During extreme storm water events, the WSUD can soften the pressure on the city storm water drainage system by locally managing the extra storm water and reducing the possibility of flooding. Apart from these climate adaptation benefits, the WSUD also improves quality of life. It enhances landscape design, it helps to preserve biodiversity and it provides adiabatic cooling.

The other question that this paper attempted to explore was that of scalability and application to an existing city. The paper finds through its investigation of the city of Darmstadt that a considerable number of housing developments already have the logistical suitability—physical space and appropriate vintage warranting renovation—for implementing WSUD. The paper found that 22 WSUD projects can be implemented in the city serving an impressive 2527 apartment units covering 155,153 m^2 of living space in the city of Darmstadt. Annual savings of about 147 million liters of town water and local storm water retainment capacity of 2 million liters are achieved in this assessment. These results are despite the scope of this assessment being limited to sites owned and serviced by one party—municipal housing associations—which limited the evaluation to 496 sites. Additionally, the paper adopted very strict indicators that further limited selection to existing sites that have not been renovated for at least 40 years.

Another critical finding of the paper is that even with WSUD application it would not be possible to maintain 100% irrigation through WSUD of standard greeneries during the driest portion of the summer. This is because standard irrigation rates applied in this paper [51] lead to rather high irrigation outtakes, as they are based on water-intensive greenery. This means that to obtain 100% irrigation for the whole summer, there needs to be additional tweaking in landscape design by moving away from the standard water-intensive greenery toward native drought-tolerant plants and trees. Further, the viability of the greenery can be supported by increasing the saturation capacity of the soil. These two options were not investigated in this paper as they were beyond the study scope but could be explored as part of future research. Other research opportunities include the quantification of the added benefits of adiabatic cooling, the improvement of local biodiversity and overall quality of life from this exercise, the investigation of other potential sites for WSUD prototype application incorporating mixed forms of ownership and the refinement of WSUD prototype lake design through simulations. Additionally, investigating other cities could provide further insight on the question of scalability. In this case, transferability relies first and foremost on matching the indicators described in Chapter 3.1. City size, on the other hand, can vary.

The benefits and the water saving potential of WSUD outlined in this study suggest a change in city water politics in Germany. As mentioned earlier, administrations need to develop procedures that can handle new innovative approaches like the WSUD prototype that do not correspond to the well-established understanding of water management. In addition, WSUD should be adopted as a climate adaptation policy mandate and receive support with subsidies as performed with energy conservation renovations. But this calls for a more frequent consideration of WSUD by planners which, in contrast to known design principles, also emphasizes improving the quality of life. Both could pave the way for further WSUD projects in German cities. In conclusion, this paper demonstrates that WSUD has clear potential to help build a city's climate resilience and reduce the pressure on town water systems. But it must also be noted that this paper is based on a specific WSUD prototype application, and it is only one element in the transformation process toward climate resilience. Other measures need to be investigated.

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Appendix A

$$\mathbf{A}_{\text{open space}} \times \mathbf{R}_{\text{open space}} = \mathbf{A}_{\text{greenery}} \tag{A1}$$

$$\mathbf{A}_{\text{greenery}} \times \text{Ø}\mathbf{IR}_{\text{day}} \times 15 = \sum \text{liters IW pre} \tag{A2}$$

$$\mathbf{L}_{\text{width}} \times \mathbf{L}_{\text{length}} \times 0.4 = \mathbf{L}_{\text{areapre}} \tag{A3}$$

(with a ratio of 1:7 and in accordance with (A2))

$$\mathbf{A}_{\text{base}} \times \mathbf{SW}_{\text{max}} = \sum \text{litres from SW inflow} \tag{A4}$$

$$\mathbf{L}_{\text{width}} \times \mathbf{L}_{\text{length}} \times 0.2 = \mathbf{L}_{\text{areaextension}} \tag{A5}$$

(with a ratio of 1:7 and in accordance with (A4))

Table A1. Ratios of greenery to open space of common urban morphologies.

Type	Detached Houses	Row Houses	Row Structures with Low Density	Row Structures with High Density	Block Structure	Rural Houses	Historical Center	City Center
$R_{\text{open space}}$	0.9	0.97	0.89	0.82	0.54	0.62	0.57	100

Table A2. Average irrigation demands.

	J	F	M	A	M	J	J	A	S	O	N	D
mm per mth	0	0	0	20	50	70	100	100	50	0	0	0
mm per day	0	0	0	0.67	1.61	2.33	3.23	3.23	1.67	0	0	0
Ø mm per day	2.12 (from April to September)											

$$\mathbf{L}_{\text{areapre}} \times \text{Ø}\mathbf{IR}_{\text{day}} \times 15 = \sum \text{liters IW lake} \tag{A6}$$

$$\sum \text{liters IW pre} - \sum \text{litres IW lake} = \sum \text{liters IW} \tag{A7}$$

$$\mathbf{L}_{\text{width}} \times \mathbf{L}_{\text{length}} \times 0.4 = \mathbf{L}_{\text{area}} \tag{A8}$$

(with a ratio of 1:7 and in accordance with (A7))

$$\mathbf{A}_{\text{greenery}} - \mathbf{L}_{\text{area}} = \mathbf{A}_{\text{irrigation}} \tag{A9}$$

Table A3. Maximum daily storm water event Darmstadt.

Day	Hour	SW [mm]	Day	Hour	SW [mm]
26 August 2011	00:00	0	26 August 2011	12:00	0
26 August 2011	01:00	0	26 August 2011	13:00	0
26 August 2011	02:00	21.4	26 August 2011	14:00	0
26 August 2011	03:00	22.8	26 August 2011	15:00	0
26 August 2011	04:00	0	26 August 2011	16:00	0
26 August 2011	05:00	0	26 August 2011	17:00	0
26 August 2011	06:00	0	26 August 2011	18:00	0
26 August 2011	07:00	0	26 August 2011	19:00	1.1
26 August 2011	08:00	0	26 August 2011	20:00	10.4
26 August 2011	09:00	0	26 August 2011	21:00	1.6
26 August 2011	10:00	0	26 August 2011	22:00	0.6
26 August 2011	11:00	0	26 August 2011	23:00	0.6
Sum total: 58.5					

Appendix B

Table A4. Monthly storm water Darmstadt.

