Urban Waterfront Protection: retrofitting the Briarcliff Waterfront District using systematic approaches with blue-green infrastructure

by
Noah Brizendine

A REPORT
submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture and Regional and Community Planning
College of Architecture Planning and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2023

Approved by:

Major Professor
Lee R. Skabelund

Abstract

Blue-Green Infrastructure (BGI) has become an increasingly important best management practice (BMP) when it comes to stormwater runoff and flooding. Most modern-day engineering-based stormwater management strategies, often referred to as grey infrastructure, are made of impervious material leading to increases in flooding and water contamination. One of the main goals of BGI is to reduce impervious surfaces and focus on more natural systems using vegetation. BGI typologies perform differently in different site conditions, and therefore it is important to study these components to determine their flood management performance. This project systematically studies BGI typologies using a site suitability matrix and precedent analysis framework to determine the performance of each typology. Water management selection criteria based off current site conditions (drainage, soil type, topography, etc.) were used to demonstrate performance of each BGI typology. Precedent analyses helped assess the BGI typologies by providing real-world examples of their performance and usage as design features. The information collected contributes to a site analysis process influencing design decisions that can be adapted to guide BGI design near and within communities that are vulnerable to flooding.

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Acknowledgments

To My Family...
Mom and Dad, Thank you for all of the resources, help, and love to guide me where I am today. I truly could not have succeed without you guys. Isaac, Trisha, and Eli, thank you for the constant encouragement in helping me achieve this goal. Grandma and Grandpa, thank you for helping me with this opportunity with your love and guidance.

To My Friends and Colleagues...
Class of 2023, Thank you for your friendship these last several years, I am glad to call you guys friends. To my KC friends, thank you for sticking by my side all of these years with love and support. BEAT!

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Abstract

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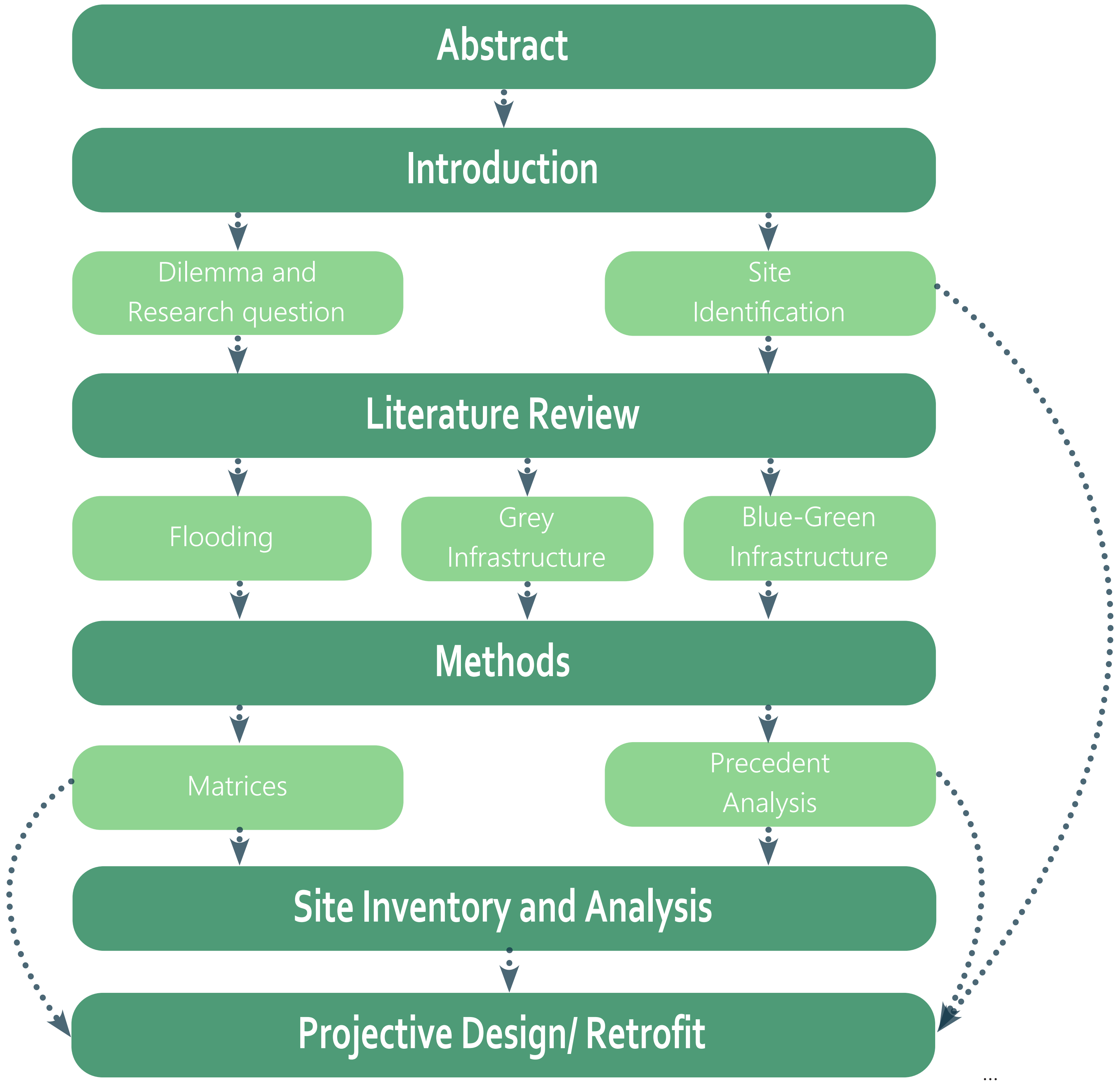


Figure 1.1 Flowchart of proposal outline (Brizendine, 2022).

Infrastructure - The system of public works for a country or state...the resources such as personnel, buildings, or equipment) for a required activity.

Green Infrastructure - "The range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters" (US EPA, 2015b).

Blue-Green Infrastructure - "An interconnected network of natural and designed landscape components, including water bodies and green and open spaces, which provide multiple functions such as: (i) water storage for irrigation and industry use, (ii) flood control, (iii) wetland areas for wildlife habitat or water purification, and many others" (Ghofrani et al., 2017).

Low Impact Development - "Land management practices that aim to reduce impervious surfaces and increase natural hydrologic functions such as infiltration and evapotranspiration" (US EPA).

Flooding - "Rising and overflowing water bodies of a body of water, especially onto normally dry land" (US EPA, 2015c).

Infiltration - The process of passing slowly into something particularly into the soil and vegetation. Adapted from (Infiltration Definition, n.d.) and (Tucci et al., 2007).

Evapotranspiration - "Evaporation from plant and landscape surfaces, and transpiration wherein water is moved along the soil-plant atmosphere continuum as soil water is taken up by plants and subsequently lost through leaf surfaces to the atmosphere." (Berland et al., 2017).

Best Management Practice- "Stormwater BMPs are devices, practices, or methods that are used to manage stormwater runoff by controlling peak runoff rate, improving water quality, and managing runoff volume" (Southwestern Pennsylvania Commission, 2023).

Pluvial Flooding - "Rainfall intensity exceeding infiltration capacity" (Tanaka et al. 2020).

Fluvial Flooding - "High-water levels in river channels exceeding bank heights and/or causing dyke breach" (Tanaka et al. 2020).

Systematic Approach - An approach done or acting according to a fixed plan or system.

Glossary

01 | Introduction

Overview

Flooding is one of the largest climate-related issues we face today, causing millions of dollars' worth of damage to vast ranges of urban areas and cities (Ghofrani, Sposito, and Faggian 2017). Grey Infrastructure has become a common method when it comes to managing stormwater. Using concrete pipes and other impervious material, grey infrastructure diverts water away from homes, buildings, and other structures into designated drainage ways (Berland et al. 2017). The result, however, has not always proved favorable when it comes to the environment. Grey infrastructure can contribute to a multitude of issues related to flooding and contamination of streams, rivers, oceans, and other water bodies. The impervious surfaces that often accompany grey infrastructure increase stormwater runoff and thus do not allow for much needed stormwater infiltration. Increases in stormwater runoff deteriorates landscapes, buildings, and infrastructure.

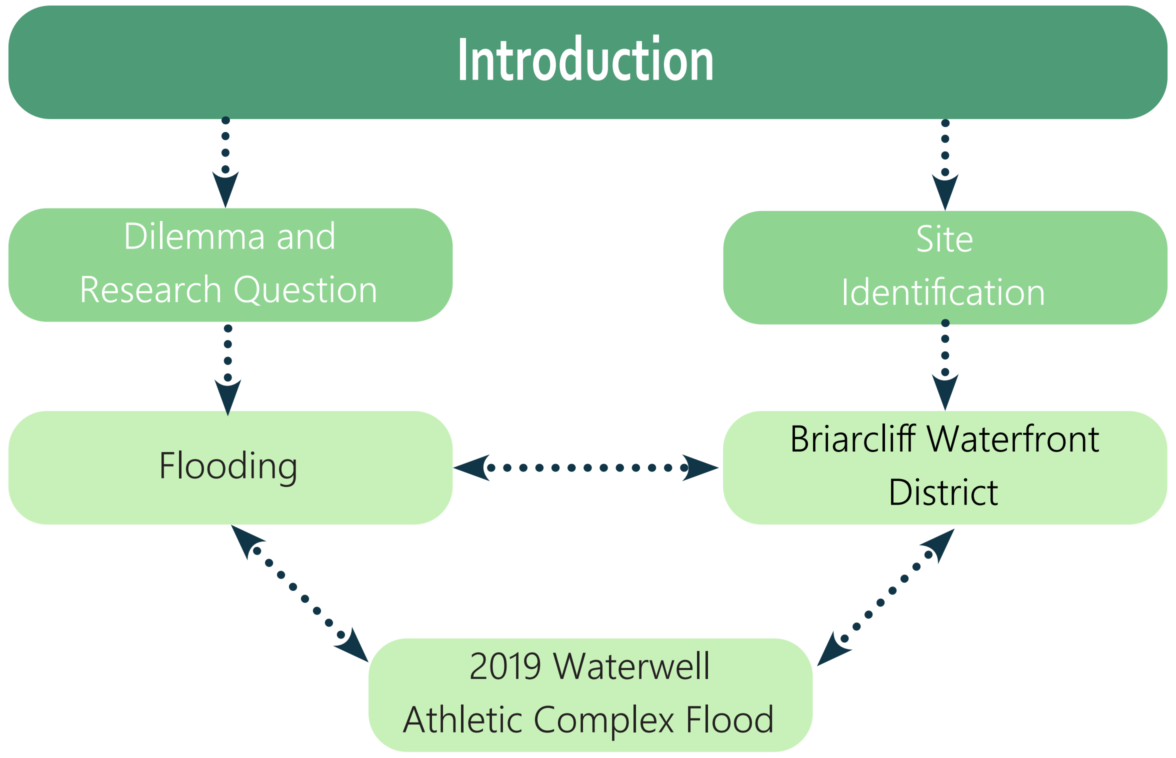


Figure 1.2
Flowchart of Introduction Chapter (Brizendine, Noah).

Conversely, Blue Green Infrastructure (BGI) is a low impact development (LID) strategy that mitigates the potential destructive flooding resulting from grey infrastructure. BGI makes use of plant life, permeable material, natural landscapes to decrease impervious surfaces and increase and enhance naturalized environments. Minimizing impervious surfaces and expanding BGI allows for infiltration and evapotranspiration of stormwater, resulting in a multitude of benefits including reduced flooding and contamination (Szota et al. 2019).

Common BGI typologies include rain gardens and other infiltration areas, sedimentation basins, and constructed wetlands. These typologies address one or more of the pressing issues related to stormwater quality or quantity. Implementing BGI helps create, functional, and efficient stormwater management often leading to enhanced site aesthetics.

Frequent and ongoing flooding continues to damage communities such as Riverside, Missouri, a small Kansas City suburban community nestled in the bend where the Missouri River's path changes from south to east. The Briarcliff Waterfront District (BWD) in Riverside is a multi-use district located along the river that bears the brunt of frequent floods.

Figure 1.3
Picture of a bioswale between roads (Volkening, 2023).

Figure 1.4
Constructed wetland at Assateague Island (Cottle, 2021).

Figure 1.5
Picture of circular street drain and gutters at The Landing at Briarcliff in Kansas City, Missouri (Brizendine, 2022).

Figure 1.6
Picture of concrete swale at The Landing at Briarcliff in Kansas City, Missouri (Brizendine, 2022).

Figure 1.7
Picture of square street drain The Landing at Briarcliff in Kansas City, Missouri (Brizendine, 2022).

Flooding from both stormwater runoff and river adjacency are contributors to paralyzing the area from normal life, work, and play from a few days to as long as a few weeks.

With little BGI on site, the BWD will continue to face many obstacles, including but not limited to, infrastructure damage, ongoing and repeated high repair costs, and continued environmental deterioration to the surrounding site.

The primary objective of this study is to analyze BMPs and retrofit them to the BWD based on their suitability to different site conditions. By finding the best suited BGI typology for this site, it is predicted to assist and strengthen the current stormwater management practices on site. A variety of different BGI typologies are compared using a site suitability matrix. The matrix represents each typologies' characteristics and each BGI type was evaluated to determine the best solutions for the BWD. The result is a projective design using BGI typologies implemented throughout the site at the most ideal location, with the goal to improve and optimize the site's current stormwater management system.

Dilemma, Research Question, and Objectives

The flooding and contamination issues related to grey infrastructure and impervious surfaces continuously damage low lying communities and urban areas. With climate change and flooding on the rise, the need for BGI is more prevalent than ever (Ghofrani, Sposito, and Faggian 2017). It is therefore important to study best management practices (BMPs) as a fluvial and pluvial flooding management strategy to help address the increased flooding risk of waterfront sites and communities. Equally important is that the BMPs be studied systematically to help increase an effective and efficient analysis followed by a projective design.

How can the Briarcliff Waterfront District be retrofitted with blue-green infrastructure (BGI) to help reduce flooding?

- What selection criteria should be used to assess the suitability of BMPs along waterfront parks?
- How do site suitability matrices impact design decisions for BMP implementation?
- What other programing and design elements can be implemented in the BWD to enrich the overall feeling of the site?

Objectives:

- Bring awareness to BGI infrastructure
- Identify why different areas flood
- Become familiar with commonly used BMPs
- Create a comprehensive matrix that can be used to analyze BMPs and compares them with current site conditions
- Identify suitable BMPs to implement in the BWD area of Kansas City
- Create a projective design that displays logical and thoughtful processes to aid in stormwater management and appeals to the local community

Study Area

The proposed site boundary incorporates three separate sites: The Landing at Briarcliff Apartment Complex, McCrite Plaza Retirement Homes, and Waterwell Athletic Complex. The upscale multi-family complexes are located in the Briarcliff district of Kansas City, Missouri which encompasses a shopping, dining, entertainment, and an office complex. Beginning with construction in 2010, The Landing at Briarcliff and McCrite Plaza communities are recent additions to the area with approximately 21 acres currently zoned as Urban Development (UR), and/or Residential (R).

Directly adjacent to the residential complexes is the Waterwell Athletic Complex, an outdoor baseball and football complex situated in the southwest corner of the Briarcliff area. The complex was acquired by Kansas City Parks and Recreation in 1990 and is an active hub for youth sports. Although Waterwell Athletic Complex serves as a recreational park, it is zoned similarly to The Landing at Briarcliff with residential (R) and urban development (UR) but there are currently no plans for future redevelopment. In total, the Waterwell Athletic Complex is 66 acres, however, the main area where people interact equates to approximately 39 acres. The remaining 27 acres are undeveloped with an unmaintained woody marsh. Together, these three sites make up the 88-acre project area and location for this study, named The Briarcliff Waterfront District (BWD).

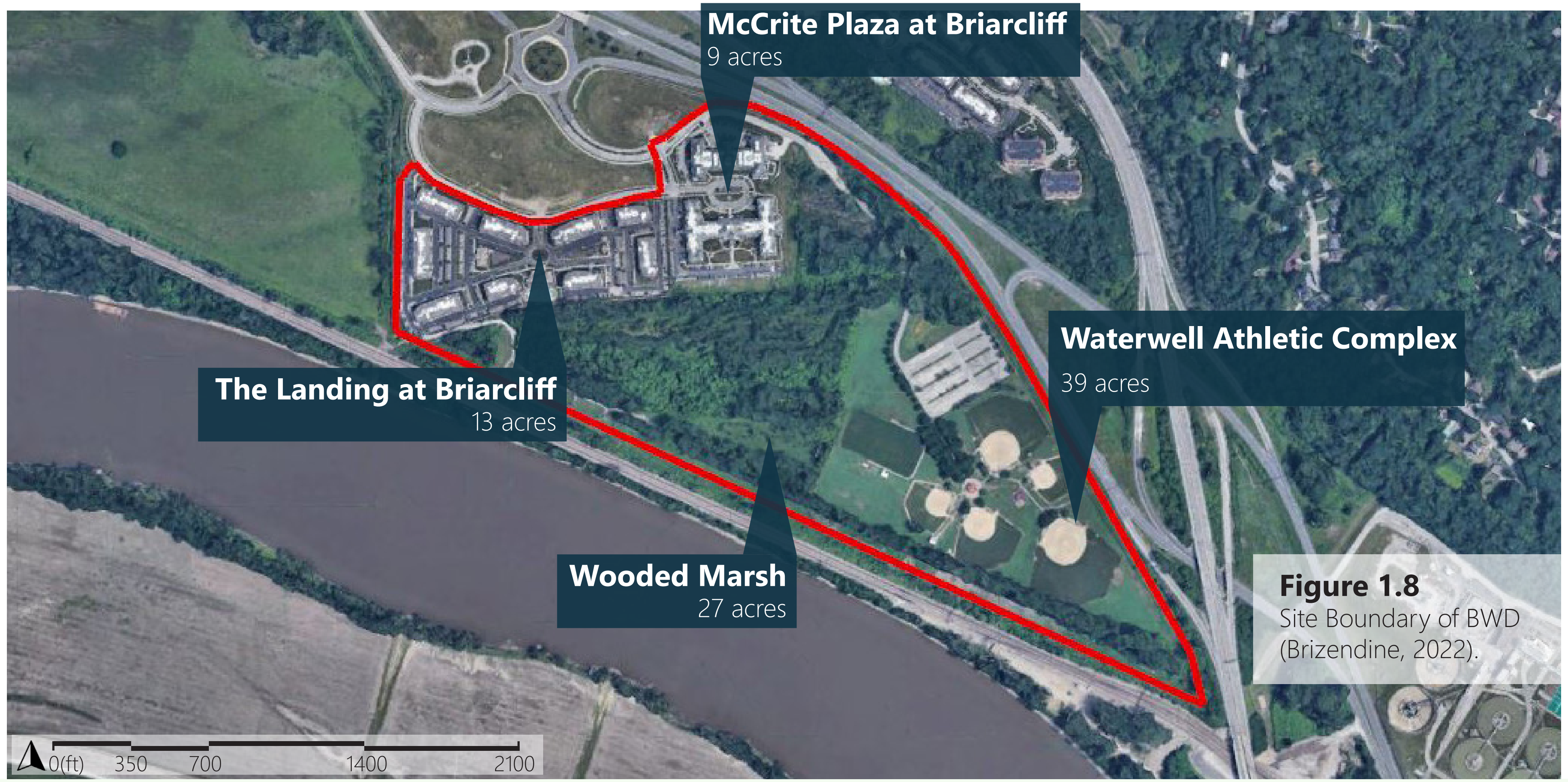
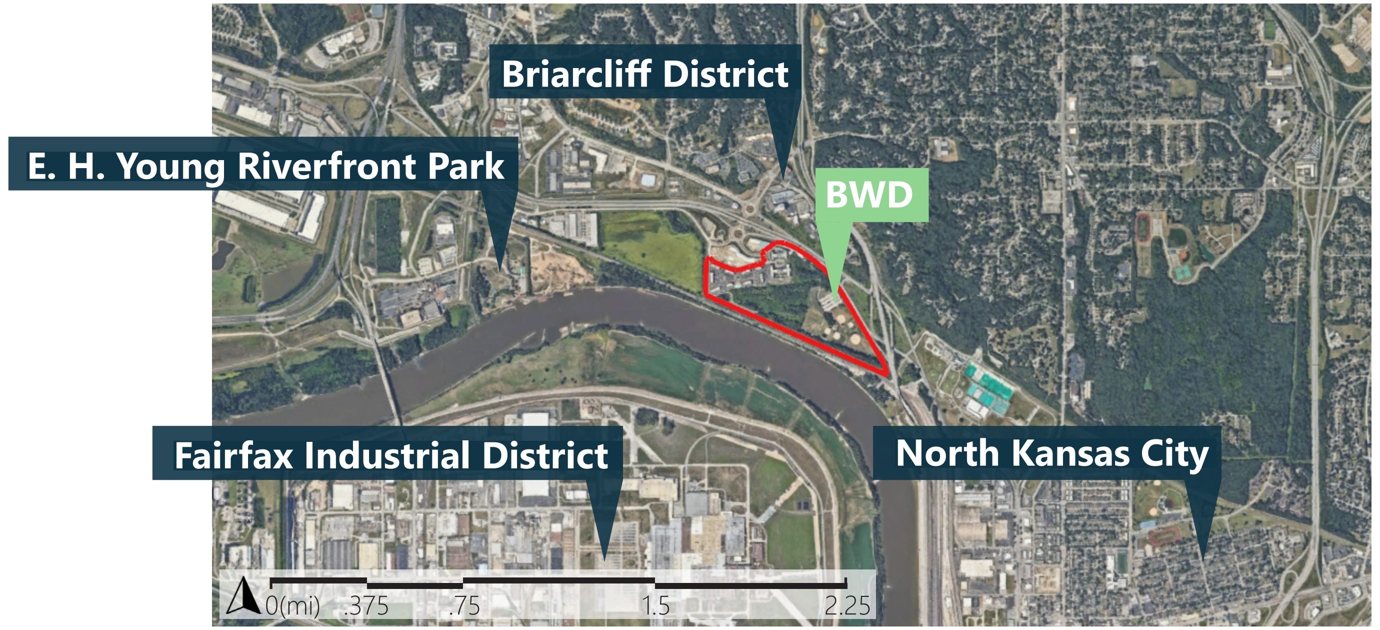


Figure 1.8
Site Boundary of BWD (Brizendine, 2022).

Certain areas of the site have an increased risk in flooding due the BWD's unique location: being downstream in its watershed, adjacency to the Missouri River, and lack of protection by the levee system that much of Kansas City uses to manage the Missouri River. This results in the BWD being one of the only areas to flood in Kansas City from the Missouri River, causing long periods of flooding. The context, protected by the levee, is primarily residential to the north and northeast as with manufacturing and retail to the south and southwest.



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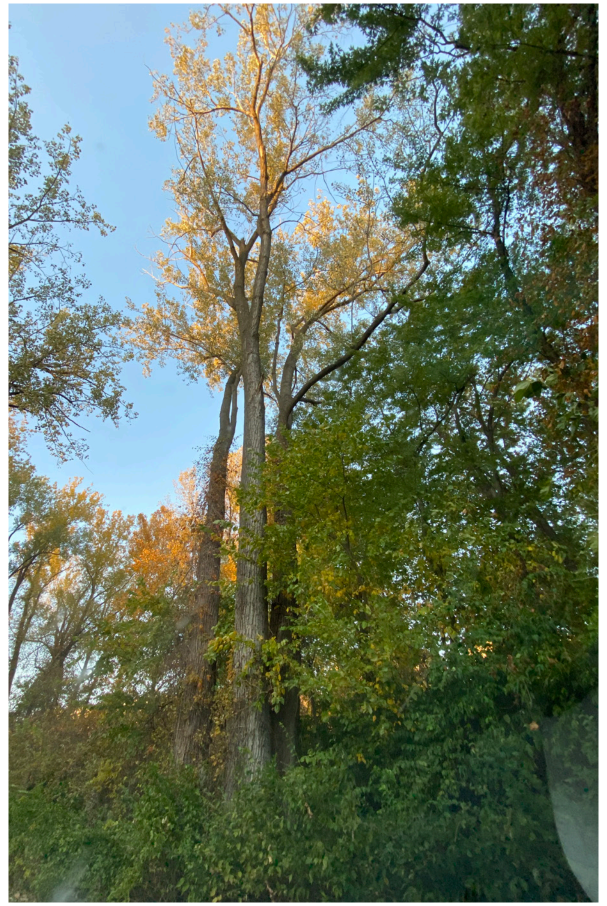

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Figure 1.21 Allee of trees at Waterwell Athletic Complex (Brizendine, 2022).

