A 3D Spatial Model to integrate Stormwater Drainage Design into Public Space

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Abstract

This paper explores the integration of water sensitive urban design within public space planning using integrated 3D digital technologies. In traditional design processes, drainage and public space design often utilise distinct software and are led by different professionals, which creates significant communication barriers.Although civil and hydraulic engineers have made significant strides in integrating hydrology analysis with multi-objective space design, the collaboration of conventional 2D hydrology with 3D landscape design still presents challenges. To address these challenges, this study proposes a novel approach that integrates drainage analysis and design within a 3D design model. This methodology is specifically designed to aid landscape and urban designers in incorporating stormwater management and drainage systems early in the design process. The approach involves three key steps: (1) identifying critical factors that impact, or are impacted by, drainage design; (2) translating these factors into specific spatial parameters; and (3) developing a workflow to integrate these parameters. This integration not only streamlines the design process, making it more cohesive and efficient but also mitigates potential conflicts between drainage requirements and spatial design, thereby reducing unnecessary revisions. Ultimately, this approach enhances the incorporation of essential drainage considerations into urban and landscape planning, leading to more sustainable and functional public spaces.

1. Introduction

In urban environments, effective stormwater management is crucial not only for the functionality of infrastructure but also for enhancing the quality of life and sustainability of communities (Hawken et al., 2021). Urban and landscape designers have extensively researched and implemented integrated stormwater management within multifunctional space design to support sustainable urban development. However, traditional stormwater management, which operates with vast datasets and is inherently complex, poses significant challenges. Therefore, designers are striving to simplify stormwater management practices to seamlessly integrate with traditional landscape design.

Traditional approaches to stormwater management typically separate the processes for drainage and landscape design, often resulting in conflicting design outcomes and an inefficient design process (Brown, 2005, Jia et al., 2020). For instance, the planned location of a drainage channel might overlap with essential site features such as plantings or buildings. This misalignment often necessitates additional revisions, increasing the time and cost of design projects and missing opportunities to create multifunctional public spaces that enhance ecological resilience. By integrating drainage design into the landscape design process through 3D modeling from the outset, it is possible to enhance design efficiency and support multi-objective design initiatives. Such integration not only streamlines communication among professionals but also ensures that drainage solutions are considered alongside aesthetic and functional aspects of landscape design, thereby optimising the overall effectiveness of urban space development.

To integrate stormwater management within landscape design at an early stage, researchers and designers are developing spatial data analysis methods tailored for stormwater management design. For instance, Chen et al. (2016) developed a stormwater analysis tool named Rainwater+ to simulate runoff and determine the optimal location of Water Sensitive Urban Development (WSUD) facilities using a spatial model (Chen et al., 2016). Similarly, Jia et al. (2022) explored a parametric method to simulate and quantify runoff within a 3D model, aiding stormwater management at the early stages of landscape design (Jia et al., 2022). This research demonstrates the feasibility of applying spatial analysis and 3D modeling to support stormwater management throughout the landscape design process.

However, to further enhance the integration of stormwater management within landscape design, it is crucial to recognise stormwater management as a network system (Hoang and Fenner, 2016, Piro et al., 2019, Valizadeh et al., 2019). Current research focusing on stormwater facility design does not adequately support integrating the entire network system within multifunctional landscape design. Stormwater drainage, a vital part of the stormwater management network, effectively collects and directs stormwater to specific facilities or out of the area. Considering the limited relevant research, this paper intends to explore a novel approach to integrate 3D drainage design into the early stages of landscape planning, aiming to bridge the gap between functional engineering and creative landscape solutions. It includes the following steps:

- (1) Discuss mutual influence between landscape spatial factors and drainage design to extract relevant spatial factors;
- (2) Create design criteria for further spatial analysis and design decision;
- (3) Develop design workflow to integrate drainage design within 3D spatial analysis and design.

1.1 Literature Review

As discussed above, this paper focuses on simplifying hydrology analysis for channel drainage design and integrating it with landscape design using 3D modeling. In this section, we review the existing hydrology models, drainage calculations, and the evolution of 3D modeling in landscape design.

