ABSTRACT

Title of Thesis:	FLOOD THE SWAMP; HOW CAN URBAN WETLANDS FUNCTION SYMBIOTICALLY WITH URBAN ENVIRONMENTS?
	Erin Kremer, Master of Landscape Architecture, 2026
Thesis Directed By:	Professor, Dr. Byoung-Suk Kweon, Landscape Architecture

This thesis explores methods for designing urban wetlands that assimilate into urban fabric, with a theoretical design in Washington D.C. Continual urbanization increases stress on urban environments, and urban wetlands represent a potential green infrastructure solution — though they often feel out of sync with existing urban fabric. Beyond expanding green space and biodiversity, wetlands provide ecosystem services with clear economic benefits, including water filtration, flood mitigation, and reduced strain on stormwater systems. Better-designed urban wetlands will be more readily accepted and cared for, allowing communities to fully benefit from their services.

A theoretical site was selected using environmental and community criteria, then analyzed through GIS mapping, historical research, and site observations. The final design identifies six key methods for creating cohesive urban wetlands: providing green space, creating sustainable water systems, defining human/nature interaction, balancing man-made materials, providing

visitor education, and controlling created systems. These methods can guide future urban wetland designs.

FLOOD THE SWAMP

HOW CAN URBAN WETLANDS FUNCTION SYMBIOTICALLY WITH URBAN ENVIRONMENTS?

by

Erin Noelle Kremer

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
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Advisory Committee:
Dr. Byoung-Suk Kweon, Chair
Dr. Christopher Ellis
Dr. Andrew Baldwin

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List of Abbreviations

1. **LSM**: Landscape-based Stormwater Management
2. **NBS**: Nature Based Solutions
3. **CSS**: Combined Sewer System

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Chapter 1: Introduction

This Master of Landscape Architecture thesis study will address the question of if and how wetlands can function symbiotically with urban environments. This will be broken down into two main questions. The first question – in what ways can urban wetlands be used to address a plethora of issues facing urban environments? – will give reasoning to why urban environments would benefit from wetlands. Wetlands provide many ecosystem benefits, such as reducing flooding risks, filtering water, and providing green patches within the city (*Urban Wetland Design Guide*, n.d.). These functions address many urban problems, such as flash flooding, contaminated water supplies, and urban heat. Locating wetlands throughout urban areas facing these problems would be a sustainable way of addressing multiple of these issues on one site with green infrastructure. The second question – how can wetlands be designed to better fit within the urban fabric? – will address the other side of the equation, regarding how urban environments can support wetlands. Wetlands are very important, niche habitats, which provide a wide range of ecosystem benefits, as discussed above. They have also been rapidly destroyed around the world due to need for large plots of land, with very specific design requirements (Craft, 2022). The specificity of wetland design, paired with the harshness of urban environments, makes the creation of urban wetlands difficult. Urban environments require the community to establish a sense of place within the site, so as to promote upkeep and respect of the site. Thus, this paper will attempt to address ways in which an urban wetland can be designed to promote this care.

As the planet continues to urbanize, finding sustainable ways of creating cooler, safer, and more pleasant cities is of the utmost importance. One avenue for this is by protecting land in urban areas for sustainable development and green infrastructure before all the land is rapidly densified. If these potential green infrastructure lots are not quickly protected, cities will become incapable of supporting the continuing influx of people, while sustaining basic levels of quality of living.

In order to find potential solutions to these questions, this thesis will explore larger infrastructure systems related to urban stormwater, the benefits and restrictions of various wetlands types, and the importance of specific site and design considerations in the creation of urban wetland parks. This research, carried out with the help of specific case studies, will then be used to create an initial set of design programs to guide the final design. This process, of creating design programs, will be repeated after gathering further information from site context research, historical examination, and site analysis, before creating four overarching design goals for the theoretical final design. This design aims to test the feasibility and bring awareness to the possibilities of urban wetland parks. By doing this, the field of Landscape Architecture, as well as many others, will be able to create more productive wetland systems in areas where wetlands are few and far between.