Year	Month	Σ SW [mm]	Year	Month	Σ SW [mm]
2011	January	59.2	2017	January	25.5
2011	February	18.4	2017	February	27.2
2011	March	16.1	2017	March	48.6
2011	April	12.3	2017	April	14.9
2011	May	15.3	2017	May	80.8
2011	June	66.9	2017	June	52.6
2011	July	75.8	2017	July	130.3
2011	August	151	2017	August	93.6
2011	September	42.1	2017	September	61.9
2011	October	28.2	2017	October	50.1
2011	November	1.2	2017	November	108.6
2011	December	104.6	2017	December	74.9
2012	January	70.6	2018	January	79.3
2012	February	10.5	2018	February	15.8
2012	March	19.3	2018	March	55.8
2012	April	42.5	2018	April	54.4
2012	May	48.5	2018	May	43.5
2012	June	89.6	2018	June	22.6
2012	July	123.9	2018	July	8
2012	August	62.7	2018	August	15.9

Table A4. *Cont.*

Year	Month	Σ SW [mm]	Year	Month	Σ SW [mm]
2012	September	42.3	2018	September	34.6
2012	October	60.5	2018	October	7.9
2012	November	45.2	2018	November	24.7
2012	December	94.1	2018	December	113
2013	January	47.3	2019	January	58.7
2013	February	47	2019	February	10.2
2013	March	29	2019	March	50.8
2013	April	78.1	2019	April	43.1
2013	May	136.3	2019	May	109.2
2013	June	69.4	2019	June	49
2013	July	26.8	2019	July	41.2
2013	August	72.1	2019	August	49.6
2013	September	83.2	2019	September	75.6
2013	October	90.3	2019	October	93.4
2013	November	68.6	2019	November	63.8
2013	December	42	2019	December	69
2015	January	88.6	2020	January	37.4
2015	February	25	2020	February	108.8
2015	March	31.2	2020	March	66
2015	April	25.2	2020	April	14.7
2015	May	10.1	2020	May	67.1
2015	June	24	2020	June	48.5
2015	July	28.2	2020	July	21.9
2015	August	40.4	2020	August	75.5
2015	September	62.1	2020	September	38.4
2015	October	16.8	2020	October	65.1
2015	November	74.7	2020	November	22.2
2015	December	30.5	2020	December	91.5
2016	January	72.4	2021	January	77.4
2016	February	99.8	2021	February	44.2
2016	March	45.6	2021	March	22.8
2016	April	72.2	2021	April	22.2
2016	May	81.4	2021	May	88.4
2016	June	103.1	2021	June	97
2016	July	43.5	2021	July	95.1
2016	August	35.9	2021	August	61.2
2016	September	27.4	2021	September	25.9
2016	October	53	2021	October	53.7
2016	November	48.4	2021	November	42
2016	December	9.8	2021	December	53.1

Table A5. Shortlisted sites.

Indicator			**Value**			**Number**
Number of units and or grand total of living space			≥70 and or ≥5900 m^2			1
State of refurbishment			Building stock that was erected at least 40 years ago and that has never been renovated			2
			Building stock that was renovated at least 40 years ago			3
			Building stock that by the year 2030 will have been unrenovated for 40 years			4
Number of site [-]	Levels per building [-]	Erection year	State of refurbishment	Number of units [-]	Living space [m^2]	Indicator match
1	4	1929	Not refurbished	10	505	1 and 2
1	4	1929	Not refurbished	10	505	
1	4	1929	Not refurbished	10	517	
1	4	1929	Not refurbished	9	502	
1	4	1929	Not refurbished	10	502	
1	4	1929	Not refurbished	10	522	
1	4	1929	Not refurbished	10	520	
1	4	1929	Not refurbished	9	507	
1	4	1929	Not refurbished	9	505	
1	4	1929	Not refurbished	10	517	
1	4	1929	Not refurbished	10	511	
1	4	1929	Not refurbished	10	521	
Total				117	6135	
2	2	1950	Not refurbished	6	304	1 and 2
2	2	1950	Not refurbished	6	300	
2	2	1950	Not refurbished	6	301	
2	2	1950	Not refurbished	6	323	
2	2	1950	Not refurbished	6	323	
2	2	1950	Not refurbished	6	323	
2	2	1950	Not refurbished	6	301	
2	2	1950	Not refurbished	6	304	
2	2	1950	Not refurbished	6	300	
2	2	1950	Not refurbished	6	301	
2	2	1950	Not refurbished	6	301	
2	2	1950	Not refurbished	5	264	
2	2	1950	Not refurbished	6	309	
2	2	1950	Not refurbished	6	307	
2	2	1950	Not refurbished	6	323	
2	2	1950	Not refurbished	6	323	
2	2	1950	Not refurbished	6	316	
2	2	1950	Not refurbished	6	322	
2	2	1950	Not refurbished	6	382	

Table A5. *Cont.*

Indicator			Value			Number
2	2	1950	Not refurbished	6	322	
2	2	1950	Not refurbished	6	322	
2	2	1950	Not refurbished	6	323	
2	2	1950	Not refurbished	6	303	
2	2	1950	Not refurbished	6	303	
2	2	1950	Not refurbished	6	343	
2	2	1950	Not refurbished	5	291	
Total				154	8139	
3	9	1971	Not refurbished	38	3048	1 and 2
3	9	1971	Not refurbished	16	1360	
3	9	1971	Not refurbished	10	608	
Total				64	5015	
4	5	1951	Not refurbished	9	507	1 and 2
4	5	1951	Not refurbished	10	619	
4	5	1951	Not refurbished	15	721	
4	5	1951	Not refurbished	9	507	
4	5	1951	Not refurbished	10	619	
4	5	1951	Not refurbished	15	721	
4	5	1951	Not refurbished	9	507	
4	5	1951	Not refurbished	10	619	
4	5	1951	Not refurbished	15	721	
Total				102	5542	
5	4	1930	Not refurbished	10	394	1 and 2
5	4	1930	Not refurbished	10	397	
5	4	1930	Not refurbished	9	374	
5	4	1930	Not refurbished	9	585	
5	4	1930	Not refurbished	10	533	
5	4	1930	Not refurbished	9	408	
5	4	1930	Not refurbished	9	460	
5	4	1930	Not refurbished	5	280	
5	4	1930	Not refurbished	4	271	
5	4	1930	Not refurbished	10	384	
5	4	1930	Not refurbished	8	315	
5	4	1930	Not refurbished	10	396	
5	4	1930	Not refurbished	8	312	
5	4	1930	Not refurbished	10	391	
5	4	1930	Not refurbished	9	396	
5	4	1930	Not refurbished	4	281	
5	4	1930	Not refurbished	10	415	
Total				144	6591	

Table A5. *Cont.*

Indicator			**Value**			**Number**
6	5	1984	Not refurbished	11	837	1 and 4
6	5	1984	Not refurbished	10	692	
6	5	1984	Not refurbished	20	1198	
6	5	1984	Not refurbished	20	1255	
6	5	1984	Not refurbished	12	938	
Total				73	4920	
7	8	1969	Not refurbished	19	1965	1 and 2
7	8	1969	Not refurbished	25	1872	
7	8	1969	Not refurbished	18	1904	
Total				62	5741	
8	3	1966	Not refurbished	6	414	1 and 2
8	3	1966	Not refurbished	6	433	
8	3	1966	Not refurbished	6	433	
8	3	1966	Not refurbished	6	414	
8	3	1966	Not refurbished	6	433	
8	3	1966	Not refurbished	6	414	
8	12	1966	Not refurbished	60	3566	
8	4	1966	Not refurbished	8	573	
8	4	1966	Not refurbished	8	673	
8	4	1966	Not refurbished	8	618	
8	4	1966	Not refurbished	8	618	
Total				128	8586	
9	14	1967	Not refurbished	69	5161	1 and 2
Total				69	5161	
10	12	1968	Not refurbished	72	4293	1 and 2
Total				72	4293	
11	11	1974	Not refurbished	46	3277	1 and 2
11	11	1974	Not refurbished	61	4677	
Total				107	7954	
12	9	1975	Not refurbished	30	2296	1 and 2
12	5	1975	Not refurbished	13	764	
12	9	1975	Not refurbished	14	1049	
12	9	1975	Not refurbished	46	3401	
12	5	1975	Not refurbished	13	764	
12	9	1975	Not refurbished	46	3289	
12	5	1975	Not refurbished	13	764	
12	9	1975	Not refurbished	14	1049	
12	9	1975	Not refurbished	45	3214	
12	9	1975	Not refurbished	45	3238	
12	5	1975	Not refurbished	13	764	