2019 Waterwell Athletic Complex Flood

The widespread flooding in spring 2019 that overtook Waterwell Athletic Complex and several nearby areas reveals some of the damage throughout Kansas City. Upstream dams in Nebraska quickly exceeded water capacity due to the combination of increased precipitation and frozen soil through the beginning of the year, causing little infiltration and high amounts of stormwater runoff. Needing to preserve structural integrity, the dams were forced to release water downstream, resulting in extensive amounts of flooding in several waterfront developments (Evans, 2019).

One of these developments was the Waterwell Athletic Complex. Waters quickly exceeded the adjacent railroad barrier and flooded the complex for several weeks (Dempsy, 2019). Standing water throughout the area as shown in Figure 1.23 and 1.24 resulted in months of closures, excessive damage, and high costs.

Figure 1.23
Aerial Screenshot of Video of 2019 Kansas City flood (Evans, 2019).

Figure 1.24
Aerial Screenshot of Video of Waterwell Athletic Complex flood of 2019 (Dempsy, 2019).

02 | Literature Review

Overview

Infrastructure systems such as architecture, transportation, and utilities provide public services that support the foundation for society (Sun et al. 2020). When referring to stormwater and flooding, one of the main functions of infrastructure is to aid in the safe removal and treatment of polluted stormwater from roads and buildings. Traditionally, grey infrastructure was the primary approach for stormwater management, however, green and blue-green infrastructure features are rapidly becoming a more common and accepted practice (Sun et al. 2020; Berland et al. 2017; Doyle and Havlick 2009; Suleiman, 2021). Therefore, to be familiar with the project is to be familiar with infrastructure and how it works. The literature reflects these existing and new approaches to flooding management and how greater ideologies of Low Impact Development (LID) can impact construction.

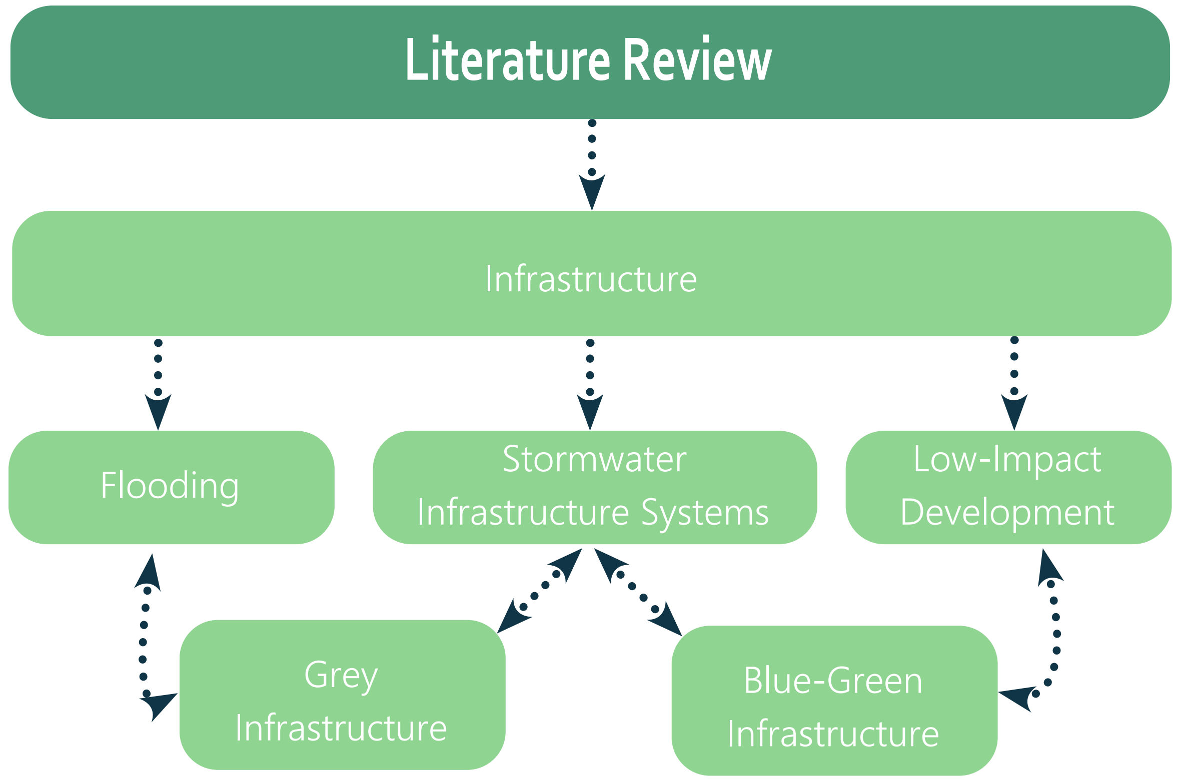


Figure 2.1
Flowchart of Research Chapter (Brizendine, 2023).

Flooding

Flooding events happen for tow primary reasons: from water body adjacency or from stormwater due to increased urbanization and other land uses in the watershed (Tucci et al. 2017; US EPA 2015c). Flooding from water body adjacency is described as "rising and overflowing water bodies of a body of water, especially onto normally dry land" (US EPA 2015c). Exceeding their maximum storage limit, water bodies are forced to discharge water into their floodplain which can seriously damage waterfront communities. Flooding from increased urbanization is a result of the number of impermeable surfaces, conventional detention basins, and extensive stormwater pipes, due to urbanization: roads, stormwater drains, building roofs, and sidewalks. Due to lack of infiltration, the stormwater runoff does not penetrate the soil and accumulates on the surface of impermeable surfaces, leading to flooding (Tucci et al. 2007). Regardless of how areas flood, the result of flooding may be catastrophic by deteriorating water quality, building structures, and wildlife (Tucci et al. 2007; Drosou et al. 2019).

In areas such as Kansas City, Missouri, a primary way flooding is being managed along the Missouri River is through a series of levees. Levees are man-made structures, located along the rivers edge, that prevent water from adjacent water bodies from entering the floodplain (Heine and Pinter 2012). While levees protect buildings and structures from flooding, they can degrade the river and change important hydrologic processes (Knox, Wohl, and Morrison 2022). This includes more quickly forcing flood waters downstream where increased flooding can occur in low-lying areas unprotected by well-functioning levees.

Removing floodplain land for levees and development can result in excess flooding in areas that are not protected by levee systems. The increase in water volume the floodplain receives, results in longer flooding periods, as has happened with specific areas in Kansas City such as downtown Parkville, Riverside, and the Waterwell Athletic Complex.

Stormwater Infrastructure Systems

Grey infrastructure seeks to manage stormwater and waste water through discharge and treatment systems using underground utilities such as pipes, storm inlets, and sewer systems to direct water away from buildings and other essential structures (Berland et al. 2017; Sun et al. 2020; Ashley, Gersonius, and Horton 2020). However, one of the main issues with grey infrastructure is its use of impervious material, such as concrete and asphalt. Several consequences arise as a result of managing water with impervious material, most importantly increases in flooding frequency and duration. The increase in impervious material reduces natural environments that use infiltration into the soil and vegetation to manage stormwater (Dagenais et al. 2018; Chen et al. 2015; Szota et al. 2019; Sun et al. 2020). Infiltration is a key component in stormwater management as the infiltration of stormwater into soil and vegetation helps retain stormwater better than impervious material (Szota et al. 2019).

Moreover, pollutants such as heavy metals, oils, suspended solids, and other waste from buildings and roads may accumulate on the surface of the impervious material, which are then collected by stormwater and transported to nearby water bodies (Sun et al. 2020).

Impacts of using grey infrastructure results in increases in pollutant load, water velocity, urban heat island effect, and, climate change (Sallustio et al. 2019; Doyle and Havlick 2009) which then can result in contaminated water bodies which impact potable water, the wellbeing people and wildlife, and environmental health (Radinja, Atanasova, and Zavodnik Lamovšek 2021, Suppakittpaisarn et al. 2017).

With a blue-green infrastructure approach, additional stormwater storage can be used to saturate soils for a period of time, and also aid in pollutants being absorbed and broken down by vegetation if allowed to infiltrate into the soil (Tucci et al. 2007, Dagenais, et al. 2018).

Grey infrastructure can be classified into two categories: Combined and separate sewer systems (Berland et al. 2017). Combined sewers refer to systems that bring both stormwater runoff and sewer water from waste systems of residential, commercial, and industrial buildings into the same system. In large storm events, these systems are susceptible to overfilling and spilling into common water ways, causing large amounts of contamination and flooding to the surrounding development (Berland et al. 2017; US EPA 2015d). On the other hand, separate sewer systems manage stormwater and waste by using multiple pipes to separate stormwater and sewage water to help lower the risk of flooding and contamination within both systems (Berland et al. 2017). However, pollutants frequently enter major water ways in both scenarios.

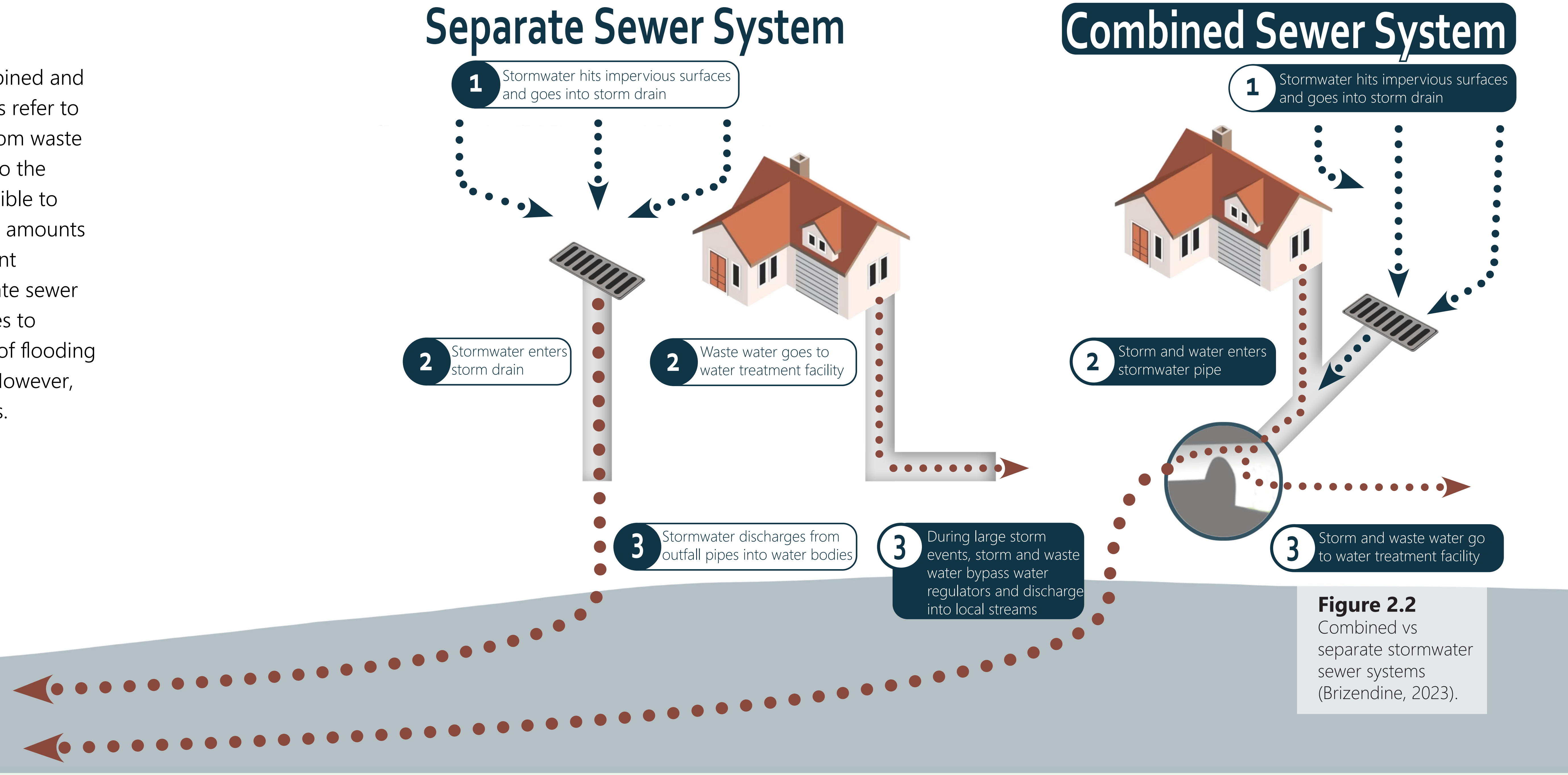


Figure 2.2
Combined vs separate stormwater sewer systems (Brizendine, 2023).

Blue-green infrastructure (BGI) and green infrastructure (GI) are similar Low-Impact Development (LID) approaches that introduce more natural environments to address flooding. Both approaches focus on decreasing impervious surfaces and increasing natural environments to therefore increase infiltration processes into the soil and plant life (Hopkins et a. 2018). While similar, these approaches have a key difference: While GI focuses on plants and natural areas to address stormwater issues, BGI uses similar principles, but also incorporates separate water bodies such as rivers, canals, reservoirs, etc. (Dai et al. 2021; Iojă et al. 2021). This means that BGI addresses several more types of flooding rather than from just stormwater runoff (Lamond and Everett 2019). Typologies that reflect BGI and GI include: rain gardens, bioretention cells, permeable pavement, green roofs, and green parking (Berland et al. 2017; Jia et al. 2013; Suppakittpaisarn et al. 2017; Radinja, et al. Lamovšek 2021). Figure 2.3 notes the primary BGI typologies and their definitions.

Green Roof	"A green roof, also known as a vegetated roof, is a roof that has been covered with a growing medium and vegetation...that intercepts stormwater run off".
Porous Pavement	"A previous paving system is a stormwater management facility used to address the impacts of land development... Which allows stormwater runoff to move through it".
Sand Filter	"Sand filters are...designed to maximize the removal of pollutants from stormwater runoff which includes the sand bed as the filter media and its underlying materials".
Wet Detention Pond	"Wet ponds are a ...type of stormwater facility has an elevated outlet structure that creates a permanent pool where stormwater runoff is detained and attenuated".
Vegetative Filter Strip	"A vegetative filter strip is a stable, evenly graded area that removes pollutants from stormwater runoff through filtration and biological uptake... depending on the type of vegetation".
Swales	"A grass swale is a stable, parabolic or trapezoidal channel that is lined with vegetation".
Constructed Wetlands	"Standard constructed wetlands... are open marsh system where pollutants are removed through settling and vegetative uptake/filtration".
Infiltration Trench/ Basin	"Infiltration basins/ trenches are stormwater management systems constructed with highly permeable components designed to both maximize the removal of pollutants from stormwater, promote groundwater recharge and address the quantity impacts of land development".
Rain Garden	"A rain garden is an infiltration device consisting of a small excavated area that is covered with a mulch layer and planted with a diversity of woody and herbaceous vegetation".
Dry Detention Pond	"A stormwater management system that temporarily stores and attenuates stormwater runoff".
Riparian Buffer*	"...an area adjacent to a stream, lake, or wetland that contains a combination of trees, shrubs, and/or other perennial plants" (U.S. Department of Agriculture. 2023).

** not from New Jersey DEP*

Figure 2.3
Table of BGI typologies with definitions adapted from (New Jersey Department of Environmental Protection, 2023).

Several supplementary benefits are also present when using BGI over traditional grey infrastructure: increased water quality, recharging of groundwater and aquifer supply, and overall improved ecosystem health (Suleiman, 2021). However, due to modern day urbanization, development, and policies, GI and BGI approaches have been lost throughout history (Suleiman, 2021; Iojă et al. 2021; and Hopkins et al 2018). Only within the last few decades has there been more emphasis placed on blue-green infrastructure by designing more water-sensitive urban areas, landscapes, and developments using low impact approaches and features (Mell 2017; Hopkins et al. 2018).

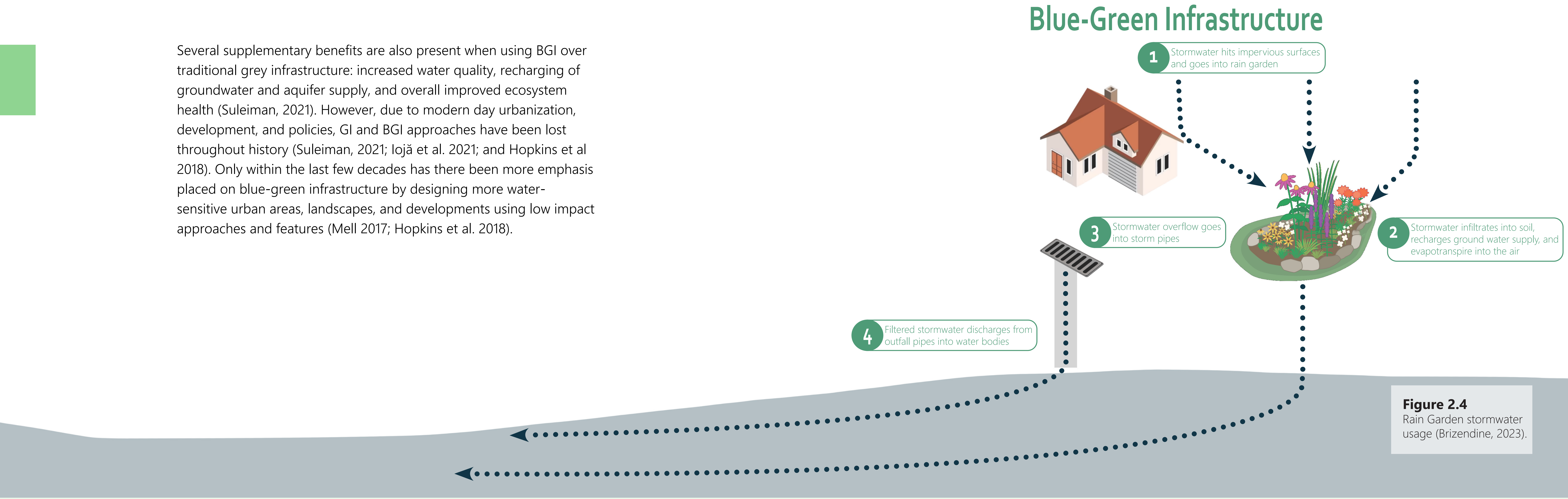


Figure 2.4
Rain Garden stormwater usage (Brizendine, 2023).

Low-Impact Development

Low-Impact Development and environmentally friendly design solutions have therefore risen in demand and need as these solutions address a number of issues regarding grey Infrastructure (Doyle and Havlick 2009; Sun et al. 2020). Low-Impact Development (LID) is a term used to describe management practices that aim to reduce impervious surfaces and increase natural hydrologic functions such as infiltration and evapotranspiration. The overall goal of LID is to replicate these natural elements to help with water quality and flood management (US EPA 2015a). The need for low-impact development has stressed the need to use created natural features and natural systems in ways that integrate green and blue-green infrastructure in existing and new urban areas (Doyle and Havlick 2009; US EPA 2015a; Dagenais, Brisson, and Fletcher 2018). The National Park Service Headquarters site in Omaha, Nebraska is one of many examples that employed an integrated stormwater management process using mostly native plant species (Figure 2.5).

Figure 2.5
Stormwater BMP at National Park Service Headquarters along the Missouri River in Omaha, Nebraska (Skabelund, 2005).

03 | Methods

Overview

One major benefit of studying BMPs systematically is that we can better understand how to increase their efficiency and effectiveness. Given that systematic approaches accomplish tasks through a fixed plan, site suitability matrices and precedent analysis frameworks can be used to simplify the complexity of BMP and design applications to the BWD. Several studies have measured and analyzed BMPs from different perspectives, which allow such studies to focus on specific issues such as the urban heat island effect (UHI), flooding, contamination, or a combination of issues (Radinja, Atanasova, and Zavodnik Lamovšek 2021; Koc, Osmond, and Peters 2016; Bartesaghi-Koc, Osmond, and Peters 2019). This project uses a comprehensive site suitability matrix based on existing matrices and a precedent analysis framework to determine where BMPs and design characteristics can be placed to create a more flood resistant waterfront area.

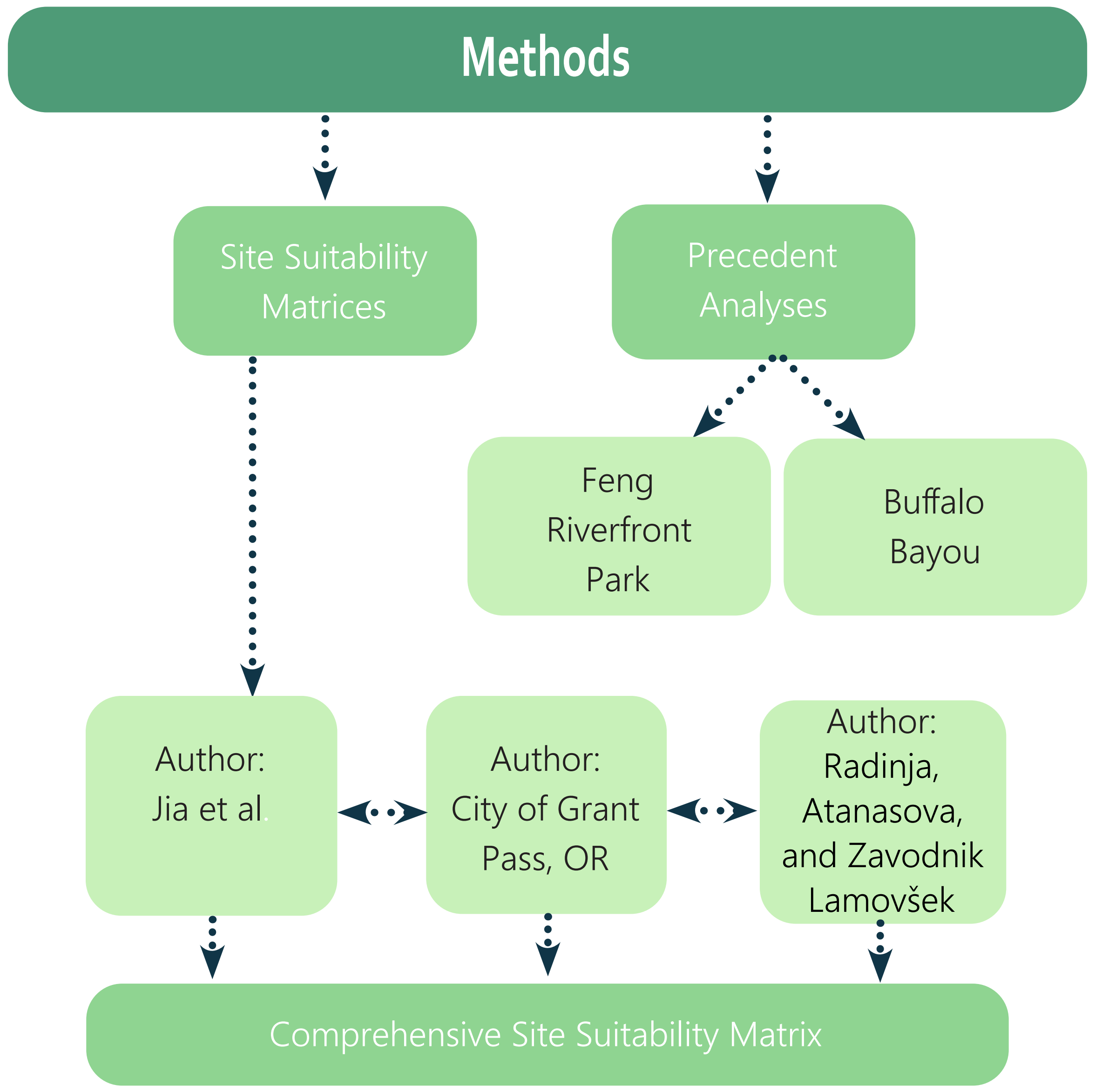


Figure 3.1
Flowchart of Methods Chapter (Brizendine, 2023).