Chapter 2: Literature Review

This section of the paper will address background information and relevant theories which impact the construction of urban wetlands. This research will encompass existing stormwater management in urban environments, defining wetlands, investigating constructed and urban wetlands, creating urban wetlands, and reviewing urban design principles. Using the information gathered, three case studies were selected to further investigate the practical use of this information in urban wetland design.

Stormwater Management in Urban Environments

Urban Environments are not a clearly defined phenomenon, as environments rarely are. The line between urban, suburban and rural is often undefined. For this thesis, the definition of Urban Environments will be determined by Merriam Webster's definitions. Urban is defined as "of, relating to, characteristic of, or constituting a city" (Merriam-Webster: America's Most Trusted Dictionary, n.d.). Environment is defined as "the circumstances, objects, or conditions by which one is surrounded: the factors and influences that affect the growth, health, progress, functioning, etc., of someone or something" (Merriam-Webster: America's Most Trusted Dictionary, n.d.). Based upon these definitions, an Urban Environment is the circumstances, objects, or conditions constituting a city.

This definition, however, does little to quantify the characteristics of an urban environment and the necessary density within that environment. The 2020 United States Census determined urban areas to "encompass at least 2,000 housing units or have a population of at least 5,000" (US Census Bureau, n.d.). This paper will also account for the 2020 census criteria when referring to urban environments. Furthermore, moving forward, this paper will focus on densely urban locations that have regular pedestrian day to day activity.

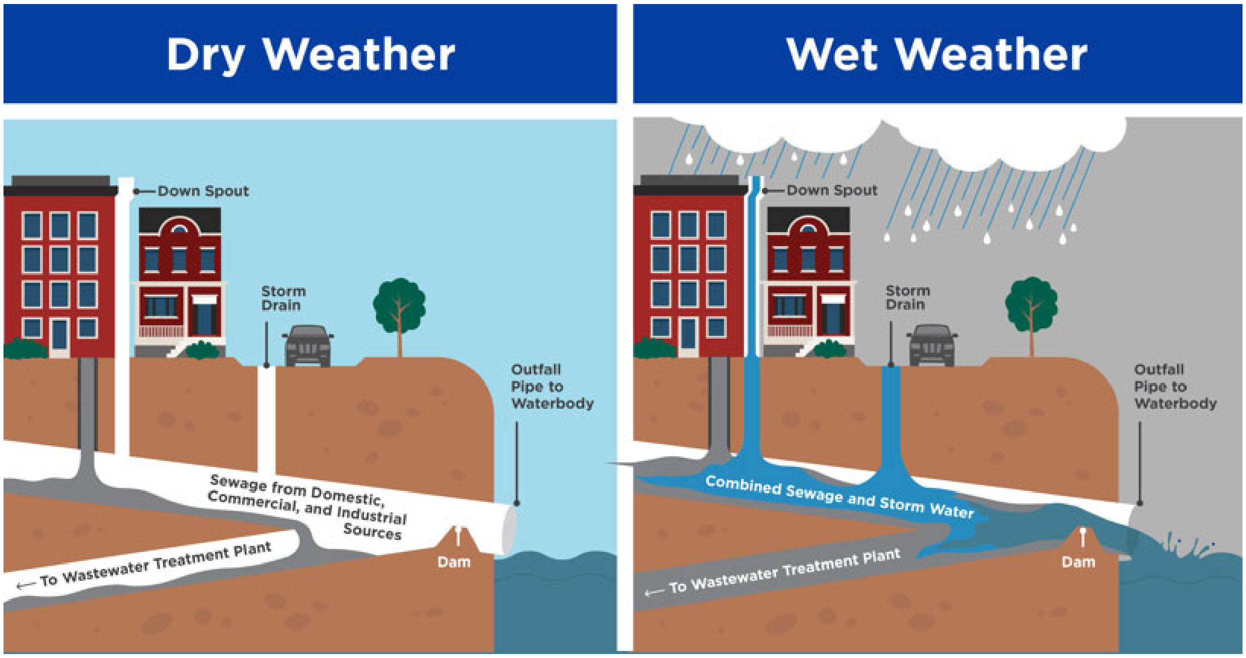

Figure 1: Combined Sewer System diagram (Photo Cred: RVA H20)