Table A5. *Cont.*

Indicator			Value			Number
12	9	1975	Not refurbished	16	1198	
12	9	1975	Not refurbished	51	3819	
12	5	1975	Not refurbished	16	954	
12	9	1975	Not refurbished	27	2066	
12	9	1975	Not refurbished	45	3214	
12	5	1975	Not refurbished	13	764	
12	9	1975	Not refurbished	14	1049	
Total				474	33,655	
13	3	1982	Not refurbished	12	773	
13	3	1982	Not refurbished	10	817	
13	3	1982	Not refurbished	8	608	
13	3	1982	Not refurbished	10	817	
13	3	1982	Not refurbished	8	607	
13	3	1982	Not refurbished	12	772	
13	3	1982	Not refurbished	11	691	1 and 4
13	3	1982	Not refurbished	7	473	
13	3	1982	Not refurbished	11	693	
13	3	1982	Not refurbished	11	691	
13	3	1982	Not refurbished	12	714	
13	3	1982	Not refurbished	7	535	
Total				119	8190	
14	3	1983	Not refurbished	7	418	
14	3	1983	Not refurbished	8	463	
14	1	1983	Not refurbished	1	90	
14	1	1983	Not refurbished	1	90	
14	3	1983	Not refurbished	8	463	
14	1	1983	Not refurbished	1	90	
14	1	1983	Not refurbished	1	90	1 and 4
14	3	1983	Not refurbished	8	607	
14	3	1983	Not refurbished	8	696	
14	3	1983	Not refurbished	10	817	
14	3	1983	Not refurbished	11	693	
14	3	1983	Not refurbished	6	464	
14	3	1983	Not refurbished	8	584	
Total				78	5562	
15	3	1984	Not refurbished	60	2929	
15	1	1984	Not refurbished	35	1738	1 and 4
Total				95	4667	

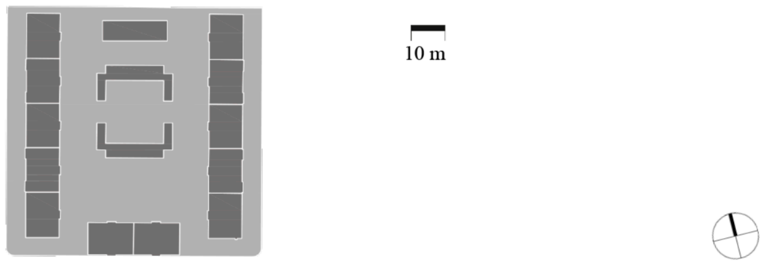
Table A5. *Cont.*

Indicator			Value			Number
16	4	1990	Not refurbished	21	1209	1 and 4
16	4	1990	Not refurbished	29	1660	
16	4	1990	Not refurbished	29	1660	
Total				79	4530	
17	3	1986	Not refurbished	8	573	1 and 4
17	3	1986	Not refurbished	2	131	
17	3	1986	Not refurbished	2	131	
17	3	1986	Not refurbished	4	304	
17	3	1986	Not refurbished	8	601	
17	3	1986	Not refurbished	2	118	
17	3	1986	Not refurbished	2	144	
17	3	1986	Not refurbished	2	144	
17	3	1986	Not refurbished	2	118	
17	3	1986	Not refurbished	8	601	
17	3	1986	Not refurbished	4	304	
17	3	1986	Not refurbished	2	131	
17	3	1986	Not refurbished	2	131	
17	3	1986	Not refurbished	8	573	
17	3	1986	Not refurbished	2	144	
17	3	1986	Not refurbished	2	144	
17	3	1986	Not refurbished	2	118	
17	3	1986	Not refurbished	8	601	
17	3	1986	Not refurbished	8	601	
17	3	1986	Not refurbished	2	118	
Total				80	5731	
18	3	1989	Not refurbished	33	1576	1 and 4
18	3	1989	Not refurbished	27	1197	
18	3	1989	Not refurbished	35	1839	
Total				95	4612	
19	3	1960	Not refurbished	47	1395	1 and 2
19	4	1960	Not refurbished	23	848	
19	3	1960	Not refurbished	38	799	
19	3	1960	Not refurbished	24	1067	
Total				132	4109	
20	4	1926	Not refurbished	8	386	1 and 2
20	4	1926	Not refurbished	8	385	
20	4	1926	Not refurbished	8	386	
20	3	1926	Not refurbished	8	387	
20	4	1926	Not refurbished	8	387	
20	4	1926	Not refurbished	8	387	

Table A5. *Cont.*

Indicator			Value			Number
20	3	1926	Not refurbished	8	387	
20	3	1926	Not refurbished	8	387	
20	3	1926	Not refurbished	8	385	
20	3	1926	Not refurbished	8	372	
20	3	1926	Not refurbished	8	400	
20	3	1926	Not refurbished	8	383	
Total				96	4632	
21	1	1951	Not refurbished	6	366	1 and 2
21	1	1951	Not refurbished	6	345	
21	1	1951	Not refurbished	3	148	
21	1	1951	Not refurbished	6	368	
21	1	1951	Not refurbished	6	345	
21	1	1951	Not refurbished	8	452	
21	1	1951	Not refurbished	6	343	
21	1	1951	Not refurbished	8	451	
21	1	1951	Not refurbished	6	343	
21	1	1951	Not refurbished	8	450	
21	1	1951	Not refurbished	6	345	
21	1	1951	Not refurbished	8	451	
21	1	1951	Not refurbished	8	445	
21	1	1951	Not refurbished	10	322	
21	1	1951	Not refurbished	8	217	
Total				103	5390	
22	4	1983	Not refurbished	8	575	1 and 4
22	4	1983	Not refurbished	8	585	
22	4	1983	Not refurbished	8	585	
22	4	1983	Not refurbished	8	585	
22	4	1983	Not refurbished	8	585	
22	4	1983	Not refurbished	8	508	
22	3	1983	Not refurbished	6	438	
22	3	1983	Not refurbished	6	438	
22	3	1983	Not refurbished	6	438	
22	3	1983	Not refurbished	6	407	
22	3	1983	Not refurbished	6	415	
22	3	1983	Not refurbished	6	438	
Total				84	5996	