Matrices

Matrices have been a successful method to organize and categorize BGI typologies (Radinja, Atanasova, and Zavodnik Lamovšek 2021; Jia et al. 2013; Young et al. 2009). Several matrices look at BMPs from different perspectives and also address other issues such as the Urban Heat Island Effect or specific pollutant removal (Young et al. 2009). For this study, three site suitability matrices were analyzed based on their water management approaches and display of different BMP characteristics.

These matrices compare commonly found typologies found in blue-green infrastructure (BGI) literature and display different performances based on specific selection criteria. The example matrices share common approaches in the selection criteria that reflect site conditions and hydrologic functions. Using site characteristics as a selection criteria allow for the projected landscape/ ecosystem performances to influence where BMPs can be retrofitted on site.

Performance goals and standards are compared to the BMPs as the necessary information used to determine water quality and quantity are used to meet regulatory water mange standards by several municipalities (Young et al. 2009; 2010). A comprehensive matrix was adapted from other matrices that use site characteristics, selection criteria, and performance goals to analyze BMP performance. The comprehensive matrix compares each BMP typology to the selection criteria and will determine which typologies are most suited for the Briarcliff and Waterwell sites.

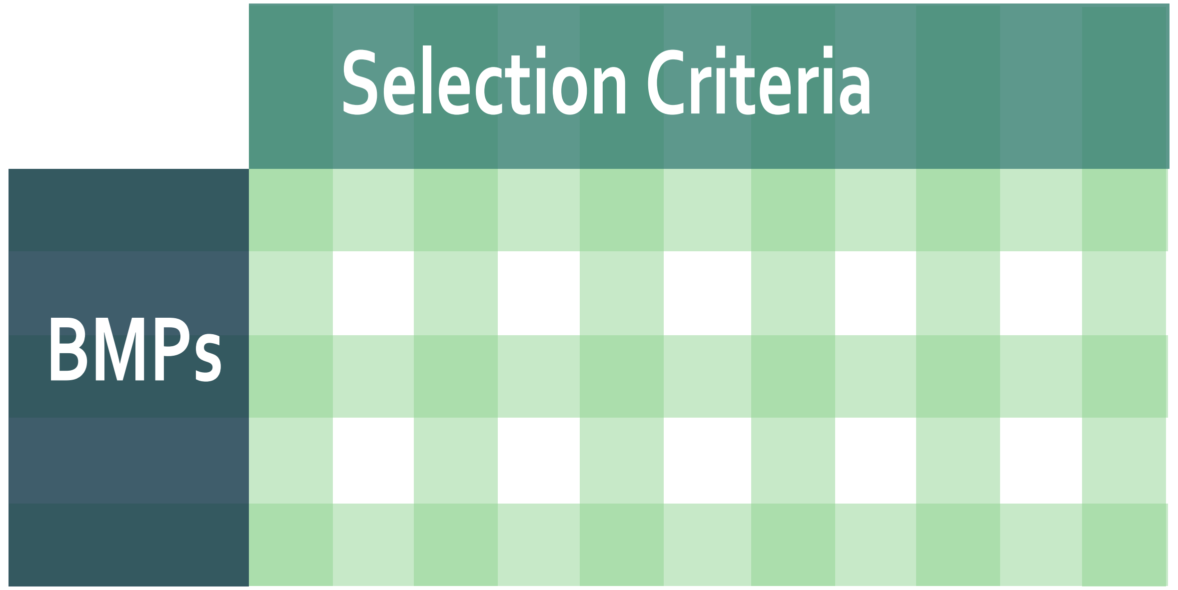


Table 3.1
Basic format layout for site suitability matrices (Brizendine, 2023).

BGI Matrix Precedents

Radinja, Atanasova, and Zavodnik Lamovšek 2021

synthesize Blue-Green infrastructure (BGI) performances through a matrix. This matrix analyzes BGI typologies from a water management perspective, similar to the perspective of this study. The BGI typologies are classified by their primary purpose of managing stormwater: reducing runoff, reducing peak flows, and improving water quality. They are also being compared to their primary hydraulic function with additional benefits shown in Table 3.2. The results show 13 selected typologies related to their performance of hydrologic functions and additional benefits (Radinja, Atanasova, and Zavodnik Lamovšek 2021).

☑ Primary function ✓ Secondary function ❖ Incidental + Additional benefit			Runoff reduction							Peak flow reduction		Improved water quality			
												Biological treatment		Physical filtration	
			Rain garden	Rainwater harvesting	Permeable paving	Green roof	Trees	Bioretention cell	Infiltration structure	Detention basins	Ponds	Constructed wetlands	Swales	Sand filter	Filter strips
Hydrologic functions	Stormwater quantity	Retention	☑	☑	☑	☑	☑	☑	☑	❖	✓	❖	❖	✓	✓
		Infiltration	☑	❖	☑		✓	☑	☑	❖	❖	❖	❖	✓	✓
		Detention	✓			✓	✓	✓	❖	☑	✓	❖	✓		✓
		Evapotranspiration	✓	❖		☑	☑	☑		✓	❖	☑	☑	❖	✓
	Stormwater quality	Sedimentation	☑	❖	✓			✓		☑	☑	☑	☑	☑	☑
		Filtration	☑	❖	☑	☑	❖	✓		❖		☑	✓	☑	☑
		Straining	✓	❖				✓		❖		☑	☑		☑
		Extended treatment (chemical)	✓			❖				❖	❖	☑	✓	✓	
		Extended treatment (biological)	☑			☑	☑	✓		❖	❖	☑	☑	☑	❖
Additional benefits (ecosystem services)		Provides wildlife habitat	+				+	+		+	+	+	+		+
		Aesthetic quality	+	+	+	+	+	+		+	+	+	+		+
		Stores runoff for alternative use		+							+				
		Provides additional permeable surfaces			+	+	+	+	+	+					+
		Improves air quality	+		+	+	+	+		+		+	+		+
		Provides educational opportunities	+		+	+		+	+			+			+

Table 3.2
Elements of BGI and its functions and benefits (Radinja, Atanasova, and Zavodnik Lamovšek, 2021).

Jia et al. 2013 have also produced matrices to organize BMPs. This matrix focuses on "site suitability" where several site characteristics reflect requirements BMPs need to perform well. In turn, the information from this matrix can be compared to specific site characteristics to determine the most suitable locations of the researched BMPs. Table 3.4 shows the site suitability matrix and some of the site conditions the authors use in the selection criteria: site conditions, soil, groundwater, topography, catchment, and space. The approach and matrix reflects a typologies instillation feasibility within specific site conditions, influencing design and retrofitting decisions.

Structural BMPs	Site conditions			Soil	Groundwater	Topography	Catchment	Space	
	Land use types	Pollution loading	Special requirement	Soil types	Distance between highest ground water level and the bottom of BMP(m)	Ground slope(%)	Drainage area(ha)	Imperviousness (%)	Area required for BMP (ha)
Infiltration trench	R, C, S, T, G	Medium	Buffer distance to building >3 m Buffer distance to stream >30 m	A–B	>3	<15	<2	>0	Medium
Infiltration basin	R, C, S, G	Medium	Buffer distance to stream >30 m	A–B	>3	<15	1–4	>0	Large
Dry detention pond	R, C, S, G	Medium	Higher elevation Buffer distance to stream >30 m	A–D	>1.5	<10	>4	>0	Large
Wet detention pond	R, C, S, G	Medium	Buffer distance to stream >30 m	A–D	>1.5	<10	>6	>0	Large
Vegetated filter strip	R, C, S, M, T, G	High	Adjacent to impervious surface Buffer distance to road <30 m	A–D	>0.60	<5	–	>0	Medium
Grassed swale	R, C, S, T, G	Medium	Adjacent to impervious surface Buffer distance to roads <30 m	A–D	>0.60	0.5–5	<2	>0	Medium
Constructed wetlands	R, C, G	Medium	Buffer distance to stream >30 m	B–D	>1.5	4–15	>10	>0	Large
Sand filter	R, C, M, T	Medium	Buffer distance to stream >30 m	A–D	>0.60	<10	<40	0–50	Small
Green roof	R, C, M	Low	Flat roof; pitched roof with small slope	–	–	<4	–	–	–
Rain barrel	R, C	Low	Buffer distance to building <10 m	–	–	–	–	–	Small
Porous pavement	R, S, C	Low	–	A–B	>0.60	<1	<1.2	>0	–
Bioretention	R, C, S, G	Low	Buffer distance to roads <30 m Buffer distance to stream >30 m Buffer distance to building >3 m	A–D	>0.60	<15	<1	0–80	Small

Table 3.3
Benchmark selection for BMP site suitability analysis (Jia et al. 2013).

The City of Grant Pass, Oregon's Stormwater Management Manual also created a site suitability matrix in which similar BMPs were ranked on their suitability with specific categories: water quality and quantity, site conditions, drainage, land use, development type, and land ownership as shown in Table 3.4 (City of Grant Pass 2018). This BMP suitability matrix is useful as it categorizes BMPs based on particular goals that BMPs address. In this case, the City of Grant Pass has categorized the BMPs based on reducing and minimizing runoff. The BMP Suitability Matrix also portrays easy-to-read graphics that display information clearly for better interpretation of the functions and roles that BMPs play in different scenarios.

Effectiveness level ***
- H Very Effective
- M Moderately Effective
- L Supports Function
- Not Applicable

Suitability level****
- 3 Well Suited to Condition
- 2 Moderately Suited to Condition
- 1 Less Suited to Condition
- Not Applicable

	Water Quality		Water Quantity			Site Conditions						Drainage Area				Land Use						Land Ownership		Development Type		
	On-site	Downstream	Flow Control	Evaporation	Aquifer Recharge	Steep Slopes	High Groundwater	Shallow Bedrock	Slow Draining Soils	Expansive Clay Soils	Contaminated Soils	Rooftops	Roadways	Sidewalks	Landscapes	Single-family Residential Lot	Subdivisions & Campuses of any land use	Commercial	Institutional	Roads and Public Right-of-Way	Industrial	Private	Public	Retrofit	Redevelopment	New Development
Prevent Runoff: Minimize Impervious Area BMPs																										
Share Parking Spaces BMP	M	H	L	M	L	3	3	3	3	3	3		3				2	3	2		1	2	2	2	2	3
Minimize Front Setbacks BMP	M	H	L	M	L	3	3	3	3	3	3		3	3		3	2		2			3	2		1	3
Prevent Runoff: Limit Disturbance BMPs																										
Construction Sequencing BMP	H	H	L	L	L	3	3	3	3	3	3					3	3	3	3	3	3	3	3	3	3	3
Conserve Fast(er) Draining Soils	M	H	L	M	L	3	3	3	3	3	3				3	3	3	3	3	1	3	3	3	3	3	3
Cluster Development BMP	H	H	L	H	L	3	3	3	3	3	3	3	3	3	3		3	2	2		2	3	3		1	2
Tree Protection BMP	H	H	L	M	L	3	3	3	3	3	3	2	3	3	3		3	2	2	3	2	3	3	3	2	2
Minimal Foundation BMP	L	M	H		L	3	3	3	3	3	3	3				3	2	3	3		3	3	3		1	3
Prevent Runoff from Landscape and Hardscape Areas																										
Restored Soils BMP	H	H	L	M	M	3	3	3	3	3					3	3	3	3	3	3	2	3	3	3	3	3
Tree Planting BMP	M	H	M	M	M	3	3	3	3	3	3	1	2	2	3	2	3	1	2	2	2	3	3	3	3	3
Depave Existing Pavement BMP	M	H	M	M	M	3	3	3	3	3	3		2	2		2	3	2	3	2	2	3	3	3	3	2
Contained Planter(s) BMP	M	M	L	H		3	3	3	3	3	3	2	3	3		3	3	3	3	2	2	3	3	3	3	2
Vegetated Roofs (Green Roofs) BMP	M	M	M	H		3	3	3	3	3	3	3				2	2	3	2		3	2	3	1	2	3
Porous Pavement (Rainfall) BMP	H	H	H		H		1	1	3				3	3		2	2	3	3	2	2	2	3	1	1	3
Reduce Runoff from Landscape and Hardscape Areas																										
Porous Pavement (Runoff) BMP	H	H	H		H		1	1	3			3	2	2		2	3	3	3	3	3	2	3	1	1	3
Infiltration Rain Garden, LID Swale, or Stormwater Planter BMP	H	H	H	M	H				2	3		3	3	3	3	3	3	3	3	2	3	3	3	3	3	3
Soakage Trench BMP*	H	H	H		H		1	1	2			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Drywell BMP**	H	H	H		H		1	3		2		3	2	2	1	3	3	3	3	3	3	3	3	3	3	3
WQ Conveyance Swale BMP	M	L	L	L	L	3	3	3	3	3		3	3	3	3	1	3	3	3	3	3	3	3	3	3	3
Dispersion: Vegetated Filter Strips BMP	M	L	L	L	L		1	1	3	3		1	3	3	3	3	3	2	3	3	2	3	3	3	3	3
Dispersion: Downspout Disconnection BMP	M	L	L	L	L		1	1	3	3		3				3	3	2	3		2	3	3	3	3	3
Provide Minimal Water Quality Treatment of Runoff from Landscape & Hardscape Areas:																										
Lined Rain Garden, LID Swale, or Stormwater Planter BMP	H	L	L	M		3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3
Wet, Extended Wet, and Dry Detention Ponds																										
Wet Pond	L	L	H	M	L	1	3	3	3	3		2	3	3	3		3	3	3	2	3	3	3	3	3	3
Extended Wet Pond	M	M	H	M	L	1	3	3	3	3		2	3	3	3		3	3	3	2	3	3	3	3	3	3
Dry Detention Pond*****	L	L	H	L	L	3	3	3	3	3		2	3	3	3		3	3	3	2	3	3	3	3	3	3

Use the LID Implementation Form to apply BMPs in the preferred order (i.e. stormwater hierarchy). Brief descriptions of column headings are as follows (see Chapter 4 for additional information):

Water Quality. Indicates which BMPs address water quality on-site and which substantially reduce runoff volume to protect against erosion and subsequent re-pollution of downstream waterways.
Drainage Area. Indicates which BMPs can be applied to which surfaces.
Challenging Sites. Indicates which BMPs are feasible at sites where infiltration of runoff is not recommended.
Flow Control. Indicates which BMPs serve as a substitute for a detention basin (i.e. are effective for flood control).
Land Use. Indicates the land uses/zoning classifications where LID can and has been implemented in Oregon.
Ownership. Indicates which BMPs may be used in private development or public development.
Development Type. Indicates which BMPs may be used in a retrofit, redevelopment or new development.

*Soakage trenches under pavement are not suitable for expansive soils, but are well suited under landscape areas with expansive soils.
** With adaptations, drywells may sometimes be used below contaminated soils. See Chapter 4 "*Drywells BMP* ".
*** Effectiveness level assumes the BMP is acting as a stand alone BMP under average conditions. When BMPs are used in a conjunction with others (e.g. any "*Minimize Impervious Area BMPs* " are combined with "*Restored Soils BMP* ") their effectiveness tends to increase.
****Suitability level accounts for general difficulty in implementing or use by stakeholders under average conditions.
*****Water quality can be addressed when modified to have a vegetated swale.

Table 3.4
BMP Suitability Matrix (The City of Grant Pass, Oregon, 2018).

Comprehensive Matrix

Selection Criteria for the comprehensive matrix were decided by reviewing the previous site suitability matrices and important BMP installation requirements. The comprehensive matrix selection criteria incorporate criteria groups such as: Hydraulic Function, Pollutant Uptake, Zoning, Soil Group, Topography, Area Required for Typology, Contributing Drainage Area, Cost at Completion, Maintenance Cost. These criteria groups were chosen based on their direct contribution to managing water, feasibility for BMP implementation, and meeting municipal water standards.

BMP selection similarly received information and inspiration from the previous matrices but also from several BMP manuals from the EPA and several cities. The typologies that were evaluated include Infiltration basin, infiltration trench, dry detention pond, wet detention pond, vegetative filter strip, grass swale, constructed wetlands, sand filters, green roofs, porous pavement, and riparian buffers. These typologies are commonly found in the literature and several BMP manuals.
BMP manuals from the EPA, Mid-America Regional Council, the City of Grant Pass, and the New Jersey Department of Environmental Protection also provided more insight on the design characteristics, requirements, and performance through several of the researched BMP manuals (Mid-America Regional Council and American Public Works Association 2012; City of Grant Pass 2018; New Jersey Department of Environmental Protection 2022). BMPs used within the matrix are categorized into Area BMPs (typologies capturing water from a specific location), Linear BMPs (narrow linear shapes that provide filtration functions), and Area BMPs (land cover and landscape management based typologies). The result is a comprehensive site suitability matrix that analyzes the performance of commonly used BMPs to specific site characteristics.

🟢 Good performance

🟡 Moderate performance

🔴 Low performance

⚪ Not applicable

Water Management

BMP	Water Quantity: Infiltration	Evapotranspiration	Retention	Detention	Filtration	Water Quality: Metals	Trash	Bacteria	Sediment	Oil and Grease	Organics	Nutrients
Area BMP												
Green Roof	🔴	🟡	🟢	🟢	🟡	🔴	🔴	🔴	🟡	🔴	🔴	🔴
Porous Pavement	🟢	🔴	🟢	🟡	🟡	🟡	🔴	🟡	🟡	🟢	🔴	🔴
Linear BMP												
Sand Filter	🟡	🔴	🟡	🟡	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟡
Riparian Buffer	🟡	🟢	🟢	🟡	🟡	🟢	🔴	🟢	🔴	🟢	🟡	🟡
Vegetative Filter Strip	🟡	🔴	🟡	🔴	🟡	🟡	🟢	🔴	🔴	🔴	🟢	🟢
Swales	🟡	🟡	🔴	🟡	🟡	🟡	🔴	🟡	🟢	🔴	🟡	🟡
Point BMP												
Constructed Wetlands	🟡	🟡	🔴	🟢	🟢	🟡	🟡	🟢	🟢	🟡	🟢	🟢
Infiltration Trench	🟢	🔴	🟢	🟡	🟢	🟢	🟢	🟢	🟡	🟢	🟢	🟢
Infiltration Basin	🟢	🟡	🔴	🟡	🟡	🟢	🟢	🟢	🟡	🟢	🟢	🟢
Dry Detention Pond	🔴	🟡	🔴	🟢	🔴	🟢	🟢	🟡	🟡	🔴	🟡	🔴
Wet Detention Pond	🔴	🔴	🔴	🟢	🔴	🟡	🟢	🟡	🟢	🔴	🟡	🟡
Rain Garden	🟢	🟡	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟡

Site Characteristics

BMP	Depth of Water Table (ft): >8	8-6	6-4	4-2	<2	Hydrologic Soil Group: A	B	C	D	Topography (%): <2	2-5	5-8	8-10	10<	Area Required for Typology (sqft): Small	Medium	Large	Contributing Drainage Area (Acres): >8	8-6	6-4	4-2	<2
Area BMP																						
Green Roof	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	🟢	🟢	🔴	🔴	🔴	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪
Porous Pavement	🟢	🟢	🟢	🟡	🟡	🟢	🟢	🟢	🔴	🟢	🟡	🔴	🔴	🔴	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪
Linear BMP																						
Sand Filter	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟡	🔴	🟢	🟢	🟢	🟢	🟢
Riparian Buffer	🟢	🟢	🟢	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Vegetative Filter Strip	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🟡	🟢	🟡	🟢	🔴	🔴	🔴	🔴
Swales	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🟡	🟢	🟡	🟢	🟢	🟢	🟢	🟢
Point BMP																						
Constructed Wetlands	🔴	🔴	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🔴	🟡	🟢	🟢	🟢	🟡	🟡	🟡
Infiltration Trench	🟢	🔴	🔴	🔴	🔴	🟢	🟢	🔴	🔴	🟢	🟢	🟢	🟢	🟢	🟡	🟢	🟡	🟢	🟡	🔴	🔴	🔴
Infiltration Basin	🟢	🔴	🔴	🔴	🔴	🟢	🟢	🔴	🔴	🟢	🟢	🟢	🟢	🟢	🔴	🟡	🟢	🟢	🔴	🔴	🔴	🔴
Dry Detention Pond	🟢	🟢	🟢	🟡	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟡	🟢	🟢	🟢	🟢	🟢	🟢
Wet Detention Pond	🔴	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟡	🟢	🟢	🟢	🟢	🟢	🟢
Rain Garden	🟢	🔴	🔴	🔴	🔴	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟡	🔴	🔴	🟢	🟢	🟢	🟢

Cost and Maintenance

BMP	Cost at Completion (USD/m³): 50	100	150	200	250	Maintenance Cost (USD/m³): 2	4	6	8	10
Area BMP										
Green Roof						🟢	🔴	🔴	🔴	🔴
Porous Pavement	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🔴
Linear BMP										
Sand Filter						🟢	🔴	🔴	🔴	🔴
Riparian Buffer										
Vegetative Filter Strip	🟢	🔴	🔴	🔴	🔴	🟢	🔴	🔴	🔴	🔴
Swales	🟢	🔴	🔴	🔴	🔴	🟢	🔴	🔴	🔴	🔴
Point BMP										
Constructed Wetlands	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Infiltration Trench	🟢	🟡	🔴	🔴	🔴	🟢	🟢	🟡	🔴	🔴
Infiltration Basin	🟢	🟡	🔴	🔴	🔴	🟢	🟢	🟡	🔴	🔴
Dry Detention Pond	🟢	🟢	🔴	🔴	🔴	🟢	🔴	🔴	🔴	🔴
Wet Detention Pond	🟢	🟢	🟢	🔴	🔴	🟢	🔴	🔴	🔴	🔴
Rain Garden	🟢	🟢	🟢	🔴	🔴	🔴	🟢	🟢	🟢	🟢

Table 3.5
Comprehensive Site Suitability Matrix
(Brizendine, Noah 2023).

Precedent Analysis

Another important method to assess site suitability for stormwater management typologies are precedent analyses. Two projects with similar conditions to the BWD have incorporated BGI into their designs. The principles used in these project designs are used in the retrofitting of the BWD with Blue-Green Infrastructure BMPs. For the precedents to be useful, each precedent study is assessed using a framework. The framework reveals important information regarding the implementation of BMPs and design interventions that impact the overall projective design. The framework template is shown in Table 3.6 and demonstrates how the precedents will be analyzed.

Location	
Size	
Designer	
BMPs used	
Addresses Pluvial Flooding	
Addresses Fluvial Flooding	
Programming	

Table 3.6
Structure of precedent analysis framework (Brizendine, 2023).

Buffalo Bayou Park

Located outside of the Houston Downtown area, Buffalo Bayou Park is an urban greenway that focuses on floodplain restoration and ecosystem creation in an attempt to lessen the flooding damage for the city. The Buffalo Bayou is a current and major drainage basin for the Harris County area. Before reconstruction, the Buffalo Bayou Park was a straight, turf-lined drainage area. This flow path for increased amounts of stormwater made the surrounding area very susceptible to long-term flooding which would freqently increase damage to infrastructure. Today, the Bayou serves its purpose to the community and the environment by acting as an active flooding prevention space while also connecting several spaces within the Houston area (Landscape Architecture Foundation 2019; Urban Land Institute 2021).

Figure 3.2
Photo of Buffalo Bayou River with Houston Skyline (SWA Group, 2023).

Figure 3.3 Diagram of Site Inventory Characteristics for the Buffalo Bayou (Aman and Yildirim 2019).

To constantly manage the flooding and stormwater management, the park is equipped with several BMPs and design strategies. The increased sinuosity of the bayou allows the for a larger floodplain to support riparian landscapes, wet meadows, and other ecosystems that serve as filtration and infiltration areas. The riparian and wet meadows have native trees and prairie plantings which are adapted to Houston's climate to manage extreme weather events. These BMPs allows the park to handle increases in flooding which preserves surrounding infrastructure (Landscape Architecture Foundation 2019; Urban Land Institute 2021).