With more and more of the world's population moving to urban areas (US Census Bureau, n.d.), the problems of urban environments will continue to worsen if nothing is done. Food and water insecurity, damage to infrastructure, economic disruptions, and poverty, are just some of the issues predicted to increase in urban areas with the worsening state of the climate (Gasper et al., 2011). Focusing on how to remedy these problems and create healthier urban environments is of the utmost importance for the urbanizing world.

One of the largest problems facing cities includes those of stormwater, like pollution, sewage, and flooding. A singular facet of this issue is that the runoff from urban environments, which is usually higher than in natural environments, tends to be higher in pollution loads (*Urban Wetlands | Urban Green-Blue Grids*, n.d.). Additionally, many older cities dealt with sewage by pumping into local waterways with Combined Sewer Systems (See Figure 1). This infrastructure, often underground, is difficult and expensive to remedy. To prevent overflows of sewage into local water bodies, the EPA suggests finding ways to divert runoff and stormwater from entering the sewer systems (US EPA, 2023). Finally, in a world with rising sea levels and worsening storms, flooding is a more pressing issue than ever. Most cities are predominantly impermeable, leaving nowhere for the water to go but into sewer systems which are only equipped to handle so much water before it backs up and floods low lying areas of cities.

Defining Wetlands

Wetlands, according to Christopher Craft (2022), are the lands between aquatic and terrestrial ecosystems. There are many types of wetlands, each with distinctive characteristics. However, regardless of type, all wetlands are saturated or shallowly inundated for prolonged periods of time. This inundation creates very specific soils and flora that can help identify them (Craft, 2022). Additionally, wetlands can be distinguished based on shape, size, and location. Regardless of these unique characteristics, all wetlands create substantial benefits to the surrounding ecosystem.

These benefits are often termed as ecosystem services; the systems provided by natural environments and elements that assist in human functions. As wetlands provide many ecosystem services, many ecologists, landscape architects, and environmental engineers have begun to view wetlands as a potential Nature Based Solution (NBS) (Thorslund et al., 2017). Generally recognized benefits of wetlands include improved water quality, flood regulation, improved groundwater and soil, in addition to sequestering carbon, creating biodiversity, and providing green space (Thorslund et al., 2017).

These benefits are becoming fewer and further between. Significant portions of the world have lost massive amounts of wetlands since the 1700's (Fluet-Chouinard et al., 2023). Much of this loss has occurred in densely habituated regions, such as Western Europe, East Asia, and the Eastern United States (See Figure 2.)