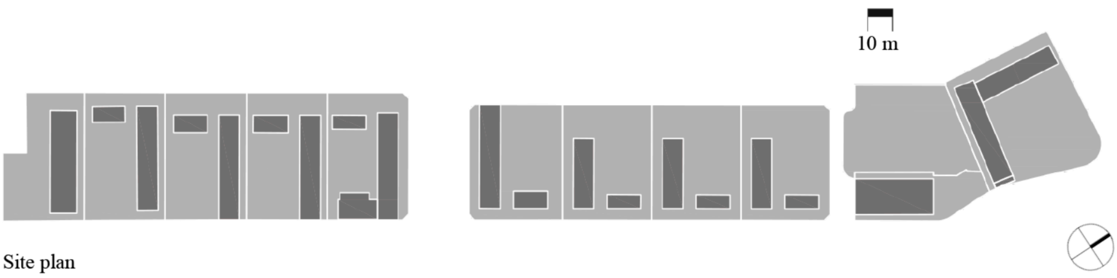
Number of site	**01**	
Base area of buildings [m²]	2170	Color matches site plan
Grand total of open space [m²]	4025	Color matches site plan
Grand total of greenery [m²]	2174	
Area of main water body [m²]	160	
Capacity of main water body [m³]	64	
Capacity of extension [m³]	127	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	100%	100%	100%	100%	0%	0%	0%
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Storm water inflow[L/mth]	133,762	88,300	83,591	82,375	147,694	135,130	129,053	142,768	107,092	112,626	108,373	148,107
Irrigation outtake [L/mth]	0	0	0	40276	100690	140966	201379	201379	100690	0	0	0
Service water inflow[L/mth]	106,985	106,985	110,551	106,985	110,551	106,985	110,551	110,551	106,985	110,551	106,985	110,551
Total litre [L]	64,000	64,000	64,000	64,000	64,000	64,000	64,000	64,000	64,000	64,000	64,000	64,000
Evaporation [L/mth]	640	1919	4478	11,835	18,233	19,672	22,871	20,152	11,676	5598	1759	960
Lake level	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Number of site	**02**	
Base area of buildings [m²]	5608	Color matches site plan
Grand total of open space [m²]	14935	Color matches site plan
Grand total of greenery [m²]	13292	
Area of main water body [m²]	973	
Capacity of main water body [m³]	389	
Capacity of extension [m³]	328	



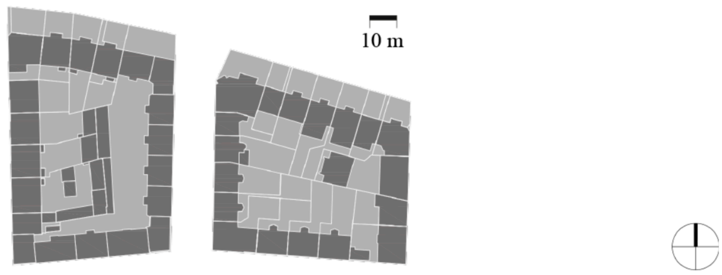
Site plan

Irrigation rate	0%	0%	0%	100%	100%	50%	25%	33%	50%	0%	0%	0%
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Storm water inflow[L/mth]	345,664	228,181	216,012	212,872	381,666	349,197	333,495	368,936	276,744	291,044	280,053	382,731
Irrigation outtake [L/mth]	0	0	0	246,382	615,956	431,169	307,978	406,531	307,978	0	0	0
Service water inflow[L/mth]	140,818	140,818	145,512	140,818	145,512	140,818	145,512	145,512	140,818	145,512	140,818	145,512
Total litre [L]	389,000	389,000	389,000	389,000	189,296	128,459	160,344	145,659	184,212	389,000	389,000	389,000
Evaporation [L/mth]	3892	11,676	27,245	72,004	110,925	119,683	139,143	122,602	71,031	34,056	10,703	5838
Lake level	100%	100%	100%	100%	49%	33%	41%	37%	47%	100%	100%	100%

Figure A1. Site sheets 01 and 02.

Number of site	**05**	
Base area of buildings [m^2]	5844	Color matches site plan
Grand total of open space [m^2]	5464	Color matches site plan
Grand total of greenery [m^2]	2950	
Area of main water body [m^2]	218	
Capacity of main water body [m^3]	87	
Capacity of extension [m^3]	342	

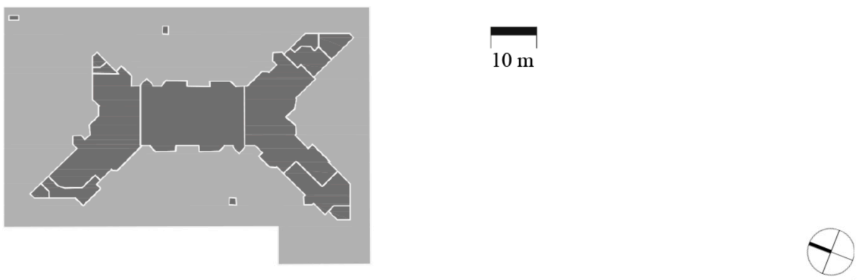
Site plan



Irrigation rate	0%	0%	0%	100%	100%	100%	100%	100%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	360,222	237,791	225,109	221,837	397,740	363,903	347,540	384,474	288,399	303,302	291,847	398,850
Irrigation outtake [L/mth]	0	0	0	54,650	136,624	191,273	273,248	273,248	136,624	0	0	0
Service water inflow[L/mth]	131,674	131,674	136,063	131,674	136,063	131,674	136,063	136,063	131,674	136,063	131,674	136,063
Total litre [L]	87,000	87,000	87,000	87,000	87,000	87,000	87,000	87,000	87,000	87,000	87,000	87,000
Evaporation [L/mth]	872	2615	6103	16,129	24,847	26,808	31,168	27,462	15,911	7628	2398	1308
Lake level	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Number of site	**06**	
Base area of buildings [m^2]	1270	Color matches site plan
Grand total of open space [m^2]	3248	Color matches site plan
Grand total of greenery [m^2]	1754	
Area of main water body [m^2]	129	
Capacity of main water body [m^3]	52	
Capacity of extension [m^3]	74	

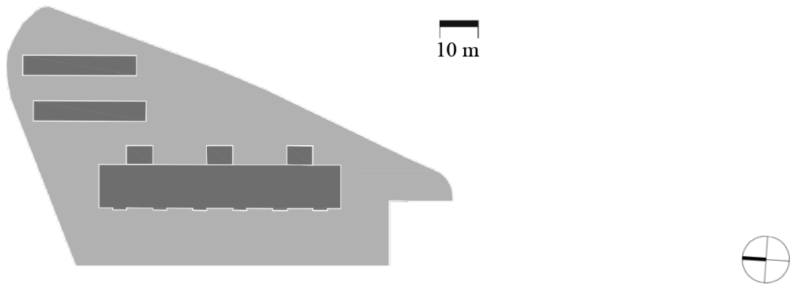
Site plan



Irrigation rate	0%	0%	0%	100%	100%	100%	100%	75%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	78,271	51,669	48,913	48,202	86,423	79,071	75,516	83,541	62,665	65,903	63,414	86,665
Irrigation outtake [L/mth]	0	0	0	32,486	81,215	113,701	162,431	121,823	81,215	0	0	0
Service water inflow[L/mth]	66,751	66,751	68,976	66,751	68,976	66,751	68,976	68,976	66,751	68,976	66,751	68,976
Total litre [L]	52,000	52,000	52,000	52,000	52,000	52,000	15,553	29,939	52,000	52,000	52,000	52,000
Evaporation [L/mth]	518	1553	3624	9578	14,755	15,920	18,508	16,308	9448	4530	1424	777
Lake level	100%	100%	100%	100%	100%	100%	30%	58%	100%	100%	100%	100%

Figure A2. Sites 05 and 06.