1.1.1 Existing Hydrology Model Current models for analysing stormwater drainage, such as the Storm Water Management Model (SWMM) and the Model for Urban Stormwater Improvement Conceptualisation (MUSIC), have significantly advanced our ability to manage urban stormwater (Taji and Regulwar, 2021, Dotto et al., 2011). These models typically represent the drainage system using sets of 2D linear segments, prioritizing efficiency in water removal. However, contemporary concepts like Sponge City and Water Sensitive Urban Design propose multiple needs and targets for stormwater management. They require new design methods or models not only to manage stormwater effectively but also to harmonise with other urban space facilities.

The limitations of these 2D models include their inability to accurately represent complex topographies and the interaction of water flow with various landscape features. For example, SWMM outputs drainage designs as linear maps, which do not adequately reflect the width and depth of drainage channels. This lack of detail can obscure potential conflicts between the drainage system and its surrounding environment. For instance, in open spaces with limited area, the area must also be distributed among different landscape infrastructures for various uses. although wider drainage channels may facilitate faster runoff into stormwater facilities, they could also limit the space available for other uses or lead to damage from plant roots. As a result, designers cannot determine if drainage channels and landscape infrastructure overlap based on the linear maps generated by SWMM alone. Consequently, it becomes challenging to visually identify spatial conflicts between drainage channels and other landscape infrastructures, limiting the ability to effectively integrate drainage systems within urban landscapes. These potential conflicts might result in avoidable design revisions during the detailed design or construction phases.

1.1.2 Drainage Calculation Although hydrological models for drainage design have significantly advanced over the decades, the foundational principles for calculating drainage capacity and size have remained largely unchanged, predominantly relying on the Manning Equation (Basnet and Neupane, 2018, Zheng et al., 2018, Abdullah et al., 2023). This equation is extensively utilised to calculate flow parameters in gravity-flow systems, underpinning many traditional hydrological applications (García Díaz, 2005). Compared to the Hazen-Williams or Darcy-Weisbach equations, the Manning Equation is simpler, requiring fewer parameter inputs (Christensen et al., 2000, Jamil, 2019). It calculates the flow rate as a function of hydraulic radius, slope, and a roughness coefficient, as shown below (García Díaz, 2005):

As the roughness coefficient n in the Manning Equation is adjustable based on a wide range of conditions and materials, this flexibility allows it to be adapted to various situations with reasonable accuracy. Moreover, the Manning Equation is applicable to a broad array of hydraulic systems beyond open channel flow, demonstrating its extensive versatility (Delleur, 2006, Mays, 2010). It can be effectively used for designing and analysing flow in channels, swales, pipes, and other components of storm drainage systems (Barr et al., 1986). Consequently, many hydrological methods, including the Storm Water Management Model (SWMM) and MIKE URBAN, adopt Manning Equation for drainage system design (Rossman et al., 2010, Bisht et al., 2016).

Clearly, the Manning Equation is flexible enough to fit different environmental drainage designs and has been validated through years of operation. Due to its simplicity and versatility, it is easy for us to adopt in further 3D spatial drainage analysis and design.

$$Q = \frac{1}{n} A \sqrt{R^3 S} \tag{1}$$

where:

$Q =$ flow rate (m^3/s),
$n =$ Manning's roughness coefficient,
$A =$ cross-sectional area of flow (m^2),
$R =$ hydraulic radius (m),
$S =$ slope of the energy grade line (m/m).

1.1.3 Evolution of 3D Modeling in Landscape Design The advent of 3D modeling technology has profoundly impacted various fields, including urban design. This innovative approach offers a comprehensive view of urban landscapes, going beyond the capabilities of traditional 2D models. 3D modeling facilitates detailed representations of spatial relationships and topographical elements, crucial for effective urban planning and management (Ying et al., 2020, Diakité and Zlatanova, 2018, Wang et al., 2021, Wang et al., 2020). By integrating the depth of channels, site topography, and other critical spatial features, this technology enables urban designers to simulate complex environmental interactions and envision how drainage systems can coexist harmoniously with other infrastructural elements.

