Public space as water infrastructure strategy in achieving runoff flood resilience on a neighborhood scale

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Abstract. Jakarta is a delta city that stands on an alluvial deposits land with 13 rivers from various parts of the city flowing through the town. It makes Jakarta vulnerable to natural disasters related to water elements, one of which is runoff flooding caused by insufficient river water capacity to accommodate an additional water volume. With the extra unaccommodated water volume, water overflows and cannot be reabsorbed by the land surface to stagnate into areas prone to flooding and disrupt people's activities. Jakarta needs an area resilience against runoff flood disasters, which can be achieved by building infrastructure that is constructed holistically against the city's water elements to accommodate temporary storage of falling rainwater. We used case studies to analyze Jakarta’s existing park and its potential. We also analyzed Benthemplein Water Square, Rotterdam, Netherlands, to see how the city can build neighborhood resilience. We conclude that public space as the solution for Jakarta’s runoff floods is possible as long as its site context is considered during the design phase. Rotterdam shows that even though the green area is not the dominant part, the built environment can help discharge the rainwater to the nearby river as long as it has a good infrastructure design that can accommodate rainwater storage.

1. Introduction
The city of Jakarta stands on the land of alluvial deposits consisting of clay and sand. As a delta city, Jakarta is very vulnerable to natural water disasters. Apart from standing on alluvial deposits, 13 rivers are flowing through Jakarta that originates from various parts of the city, which accommodate water flows from the higher ground located south of Jakarta. Jakarta has difficulties dealing with floods, especially since Jakarta’s spatial layout is still not friendly to the water element. Jakarta’s density with its tall buildings reduces the number of green land as a natural element. Flooding has become an unresolved problem for Jakarta, especially runoff flooding. It is caused by falling rainwater that cannot be accommodated in the river so that it overflows. It is also caused by the water sent from upstream of the river.

Runoff flooding is quite disruptive to the continuity of urban life; therefore, a city should have the resilience to runoff flooding. The concept of resilience first originated from ecology. Resilience is the system's capacity to deal with external changes while maintaining its structure, function, and identity [1]. With resilience, a system can adapt to pressure and reduce its vulnerability along with the developing concept of resilience in ecology, the socio-ecological system used as an integrated human-in-nature perspective [2]. They also related it to the idea of resilience. Socio-ecological frameworks can likewise
be deciphered as an intelligible arrangement of biophysical and social factors that normally connect in a versatile and practical manner; a framework characterized on a few spatial, worldly, and authoritative scales, which might be progressively related; a lot of primary assets (natural, social-economic and cultural) whose stream and use are represented by a blend of ecological and social frameworks; and consistent perplexing and dynamic frameworks with endless variation [3][4][5]. Therefore, city resilience is needed so that the system between humans and ecosystems always runs well.

While planning to achieve an urban water resilience, some aspects that must be considered in a city-scale context, such as the hydrological context of a city, the infrastructure, especially the water infrastructure, and also socio-political and economic context which consists of human, social, political, economic, physical and natural capital of the city [6]. Therefore, resilience to water must consider the relationship between water and vital urban systems. A comprehensive way to deal with resilience is critical to planning interventions that make a more robust system [7]. With a more holistic view of the city water element, existing development will always pivot with water in the city. It can be achieved by building urban water infrastructure, giving space to the urban water element, or moving the city away from the water element. Water infrastructure greatly influences a city's economic value, especially on the environmental, economic, and social aspects of areas near rivers [8]. In its development, water infrastructure must pay attention to cities' impact, especially structures that are mostly underground and human-made construction. One of the city-scale water infrastructures that play an essential role and can be the solution to climate change pressures that hit cities is rainwater management.

Climate change causes higher rainfall and directly impacts rivers, which are a medium for collecting rainwater. Urbanization will trigger city development that results in land use modifications. Two examples of them are removing vegetation and replacing green areas that can absorb water with a waterproof surface. It changes the land surface characteristics, functioning as water absorption into a medium for water runoff [9]. The change in surface hinders the function of land from absorbing and infiltrating water. Therefore, good rainwater management can reduce rainwater overflow from rivers.