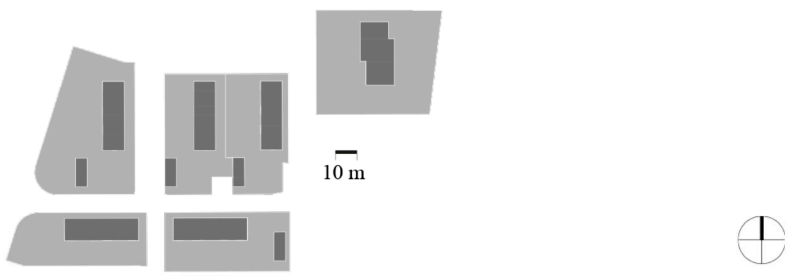
Number of site	**07**	
Base area of buildings [m²]	1283	Color matches site plan
Grand total of open space [m²]	4216	Color matches site plan
Grand total of greenery [m²]	3753	
Area of main water body [m²]	276	
Capacity of main water body [m³]	110	
Capacity of extension [m³]	75	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	50%	25%	33%	50%	0%	0%	0%
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Storm water inflow[L/mth]	79,084	52,205	49,421	48,702	87,320	79,892	76,299	84,408	63,316	66,587	64,073	87,564
Irrigation outtake [L/mth]	0	0	0	69,530	173,826	121,678	86,913	114,725	86,913	0	0	0
Service water inflow[L/mth]	56,693	56,693	58,583	56,693	58,583	56,693	58,583	58,583	56,693	58,583	56,693	58,583
Total litre [L]	110,000	110,000	110,000	110,000	50,605	31,555	40,046	33,527	46,469	110,000	110,000	110,000
Evaporation [L/mth]	1104	3313	7730	20,429	31,472	33,956	39,478	34,785	20,153	9662	3037	1656
Lake level	100%	100%	100%	100%	46%	29%	36%	30%	42%	100%	100%	100%

Number of site	**08**	
Base area of buildings [m²]	2716	Color matches site plan
Grand total of open space [m²]	10183	Color matches site plan
Grand total of greenery [m²]	9063	
Area of main water body [m²]	661	
Capacity of main water body [m³]	265	
Capacity of extension [m³]	159	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	33%	12.5%	33%	50%	0%	0%	0%
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Storm water inflow[L/mth]	167,438	110,530	104,635	103,114	184,877	169,149	161,543	178,711	134,053	140,980	135,656	185,393
Irrigation outtake [L/mth]	0	0	0	168,032	420,081	194,077	105,020	277,253	210,040	0	0	0
Service water inflow[L/mth]	117,043	117,043	120,945	117,043	120,945	117,043	120,945	120,945	117,043	120,945	117,043	120,945
Total litre [L]	265,000	265,000	265,000	265,000	75,347	86,116	169,011	108,083	100,861	265,000	265,000	265,000
Evaporation [L/mth]	2645	7936	18,518	48,940	75,394	81,346	94,573	83,330	48,278	23,147	7275	3968
Lake level	100%	100%	100%	100%	28%	32%	64%	41%	38%	100%	100%	100%

Figure A3. Sites 07 and 08.

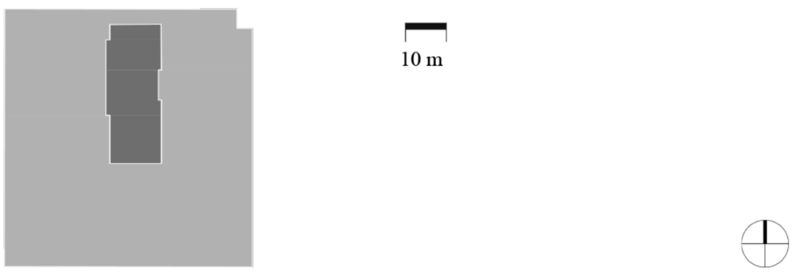
Number of site	**09**	
Base area of buildings [m^2]	464	Color matches site plan
Grand total of open space [m^2]	4199	Color matches site plan
Grand total of greenery [m^2]	3443	
Area of main water body [m^2]	252	
Capacity of main water body [m^3]	101	
Capacity of extension [m^3]	27	

Site plan

	January	February	March	April	May	June	July	August	September	October	November	December
Irrigation rate	0%	0%	0%	100%	75%	33%	12.5%	25%	33%	0%	0%	0%
Storm water inflow[L/mth]	28,619	18,892	17,884	17,624	31,600	28,911	27,611	30,546	22,913	24,097	23,187	31,688
Irrigation outtake [L/mth]	0	0	0	63,827	119,676	73,721	39,892	79,784	52,658	0	0	0
Service water inflow[L/mth]	63,094	63,094	65,197	63,094	65,197	63,094	65,197	65,197	63,094	65,197	63,094	65,197
Total litre [L]	101,000	101,000	101,000	99,243	47,635	34,923	51,803	36,009	50,962	101,000	101,000	101,000
Evaporation [L/mth]	1008	3024	7056	18,648	28,728	30,996	36,036	31,752	18,396	8820	2772	1512
Lake level	100%	100%	100%	98%	47%	35%	51%	36%	50%	100%	100%	100%

Number of site	**10**	
Base area of buildings [m^2]	499	Color matches site plan
Grand total of open space [m^2]	3797	Color matches site plan
Grand total of greenery [m^2]	3114	
Area of main water body [m^2]	227	
Capacity of main water body [m^3]	91	
% of lake area to greenery	29	