The benefits of 3D modeling are extensive and include enhanced accuracy in simulating water flow, improved integration of drainage systems with structural and landscape features, and the ability to test the impact of various design solutions in a virtual environment. These capabilities not only support detailed planning but also foster innovative approaches to urban design that effectively blend functionality with aesthetic appeal (Yan et al., 2019, Du and Zlatanova, 2006).

Despite these significant advancements, the application of 3D modeling in stormwater management still faces critical limitations. Current models often focus predominantly on surface runoff and stormwater treatment facilities, neglecting a comprehensive analysis of entire drainage systems. For instance, Jia et al. (2022) proposed a new method to visualise and quantify runoff on site; however, their study overlooked the integration of the drainage system (Jia et al., 2022). Similarly, research by Edelman et al. (2023) and Chen et al. (2016) emphasised the effectiveness of rain gardens and water tanks etc. stormwater treatment facilities in managing runoff volumes and mitigating pollution but fell short in addressing the holistic design of drainage systems and their impact on urban surroundings (Edelman et al., 2023, Chen et al., 2016). This gap highlights a crucial need within urban design: the development of more sophisticated 3D modeling tools that not only enhance stormwater treatment designs but also provide comprehensive insights into the performance and impact of drainage systems.

2. Design Method

This paper focuses on the development of spatial parameters and an analysis workflow for stormwater drainage evaluation. It operates under the assumption that data on site sub-catchments and the required volume of stormwater for treatment are pre-established. Therefore, we did not include the runoff coefficient in the analysis but used the design flow rate (Q_d) to support channel design with the Manning Equation. The paper concentrates on defining relevant spatial factors rather than calculating the total volume of stormwater. The discussion prioritises the conveyance features of drainage systems, specifically addressing runoff volume while omitting pollution treatment aspects.

There are diverse spatial factors on-site that impact the design of drainage systems. Given that this research is in its initial stages, we have identified only the critical factors affecting drainage design, such as regular spatial factors in open spaces represented by plants and buildings. Additionally, we have tested the proposed workflow exclusively with straight channels, including grass swales, concrete channels, and concrete spoon drains.

The entire analysis used a 3D model based on the Rhino and Grasshopper platform. We adopted Rhino version 7.1.2 and Grasshopper Build 1.0.0007, released on December 8, 2020. To facilitate diverse spatial analysis, we also utilised IronPython 2.7, which is embedded in Grasshopper.

2.1 Relevant Spatial Factors

We have selected several spatial factors based on two criteria: the effectiveness of the drainage system in directing stormwater and the potential for spatial conflicts between the drainage system and existing landscape infrastructure. We have identified several key spatial parameters derived from common elements of public spaces. These include site slope (terrain), site shape, and the locations of trees and buildings. These parameters reflect the limitations imposed by existing natural and built elements on-site.

2.1.1 Site slope and pavement material: Normally, to minimise earthwork and enhance drainage efficiency, straight channels should be aligned with the natural slope and consistently maintain the same direction to efficiently convey stormwater to the low point (Heede, 1980, Ferguson, 1998). However, the site’s topography isn’t always conducive. Given that the longitudinal slope of stormwater swales typically ranges from 1% to 4% (García-Serrana et al., 2017), the topography can be categorised into three types based on the slope range: slopes less than 1% are considered too flat for proper drainage; slopes ranging from 1% to 4% are deemed suitable; slopes over 4% are considered too large.

To test the influence of site slope on drainage design, we set three site conditions to simulate stormwater drainage. In order to drain out the stormwater onsite, the slope of the channel is set as 1%.

- Site 1 - flat site : At Site 1, characterised by its flat terrain, effective stormwater drainage requires a channel with a designed slope. We set a channel with a slope of 1% to facilitate stormwater flow. In this way, stormwater can be conveyed downwards effectively. However, the intentional slope on a flat site would cause the channel to deepen over distance. Considering practicality, a depth of over 5 meters for a channel brought by a 500-meter-long flat site may pose challenges.

- Site 2 - Site with Moderate Slope (1%): As Site 2 features a moderate slope of 1%, the channel design only needs to align with this natural slope without requiring additional slope. Consequently, the channel depth remains consistent on a site with a moderate slope.