Location	Houston, Texas, USA
Size	166 acres
Designer	SWA Group
BMPs used	Riparian buffers, detention basin, infiltration basins
Addresses Pluvial Flooding	Upland plants intercept and treat stormwater going into the Bayou
Addresses Fluvial Flooding	Riparian areas and designated flooding areas aid in fluvial flooding and silt deposition for easier maintenance
Programming	Paths and trails, interactive water play, recreational areas, pedestrian bridges

Table 3.7 Precedent analysis table of Buffalo Bayou project (Brizendine, 2023).

Feng Riverfront Park

Feng River Park is an 880,000 square meters park in Central China along the Feng River that is focuses on environmental restoration due to rapid urbanization along the river. Three project goals guided the design of the park: (1) to tie the Feng River's ancient history throughout the design, (2) create sustainable ecology and seasonal experiences, and (3) and develop innovative infrastructure, micro tourism. To manage urban stormwater, flooding, and contamination, the design replicates a sponge city typology that is used to increase infiltration and act as a "sponge" for the river and surrounding context. Several BMPs were used to manage flooding: rain gardens, constructed wetlands, bioswales, infiltration ponds, detention areas, and permeable paving. All of these BMPs have successfully increased infiltration and helped reduce stormwater runoff and flooding (Holmes, 2020; Landizer 2020).

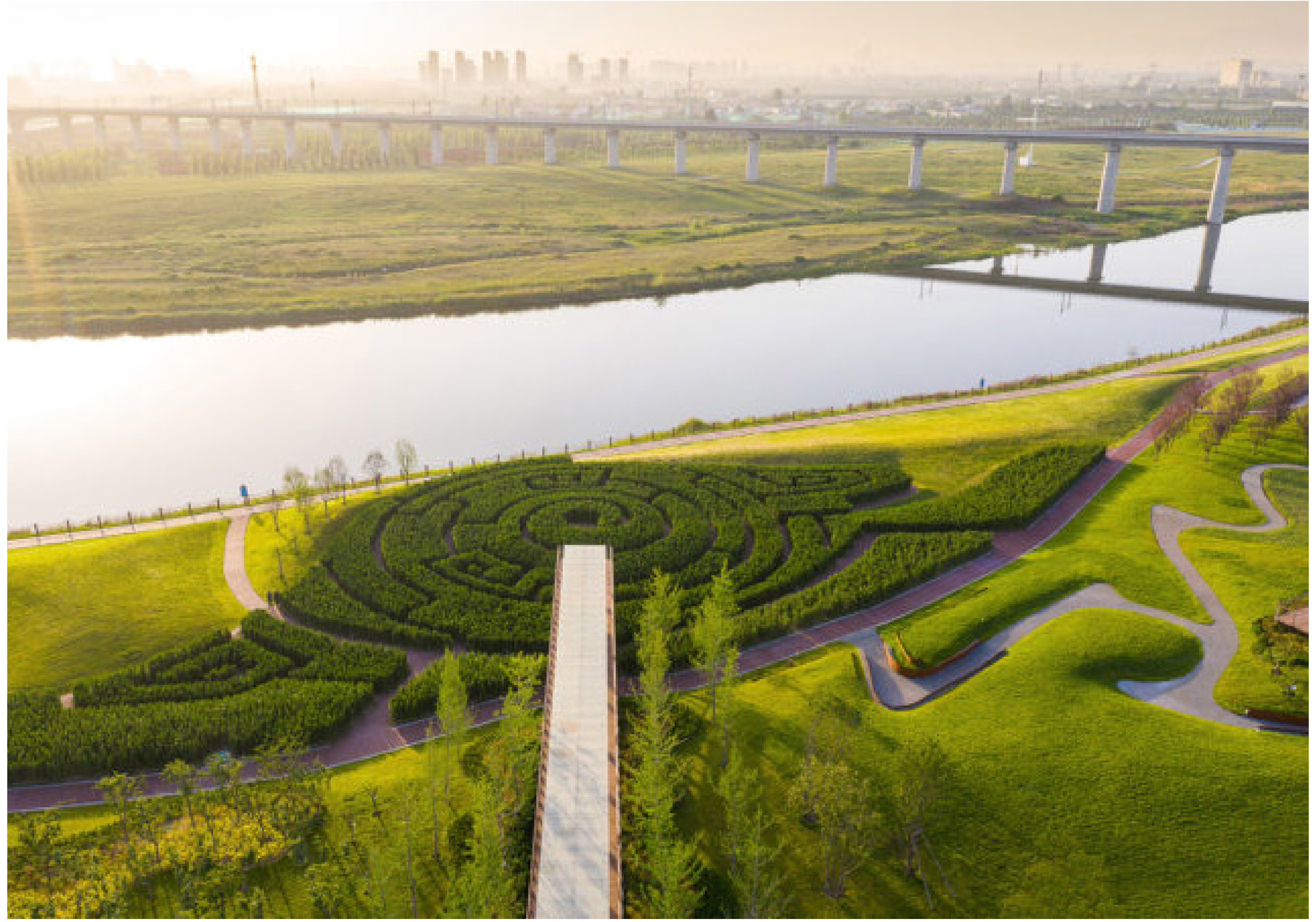


Figure 3.4
Photograph of outlook of Feng Riverfront Park (Holmes, 2020).

Feng River Park also incorporates sponge city techniques into the design, engineering, and construction as well. Rather than implementing specific BMPs to constantly address flooding, strategic topographic features are used. By using cut and fill techniques, the voids and berms allow water sit within "wetland" depressions for an extended period of time (Holmes 2020; Landizer 2020).

Location	Xi'an International New Area, Shaanxi Province, China
Size	217 acres
Designer	GVL (Gossamer)
BMPs used	Detention basins, wetlands and other vegetated areas, rain gardens, permeable paving
How BMPS address pluvial flooding	Rain Gardens and other upland BMPs intercept run off from the immediate context
How BMPS address fluvial flooding	Strategic topographical cut and fill techniques are used to create designated flood areas within the park
Programming	Recreation areas, flower gardens, winding trails, labyrinth path, way finding, retail and restaurants

Table 3.8
Precedent analysis table of Feng River Park project (Brizendine, 2023).

Figure 3.5
Plan rendering of Feng River Park (Holmes, 2020).

Figure 3.6
Aerial Photograph of Floodplain of Feng River Park (Homes, 2020).

Figure 3.7
Photograph of Infiltration steps in Feng River Park (Holmes, 2020).

04 | Site Inventory and Analysis

Overview

Site Inventory and Analysis are processes used in design to assess current conditions and possible design outcomes of a development site. Retrofitting of Blue-Green Infrastructure (BGI) typologies requires an in-depth site analysis process focusing on several important site characteristics. Figure 4.1 shows important categories and site characteristics that are studied through the site analysis process. The information gathered from the site inventory and analysis, with the addition of the comprehensive matrix and precedent analyses, provides information that directly influences design decision making to the Briarcliff Waterfront District (BWD). The decisions revolve around goals being focused on flood prevention, effective stormwater management, and user enjoyment of outdoor/landscape areas.

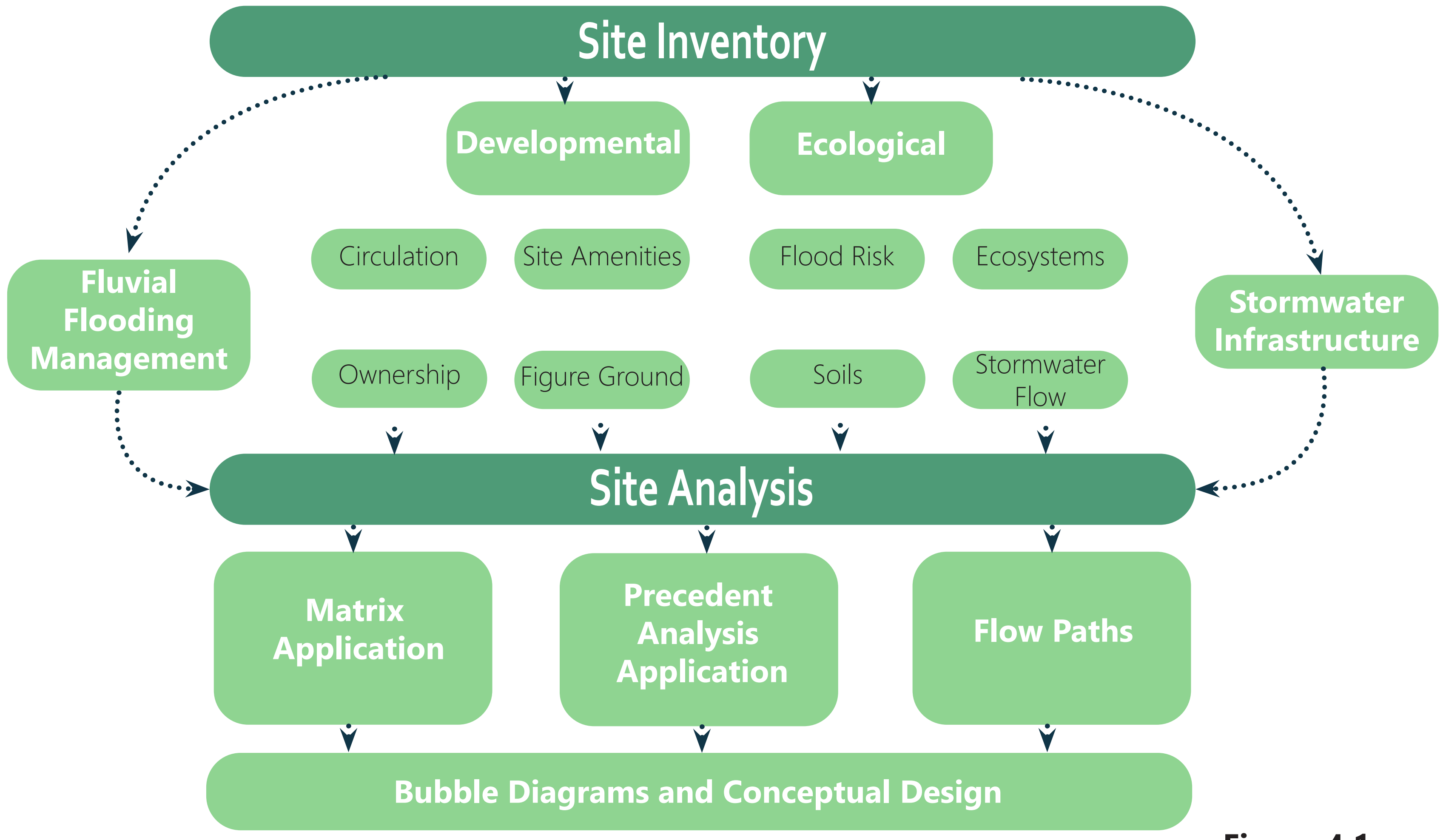


Figure 4.1
Flowchart of Methods Chapter (Brizendine, 2023).

Circulation

169 Highway and 9 highway are the main highways adjacent to the Briarcliff Waterfront District (BWD). Incoming visitors access the BWD via these highways. Secondary roads running north-south act as secondary entrances.

- Primary Vehicular Circulation
- Secondary Vehicular Circulation
- Railroad
- Pedestrian Circulation

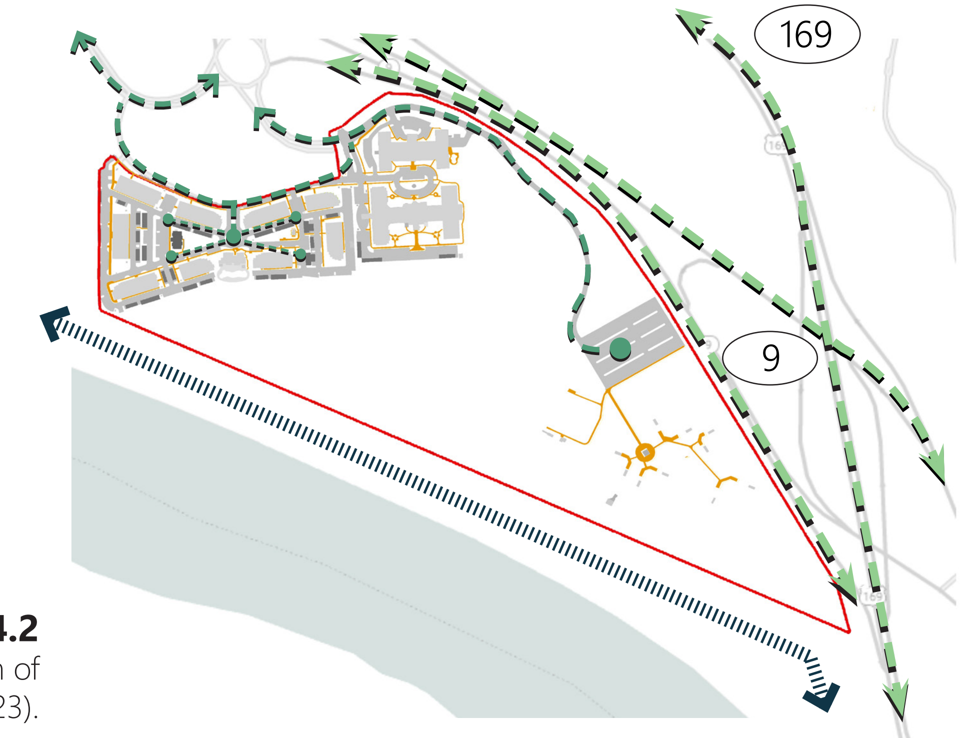


Figure 4.2
Circulation Diagram of BWD (Brizendine, 2023).

Ownership

Examining the public-private relationship between the different ownerships influence the accessibility, programming, and connection between and uses in the projective design.

- The Landing at Briarcliff Apartments
- McCrite Plaza Senior Living Community
- Waterwell Athletic Park

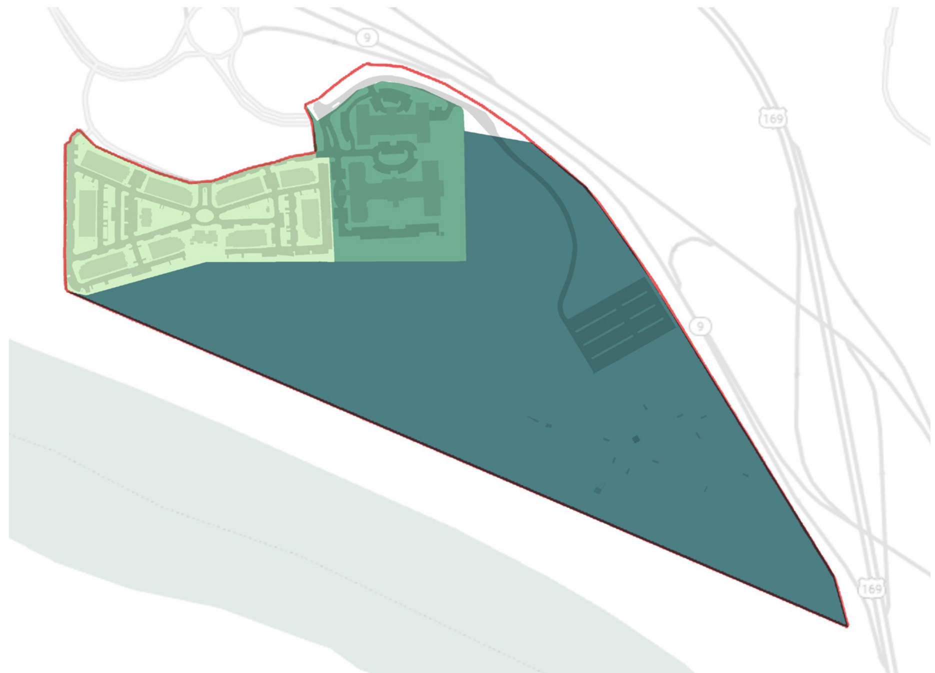


Figure 4.3
Parcel Ownership Diagram of BWD (Brizendine, 2023).

Site Amenities

Several of the site amenities are private to their respective developments. The dog park, pool, and community gardens are in The Landing at Briarcliff. The recreational fields, while public, are closed during winter.

- Community Areas
- Dog Park
- Athletic Fields/Surfaces
- Pool

Figure 4.4
Site Amenities Diagram of BWD (Brizendine, 2023).

Figure Ground

The BWD is around 25% developed with the majority of the development being The Landing at Briarcliff and McCrite Plaza. These locations accompany minimal public open spaces and are constructed with grey infrastructure and impervious material.

- Building Footprints
- Parking Structures
- Driveways
- Sidewalks
- BNSF Railroad

Figure 4.5
Figure Ground Diagram of BWD (Brizendine, 2023).

Flood Risk

The BWD sits in the 100-year floodplain of the Missouri River and downstream in its watershed. This combination significantly increases flood risk and damage for the site.

- Watershed Boundary
- 100-year Floodplain
- Regulatory Floodplain

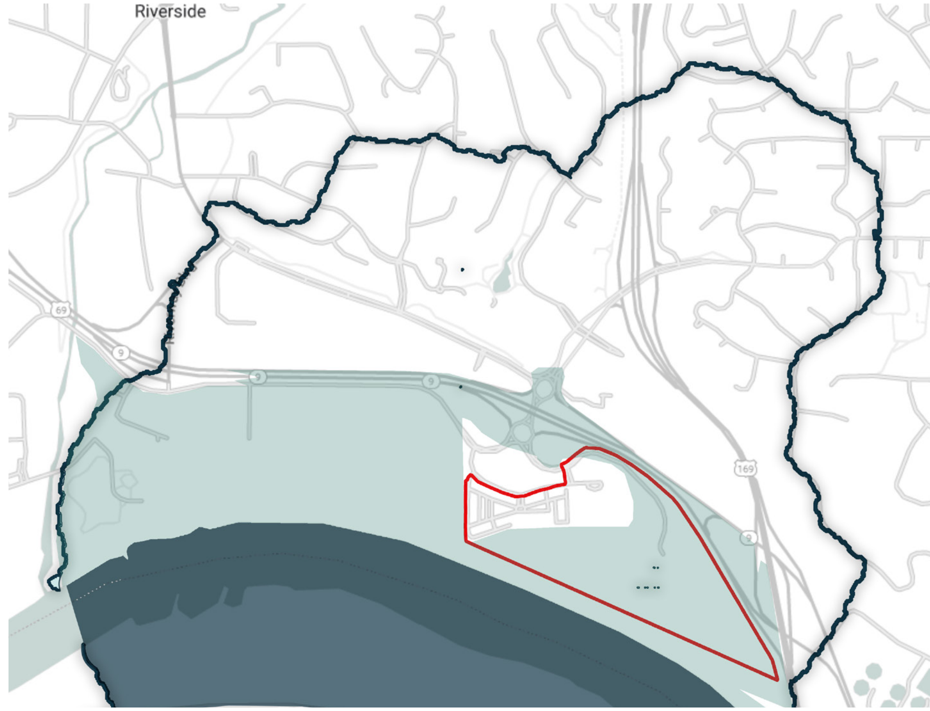


Figure 4.6
Flood Risk Diagram of BWD (Brizendine, 2023).

Soil Characteristics

The three native soils found all share similar characteristics: silty clay loam soil, C/D hydrologic soil group, and shallow slopes. The local fill soil may share some properties as Missouri soils commonly reflect these properties, however, rock and rubble are also likely.

- Waldron Silty Clay Loam Soil
- Leta Silty Clay Soil
- Hayine Silt Loam Soil
- Local Fill Soil
- BNSF Railroad

Figure 4.7
Soil Characteristics Diagram of BWD (Brizendine, 2023).

Ecosystems

The vegetation in the BWD can be split into 3 different functioning ecosystems: floodplain forest, urban floodplain trees, and urban street trees.

Urban Street Trees
White Oak *(Quercus alba)*
White Mulberry *(Morus alba)*
Eastern Redbud (*Cercis canadensis)*
Red Oak *(Quercus rubra)*

Urban Floodplain Trees
Sycamore (*Platanus occidentalis*)
Honeylocust (*Gleditsia triacanthos)*
Red Mapple *(Acer rubrum)*

Floodplain Forest
American Sycamore (*Platanus occidentalis*)
Eastern Cottonwood (*Populus deltoides*)
Silver Maple (*Acer saccharinum)*

Figure 4.8
Ecosystems Diagram of BWD (Brizendine, 2023).

Stormwater Flow

The Landing at Briarcliff and the west Briarcliff district drain primarily to the adjacent drainage way. However, McCrite Plaza and east Briarcliff drain into the floodplain forest.

- Development areas
- Stormwater Flow
- Discharge Areas
- Natural Drainage Ways
- BNSF Railroad

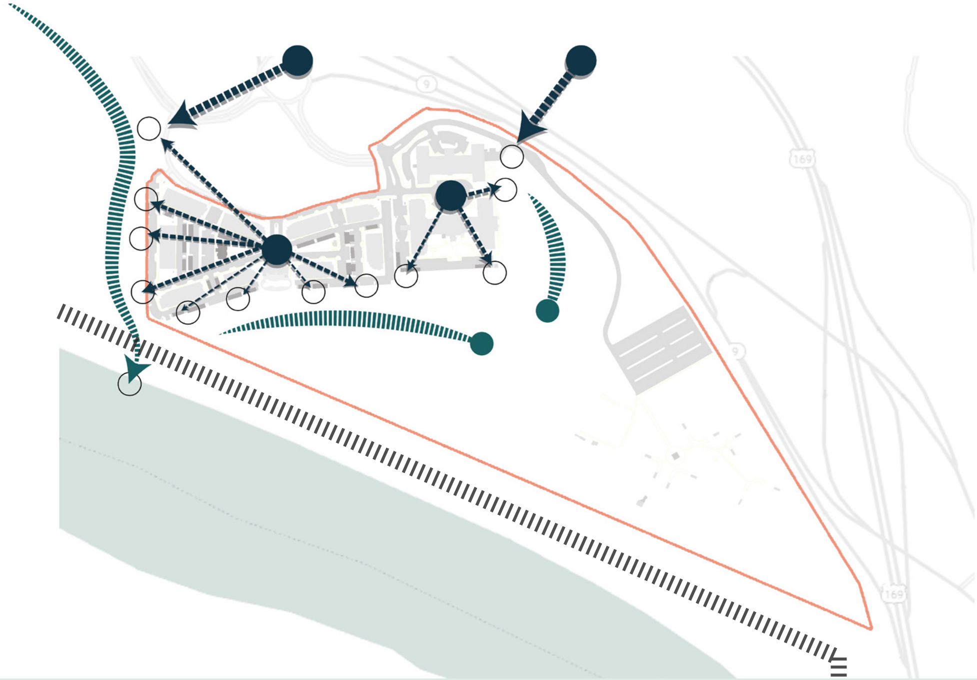


Figure 4.9
Stormwater Flow Diagram of BWD (Brizendine, 2023).

Stormwater Infrastructure

Being the largest development area on the site, The Landing at Briarcliff includes little to no BGI. Current stormwater management is managed by grey infrastructure, allowing for little infiltration into the soil. Permeable pavement is present on site; however, it also appears to be quickly drained by pipes underground. The McCrite Plaza at Briarcliff uses similar grey infrastructure to manage their stormwater with the addition of a concrete settling basin shown in Figure 4.13. This settling box acts as a sedimentation basin to allow large material to settle at the bottom. The Waterwell Athletic Complex uses low-lying areas that act as naturalized stormwater detention areas. These designated areas are connected by pipes that are located underneath sidewalks to connect the low areas. McCrite Plaza, The Landing at Briarcliff, and Waterwell Athletic Complex all use the floodplain forest as a drainage basin.

Figure 4.10- Infiltration trench at the landing at Briarcliff (Brizendine, 2023).

Figure 4.11- Storm drain at the landing at Briarcliff (Brizendine, 2023).

Figure 4.12- Stormwater weep holes at bottom of retaining wall (Brizendine, 2023).

Figure 4.13- Settling basin at McCrite Plaza (Brizendine, 2023).

Figure 4.14- Water settling area in Waterwell Athletic Complex (Brizendine, 2023).

Figure 4.15- Floodplain Forest of BWD (Brizendine, 2023).