Ways to manage rainwater or stormwater are rainwater runoff planning, water system maintenance, regulating rainwater storage and movement, and considering drainage in urban design and home development [10]. The purpose of rainwater management is to protect the natural water cycle by treating natural biological systems in cities and constructing human-made structures, such as ponds, wetlands or wetlands, reservoirs, dams, and others that can prevent rainwater from inundating the city. On a micro-scale, Rainwater management – for example, on a neighborhood scale – can build water resilience on a macro scale.

Socio-ecological factors from the existing context significantly influence water infrastructure development. Water infrastructure combines the city's two elements, namely the built element (technology in water element management) and the natural element (the water element itself). Green Infrastructure is one solution to maintain ecological factors in infrastructure development because it is built to protect or restore the natural hydrology of a site and capture stormwater volumes using the technology that mimics natural hydrological systems [11]. Green Infrastructure can be implemented for various desired outcomes, including flood control, improved surface water quality, and water harvesting, in conjunction with many co-benefits such as ecosystem restoration, improved air quality, and urban heat reduction [12][13][14][15].

An urban water system can be understood as a socio-ecological system (SES). It collects dynamic systems that co-evolve through interactions between actors, institutions, and water systems, such as water sources, groundwater, wastewater, and runoff [16][17]. Rainwater flows and storage volumes in urban water systems, the cities' socio-ecological systems, represent a shared resource. Water quality and available storage volume decrease as runoff flow through the urban environment. These problems lead to the need for public authorities to set various standards related to rainwater management.

2. Method
We conducted a precedent study by analyzing videos about a water plaza workings in Rotterdam, namely the Benthemplein Water Square. Benthemplein Water Square is a public space that functions as
rainwater management by turning social spaces for sports activities into a water storage pool during rainy days to lessen the water system network’s burden in Rotterdam. After that, we looked at Jakarta’s public spaces, namely RPTRA (Ruang Publik Terpadu Ramah Anak) and Taman Maju Bersama, and analyzed their potential in becoming a public space that can offer the solution to runoff floods in Jakarta. We chose Kalijodo RPTRA and three Taman Maju Bersama parks: Taman Piknik, Taman Dukuh, and Taman Papyrus, as our case study due to the similarity in their site context. With four of them are located near the riverbank, we deemed it safe to compare the Kalijodo RPTRA and the other Taman Maju Bersama. The three selected Taman Maju Bersama also have their rainwater management method, which we would also like to compare them to each other.

The study that will be carried out by the author is in the form of a literature study and taking examples that will be discussed further through secondary data. Through literature studies, the authors studied the literature on the presence of water in a city, disasters, and variations of flooding, especially further discussion of flood runoff, then continued with a discussion of resilience theory and application of resilience in a city, water resilience and city strategies in achieving water resilience, and how socio-ecological factors can help achieve resilience to runoff flooding on a neighborhood scale. For the discussion of examples, will take secondary data from the internet for analysis.

3. Results and discussion

3.1. Ruang Publik Terpadu Ramah Anak (RPTRA) Kalijodo, Jakarta, Indonesia

Ruang Publik Terpadu Ramah Anak (RPTRA) is a work program launched by Jakarta Governor Basuki Tjahaya Purnama to provide green open space and friendly and comfortable city public space, especially for children. Although RPTRA development seems to be focused on children, it also functions as an integrated public space, such as playing and learning for children, places for social interaction between the residents, an evacuation zone during a disaster, and a place for economic activities organized by a group of women from the Family Welfare Program (Pemberdayaan Kesejahteraan Keluarga or PKK for short).

RPTRA is an environmental park. It belongs to a small public urban green spaces category and has the same typology as Taman RT and Taman RW. A park can be categorized as a small public urban green space if it has an area of no more than 5000 m², has plants (green space), a separate entrance, and has physical boundaries that separate the park from its surrounding environment[18]. The DKI Jakarta Provincial Government did not provide any design guidelines for environmental parks, but we could find similar conditions in each RPTRA. They all have indoor room programs like multipurpose room, library, lactation room, unisex and accessible toilets for disabled people, pantry, and a warehouse. These indoor programs are located in a maximum of 145 m² building area.