- Site 3 - Site with large slope (over 4%): Site 3 represents sites with slopes larger than 4%. Due to the large slope, stormwater easily flows downward, often carrying sediment along with it. To prevent stormwater from carrying too much sediment and causing erosion, the stormwater drainage strategy should be adjusted. For example, in Site 3, channels are designed perpendicular to the site slope to help minimise sediment and mitigate the risk of soil erosion.

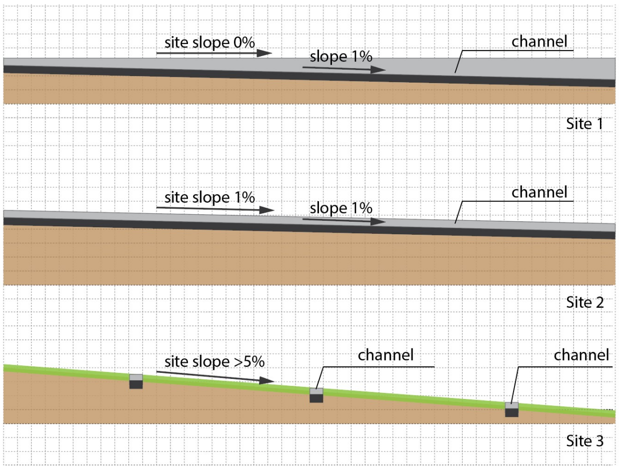


Figure 1. Influence of site slope on channel design

The above discussion shows that the slope of the site impacts both the depth of the channel and the arrangement direction of the channel. At the same time, the roughness degree of the pavement also affects channel design by influencing the flow speed. We introduced Manning’s roughness coefficient to indicate the differences between concrete channels and planted swales. Specifically, a higher roughness coefficient for planted swales indicates slower water flow compared to smoother concrete channels.

Additionally, the interaction between these factors highlights the need for a comprehensive approach to channel design that considers both hydraulic efficiency and environmental integration. The slope of the site dictates the gradient required for effective drainage, while the surface roughness influences the velocity and turbulence of the water flow. By utilising Manning’s roughness coefficient, we can more accurately model and predict the behavior of different channel types under various conditions. Future studies should also explore the long-term sustainability of different channel materials and designs. For instance, while concrete channels may offer immediate hydraulic efficiency, planted swales provide ecological benefits such as improved water quality, habitat creation, and enhanced aesthetic value. Integrating these aspects into the design process ensures that stormwater management systems contribute positively to urban environments.

2.1.2 Elevation of Outfall: The elevation of an outfall is a critical factor in the design of effective drainage systems. On-site drainage systems primarily rely on gravity to channel collected stormwater to treatment facilities or municipal stormwater systems. Therefore, the elevation of the outfall must be lower than the endpoint of the drainage system. If this is not the case, additional measures, such as pumping, may be required to lift stormwater to the outfall, incurring extra costs and complexity.

Consequently, it is essential to consider the elevation of the outfall in conjunction with the site surface elevation. This assessment will determine whether the designed channel depth and slope are sufficient to successfully direct stormwater into the treatment facility or municipal stormwater system via the outfall.

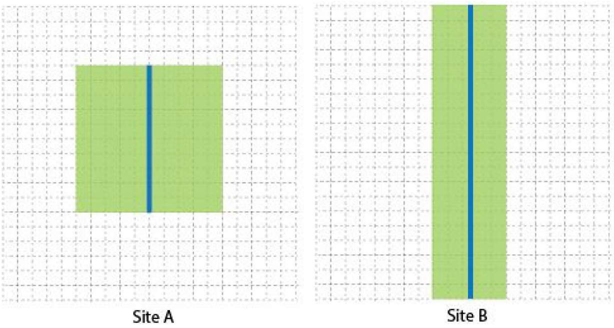
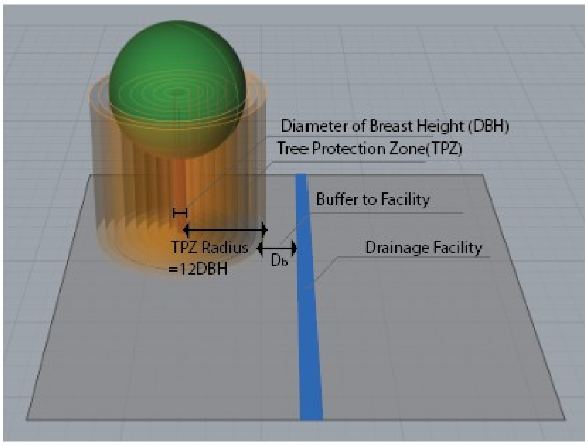