Fluvial Flooding Management

Much of downtown Kansas City and adjacent metro areas are protected by a system of levees surrounding the Missouri and Kansas Rivers. However, the Briarcliff Waterfront District (BWD) is not fully protected. The levee system breaks between E.H. Young Riverfront Park to the Waterwell Athletic Complex. This entire area floods except for the Landing at Briarcliff and McCrite Plaza developments which are above the floodplain due to extensive filling. Due to the lack of protection and direct adjacency to the Missouri River, Waterwell Athletic park is classified in a regulatory floodplain zone. This means that when the Missouri river floods, the majority of the BWD is one of the first and only public areas to flood, causing modest extreme damage to the area depending on the flooding intensity.

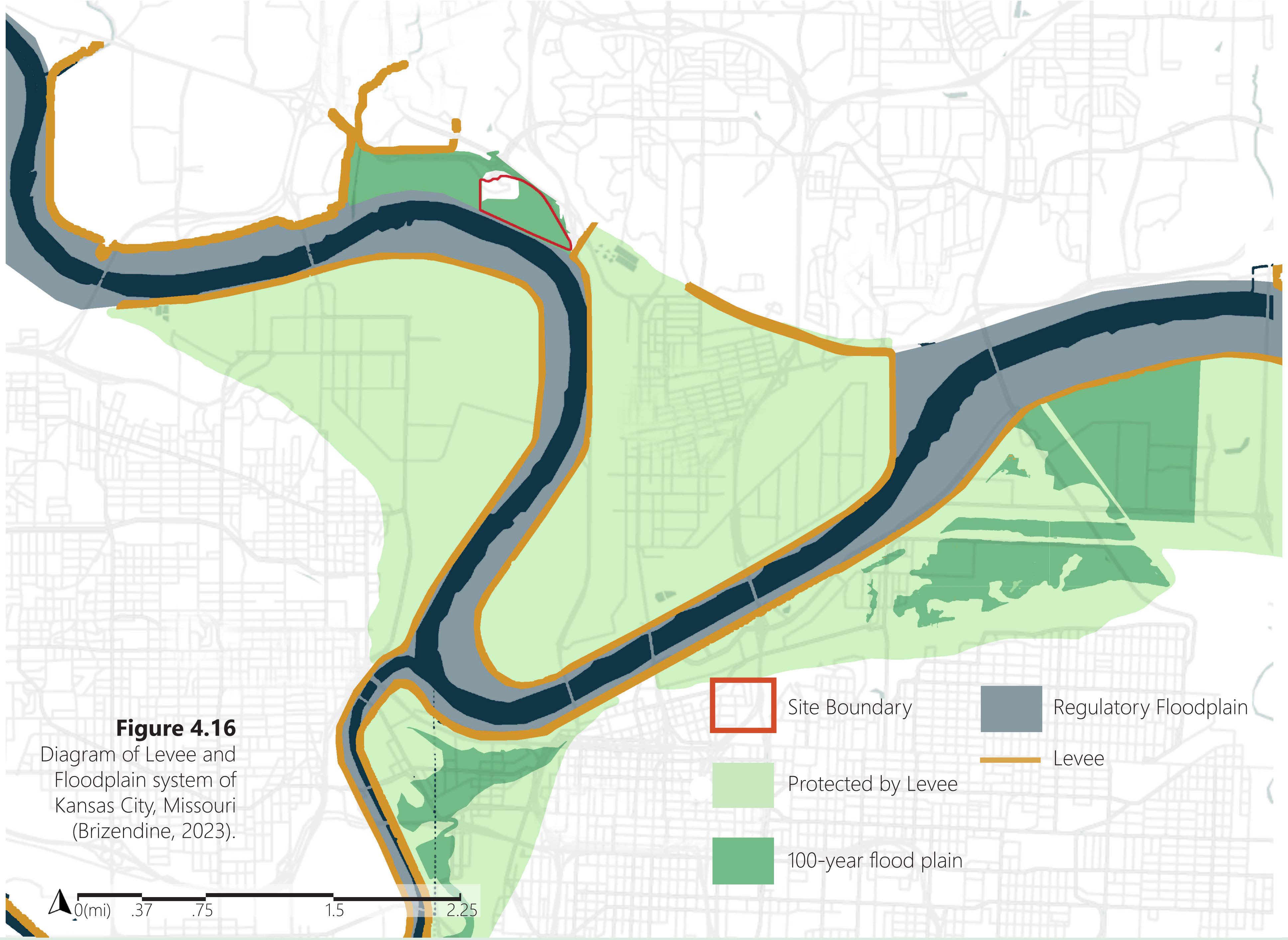


Figure 4.16
Diagram of Levee and Floodplain system of Kansas City, Missouri (Brizendine, 2023).

Flow Paths

Flow paths are the direction in which stormwater flows and is heavily influenced on topography and impervious surfaces. Examining existing topography through GIS data, site photos, and online aerial imagery guided the creation of flow paths. Understanding flow paths is crucial for BMP placement as several of these features need an increase in water to keep vegetation healthy and active. However, using native vegetation can lower irrigation and maintenance as these species are adapted to Missouri's climate. Flow paths contribute to the creation of watersheds and reveal where specific site areas are receiving more runoff than others. Ideally, each drainage area can be used to slow and hold stormwater runoff, although this may not always be possible or feasible (cost effective) when trying to retrofit existing conditions.

Figure 4.17- Flow paths of roofs of The Landing at Briarcliff and McCrite Plaza (Brizendine, 2023).

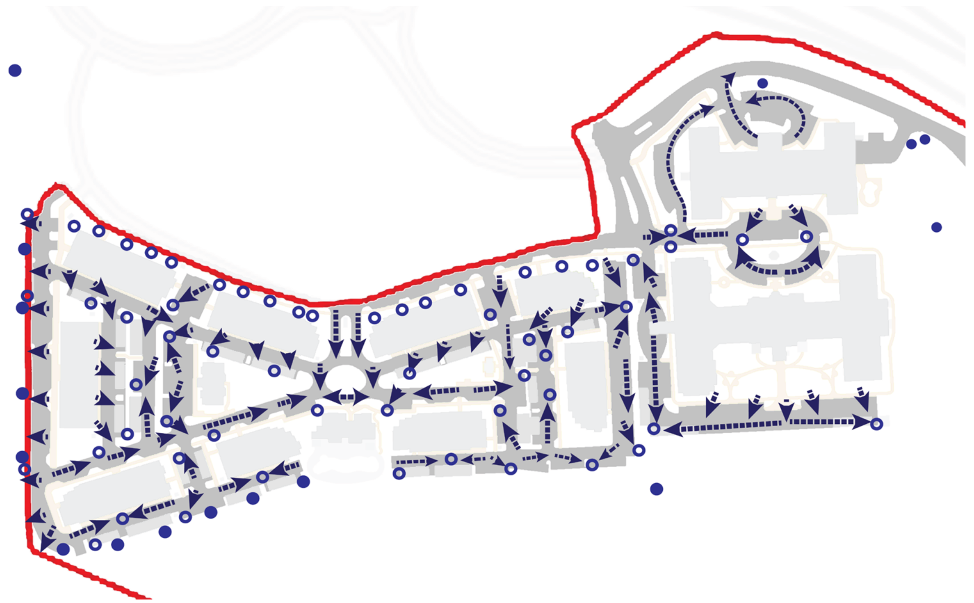
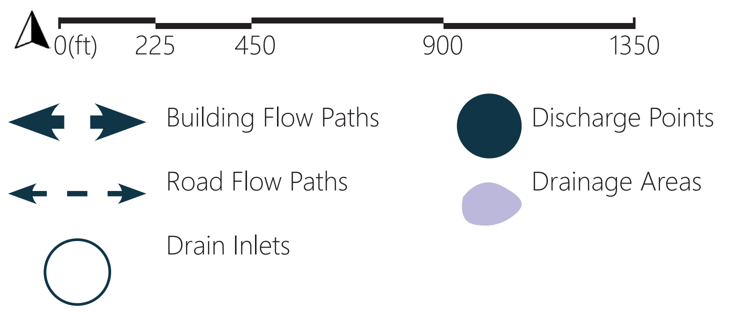


Figure 4.18 Flow paths of roads of The Landing at Briarcliff and McCrite Plaza (Brizendine, 2023).



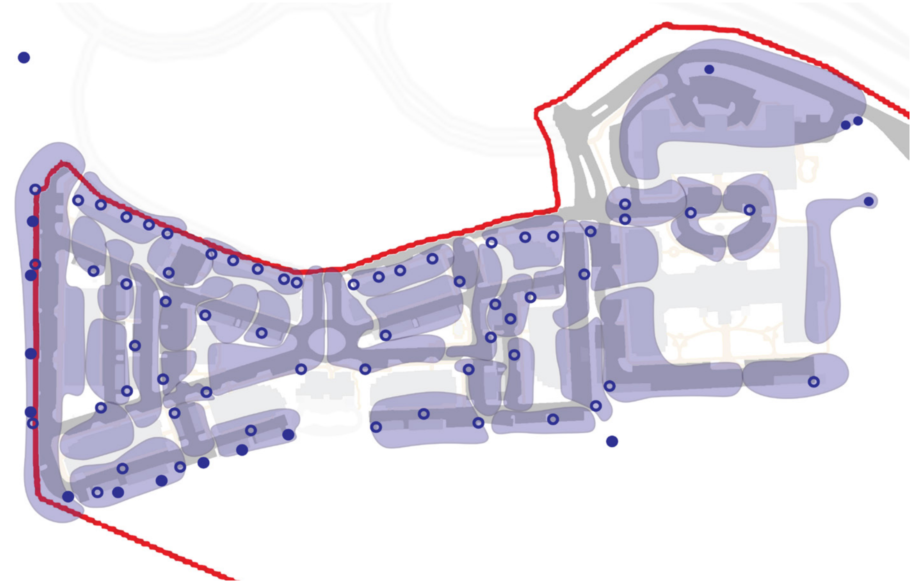


Figure 4.19 Drainsheds of The Landing at Briarcliff and McCrite Plaza (Brizendine, 2023).

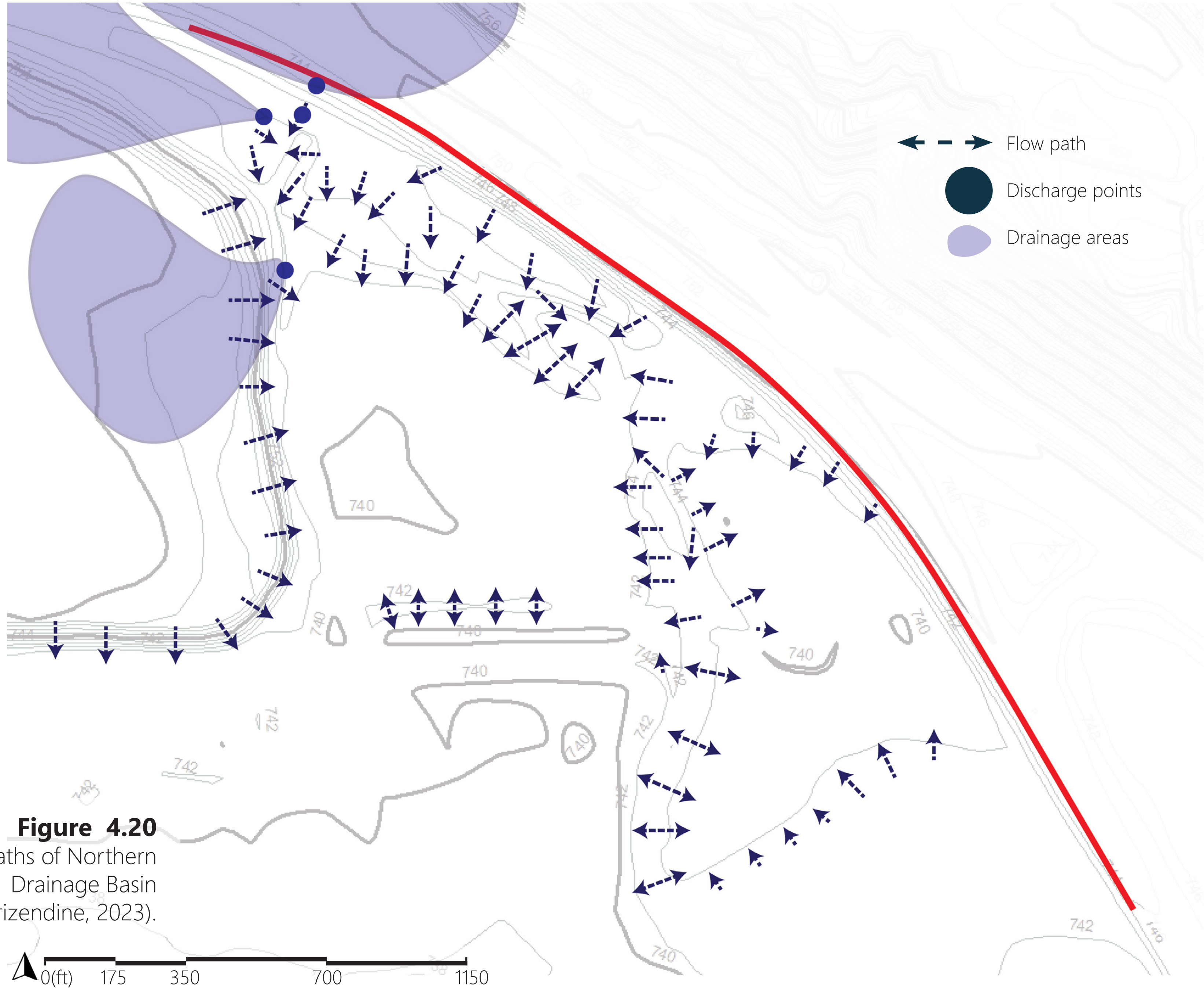


Figure 4.20
Flow Paths of Northern Drainage Basin (Brizendine, 2023).

Figure 4.21
Flow Paths of Waterwell Athletic Complex (Brizendine, 2023).

Matrix Application

Applying the matrix to the Briarcliff Waterfront District (BWD) consists of first identifying the relationship between the site locations in which the BMPs will be placed, and the BMPs themselves. The site characteristics from the comprehensive matrix's selection criteria act as corresponding characteristics from the site locations and BMPs. The relationships between these three characteristic groups ultimately influences where the BMPs will perform the best and thus can be placed in the BWD. Figure 4.22 shows how the site locations and BMPs share the selection criteria as common data while Figure 4.33 shows where specific site characteristics are on site.

It is also important to note that while some of the values within the matrix may not reflect a suitable locations for BMPs, several other design characteristics and factors also influence values. For example, shallow water tables may render most point BMPs unsuitable for several areas, however, using native vegetation that have adapted to wetter soil conditions still help stormwater management.

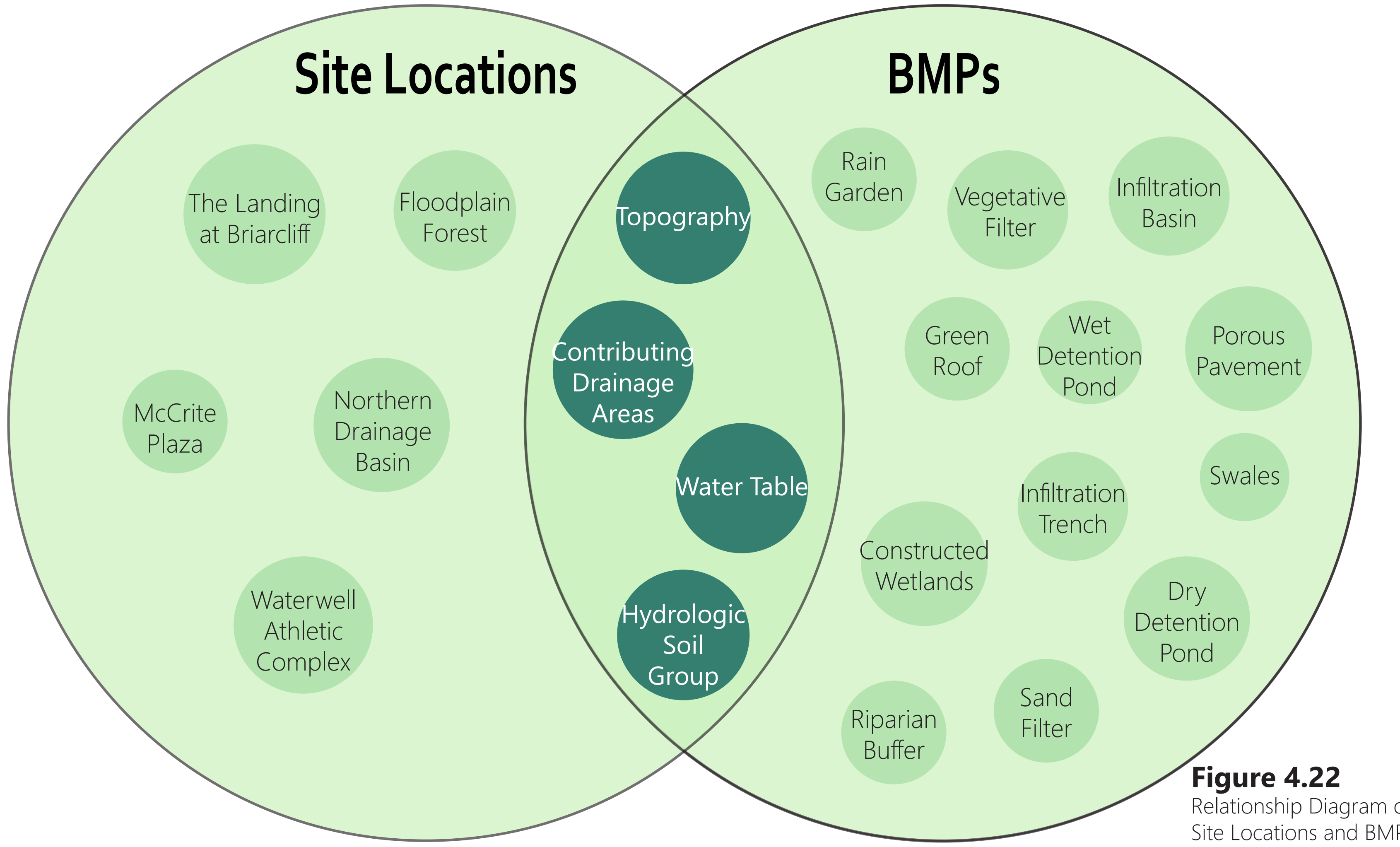


Figure 4.22
Relationship Diagram of Site Locations and BMPs (Brizendine, 2023).

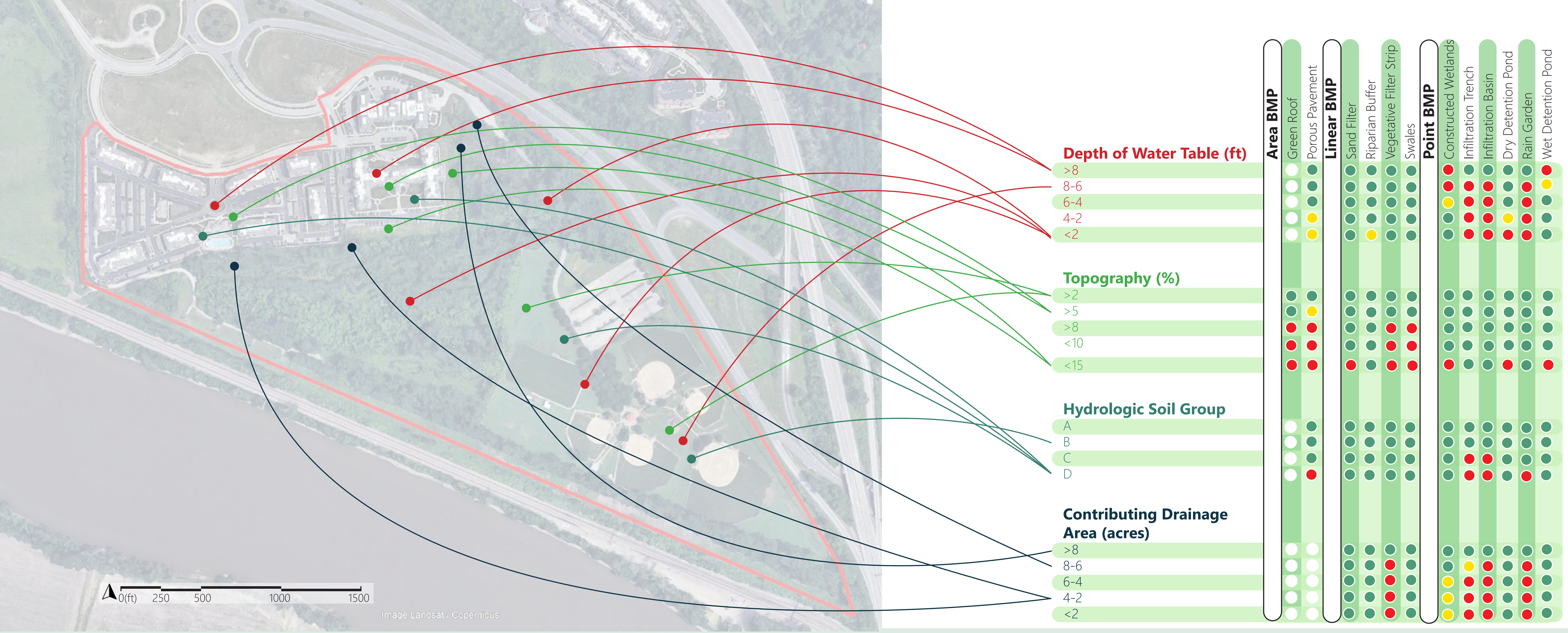


Figure 4.23
Representation of BMPs with performances in specific site locations (Brizendine, 2023).

Precedent and Design Inspiration

While looked at for their stormwater management, The Buffalo Bayou and Feng River Park projects hold design aspects that create a lively and programmed space that people enjoy. General programming and design characteristics such as walking trails, playground accessories, shade structures, and community gathering areas possess high potential for use in the Briarcliff Waterfront District (BWD). Other precedents and design inspirations come from nearby baseball complexes and the general Kansas City area. Enhancing the existing programmed community areas with BGI typologies and general design characteristics will further improve the environmental functionality, usefullness, and community feel to the BWD.

Figure 4.24
Photograph of man running on bridge in Feng River Park (Holmes, 2020).

Figure 4.25
Photograph of people laying on path in tall grass Labyrinth (Holmes, 2020).

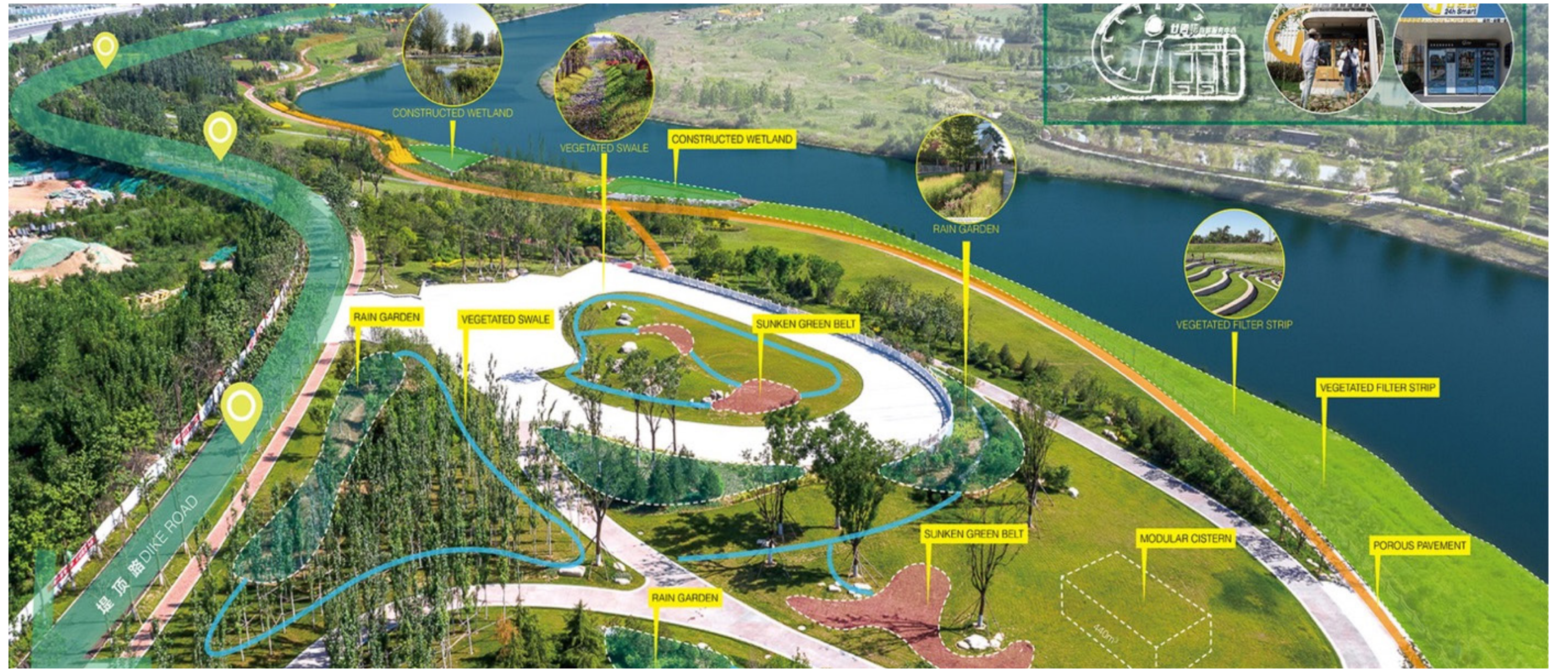


Figure 4.26
Diagram showing BMP and programmatic elements (LILA, 2023).

