Climate Change on Water Sensitive Urban Design Technologies

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Water Sensitive Urban Design (WSUD) technologies are green infrastructures those aim to restore the hydrological balance of urban catchments.

Keywords: water sensitive urban design ; climate change ; soak-away

1. Introduction

Future climate projections indicate that there will be an increase in the frequency of extreme weather events, causing drought and flooding conditions [1]. Meanwhile, rapid urbanization further aggravates this scenario by increasing the impervious surface in urban areas [2]. Water Sensitive Urban Design (WSUD) approaches could provide a sustainable solution to assist in urban stormwater management and ease the burden of conventional drainage systems [3]. There are several types of WSUD technologies available, and the common trait among them is the principle of restoring the natural balance as far as practicable in urban scenarios [4].

According to Ahammed [3], one of the most popular infiltration-based WSUD devices in Australia is the soak-away, an underground system. This structure can contain stormwater runoff, reduce peak surface runoff and assist in the flood management of urban catchments [5]. Those benefits can have a fundamental role in building climate change resilience in populated areas [6]. To evaluate climate risks, the utilization of models can be a useful tool to assess the reliability of systems considering different future scenarios [7].

Research Background and Problem Statement

The Intergovernmental Panel on Climate Change (IPCC) has recently released its Sixth Assessment Report called ‘AR6’, predicting a global average warming of 1.5 °C or higher levels that will affect rainfall patterns and intensify precipitation events and associated flooding [8]. Australia is already experiencing worsening weather events because of climate change, causing environmental disasters, risking the wellbeing of the population and challenging the agriculture sector [9]. The WSUD practices have shown great potential to solve some of those problems by decentralizing the water management systems and improving a series of aspects related to water [10].

In fact, WSUD technologies may provide additional climate change resilience in terms of increasing water demands and a greater need for soil moisture retention within urban areas, which points to a necessity for further evaluation of WSUD assets in view of climate change impacts [11]. It is known that climate conditions and catchment characteristics influence the hydrologic design and, ultimately, the overall pollutant removal effectiveness of water management devices [12]. However, to the authors’ knowledge, very few studies have investigated the impact of climate change on WSUD systems. Ahammed et al. [3] investigated a case of stormwater management with climate change impacts for Dhaka City and demonstrated how leaky well-based WSUDs could transform Dhaka’s unsatisfactory drainage network into one that is sustainable.

2. Climate Change Impacts in South Australia

According to IPCC [8], countries including Australia have been experiencing more frequent and heavy rainfall events since the 1950s. The Bureau of Meteorology (BoM) [13] confirms that information by stating that rainfall intensities have indeed increased in Australia, especially short-term extreme rain events, particularly in South Australia. Although heavy rains are expected to become stronger, the region is experiencing drier weather conditions, higher evapotranspiration and increases in rainfall intensity, a pattern that is likely to continue in the future [11][14].

South Australia is already witnessing more intense summer storms (flood events) and winter rainfall declines [15][16]. On top of that, bushfire risks have risen in the region and longer fire seasons are expected due to dryness, annual temperature increases and extremely hot days (>40 °C) [14]. This scenario is causing severe economic losses, mostly for the agricultural industries, and harming the well-being of the population [17]. Therefore, climate change has become an important consideration for the country's economies and sustainable development, especially considering long-term water resources management.

3. Future Climate Change Projections

Overall, climate change is expected to have an adverse effect on rainfall intensities for many locations in Australia. The Australian Rainfall and Runoff (ARR) is a part of the National Climate Change Adaptation Framework, which is being recognized as an important planning initiative to promote the safety and well-functioning of new and existing infrastructure [18]. Future climate tendencies are intrinsically dependent on human behaviours and, therefore, subject to a lot of uncertainties [19].

The RCP scenarios are used in global climate models (GCMs) and can range from the lowest carbon emission scenario (RCP 2.6) to the highest concentration pathway (RCP 8.5) [20]. It is worth mentioning that although RCP 8.5 is considered an 'extreme' scenario, research is labelling it as the most 'normal' or realistic future scenario [19].

4. WSUD Infiltration Systems

In the Australian context, three WSUD infiltration systems are frequently used: leaky wells, infiltration trenches and soak-aways [3]. Those systems can alleviate the quantity of water being directed to the conventional drainage systems by collecting stormwater runoff, storing it and slowly releasing it into the soil, not only assisting in flood management and soil irrigation but also in the removal of pollutants from the water [10][21]. Ahammed et al. [21] investigated the techno-economic analysis of WSUD technologies with conventional drainage systems for a medium catchment of South Australia and observed that the systems are techno-economically feasible. Despite its benefits, there are some constraints to infiltration systems: the structure must be placed in soils with high permeability and with a relatively low water table [3][22].

Furthermore, infiltration might also require the implementation of a pre-treatment, such as a gross pollutant trap (GPT), to remove larger solids of the stormwater runoff before it enters the infiltration system. Those systems are also known as 'sediment traps' or 'litter traps', and they will reduce the risks of clogging the infiltration device [12].

5. Soak-Away Device

The soak-away is an infiltration 'tank' system placed underground, which can offer great advantages by not sacrificing areas that could be destined for other purposes. These infiltration systems can be placed in highly populated areas, reducing local runoff volume and mitigating flood events [5]. The structure of the soak-away can be enveloped within a permeable geotextile to allow the gradual release of water collected from the roof and other sources to the surrounding soil [23]. To attend to a larger catchment area, the soak-away structures can be combined to increase their capability to store a bigger volume of stormwater runoff [23].

The soak-away size will depend on some factors such as the soil type of the region as well as the amount of predicted stormwater volume to be received and stored by the system [24]. As mentioned before, an important cause of failure of the soak-away is clogging, which happens when solids accumulate in between void spaces of the structure, leading it to easily overflow [25]. Another concern is the stability of nearby foundations as soak-aways tend to increase the water content in the soil, which might be dangerous in expansive soils [22]. As an example of soak-away implementation, the City of Burnside Council has recently started a project regarding the installation of infiltration systems for capturing stormwater and delivering it to young tree surroundings. Those systems were called 'B-pods', which also contributed to reducing the velocity and amount of stormwater volumes flowing to urban watercourses [26]. With the impermeabilization of the surface, projects like 'B-pods' can make a great difference, especially during drought periods or extreme weather events due to climate change impacts.

6. Knowledge Gap

Currently, very little academic research focuses on the design resilience of infiltration-based WSUD technologies to climate change, such as Zhang et al. [27] who investigated a constructed wetland and a biofilter system and Tirpak et al.

[28] who evaluated bioretention cells. There is limited information regarding the performance of soak-away in the long term, considering climate change impacts on rainfall patterns.

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