Figure 2. Influence of site shape on channel design

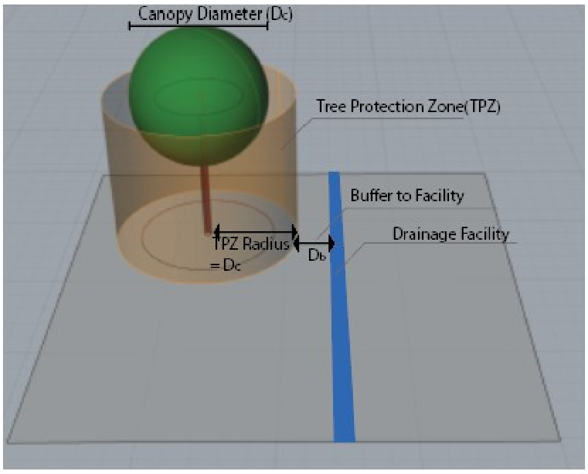
2.1.3 Site shape: The shape of a site also can significantly affect the design of its drainage system, particularly through the site’s length and width. For example, as illustrated in Figure 2, Sites A and B have identical sizes and topographical conditions, but Site A is square, and Site B is rectangular. Given that Site B has a greater length than Site A, the drainage length in Site B would be longer than in Site A if both of them intend to connect drainage outlets are located at the lowest points at the bottom edge.

2.1.4 Tree Protection Zone: Trees play a crucial role in open space design and significantly influence channel design. To protect tree root systems, governments and arborists establish Tree Protection Zones (TPZ), which dictate the minimum distance that construction activities must maintain from trees (Lauder, 2022, Moore, 2018). Consequently, to ensure that tree roots have adequate space to grow without being damaged by channel construction or stormwater flow, channels are strategically placed to maintain a certain distance (radius of TPZ from the tree) as shown in Figure 3.

Various methods are used to estimate the scope of TPZ based on tree characteristics. In Australia, the Australian Standard AS 4970-2009 dictates that the TPZ radius should be calculated using the diameter of the tree at breast height (DBH). Specifically, the radius of the TPZ is commonly determined by multiplying the DBH (Moore, 2018, Hassanin, 2021).



A. Tree Protection Zone (TPZ) Calculation based on Diameter of Breast Height (DBH)



B. Tree Protection Zone (TPZ) Calculation based on Canopy Diameter (D_c)

Figure 3. Influence of tree location and size on channel design

The International Society of Arboriculture (ISA) publishes Best Management Practices (BMPs) for managing trees during construction, which advises using the 1 foot per inch rule, though these documents typically emphasize a more comprehensive approach based on specific site assessments (Pike et al., 2021). In contrast, the American National Standards Institute (ANSI) A300 standards recommend protecting tree root systems during construction but do not specify the 1 foot per inch rule. These standards are developed by the Tree Care Industry Association (TCIA) in conjunction with the ISA (Bown, 2024, Pike et al., 2021). Therefore, when calculating the TPZ, it is advisable to select the most suitable method based on local guidelines or available data.

2.1.5 Building foundation zone This Building Foundation Protection Zone (BFPZ) is critical in urban planning, particularly in areas subject to heavy construction or extensive landscaping. This zone should be free from any significant load-bearing activities to maintain the structural integrity of the foundation. The extent of this zone typically correlates with the depth and width of the foundation itself. A widely accepted guideline is to extend the protection zone at least as far out as the depth of the foundation(Fang, 2013, Ching, 2020). For example, if the foundation is 1 meter deep, the protection zone should also extend 1 meter from the outer edges of the foundation (Fang, 2013).