Along with the indoor program, the outdoor program in the RPTRA is a sports court, a kid's playground, a jogging track, a foot reflexology path, an amphitheater, and a family medical herb garden. The area for the outdoor program is 1750 m². For the RPTRA location distributions, we could find one RPTRA for each Rukun Warga (RW) in a densely populated area.

The primary purpose of RPTRA development is to implement a child-friendly Jakarta program. Therefore, each RPTRA’s design has functional elements such as PKK Mart, library area, multipurpose area, lactation room, office, etc. With these functional elements in mind, three functional units are constructed to have generic and lego-inspired plans that are easy to replace so they can meet the mandatory building requirement for RPTRA and can be easily replicated.

An example of an RPTRA is RPTRA Kalijodo, which is integrated into the green open space, which makes its area exceeds other RPTRAs. RPTRA Kalijodo is located east of the Banjir Kanal river and adjacent to the Kalijodo Green Open Space (Ruang Terbuka Hijau) located on the riverbank's riverbank. The adjacent green space helps expand the green space in the RPTRA. The following is the zone division in RPTRA and RTH Kalijodo. In addition to the RTH and RPTRA zones, there is also a mosque zone, a designated eviction area, and a culinary area. They serve as one of Kalijodo tourist destinations. By having the RPTRA and the green open space in the flood canal's riverbank, the park has its potential to
solve the runoff flood problem on the neighborhood scale. Even though the green area is not the dominant part of the area, it can still absorb the excess rainwater volume.

![Figure 1. Zoning in the Kalijodo area and the grey infrastructures. Source: constructionplusasia.com/id/rth-dan-rptra-kalijodo/ (with processing)](image1)

Kalijodo green open space and RPTRA have facilities like a skatepark, kids playground, sports court, foot reflexology path. Those are "grey" infrastructures that use zero runoff materials to absorb the excess volume of rainwater. Even with the plentiful green space, we feel like there should be a comprehensive study about the zero runoff material and ways to store rainwater temporarily as an effort to manage the stormwater. We believe it can lead to runoff flood resilience in a neighborhood.

3.2. Taman Maju Bersama, Jakarta, Indonesia

Taman Maju Bersama is a work program from the DKI Jakarta Provincial Government during Governor Anies Baswedan. In addition to utilizing abandoned land as a public space, the park can also function as a green land that can become a temporary storage area for rainwater, especially during the rainy season. It is one of the efforts of the DKI Jakarta Provincial Government in preventing and reducing the potential for flooding that can inundate the surrounding environment. In the park, the government provides playing and sports facilities for the surrounding community and provides retention ponds, artificial lakes, or even vacant land that can temporarily accommodate rainwater and create a pool around the park.

![Figure 2. A view of Taman Maju Bersama and the surrounding context. Source: maps.google.com with processing](image2)

Taman Maju Bersama has a different approach in each park for rainwater management. It is adjusted to the context and size of the available land. DKI Jakarta Provincial Government built a retention pond and bioswale to carry out its primary function as a water absorber. In this paper, we analyzed three parks located near the river, as depicted in Figure 2. Two of them have retention pools to collect rainwater
temporarily and reduce the potential for flooding in the area. These parks are Taman Piknik in Kalimalang and Taman Dukuh in Kramat Jati. The two parks are located on the water flow banks to have an additional function as a separator between the water flow and the residential areas. The park's location, which is on the edge of the water flow, offers a chance to reduce water overflows and flood the residential area.

Taman Piknik has two different retention pool, as depicted in Figure 3. In the first retention pond, the pond was planted with lotus plants on its surface as an aesthetic function and clean pollutants in the water. The second retention pool is placed in the middle of the garden to help create a different space atmosphere and become exciting spots for taking photos. Located in the middle and far enough from the reach of Kali Buran, it was finally circumvented by making access between Kali Buran and the retention pool by adding a water flow that runs from the middle of the park to the river so that it can connect them. Kali Buran and the second retention pool has limited connectivity due to a wall that functions as an embankment. The embankment is the water entrance (inlet) for the excess flow of Kali Buran to temporarily accommodated the second retention pool. If there is excess in retention pond 2, the water will be infiltrated by the soil to benefit the surrounding plants.