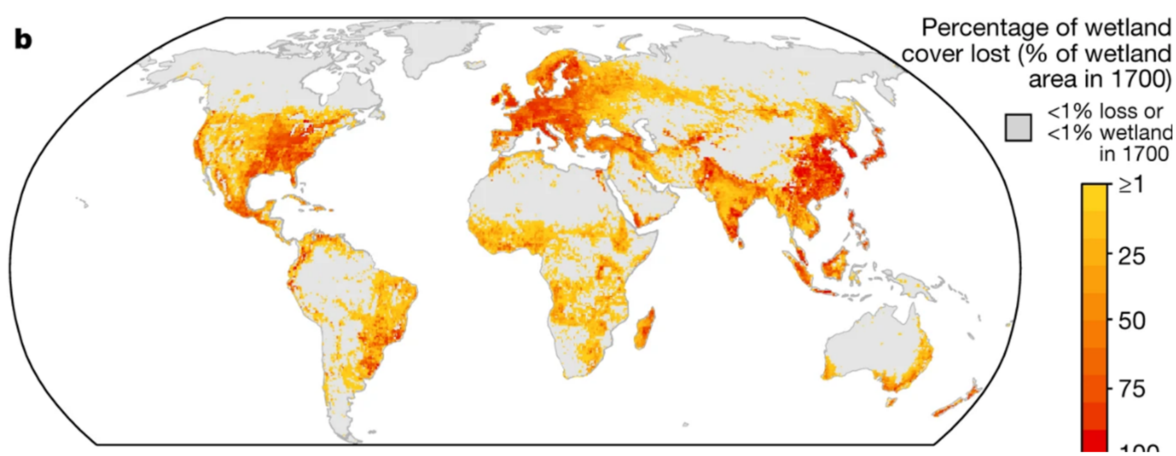

Figure 2: Graph depicting areas with varying levels of wetland loss (Photo Cred: Chouinard et al.)

Constructed and Urban Wetlands

Urban Wetlands differ from other wetlands most predominantly because they exist “inside and around urban areas and their suburbs” (Alikhani et al., 2021, p. 4). While urban and non-urban wetlands share many similarities, the unique challenges urban wetlands face sets them apart. Specifically, urban wetlands experience more drastic alterations in their hydrology, “especially the magnitude and timing of inundation driven by runoff from impervious surfaces” (Craft, 2022, p. 379). Additionally, urban areas often produce more harsh chemicals, such as heavy metals, hydrocarbons, and pharmaceutical products, which flow into the wetlands (Craft, 2022). Urban wetlands also need to exist in smaller footprints, appeal to human desires for organization, and have fewer insects such as mosquitoes (Craft, 2022).

Constructed wetlands are “treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality (US EPA, 2015, para 1).” They allow humans to harness the benefits of wetlands, generally for the benefit of cleaning water, in controlled locations. They can also be bolstered in any number of ways to combat certain difficulties, like higher pollution loads or erosion. Most constructed wetlands, however, are designed specifically for water treatment purposes, and often overlook considerations of pedestrian human interactions or aesthetic appeal.