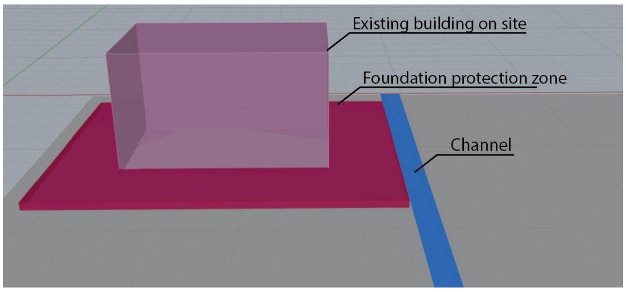


Figure 4. Influence of existing building on channel design

Similar to the way tree roots require space to grow and thrive, building foundations need a buffer zone to ensure the stability and integrity of buildings. The presence of existing buildings can significantly influence the layout of these channels, demonstrating the interconnected nature of urban design elements.The spatial factors affecting channel design include depth, length, and location, influenced by the predetermined volume of stormwater. Although this discussion does not delve into how the size of the site impacts the width and cross-section of the channel, it is important to recognise that these spatial factors should be considered collectively within an integrated framework to achieve effective design solutions.

It is worth noting that this paper aims to clearly demonstrate the proposed workflow for drainage channel design in a straightforward manner, ensuring there are no spatial conflicts with other facilities. Consequently, some spatial factors are not included in the analysis. For example, in the discussion, we only considered the Tree Protection Zone (TPZ) to avoid conflicts between channel construction and existing trees. The benefits of vegetation and living soils from the water flow will be addressed in further discussions.

Further considerations should include more spatial factors to comprehensively reflect the interaction between stormwater management and the surrounding environment in a sustainable way. Therefore, the drainage design framework should remain flexible and adaptable, accommodating various spatial factors specific to each project. This approach ensures that urban design remains both functional and aesthetically pleasing, enhancing the quality of life for city residents.

2.2 Workflow

In line with the trend of sustainable urban development, preserving existing plants on-site is highly valued and should be prioritized wherever possible. Similarly, existing buildings should generally be retained to avoid unnecessary expenses associated with rebuilding. Therefore, the drainage design must identify suitable areas to prevent conflicts with existing plants and buildings, ensuring a harmonious integration of new infrastructure with the current environment.

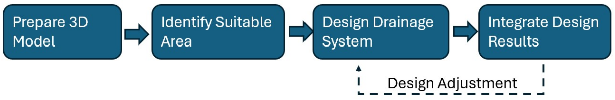


Figure 5. Workflow Diagram

Therefore the whole workflow will be designed into four steps:

(1): Prepare 3D model: Integrate spatial factors into the 3D model to encompass existing trees, buildings, and other essential facilities that need to be preserved. Additionally, to effectively visualise the channel design in 3D model, it is crucial to incorporate both the topography and the elevation of the outfall.

(2) Identify Suitable Area for Drainage System: Based on the principle of preserving all existing trees and facilities, this model delineates areas suitable for the drainage system that avoid conflicts with them. To protect existing plants and buildings, the identified areas should maintain a buffer zone around tree protection areas (TPZ) and building foundation protection zones (BFPZ). The detailed criteria for these considerations are as follows:

- Tree Protection Zones (TPZ): If TPZ is calculated based on Diameter at Breast Height (DBH), the TPZ radius should be 12 times the DBH. If TPZ is calculated based on canopy diameter (D_c), the TPZ radius should be 1 foot per inch of D_c. Follow local guidance if it provides different thresholds.

- Building Foundation Protection Zones (BFPZ): If BFPZ is calculated based on the size of the building foundation, the width of the BFPZ should be at least the same as the depth of the building foundation. Adhere to local guidance if there are specific requirements for BFPZ.

- Channel Placement Among Trees: If there are several existing trees randomly distributed rather than in a line, and considering the efficiency of a straight channel, the boundary of the suitable area should be defined by the tree closest to the proposed channel.

(3): Design Drainage System: To avoid unnecessary repeated design work, we specify not only the slope and elevation of the drainage system but also clarify the width and depth. This step enables designers to select suitable drainage facilities and estimate their sizes in advance, and identify whether the drainage system can connect outfall successfully. Subsequently, the Manning Equation can be introduced to evaluate whether the design can accommodate peak runoff rates. If the initial design does not meet the necessary criteria, the evaluation process can iterate with adjustments to the size of the drainage facility.