Unlike Taman Piknik, Taman Dukuh has only one retention pond that is not always filled with water. The pool is in the middle of the garden and connected to the tribune area. By connecting the tribune area with the retention pond, the tribune area can be used as an additional water reservoir. The tribune area is higher than the retention pond, and the ground level of the lower stand is parallel to the retention pond’s height. It is also bounded by a wall slightly higher than the retention pond’s height, as depicted in Figure 4.
Apart from retention ponds, the bioswale technique is used in Taman Maju Bersama Papyrus, Kebagusan. The park has a basketball court, children's play area, and a path surrounding a green area with a concave surface. The vast green land resembles a broad valley and serves as a temporary rainwater reservoir in the area. Taman Maju Bersama Papyrus uses natural green land as a picnic area during the dry season and transforms into a natural pool that holds rainwater during the rainy season. The difference in these functions can be seen from Figure 5, a compilation of the photos taken during the dry season, rainy season, and extreme rain that caused Jakarta's flood in early 2020. In the use of bioswale, water collected by green land will be fully absorbed by the soil. This process is known as the infiltration process.

Significant differences are found when RPTRA and the Taman Maju Bersama park are juxtaposed. The primary function of the construction of the park causes some differences in design elements. Considering its function as an integrated social space between children and PKK mothers, RPTRA park focuses more on building indoor spaces for functional purposes. Each RPTRA also has the same facilities that have a generic design. Unlike the RPTRA, Taman Maju Bersama (TMB) has a smaller building area and prioritizes the presence of green land that dominates the park's site. In addition to that, each Taman Maju Bersama has different facilities depending on the surrounding community’s needs. It happened due to a participatory and collaborative concept with the surrounding community during its development process. Taman Maju Bersama also aims to mitigate runoff flooding so that retention ponds and bioswales are built to accommodate rainwater temporarily. We believe it serves as an extra value for Taman Maju Bersama compared to RPTRA since it is based on its surrounding area's needs and context. It also has the potential to reduce runoff flooding on a neighborhood scale. The existence of references and guidelines in the design of the RPTRA can limit the potential of the RPTRA as a public space that prevents runoff flooding on a neighborhood scale.
Figure 5. The difference in the condition of Papyrus Park during the dry and rainy seasons.
Source: instagram.com/aniesbaswedan

Seeing that the existing parks have yet managed to be a place for social interaction and offer a solution in overcoming runoff, we then looked for other references as a role model for parks in Jakarta. We found Bentemplein Water Square in Rotterdam might be the perfect example for precedent study.

3.3. Bentemplein Water Square, Rotterdam, Netherlands
Bentemplein Water Square is the first public space globally that successfully combines public space and a temporary rainwater storage area in one place. This water plaza employs a dual strategy, namely a strategy to invest the money into a water storage facility that looks and feels “fun” while generating opportunities to maintain the environmental quality and create an identity of the central space in a neighborhood. Bentemplein Water Square is located in a complex of buildings near Central Station.

The density of buildings and the lack of green open space makes the region lack land for water storage. Rotterdam City Government then looked for a solution to create a place for water storage without using traditional methods like building a new canal. The Bentemplein Water Square accommodates rainwater temporarily and lessens the work of the city's sewage system. It prevents the town from being flooded and avoids high costs in improving the city's sewer quality in the future.

The water plaza, designed by De Urbanisten and completed in 2013, is a Rotterdam government project. In the design process, the local community as users of the plaza were invited to develop an idea of the plaza they needed. They involved the students and the teachers from the colleges nearby, church members, David Lloyd's youth theater, fitness center, and the neighborhood residents. The brainstorming was divided into three workshop sessions, which discussed the plaza's possible uses, the desired atmosphere, and how rainwater can affect the plaza. As a result, all agreed that the water plaza should be a dynamic place for young people, have plentiful space to play and linger, and provide a green land.