Creating Urban Wetlands

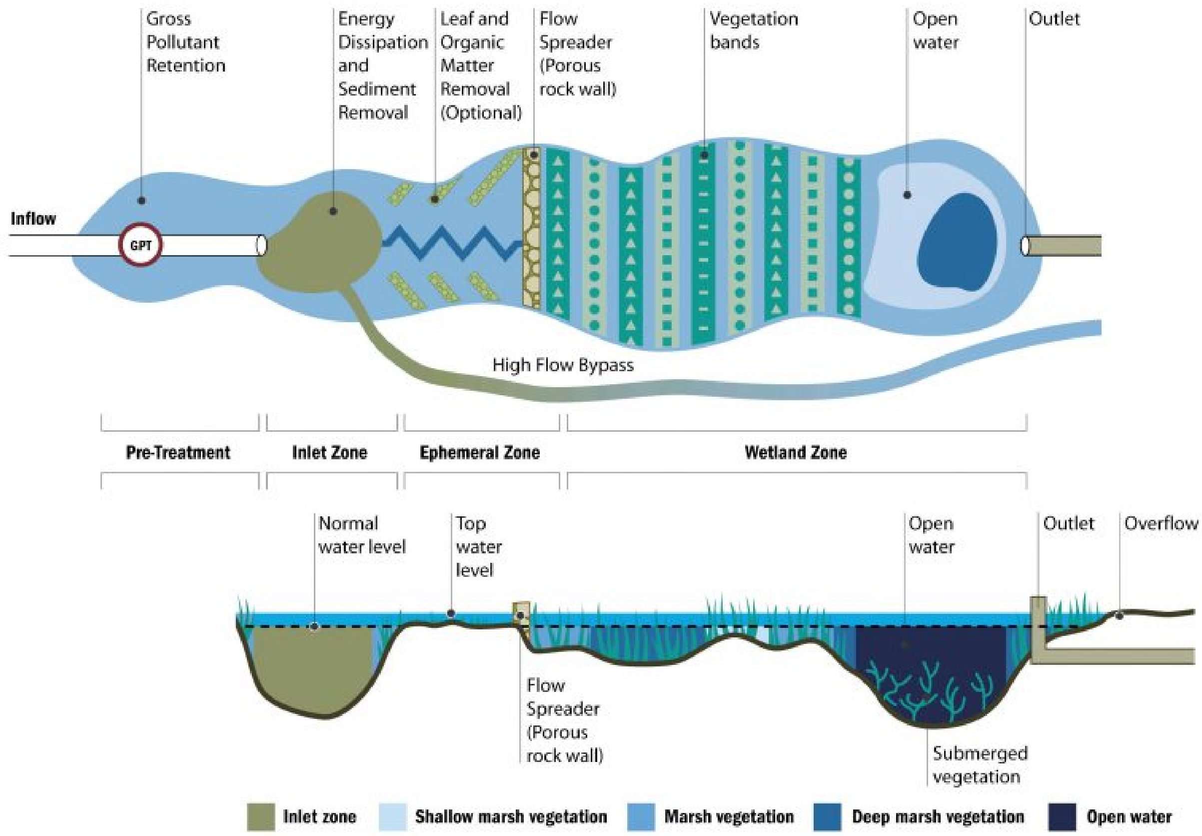

Figure 3: Diagram showing potential breakdown of constructed wetland zones (Photo Creds: Urban Green-Blue Grids)

With the growing popularity of constructed wetlands as an NBS, some general guidelines have been created to help design them to be as functional as possible. Some of the basic principles to consider are depth, shape, space, catchment area, and pollution sources (*Urban Wetland Design Guide*, n.d.). The depth needs to be deep enough so that water will flow into the site from any inflow pipes, without pushing water back up through the pipes when water levels rise. Ideally the depth would also be deep enough so as to connect back to the existing ground water levels, but no deeper than 10 feet below existing grade, where landscaping can get increasingly difficult. This impacts the discussion of shape requirements as well. Constructed wetlands are generally made up of four rough areas: pre-treatment, inlet zone, ephemeral zone, and the wetland (See Figure 3) (*Urban Wetlands | Urban Green-Blue Grids*, n.d.). Even amongst these specific zones, they can be broken into different ponding areas with weirs or pipes. These areas are often irregularly shaped to reduce the likelihood of rapid water movement through the site, creating erosion and reducing the benefits of water treatment. Thus, the area needed is not only that of one large wetland, but of subdivided and spread-out sections. These separate areas must all add up in volume to be able to hold as much incoming water as possible, but without being too large so as to dry up quickly when no inflow is present. This number is directly proportional to the catchment area and how much of the rain falling in that area will runoff into the eventual inflow pipes. The final basic principle is that of pollution. Different areas are subject to different varieties and levels of pollution. Urban areas are generally faced with pollutants including suspended solids, oxygen-demanding substances, nitrogen and phosphorus, pathogens, petroleum hydrocarbons, metals, and synthetic organics (Collins et al., 2010).

Urban Design Principles

Constructing urban wetlands can also entail creating some form of urban gathering space, whether that be a park, plaza or somewhere in between. Thus, urban wetlands not only have to abide by tight restrictions to create the wetlands, but they should also follow standard urban design principles in order to be successful. Since wetlands are fragile ecosystems, designing the site in a way that enforces the care of the site is fundamentally important. In order to accomplish this enforcement of care, founding urban design theories will be used. These include using the ideas of Sense of Place, Cues to Care, Contextualism, and Whyte's key features of small urban spaces.

A Sense of Place, "refers to the emotive bonds and attachments people develop or experience in particular locations and environments, at scales ranging from the home to the nation"(*Sense of Place*, 2009). Without these bonds, locations will lack any longevity due to the lack of care that the community will provide. While scientists and researchers have many beliefs about what creates a sense of place there are no definitive answers.