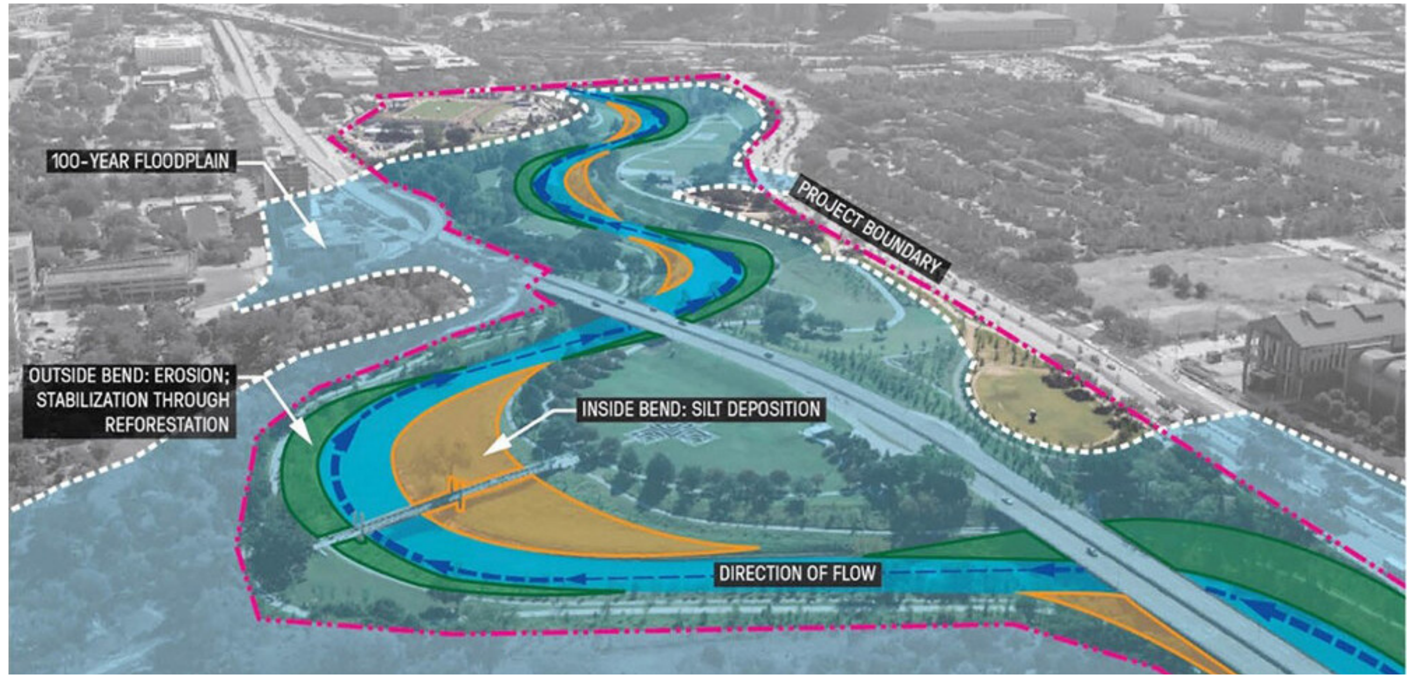


Figure 4.27
Diagram of Site Inventory Characteristics for the Buffalo Bayou (Aman, Amanda, and Yalcin Yildirim, 2019).

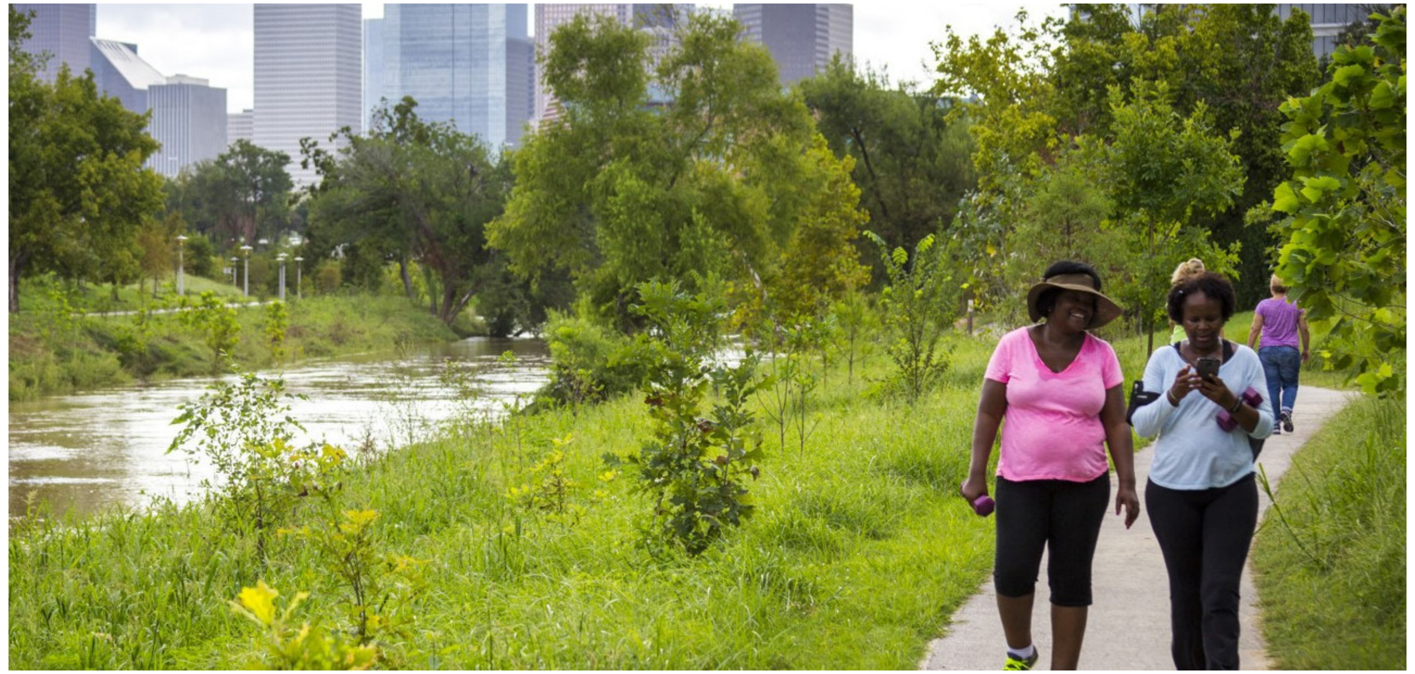


Figure 4.28
Photograph of people walking next to Buffalo Bayou (ULI, 2018).

Figure 4.29
Photograph of Pond entrance at Capitol Federal Sports Complex of Liberty (Sourced from Googe Earth, 2023).

Figure 4.30
Photograph of arbor with vines (Home Depot, 2023).

Figure 4.31
Baseball backstop (American Parks Company, 2023)

05 | Projective Design

Overview

Before a final design was reached, several concepts were produced to display and test relationships between different programmatic elements. The Briarcliff Waterfront District (BWD) was separated into three key areas (The Landing at Briarcliff Apartments and McCrite Plaza, Northern Drainage Corridor, and the Waterwell Athletic Complex) to focus on specific design and BMP applications. Each area holds different challenges and opportunities for design intervention. While looked at separately, the designs of each area include design applications to make the BWD a cohesive, functional waterfront space.

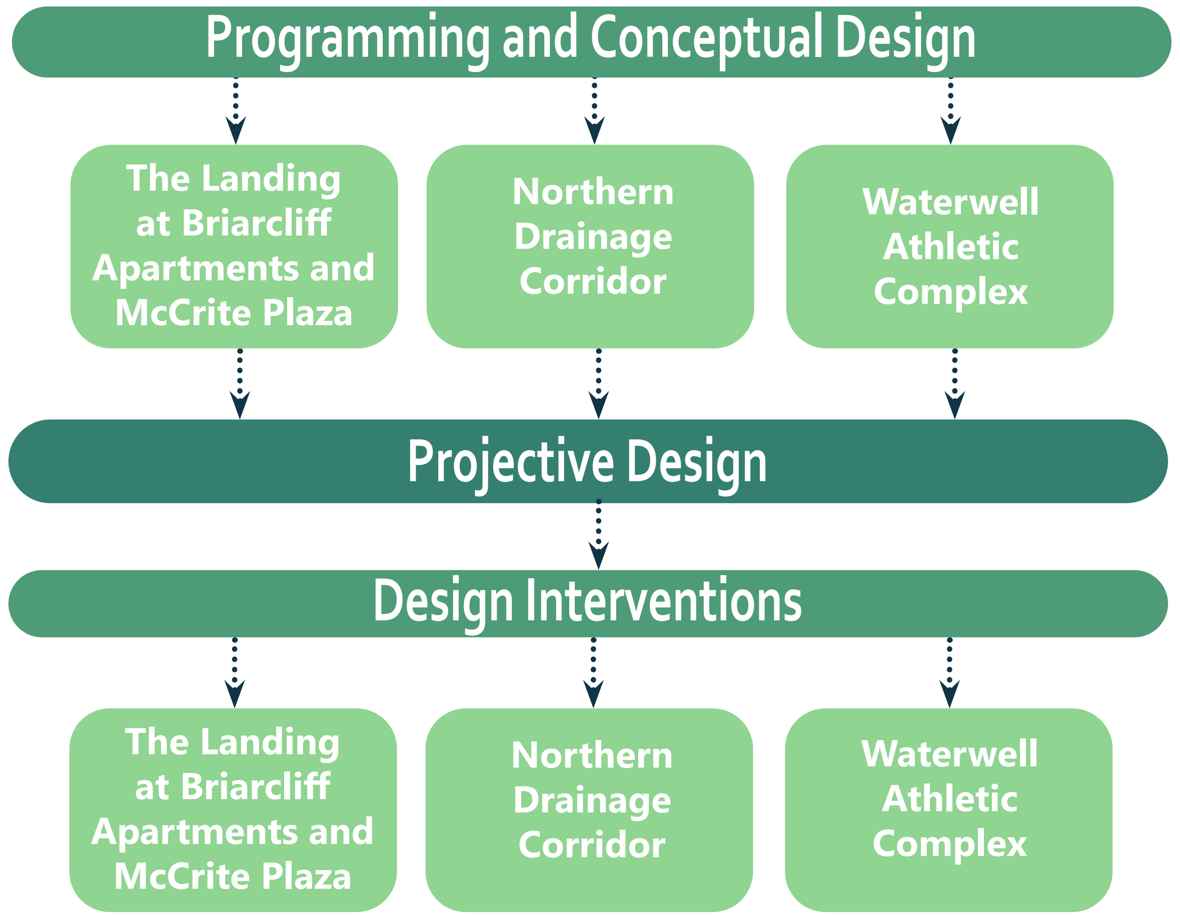


Figure 5.1
Flowchart of Projective Design Chapter (Brizendine, 2023).

Programming and Conceptual Design

Information obtained from the methods and site analysis chapters contribute to the overall design and placement of different programming elements. Understanding the relationships between the different programming elements will create for a functional and enjoyable space, especially in areas with high concentrations of people such as the Landing at Briarcliff and McCrite Plaza. These highly developed areas lack diverse, programmed spaces for their unique residents. Programmed spaces such as community gardens and dog parks are used by the community, however, these spaces are underdeveloped. The majority of the open areas are turf grass lawns in the form of parking islands and side lots which create the opportunity for integrated BGI infrastructure and other usable design features.

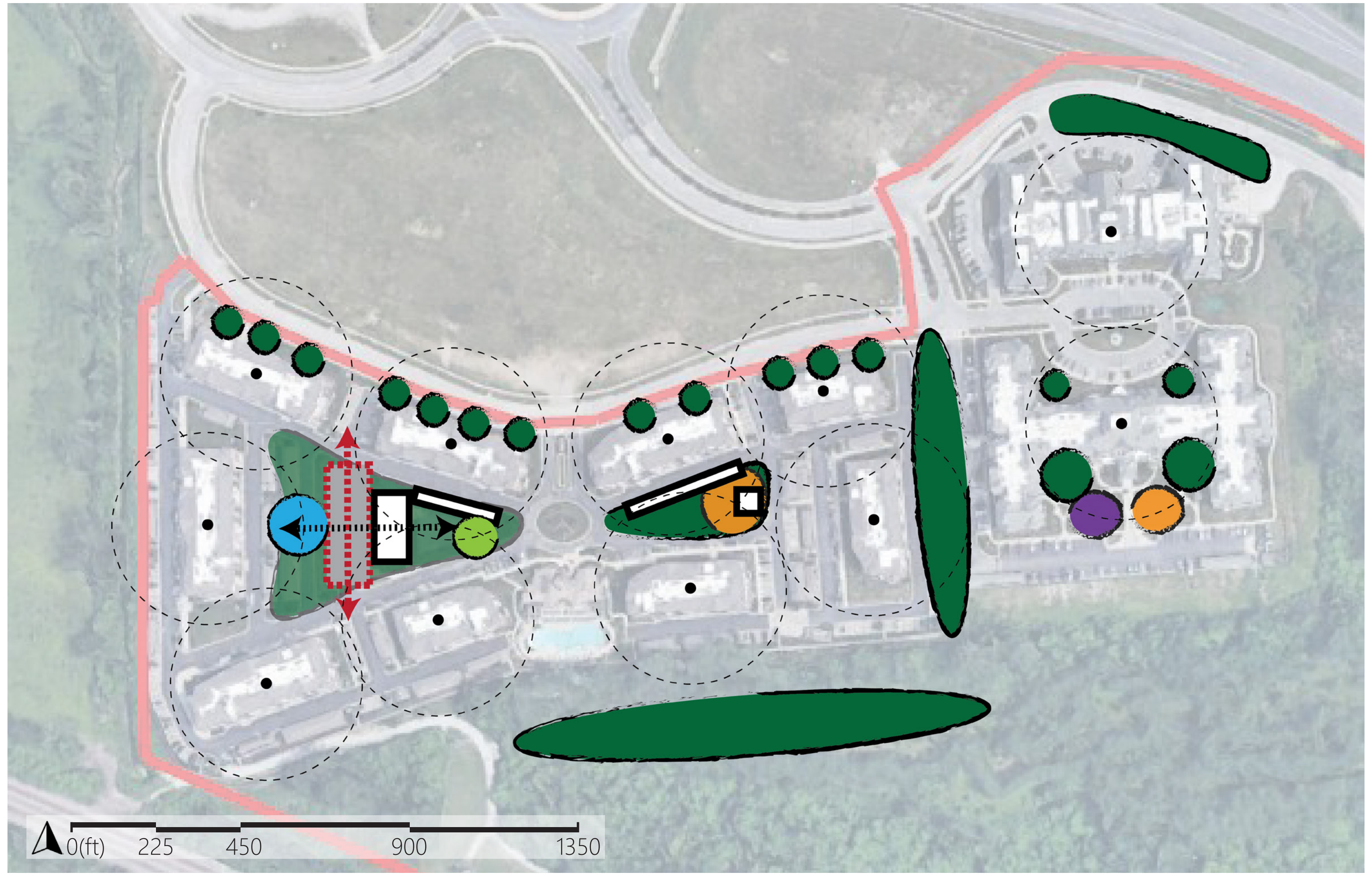


Figure 5.2
Programming and relationship diagram of The Landing at Briarcliff and McCrite Plaza (Brizendine, 2023).

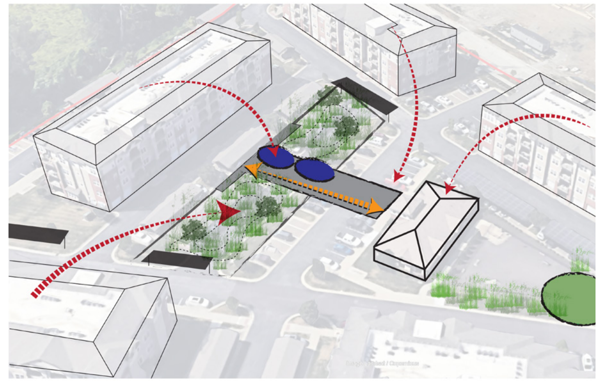


Figure 5.3
Axonometric perspective diagram of progammed space in The Landing at Briarcliff (Brizendine, 2023).

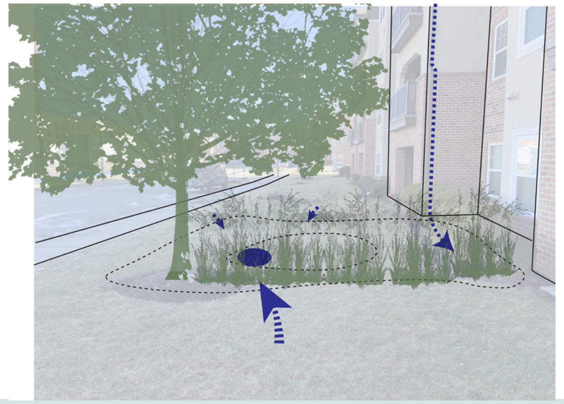


Figure 5.4
Diagrammatic perspective of natural depression at The Landing at Briarcliff and McCrite Plaza (Brizendine, 2023).

Figure 5.5
Programming and relationship diagram of Waterwell Athletic Complex (Brizendine, 2023).

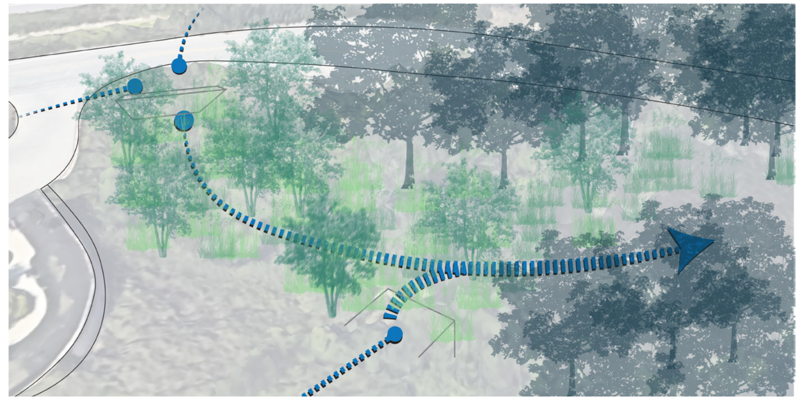


Figure 5.6
Diagrammatic perspective of stormwater flow in the Northern Drainage Basin (Brizendine, 2023).

The north drainage area of the floodplain forest also has opportunity for programmatic elements. However, several characteristics present challenges if the adjacent retirement community is to have access and use of this space. For example, the steep terrain between the two areas may be difficult for some residents. Additionally, the dense vegetation and surfaces create mobility challenges for people looking to use the area.

Emphasizing BMP placement and application in the northern drainage area creates highly effective ways to address stormwater runoff due to the established and mature vegetation. Protecting these well-established plant communities and introducing new plant species that perform well in similar conditions will create a large, effective, and natural stormwater treatment area.

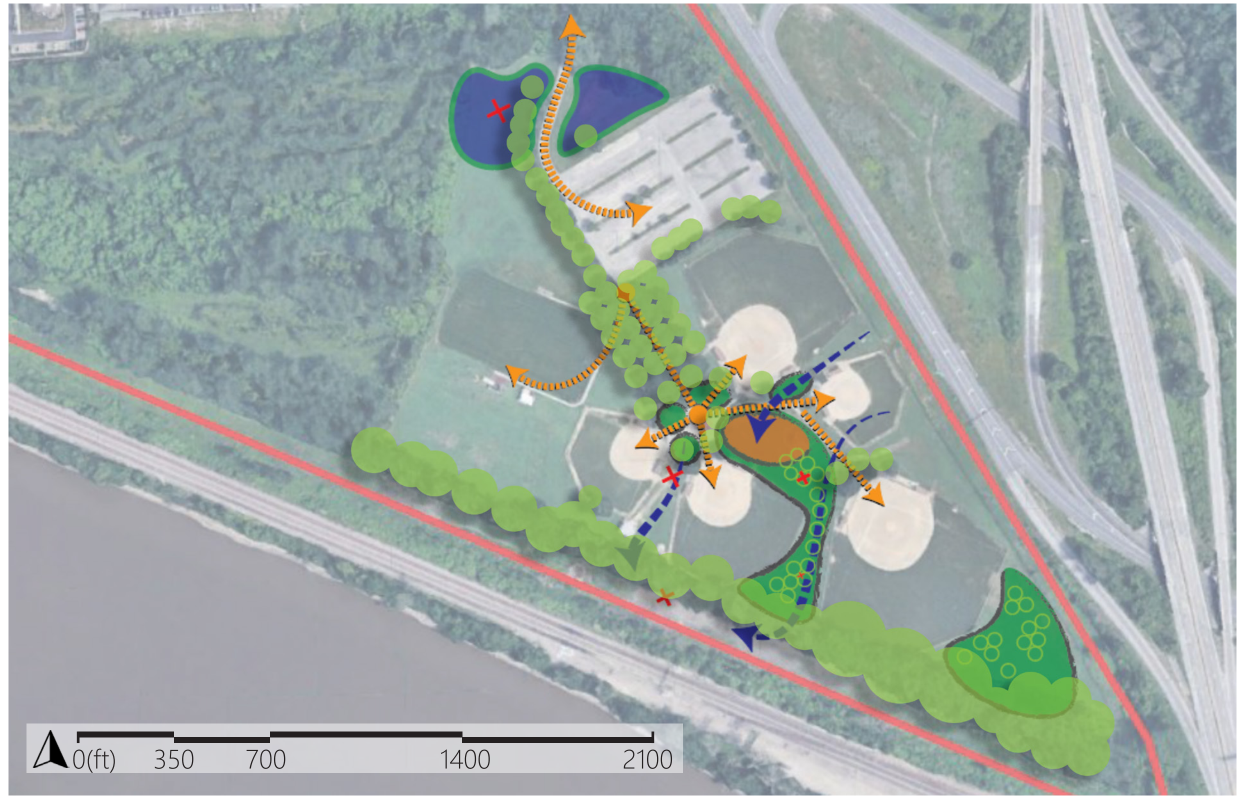


Figure 5.7
Programming and relationship diagram of Waterwell Athletic Complex (Brizendine, 2023).