(4): Integrate Design: With the drainage system designed, this step aims to integrate it with the landscape design to identify any potential conflicts. If conflicts are discovered, designers can address them in a timely manner.

3. Case study

To illustrate the workflow of integrating various spatial analyses, this paper introduces a virtual case study site for simulation. The scenario includes existing trees and buildings to provide a realistic context for analysis. To better demonstrate the impact of site slope on stormwater management, the site's slope is set at 0.2%, with a total elevation variation of around 1 meter. The drainage system is specifically designed to collect surrounding stormwater and direct it downward to an outfall, which connects to the municipal stormwater pipeline. The bottom of the outfall is 0.7 meters lower than the surface at the end of the site.

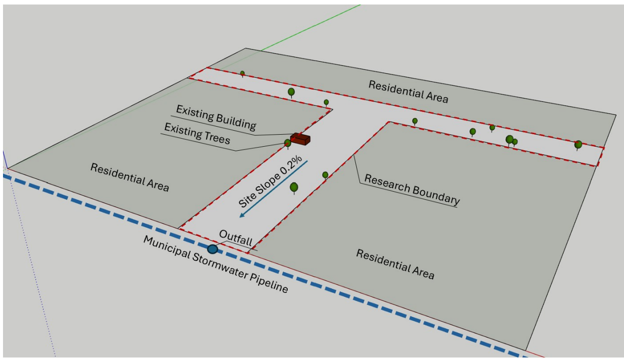


Figure 6. Study site

3.1 3D model preparation

Figure 6 illustrates the the 3D model prepared based on the new method, which collects limited spatial data and visualises all selected spatial factors in 3D. This includes site slope, existing tree locations, tree height and canopy size, as well as building footprint and height. With this data, urban and landscape designers can more easily observe and fully understand site conditions.

3.2 Suitable area delineation

As introduced in the methodology section, this step primarily relies on TPZ (Tree Protection Zone) and BFPZ (Building Footprint Protection Zone) analysis to avoid conflicts between drainage design and existing trees and buildings. Due to the single downward slope shown in Figure 6 and the T-shaped site, we intend to design a T-shaped drainage system to comply with the site shape and prevent stormwater from the upper side of site entering the residential area on the lower side.

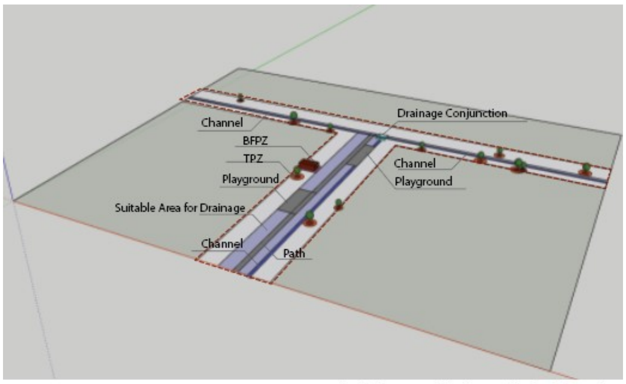
Following the organised workflow depicted in Figure 7(A), we identified the TPZ and BFPZ areas. By measuring the tree canopy size (D_c), we estimated the radius of the TPZ as 1 foot per inch of D_c for each tree. The building, which is 4.5 meters high, has a foundation depth of 1.5 meters. Therefore, we set the width of the BFPZ as 1.5 meters.

While the restricted areas for drainage construction are represented as spots, we considered the effectiveness of draining stormwater in a straight line. Based on our criteria, the defined boundary is a straight line determined by the closest tree or building. Figure 7(A) shows that trees and buildings are distributed along the site boundary, making it difficult to construct the drainage system along the perimeter. Consequently, the edges of trees and buildings far from the site boundary define the suitable area for the drainage system.