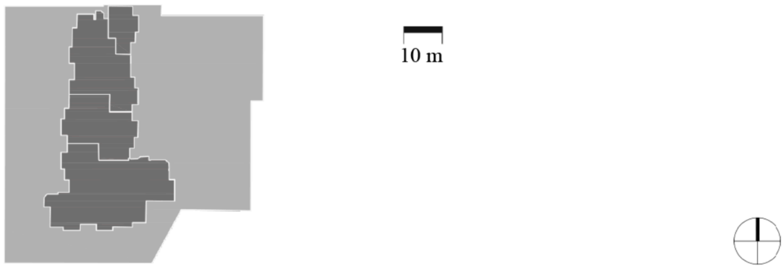
Site plan



	January	February	March	April	May	June	July	August	September	October	November	December
Irrigation rate	0%	0%	0%	100%	100%	33%	12.5%	33%	50%	0%	0%	0%
Storm water inflow[L/mth]	30,763	20,307	19,224	18,945	33,967	31,077	29,680	32,834	24,629	25,902	24,924	34,062
Irrigation outtake [L/mth]	0	0	0	57,722	144,305	66,669	36,076	95,241	72,152	0	0	0
Service water inflow[L/mth]	65,837	65,837	68,031	65,837	68,031	65,837	68,031	68,031	65,837	68,031	65,837	68,031
Total litre [L]	91,000	91,000	91,000	91,000	22,766	25,038	54,150	31,118	32,829	91,000	91,000	91,000
Evaporation [L/mth]	910	2729	6368	16,830	25,927	27,974	32,522	28,656	16,602	7960	2502	1365
Lake level	100%	100%	100%	100%	25%	28%	60%	34%	36%	100%	100%	100%

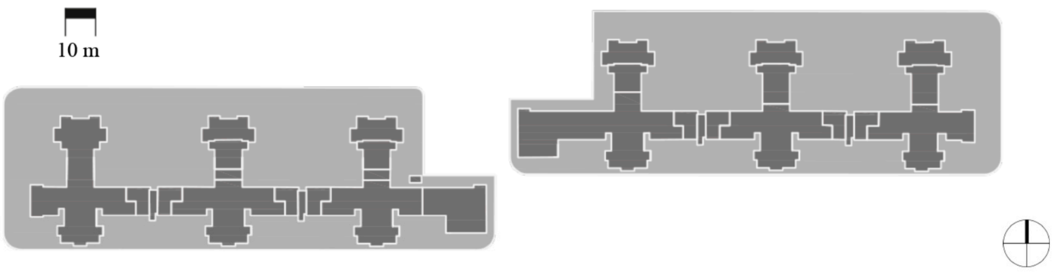
Figure A4. Sites 09 and 10.

Number of site	**11**		
Base area of buildings [m²]	1292		Color matches site plan
Grand total of open space [m²]	3250		Color matches site plan
Grand total of greenery [m²]	2665		
Area of main water body [m²]	194		
Capacity of main water body [m³]	78		
Capacity of extension [m³]	76		



Irrigation rate	0%	0%	0%	100%	100%	100%	75%	50%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	79,652	52,580	49,776	49,052	87,948	80,466	76,848	85,014	63,771	67,066	64,533	88,193
Irrigation outtake [L/mth]	0	0	0	49,415	123,538	172,953	185,307	123,538	123,538	0	0	0
Service water inflow[L/mth]	97,841	97,841	101,102	97,841	101,102	97,841	101,102	101,102	97,841	101,102	97,841	101,102
Total litre [L]	78,000	78,000	78,000	78,000	78,000	59,441	24,283	62,366	78,000	78,000	78,000	78,000
Evaporation [L/mth]	778	2333	5443	14,386	22,163	23,912	27,801	24,496	14,192	6804	2139	1166
Lake level	100%	100%	100%	100%	100%	76%	31%	80%	100%	100%	100%	100%

Number of site	**12**		
Base area of buildings [m²]	6027		Color matches site plan
Grand total of open space [m²]	11952		Color matches site plan
Grand total of greenery [m²]	9801		
Area of main water body [m²]	718		
Capacity of main water body [m³]	287		
Capacity of extension [m³]	353		



Irrigation rate	0%	0%	0%	100%	100%	100%	100%	75%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	371,480	245,222	232,145	228,770	410,170	375,276	358,402	396,490	297,413	312,781	300,968	411,315
Irrigation outtake [L/mth]	0	0	0	181,646	454,116	635,763	908,232	681,174	454,116	0	0	0
Service water inflow[L/mth]	433,426	433,426	447,873	433,426	447,873	433,426	447,873	447,873	433,426	447,873	433,426	447,873
Total litre [L]	287,000	287,000	287,000	287,000	287,000	287,000	82,323	155,004	287,000	287,000	287,000	287,000
Evaporation [L/mth]	2873	8620	20,113	53,156	81,888	88,353	102,720	90,508	52,437	25,141	7902	4310
Lake level	100%	100%	100%	100%	100%	100%	29%	54%	100%	100%	100%	100%

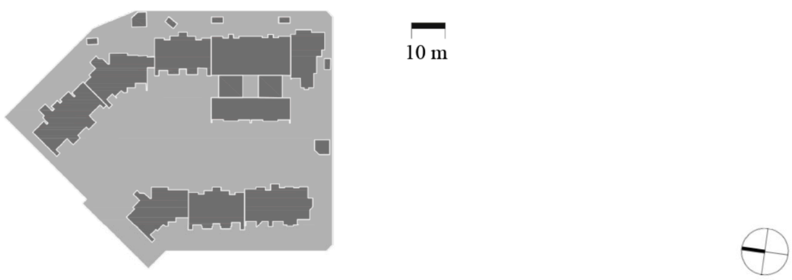
Figure A5. Sites 11 and 12.

Number of site	**13**	
Base area of buildings [m^2]	2778	Color matches site plan
Grand total of open space [m^2]	7667	Color matches site plan
Grand total of greenery [m^2]	6824	
Area of main water body [m^2]	500	
Capacity of main water body [m^3]	200	
Capacity of extension [m^3]	163	

Site plan

Irrigation rate	0%	0%	0%	100%	100%	50%	33%	33%	75%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	171,227	113,031	107,003	105,448	189,061	172,977	165,199	182,755	137,087	144,171	138,726	189,589
Irrigation outtake [L/mth]	0	0	0	126,477	316,192	221,334	208,687	208,687	237,144	0	0	0
Service water inflow[L/mth]	108,814	108,814	112,441	108,814	112,441	108,814	112,441	112,441	108,814	112,441	108,814	112,441
Total litre [L]	200,000	200,000	200,000	200,000	128,331	127,310	124,789	148,322	120,592	200,000	200,000	200,000
Evaporation [L/mth]	1999	5998	13,995	36,986	56,979	61,478	71,474	62,977	36,487	17,494	5498	2999
Lake level	100%	100%	100%	100%	64%	64%	62%	74%	60%	100%	100%	100%

Number of site	**14**	
Base area of buildings [m^2]	2106	Color matches site plan
Grand total of open space [m^2]	4292	Color matches site plan
Grand total of greenery [m^2]	3820	
Area of main water body [m^2]	281	
Capacity of main water body [m^3]	112	
Capacity of extension [m^3]	123	