Bentemplein Water Square area has areas that can turn into temporary storage pools for rainwater, in which the distribution can be depicted in Figure 6. Each pool has a different size and function. The difference in size is due to the water's starting point before it is collected, such as buildings and the surrounding environment. The pools accommodate public activities such as communal gathering, skateboarding, basketball sports, and a stage that can be used for church events, school events, or just for a small performance stage. Each pond has a different origin of water flow, thus creating two water flow systems into the pond.
Figure 6. Distribution of temporary water reservoirs along with activities that can be carried out when the pool is not holding water. Source: urbanisten.nl/wp/?portfolio=waterplein-benthemplein with processing.

The rainwater drainage system to the first pond is a rain well system. It is a rainwater drainage system for ponds 1 and 2 that holds rainwater around the building complex. Rainwater, which will be temporarily stored in the pond, will be channeled through a shallow stainless steel gutter planted on the plaza's surface. The gutter is curved to cover water from various areas of the plaza. Each pond's gutters do not intersect so that the rainwater is divided relatively according to the pool coverage.

Figure 7. The flow of rainwater to pond 1 (right) and pond 2 (left). Source: Water plaza Benthemplein Rotterdam video on Rotterdam Climate Initiative RCI YouTube channel, with processing.

Figure 7 above shows how pool 1 accommodates rainwater that falls from the buildings' roof and the car park area and how pool 2 collects rainwater from the road around the building and church complex. We believe Jakarta can adopt and integrate the Benthemplein Water Square concept into the existing RPTRA. Even though the green area is not the dominant part of the park, the skate park and jogging track use non zero runoff materials that can help discharge the rainwater from its surrounding buildings to the nearby river.

The water collected in the two pools will eventually be divided into different places. The water collected in the first pool will flow to the sewage system network on Schiekade Street, which is the closest sewage system to pool 1. Meanwhile, rainwater collected in the second pool will flow to the sewage system network on Simonstraat Street. Besides being channeled into other sewerage system networks, some water will be absorbed to the ground surface using the permeable materials covering the pond surface.

Meanwhile, the second rainwater drainage system is the Water Wall system applied to the third pool. The Water Wall system can temporarily store rainwater that comes out through the pool wall. The third pool is the deepest of the three pools in the plaza. It has the function of collecting temporary rainwater if it has rained for days because the rainwater collected in the third pool comes from the surrounding...
environment and the outside the building complex. The water distribution process can be depicted in Figure 8.

![Figure 8. Illustration of draining rainwater to ponds 3. Source: Water plaza Bentemplein Rotterdam video on Rotterdam Climate Initiative RCI YouTube channel, with processing](image)

Before being discharged into the third pool, rainwater from the surrounding environment is collected in a water storage pool located below the ground level. The wall that separates the underground water reservoir from Pool 3 has several gaps to direct the water to flow out from the underground reservoir to the third pool. The water will fill pool three and only hold the water for about 36 hours due to health reasons. Draining the water involves directing the water to flow back through the drainage at the pool's bottom. The drainage will drain water from pool three back to the Noordsingel canal, the closest open water system to the building complex.

The water system used in the Bentemplein Water Squares to distribute temporarily stored water is separated from the city water system. Therefore, the city water system is not disturbed and burdened by the temporary distribution of water square's rainwater. It is an exciting point and can serve as an example for the whole of Jakarta's water system.

4. Conclusion
From the literature studies, direct observation, and in-depth interview conducted, we conclude that public space as the solution for Jakarta’s runoff floods is possible as long as its site context is considered during the design phase. The existing facilities used "grey" or non-zero runoff materials, which reduce the green area used as runoff water absorption areas. It is miserable since the existence of a dominant green land in public space can build neighborhood resilience against runoff floods. We see the need for a more thorough study in applying zero runoff to make the entire park an entirely zero runoff area. Besides that, public space that implements the water infrastructure strategy has to be used appropriately by its user while also accommodating both the social and ecological aspects of a place. The continuity between those two can help a place achieve water-related resilience, one of which is the resilience of runoff floods. It can be achieved with a good infrastructure design that can accommodate rainwater storage.

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