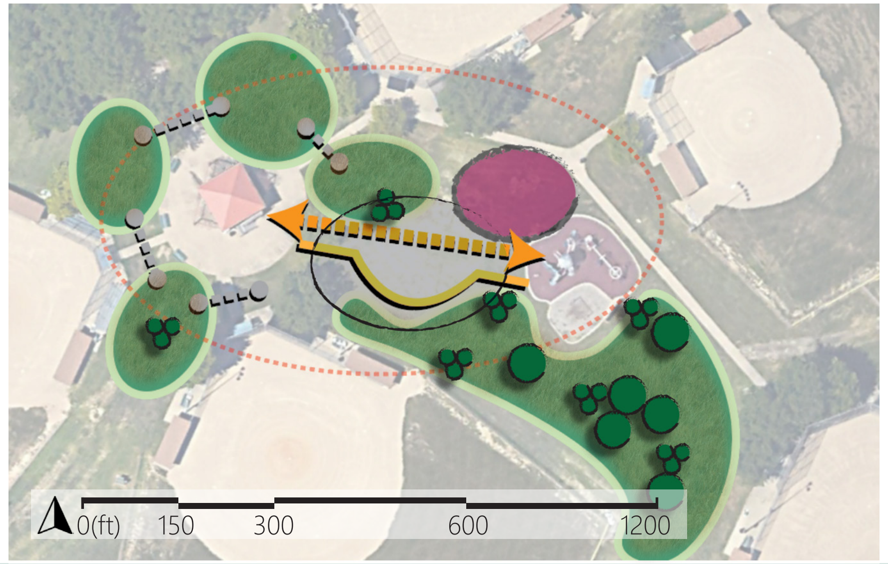


Figure 5.8
Programming and relationship diagram of Waterwell Athletic Complex's primary gathering area (Brizendine, 2023).

The Waterwell Athletic Complex proposes several similar characteristics to the Landing at Briarcliff and the floodplain forest. Pedestrians utilizing the complex for an extended duration currently have few programmed community spaces, while the lack of stormwater management continues to create flooding issues. In addition, several of the open turf grass lawns in the complex are frequently used as warm up fields for upcoming games. Reprogramming these spaces would eliminate valuable warm up time for teams waiting to play. Thus, sufficient practice (warm-up) areas need to be retained.

The design layout of the baseball diamonds focuses most of the pedestrian activity near the concession stand. The natural congregation of people within one space proposes several design opportunities that can be useful to many different ages of users. For example, play areas, benches, tables, and areas for learning about created ecosystems and their functions can all be placed in close proximity so that community members can enjoy them. Natural depressions and drainage ditches provide possible areas for BMPs and enhanced flooding management.

Design Interventions

Design interventions made to the Briarcliff Waterfront District (BWD) incorporate BMPs into public spaces. The Landing at Briarcliff and McCrite Plaza communities are retrofitted with bioswales and rain gardens as these BMPs serve urban areas well. The community areas support of the integration of these BMPs and the enhancement of existing community gardens. The northern drainage way is retrofitted with swales, however, these BMPs focus more on ecological restoration and introduction of new plant species to increase infiltration of stormwater and ecosystem services. Finally, Waterwell Athletic Complex is retrofitted with community gathering areas and infiltration areas that reflect the floodplain forest species.

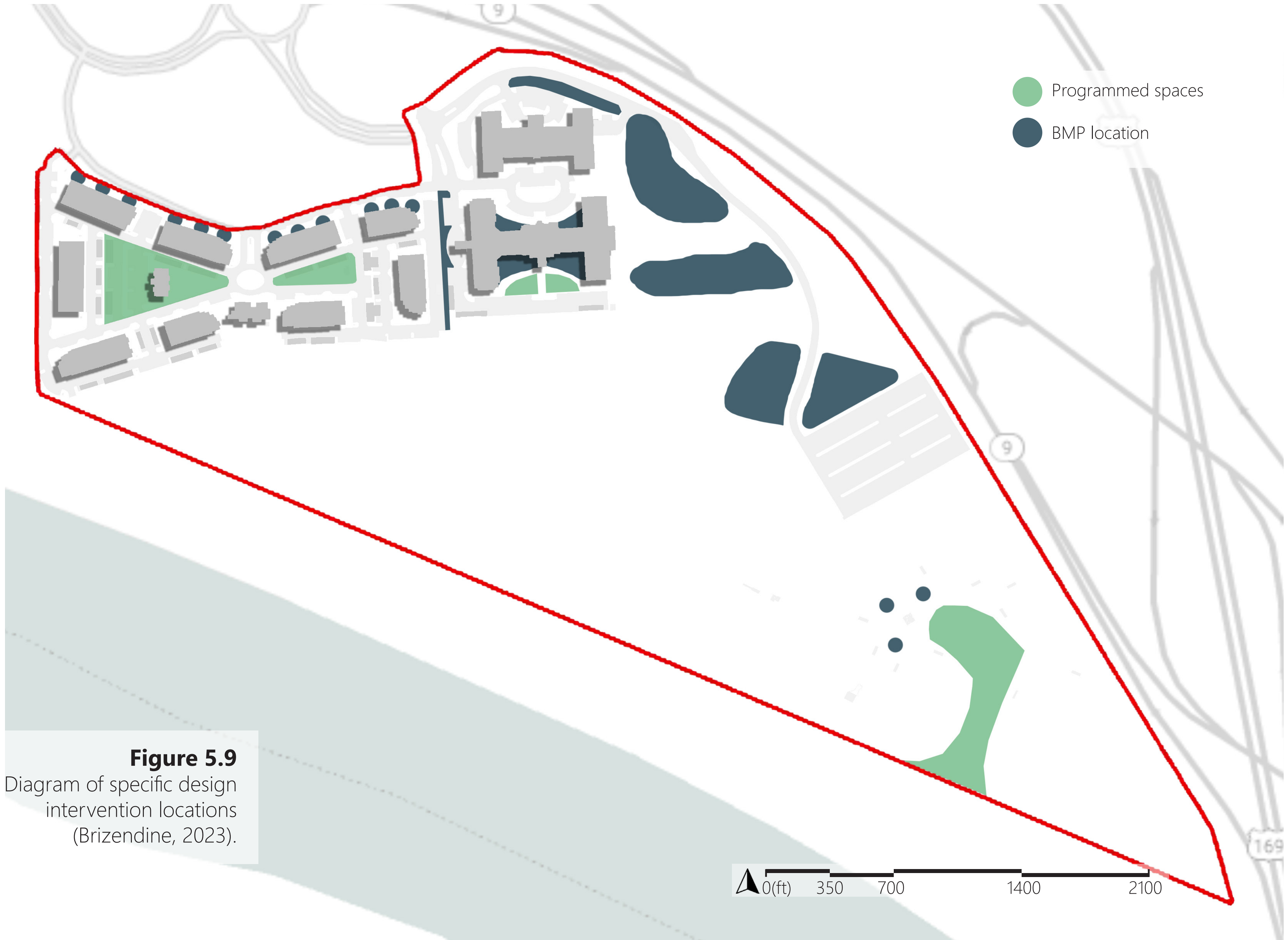


Figure 5.9
Diagram of specific design intervention locations (Brizendine, 2023).

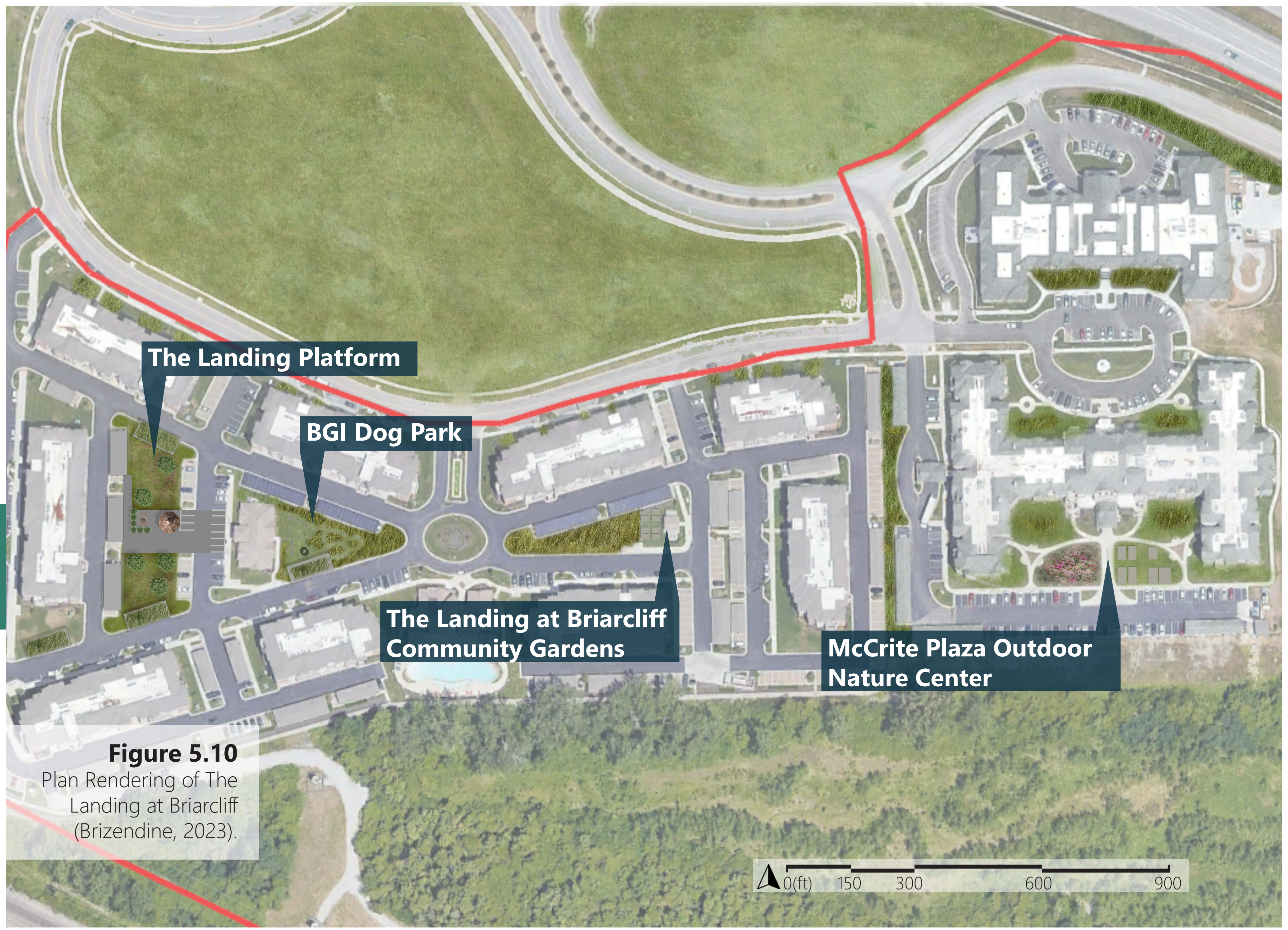


Figure 5.10
Plan Rendering of The Landing at Briarcliff (Brizendine, 2023).

The Landing at Briarcliff and McCrite Plaza Communities

The Landing at Briarcliff and McCrite Plaza Communities are provided with several new and enhanced programed spaces: The Landing Platform, BGI dog park, The Landing at Briarcliff Community Gardens, and the McCrite Plaza Outdoor Nature Center. All of which incorporate usable design elements integrated with BMPs to create more environmentally and user friendly areas. Several other turf grass areas are re-purposed to be rain gardens or bioswales to further increase infiltration.

The Landing Platform is a community gathering space equipped with a fire pit seating area with an outdoor kitchen for small gathering. By replacing the middle drive between existing parking rows, the Landing Platform is able to be equipped with two large rain gardens

Figure 5.11
Zoomed in Plan Rendering of The Landing Platform (Brizendine, 2023).

that manage stormwater from several of the buildings and roads. Plant species for these and other rain garden locations are Butterfly milkweed, Switchgrass, Big Bluestem, Prairie Dropseed, and similar native tallgrass species. Parking spaces that were removed in place of the rain gardens are relocated out to side lots and equipped with green parking structures to reduce runoff and temperature. The extended walk from the recreation center to the end of the The Landing Platform is also comprised of permeable paving that manages stormwater from the surrounding roads and buildings to further increase infiltration.

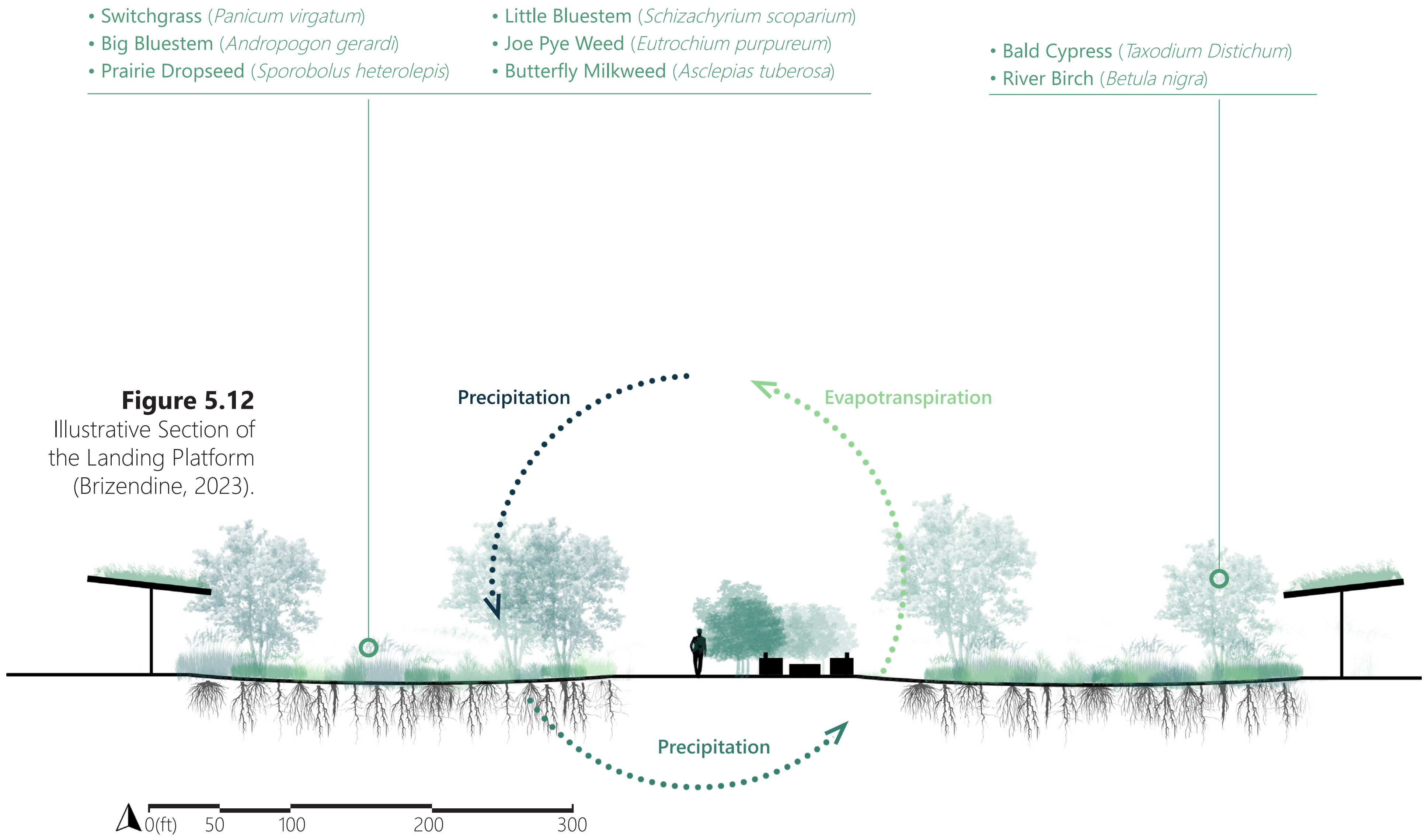


Figure 5.12
Illustrative Section of the Landing Platform (Brizendine, 2023).

Figure 5.13
Site Photograph of recreation facility parking lot and drive (Brizendine, 2023).

Figure 5.14
Perspective Rendering of the Landing Platform (Brizendine, 2023).

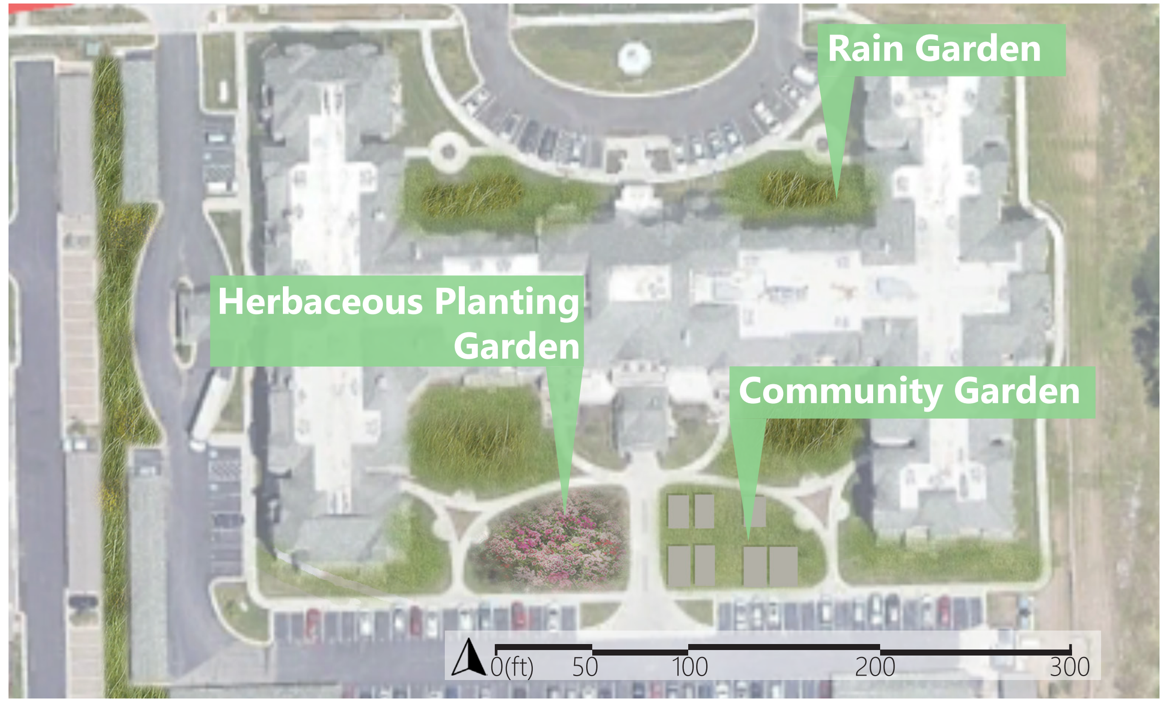


Figure 5.15
Zoomed in Plan Rendering of The McCrite Plaza Outdoor Nature Center (Brizendine, 2023).

The McCrite Plaza Retirement Community also holds programmed spaces aimed primarily for recreational gardening opportunities. The McCrite Plaza Outdoor Nature Center consists of various garden styles such as rain gardens for stormwater management, community gardens, and herbaceous planting gardens to offer recreation and educational opportunities for the residents.

Other areas such as the BGI Dog Park and The Landing at Briarcliff Community Gardens use similar plant species found in nearby rain gardens, however, these plant species are used more as visual buffers and boundaries to create programed spaces. For example, the BGI Dog park uses tall grasses to create a walking maze and boundary for residents and off leash dogs.

Figure 5.16
Site Photograph of south side of McCrite Plaza (Brizendine, 2023).

Figure 5.17
Perspective Rendering of the The McCrite Plaza Outdoor Nature Center (Brizendine, 2023).

Northern Drainage Basin

Focused on ecological restoration, the northern drainage basin consists of introducing mesic and wetland plant species to further increase infiltration of water into existing soils. The basin is currently unmanaged and has several aggressive species such as shrub honeysuckle and cattails. Cattail are important for cleansing polluted water and can be retained, but honeysuckle should be removed and native species planted or seeded in. While some of these species may be native, allowing for species such as River Birch, Bald Cypress, Big Bluestem, Switchgrass and other mesic tree and tallgrass species to grow will allow for greater biodiversity and further deepen plant communities to help with stormwater management.

Topography of the northern drainage basin is very shallow, rarely exceeding a few percent. However, the lowest elevations are near the parking lot of the Waterwell Athletic Park. The increased mesic plant species cleanse polluted runoff of sediment and bacteria before reaching lower elevations.

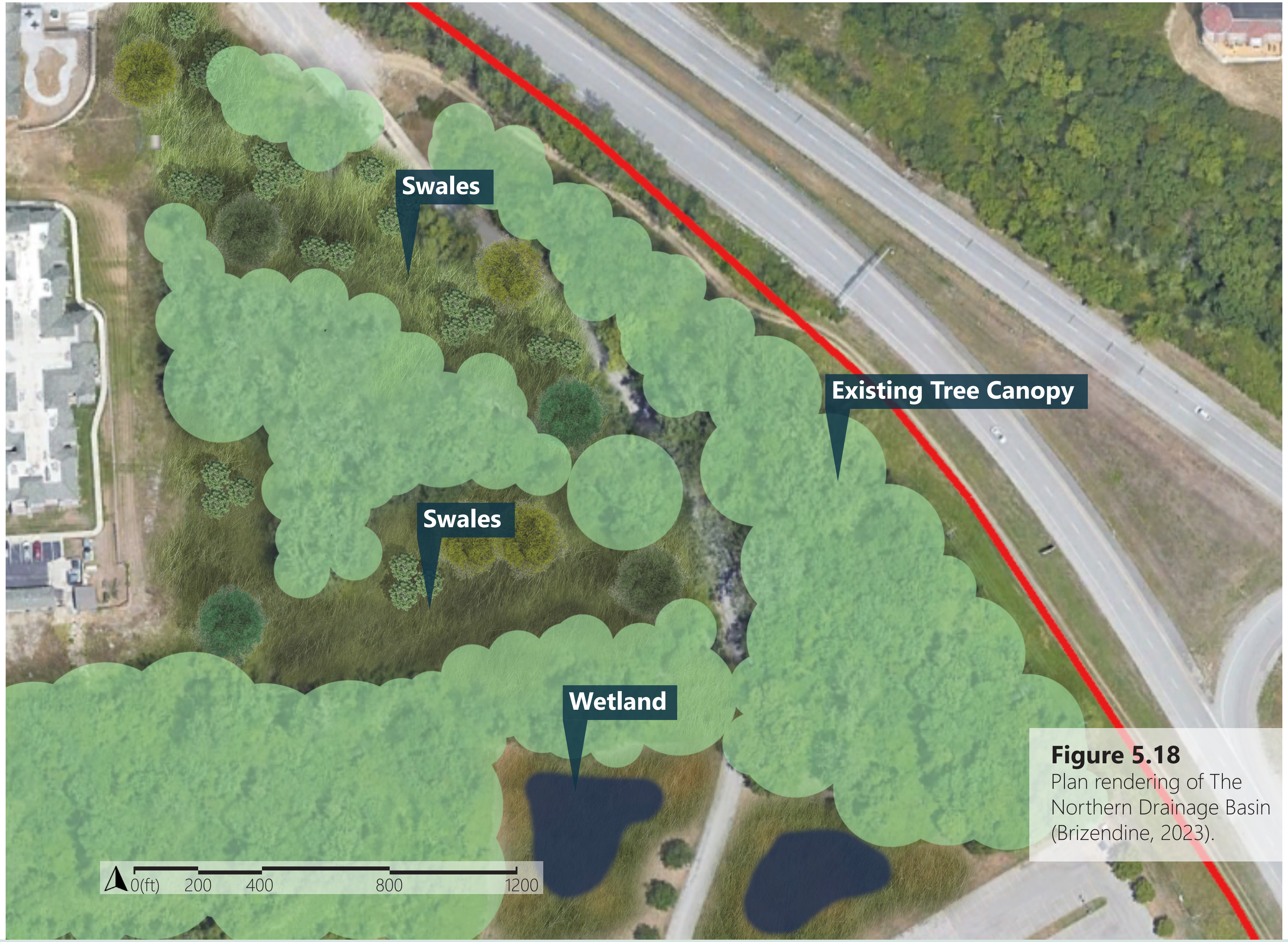


Figure 5.18
Plan rendering of The Northern Drainage Basin (Brizendine, 2023).