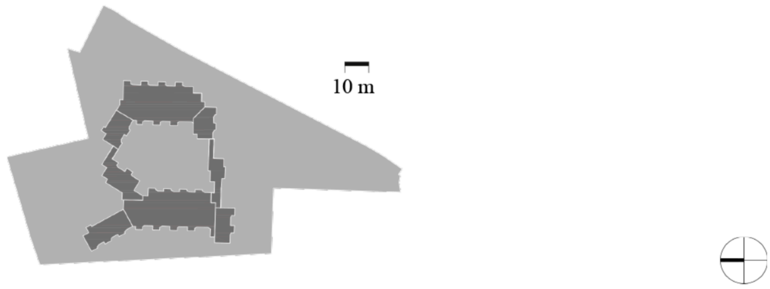


Site plan

Irrigation rate	0%	0%	0%	100%	100%	100%	33%	50%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	129,840	85,711	81,140	79,960	143,364	131,167	125,269	138,582	103,952	109,324	105,195	143,764
Irrigation outtake [L/mth]	0	0	0	70,786	176,964	247,750	116,796	176,964	176,964	0	0	0
Service water inflow[L/mth]	71,323	71,323	73,701	71,323	73,701	71,323	73,701	73,701	71,323	73,701	71,323	73,701
Total litre [L]	112,000	112,000	112,000	112,000	112,000	32,242	74,306	74,284	52,120	112,000	112,000	112,000
Evaporation [L/mth]	1122	3366	7854	20,756	31,975	34,499	40,109	35,341	20,475	9817	3085	1683
Lake level	100%	100%	100%	100%	100%	29%	66%	66%	47%	100%	100%	100%

Figure A6. Sites 13 and 14.

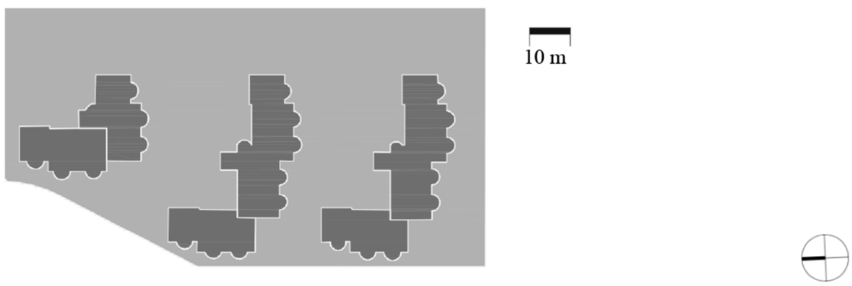
Number of site	**15**	
Base area of buildings [m²]	2051	Color matches site plan
Grand total of open space [m²]	8613	Color matches site plan
Grand total of greenery [m²]	4651	
Area of main water body [m²]	340	
Capacity of main water body [m³]	136	
Capacity of extension [m³]	120	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	75%	33%	50%	75%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	126,450	83,472	79,021	77,872	139,620	127,742	121,998	134,963	101,238	106,469	102,448	140,009
Irrigation outtake [L/mth]	0	0	0	86,216	215,540	226,317	142,256	215,540	161,655	0	0	0
Service water inflow[L/mth]	86,868	86,868	89,764	86,868	89,764	86,868	89,764	89,764	86,868	89,764	86,868	89,764
Total litre [L]	136,000	136,000	136,000	136,000	111,076	57,541	78,417	44,756	46,382	136,000	136,000	136,000
Evaporation [L/mth]	1360	4081	9522	25,165	38,768	41,828	48,629	42,848	24,825	11,902	3741	2040
Lake level	100%	100%	100%	100%	82%	42%	58%	33%	34%	100%	100%	100%

Number of site	**16**	
Base area of buildings [m²]	1970	Color matches site plan
Grand total of open space [m²]	5909	Color matches site plan
Grand total of greenery [m²]	5259	
Area of main water body [m²]	385	
Capacity of main water body [m³]	154	
Capacity of extension [m³]	115	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	50%	25%	33%	50%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	121,404	80,142	75,868	74,765	134,049	122,645	117,130	129,578	97,198	102,221	98,360	134,423
Irrigation outtake [L/mth]	0	0	0	97,464	243,659	170,562	121,830	160,815	121,830	0	0	0
Service water inflow[L/mth]	72,238	72,238	74,646	72,238	74,646	72,238	74,646	74,646	72,238	74,646	72,238	74,646
Total litre [L]	154,000	154,000	154,000	154,000	75,100	52,018	66,852	61,701	81,173	154,000	154,000	154,000
Evaporation [L/mth]	1542	4625	10,791	28,519	43,935	47,404	55,111	48,560	28,134	13,489	4239	2312
Lake level	100%	100%	100%	100%	49%	34%	43%	40%	53%	100%	100%	100%

Figure A7. Sites 15 and 16.

Number of site	**17**	
Base area of buildings [m^2]	2061	Color matches site plan
Grand total of open space [m^2]	10093	Color matches site plan
Grand total of greenery [m^2]	8983	
Area of main water body [m^2]	659	
Capacity of main water body [m^3]	263	
Capacity of extension [m^3]	121	

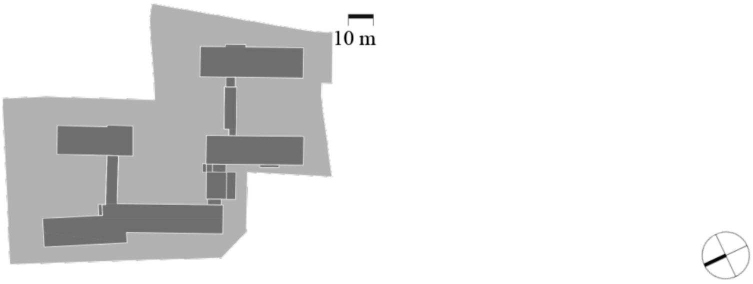
Irrigation rate	0%	0%	0%	100%	50%	25%	12.5%	12.5%	33%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	127,020	83,849	79,377	78,223	140,249	128,318	122,548	135,571	101,694	106,949	102,910	140,641
Irrigation outtake [L/mth]	0	0	0	166,484	208,105	145,674	104,053	104,053	137,349	0	0	0
Service water inflow[L/mth]	73,152	73,152	75,590	73,152	75,590	73,152	75,590	75,590	73,152	75,590	73,152	75,590
Total litre [L]	263,000	263,000	263,000	199,152	131,803	106,588	106,490	130,612	120,029	263,000	263,000	263,000
Evaporation [L/mth]	2635	7904	18,442	48,739	75,084	81,011	94,184	82,987	48,080	23,052	7245	3952
Lake level	100%	100%	100%	76%	50%	41%	40%	50%	46%	100%	100%	100%

Number of site	**18**	
Base area of buildings [m^2]	2188	Color matches site plan
Grand total of open space [m^2]	3131	Color matches site plan
Grand total of greenery [m^2]	1691	
Area of main water body [m^2]	126	
Capacity of main water body [m^3]	50	
Capacity of extension [m^3]	128	

Irrigation rate	0%	0%	0%	100%	100%	100%	100%	100%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	134,889	89,043	84,294	83,069	148,938	136,267	130,140	143,970	107,994	113,574	109,285	149,354
Irrigation outtake [L/mth]	0	0	0	31,294	78,234	109,528	156,468	156,468	78,234	0	0	0
Service water inflow[L/mth]	86,868	86,868	89,764	86,868	89,764	86,868	89,764	89,764	86,868	89,764	86,868	89,764
Total litre [L]	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Evaporation [L/mth]	503	1510	3524	9312	14,346	15,479	17,996	15,856	9187	4405	1384	755
Lake level	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Figure A8. Sites 17 and 18.