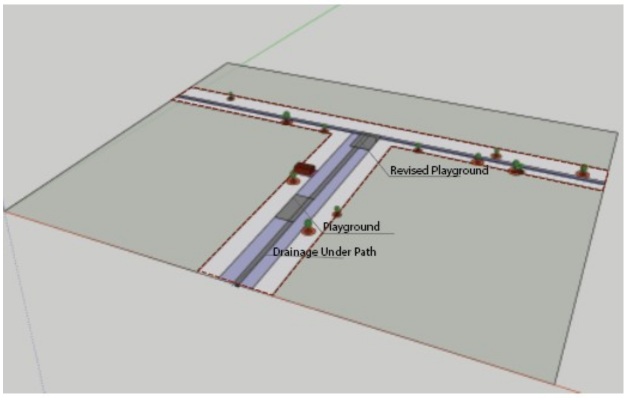
It is observed that the suitable area for the drainage system, constrained by TPZ and BFPZ, comprises less than half of the entire site, shown in light blue in the figure. This restriction highlights the site's narrowness. It would be easier for designer to clear the suitable design area and potential challenges.

3.3 Drainage System Design

At this step, we used the Manning Equation and the design flow rate (Q_d) to estimate the suitable drainage cross-section size. Given that the site is relatively flat, a single-direction drainage system with a large slope would result in the vertical channel at the end of the T shape being too deep. To ensure a successful connection to the outfall, the depth at the end of the drainage system is limited to a maximum of 0.7 meters.



A. Drainage and Landscape Design Integration



B. Integrated Design Adjustment

Figure 7. Stduy Case Design Results

As introduced above, the drainage system is designed in a T shape. The horizontal drainage channels are aligned along the main arms of the T ensuring that stormwater is collected from the upper areas and directed towards the central stem of the T. At the conjunction area, we have set a manhole for regular maintenance. Vertically, the drainage system directs stormwater downward through the site's slope. Based on the site's length, we determined that the slope of the channel should be 0.5%.

Considering the regular slope range of a planted swale, the slope of the drainage system indicates that a concrete channel is more suitable. Using the Manning Equation to verify whether the design size can achieve Q_d, the analysis results show that the channel should be 1.5 meters wide, starting at 0.3 meters deep with a 0.5% slope, and ending at 0.7 meters deep.

While this step follows the regular drainage design process, 3D modeling provides a significant benefit. It allows designers to observe how the drainage system is shaped on the site, particularly how it connects to the outfall, ensuring practical and efficient implementation

3.4 Design Integration

When integrating the proposed drainage channel with the landscape design results, the 3D model helps us identify suboptimal features. Specifically, the model reveals that the path running parallel to the channel segments the site into several smaller sections. Given the high demand for open space from surrounding residents, such fragmentation hinders diverse uses, particularly for activities involving large groups. Furthermore, the ’T’ shaped drainage system necessitates a junction at the crossing point, which should be accessible for maintenance and cleaning. Adjacent to this, a playground is proposed, located based on resident accessibility analysis. However, the proximity of the drainage junction and the playground is aesthetically suboptimal.

To address these issues, we propose relocating the drainage channel to run beneath the path, after evaluating the channel’s depth and the elevation of the outfall. To enhance spatial cohesion and aesthetic appeal, we suggest adjusting the playground’s location to coincide with the junction point. This adjustment consolidates the closely spaced artificial structures and potentially reduces construction costs.

4. Conclusion

This paper explores methods of integrating stormwater drainage into 3D models through spatial analysis. The adoption of spatial analysis not only facilitates the integration of stormwater management and landscape design but also enhances the efficiency of multifunctional design by analysing various spatial factors at an early stage. By considering factors such as site shape, topography, trees, and buildings, spatial analysis provides valuable insights into optimising stormwater management strategies within the context of landscape design.

As mentioned in the methodology section, this paper focuses on a specific set of spatial data analyses at the preliminary research stage. Our further research should aim to explore additional factors, such as soil type and land use patterns, to develop a more comprehensive understanding of stormwater management systems.

Sustainable stormwater management, represented by Sponge City and Water Sensitive Urban Design, is a complex topic, but we believe that the findings and methodologies presented in this paper can contribute to enhancing the effectiveness and sustainability of stormwater management practices. By integrating additional spatial factors in future studies, we can refine and improve the proposed design framework, ultimately supporting more resilient and adaptable urban infrastructure.

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