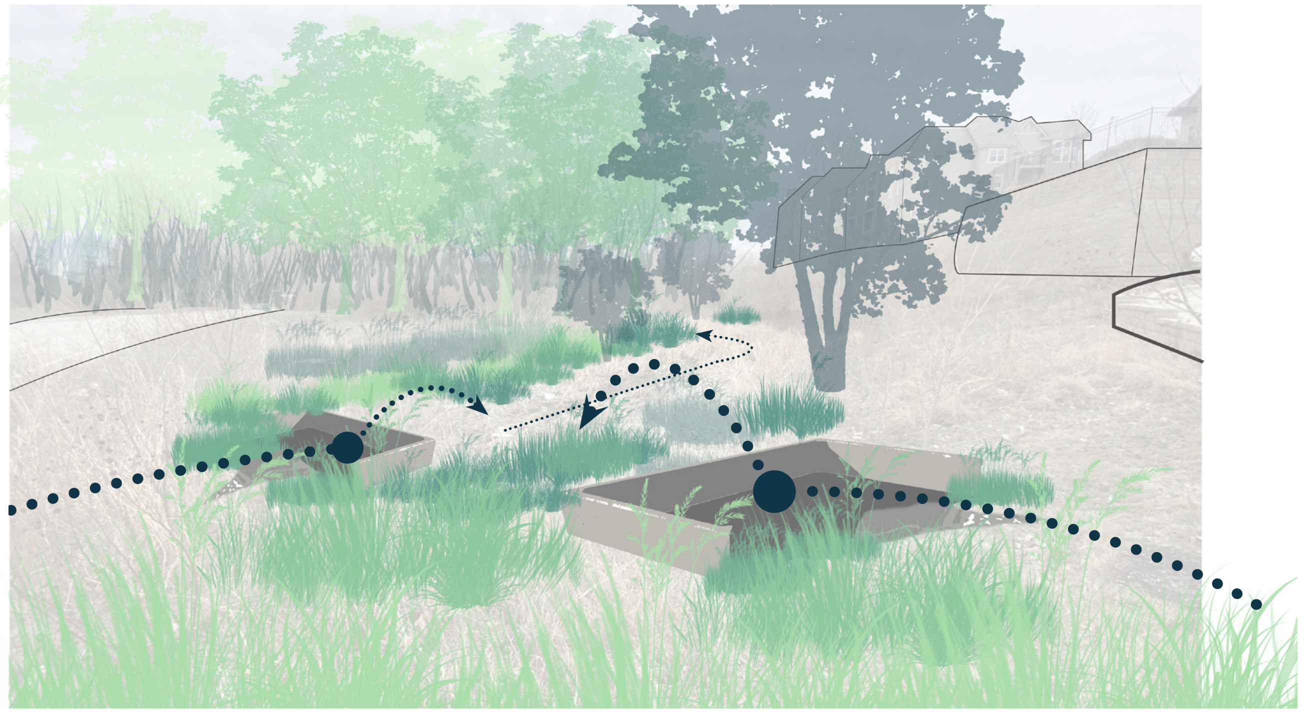


Figure 5.19
Diagrammatic rendering of settling basins and stormwater flow of the Northern Drainage Basin (Brizendine, 2023).

Concrete settling basins are added to stormwater outlet pipes leading into the site. Concrete settling basins, while allowing for no infiltration, can create settling basins for water to reduce run off velocity and large pollutants, reducing erosion. These basins also allow for easy maintenance as sediment and pollutants from the runoff can be easily removed with a backhoe or shovels. Microtopography also creates natural settling basins where introduced plant communities can filter stormwater to allow for clean water for ponds located at the entrance of Waterwell Athletic Complex.

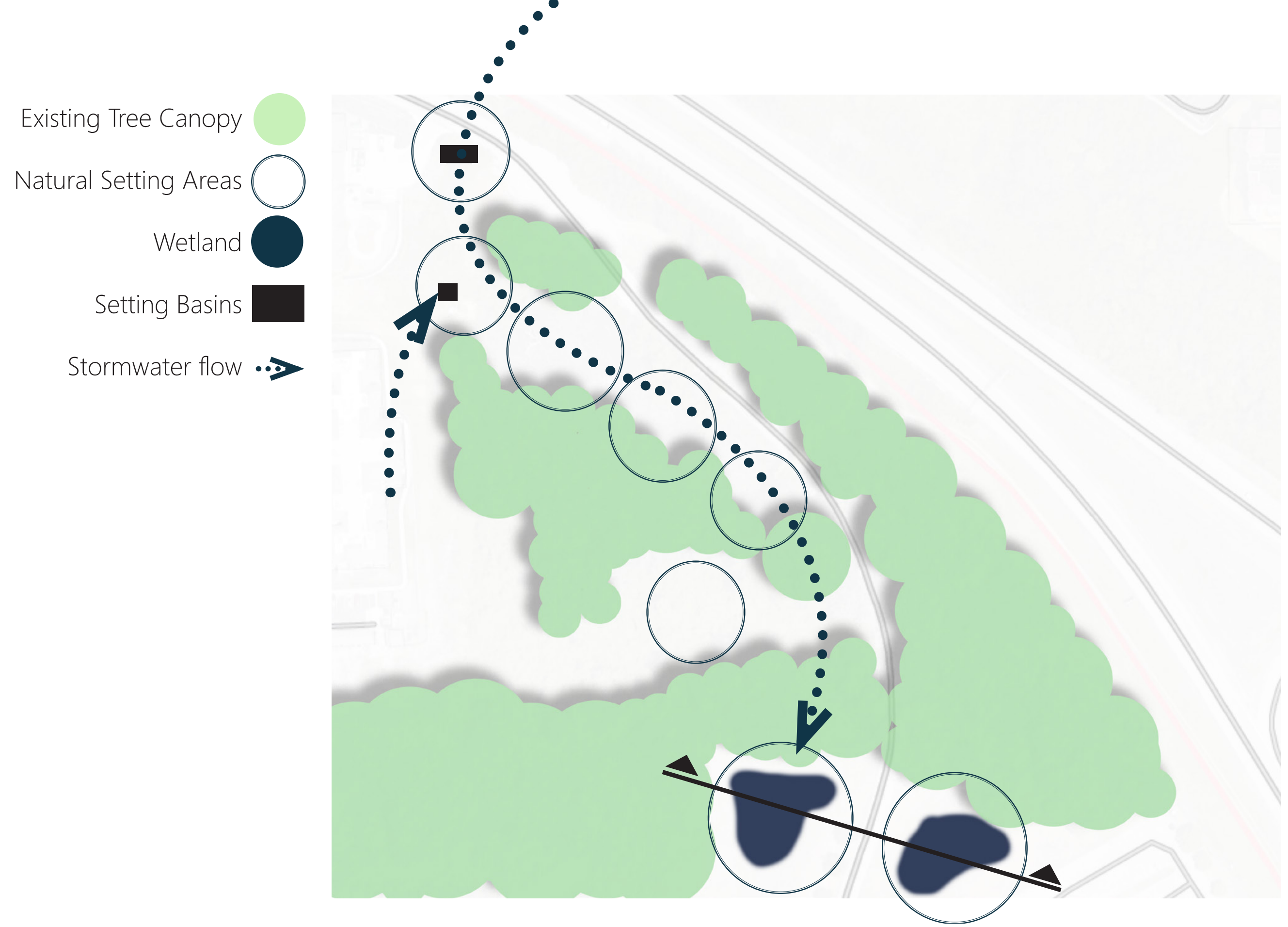


Figure 5.20
Diagram of natural settling basins and stormwater flow of the Northern Drainage Basin (Brizendine, 2023).

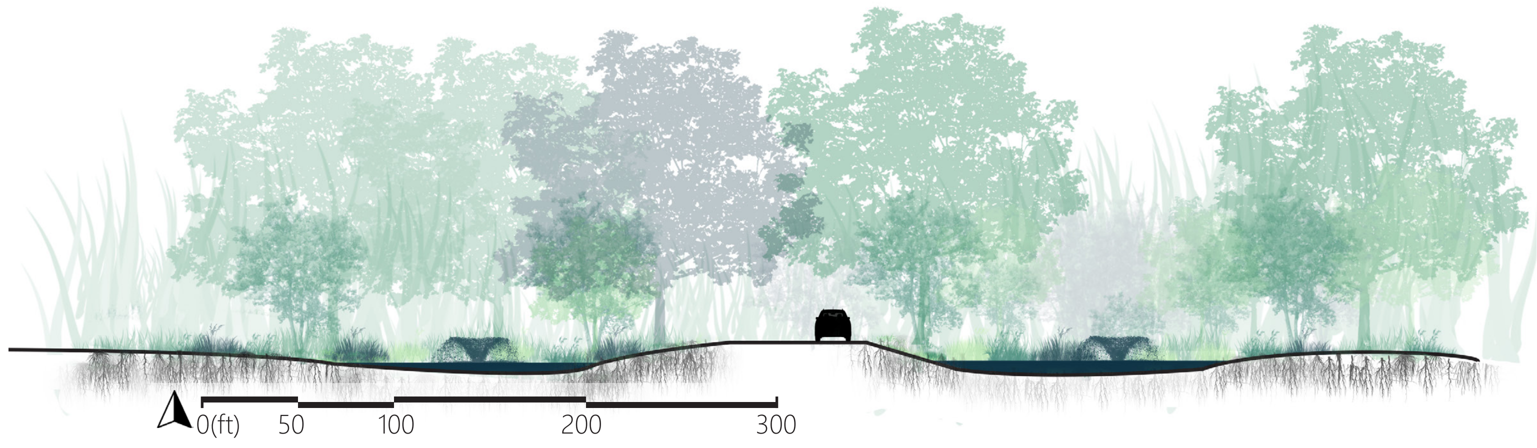


Figure 5.21
Illustrative Section of Waterwell Athletic Complex entrance (Brizendine, 2023).

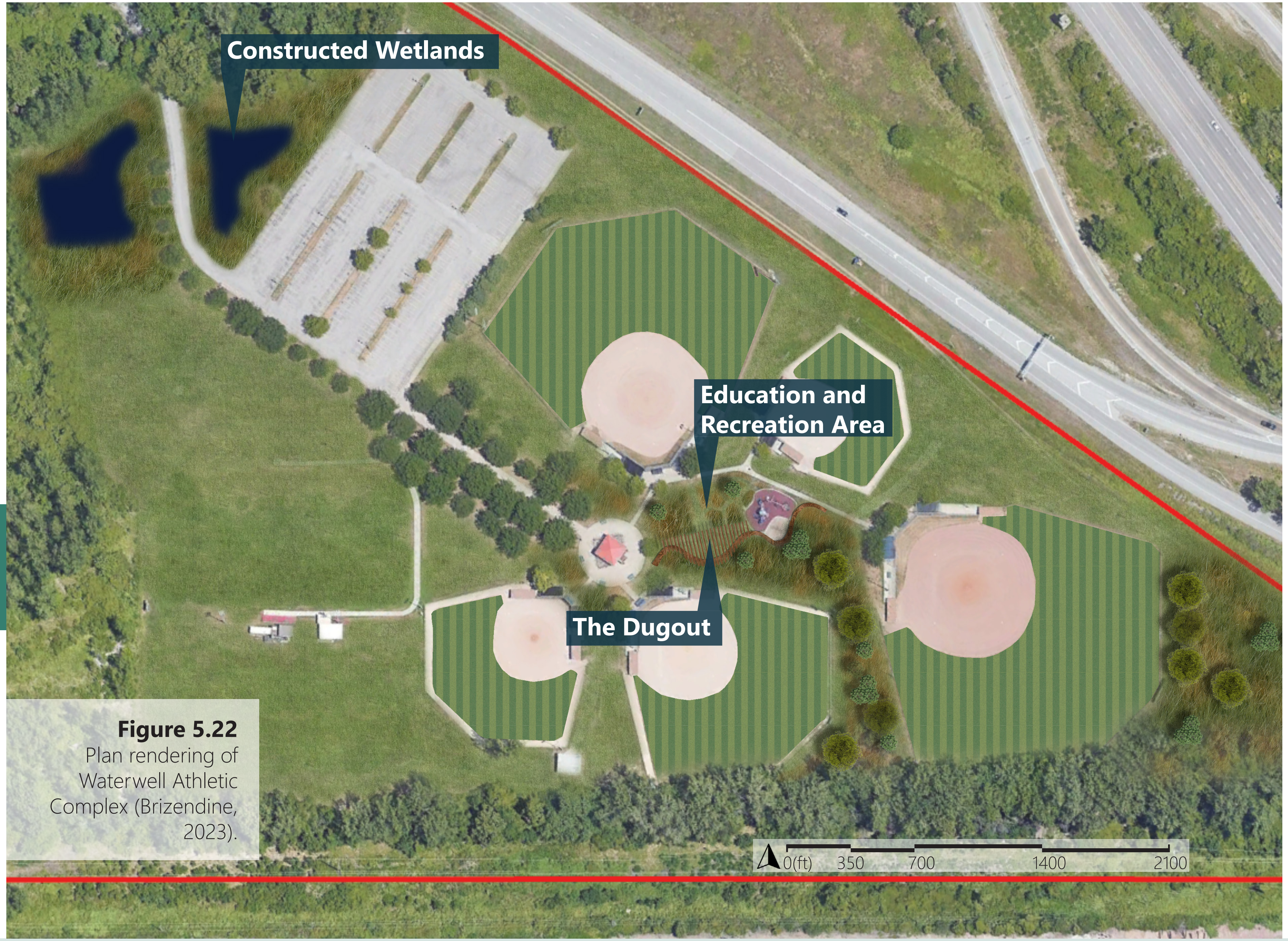


Figure 5.22
Plan rendering of Waterwell Athletic Complex (Brizendine, 2023).

Waterwell Athletic Complex

Comprised of similar design strategies from The Landing at Briarcliff and the northern drainage basin, the Waterwell Athletic Complex uses a combination of urban design and ecological restoration strategies to create a more diversely programmed athletic complex. Visitors are first greeted by wetland ponds that have been treated by the northern drainage basin, providing clean water for wildlife. The primary congregation space around the concessions stand is equipped with similar plant species found in the floodplain forest such as native tall grass species, American Sycamore, tree and shrub forms of willow, silky and red-osier dogwood, and Eastern Cottonwood to reclaim some of the lost floodplain.

Additionally, a gathering space, named the Dugout, is a low impact, educational and recreational area that can be enjoyed by a range of users. A vegetative cantilever overhang protects users from foul balls while providing an immersive experience with an educational rain garden and extended play space for the nearby playground, shown in Figure 5.23 and 5.24.

Additional areas, such as the educational Infiltration basin, provide an educational experience through signage to educate users about the need for increased BGI. Adjacent to the existing playground, and additional tallgrass prairie/meadow recreational field can be used by pets and small children as a trail with several possible experiences.

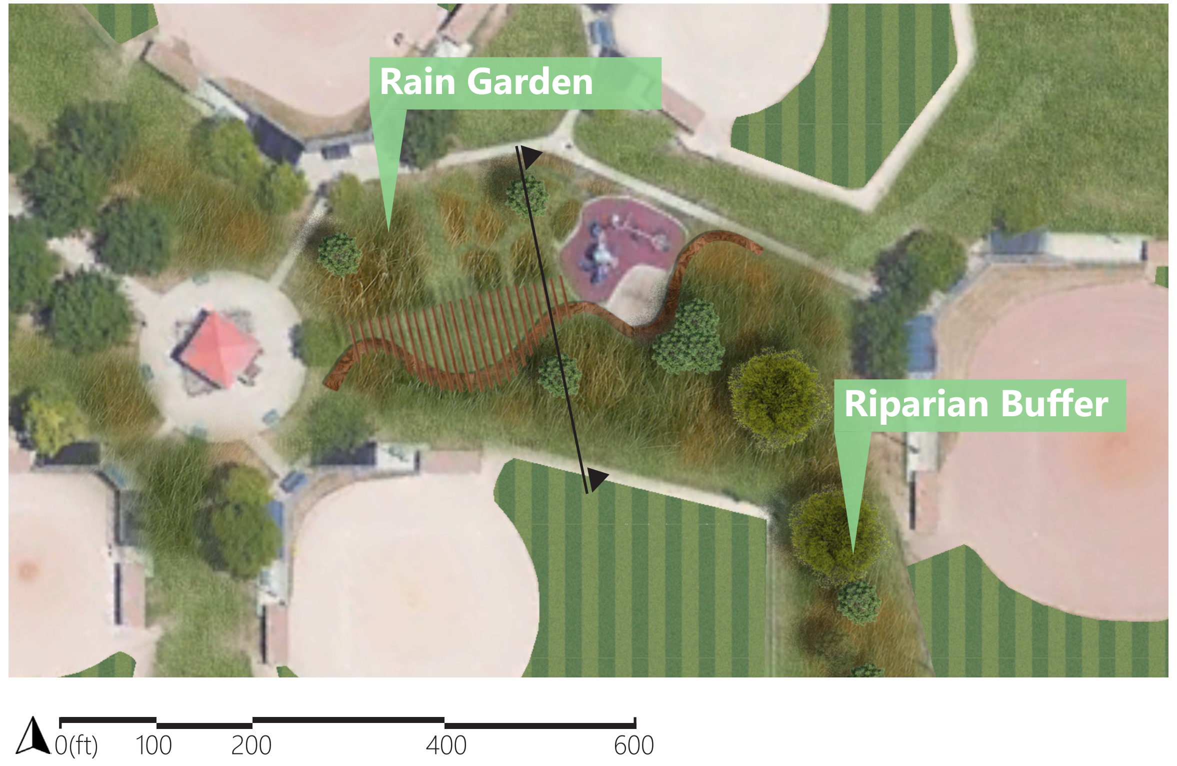


Figure 5.23
Zoomed in plan rendering of The Dugout (Brizendine, 2023).

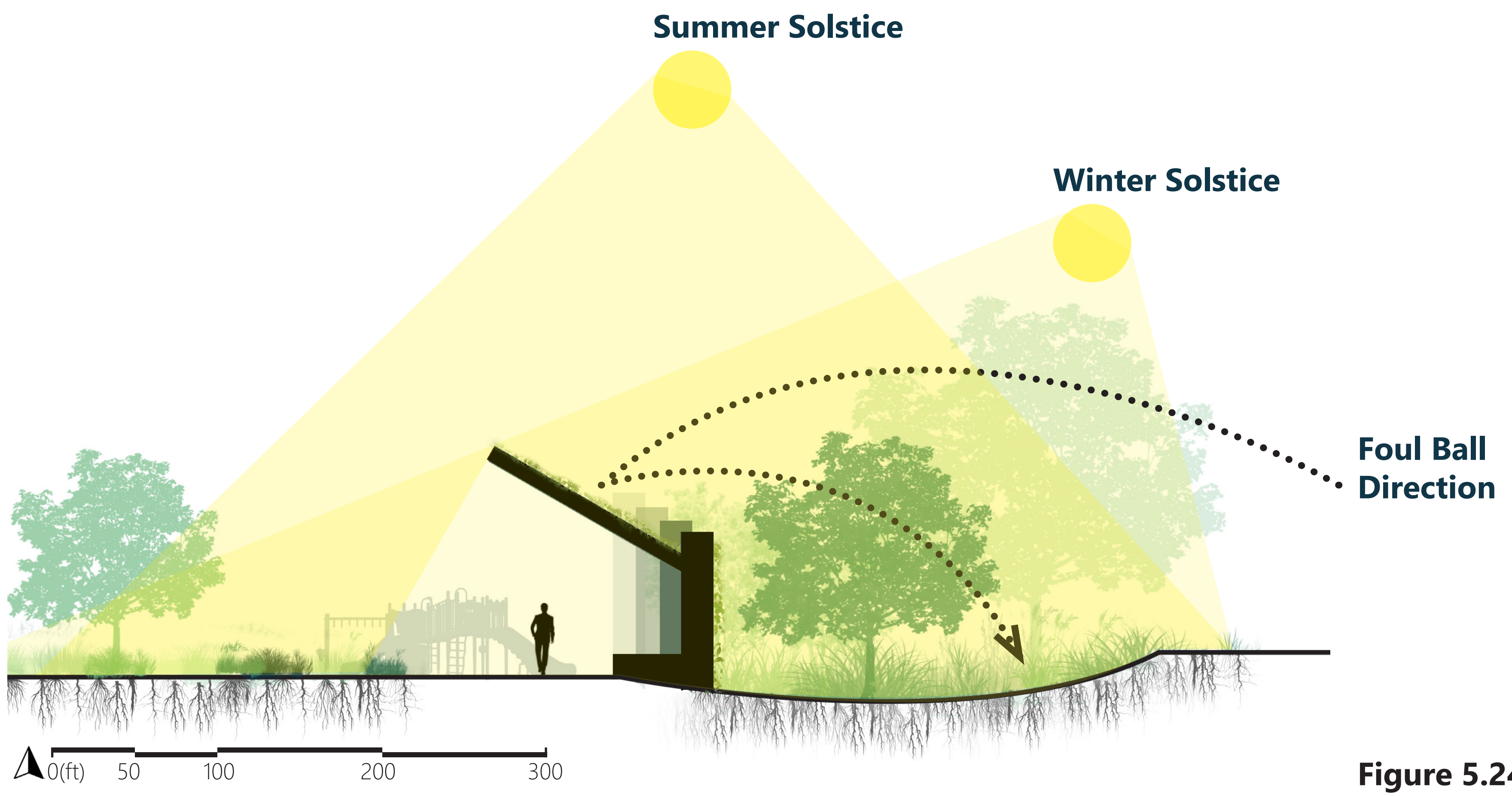


Figure 5.24
Illustrative section of the dugout (Brizendine, 2023).

Figure 5.25
Photograph of center of Waterwell Athletic Complex (Brizendine, 2023).

Figure 5.26
Perspective rendering of the Dugout (Brizendine, 2023).

06 | Conclusion

Conclusion

In conclusion, studying BMPs systematically through matrices and precedent analysis resulted in information that directly influenced decision making in the projective design. The projective design of the Briarcliff Waterfront District (BWD) reflects a more ecologically and community friendly development. The increase in stormwater infiltration using BMPs replace or enhance the existing grey stormwater infrastructure to reflect a more low impact development.

The diverse characteristics of the BWD allow the comprehensive matrix and precedent analysis to perform extensively through the projective design. Using matrices and precedent analysis to influence the design decisions are important as these systematic ways allow for a functional design within the unique characteristics on site. However, selecting BMPs is an extensive process that requires multiple disciplines. Each requirement and characteristic related to the site and the typology need to carefully analyzed for the best possible performance.

Limitations revolved around time constraints, access to confidential development documents, and more in-depth methods. Access to past developments and construction documents were not available that could provide key information and influence the projective design. A more in-depth matrix with extensive selection criteria and additional more precedent analysis could result in a more functional and meaningful design. However, these were not included in the final report due to limited time.

Key Challenges regarding the development of the project were primarily met during research and the site inventory process. Much of the literature regarding “Blue-Green Infrastructure” is overshadowed by “Green Infrastructure” that is focused strictly on stormwater management. Therefore there is knowledge gap on the awareness on how BMPs address fluvial flooding.

Similar challenges that were faced are related to obtaining basic site information of the Landing at Briarcliff and McCrite Plaza communities. Storm sewer locations, storm pipes, outfall locations, and topography were not available through GIS data or through the city. Therefore, difficulty increased when moving into site analysis and the projective design. Another limitation was accessing the whole site. Being heavily wooded and over grown in several areas, the floodplain forest was difficult to access. Google Earth and other aerial imaging were used to determine vegetation density, however, these aerial images were not of the current site conditions, only recent years prior.

Future Research of the benefits of BGI typologies are crucial as flooding continues to negatively impact vulnerable communities, such as the Riverside and Parkville areas of Kansas City, Missouri. The current levee system that lines most of the Missouri River in Kansas City restricts natural flooding process that can be important for nearby ecosystems. Likewise, areas not protected by the levee, such as the BWD, are at a much higher flooding risk. Restricting the flooding process and repurposing floodplains allows for much higher flooding frequency, durations, and load. This exponentially increases cost and maintenance for flood and stormwater management. Therefore, new flood protection strategies that incorporate BGI can significantly reduce the risk of flood and flood damage, thus reducing damage costs.

Site suitability matrices also have opportunity for further research as there are few matrices in the literature that graphically relate BMPs to specific site conditions. The matrices used within the study, while similar in information, display that information in different ways. Additionally, these matrices sometimes possess different information regarding the relationships between BMPs and specific selection criteria. Therefore, it is important to study BMPs locally to ensure that climactic, economical, and developmental impacts that impact BMP development are similar to the selected area.

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