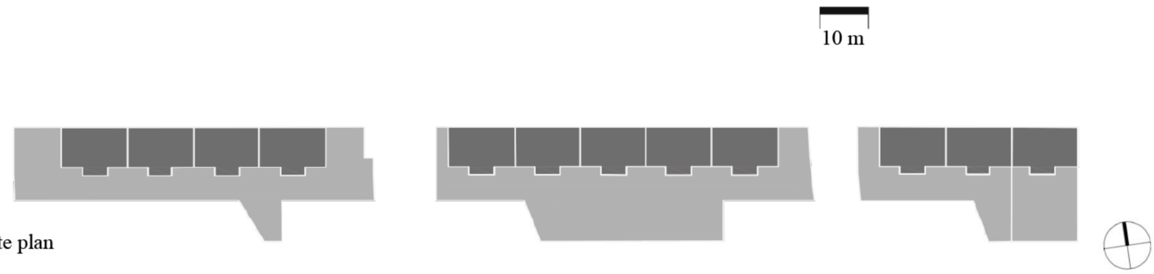
Number of site	**19**	
Base area of buildings [m²]	2917	Color matches site plan
Grand total of open space [m²]	7816	Color matches site plan
Grand total of greenery [m²]	6956	
Area of main water body [m²]	508	
Capacity of main water body [m³]	203	
Capacity of extension [m³]	171	



Site plan

Irrigation rate	0%	0%	0%	100%	100%	50%	33%	50%	75%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	179,774	118,673	112,344	110,711	198,498	181,612	173,445	191,878	143,930	151,367	145,651	199,052
Irrigation outtake [L/mth]	0	0	0	128,954	322,385	225,670	212,774	322,385	241,789	0	0	0
Service water inflow[L/mth]	120,701	120,701	124,724	120,701	124,724	120,701	124,724	124,724	120,701	124,724	120,701	124,724
Total litre [L]	203,000	203,000	203,000	203,000	145,910	160,052	172,785	102,977	88,725	203,000	203,000	203,000
Evaporation [L/mth]	2033	6098	14,228	37,602	57,927	62,500	72,663	64,025	37,094	17,785	5589	3049
Lake level	100%	100%	100%	100%	72%	79%	85%	51%	44%	100%	100%	100%

Number of site	**20**	
Base area of buildings [m²]	1607	Color matches site plan
Grand total of open space [m²]	2322	Color matches site plan
Grand total of greenery [m²]	2067	
Area of main water body [m²]	151	
Capacity of main water body [m³]	61	
Capacity of extension [m³]	94	



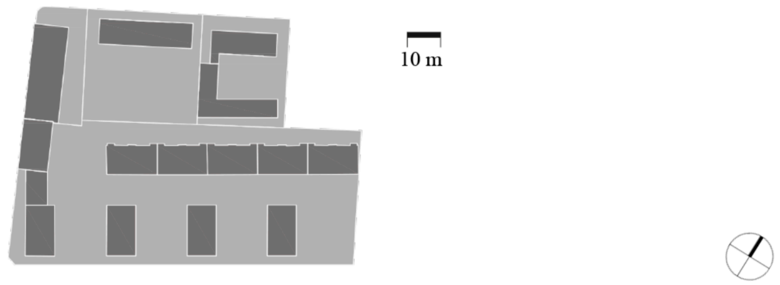
Site plan

Irrigation rate	0%	0%	0%	100%	100%	100%	100%	100%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	99,044	65,381	61,894	60,995	109,359	100,056	95,557	105,712	79,296	83,393	80,244	109,665
Irrigation outtake [L/mth]	0	0	0	38,310	95,774	134,084	191,549	191,549	95,774	0	0	0
Service water inflow[L/mth]	87,782	87,782	90,708	87,782	90,708	87,782	90,708	90,708	87,782	90,708	87,782	90,708
Total litre [L]	61,000	61,000	61,000	61,000	61,000	61,000	34,072	19,873	61,000	61,000	61,000	61,000
Evaporation [L/mth]	605	1816	4238	11,200	17,255	18,617	21,644	19,071	11,049	5298	1665	908
Lake level	100%	100%	100%	100%	100%	100%	56%	33%	100%	100%	100%	100%

Figure A9. Sites 19 and 20.

Number of site	**21**	
Base area of buildings [m²]	2580	Color matches site plan
Grand total of open space [m²]	5268	Color matches site plan
Grand total of greenery [m²]	4688	
Area of main water body [m²]	343	
Capacity of main water body [m³]	137	
Capacity of extension [m³]	151	

Site plan



Irrigation rate	0%	0%	0%	100%	100%	100%	33%	50%	100%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	159,054	104,995	99,396	97,951	175,620	160,680	153,455	169,763	127,341	133,921	128,864	176,110
Irrigation outtake [L/mth]	0	0	0	86,908	217,270	304,178	143,398	217,270	217,270	0	0	0
Service water inflow[L/mth]	94,183	94,183	97,323	94,183	97,323	94,183	97,323	97,323	94,183	97,323	94,183	97,323
Total litre [L]	137,000	137,000	137,000	137,000	137,000	45,496	103,825	110,422	89,638	137,000	137,000	137,000
Evaporation [L/mth]	1372	4116	9604	25,382	39,102	42,189	49,049	43,218	25,039	12,005	3773	2058
Lake level	100%	100%	100%	100%	100%	33%	76%	81%	65%	100%	100%	100%

Number of site	**22**	
Base area of buildings [m²]	1962	Color matches site plan
Grand total of open space [m²]	5499	Color matches site plan
Grand total of greenery [m²]	4894	
Area of main water body [m²]	359	
Capacity of main water body [m³]	144	
Capacity of extension [m³]	115	

Site plan

Irrigation rate	0%	0%	0%	100%	100%	50%	33%	33%	75%	0%	0%	0%
	January	February	March	April	May	June	July	August	September	October	November	December
Storm water inflow[L/mth]	120,912	79,817	75,560	74,462	133,506	122,148	116,656	129,053	96,804	101,807	97,962	133,879
Irrigation outtake [L/mth]	0	0	0	90,699	226,749	158,724	149,654	149,654	170,062	0	0	0
Service water inflow[L/mth]	76,810	76,810	79,370	76,810	79,370	76,810	79,370	79,370	76,810	79,370	76,810	79,370
Total litre [L]	144,000	144,000	144,000	144,000	89,217	85,311	80,366	93,918	71,274	144,000	144,000	144,000
Evaporation [L/mth]	1435	4306	10,048	26,556	40,910	44,140	51,317	45,216	26,197	12,560	3947	2153
Lake level	100%	100%	100%	100%	62%	59%	56%	65%	49%	100%	100%	100%

Figure A10. Sites 21 and 22.

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