Nassauer's theories of Cues to Care give some answers as to how to design to create legibility in landscapes that are otherwise uncommon to human settlement (Nassauer, 1995). Some of these cues include clear and clean edges, often described as mowed, repetition and evidence of maintenance in plantings, clear and accessible pathways, and recognizable human elements.

Nassauer argues that by using these cues, designers can subconsciously make visitors more comfortable, and thus caring, of more "wild" landscape typologies.

Beyond the design within the wetland, the design surrounding the urban wetland must also further this goal of creating a sense of place. For this, Rowe's theory of Contextualism can help. Contextualism, in urban design, argues that in order to design a successful site, it must take into consideration the characteristics of existing and surrounding sites, including their geometries, spatial patterns, and scales (Rowe & Koetter, 1984). By following these existing standards, the new site will better fit within an urban fabric, without being a sterile replication of other sites. However, Rowe argues against replicating historical styles or copying surface aesthetics, despite materiality and historical context being some of the most reliable and long-standing design cornerstones (Herrington, 2017).

Despite conflicting opinions of larger scale design inspiration, most designers agree on features on-site that create an inviting space for people to gather. These features are best defined in William Whyte's, *The Social Life of Small Urban Spaces*. His book determined these features to be ample and variable seating, areas of sun and shade, easy accessibility to the surrounding streets, water features and greenery, and good sightlines with a triangulation of features (Whyte, 2001).

<u>Case Studies</u>

This section will look at three different case studies. Each contains urban wetlands, but have all been chosen for different strengths and weaknesses, including scale of site, interaction between the wetland and visitors, and continuity of surrounding environments with the site. These studies will help guide the design created from this paper.

Xi'an Yannan Park

Figure 4: Turenscape's Xi'an Yannan Plan View (Photo Cred: Turenscape)

The first being Xi'an Yannan Park in China, designed by Turenscape. It should be noted that Turenscape has led the charge in urban wetland designs for many years, accomplishing a bountiful portfolio of large-scale projects across China. Their founder, Kongjian Yu, who unfortunately died in September 2025, was a leader in the movement to design places that benefitted the humans and ecology surrounding them. Xi’an Yannan Park, while not an exclusively wetland project, demonstrates a unique balance of natural beauty and man-made forms. This balance may come from their use of demolished materials being reused within the gardens as sculptures, walkways, and retaining walls (See Figure 4). The 101-acre park provides a green escape from the large city surrounding it. The park, with its significant size, offers many recreational opportunities, including running paths and lawn space for gatherings (See Figure 5). Additionally, the site boasts many gardens of varying designs, including filtration wetlands on constructed terraces (See Figure 6) (*Turenscape - Xi’an Yannan Park (Phase I)*, n.d.).

Figure 6: Xi'an Yannan constructed tiered wetlands filtering water into stream (Photo Cred: Turenscape)

Figure 5: Xi'an Yannan garden with sculpture structure (Photo Cred: Turenscape)

East Bay Public Park

Figure 7: East Bay Park plan view (Photo Cred; RWD Landscape Architects)

Figure 8: East Bay Park constructed wetland

The second case study is in stark contrast with Xi'an Yannan Park. East Bay Public Park, created by RWD Landscape Architects in Olympia, Washington, is much smaller, roughly 1 acre (See Figure 7). Sitting in front of a children's museum,


Figure 9: East Bay Park constructed interactive stream

the plaza was designed to give kids hands on experience with the importance of clean water and wetland habitats. While technically in an urban area, the surroundings are much more representative of a warehouse district, with few to no casual pedestrians passing through the site. However, East Bay Public Park does a remarkable job of imitating a natural wetland (See Figure 8), highlighting its importance with art and educational signage, while also creating interactive water features (See Figure 8) and plaza space for gatherings. Its designs highlight naturalistic shapes and invite the feeling of being within nature ("East Bay Public Plaza," n.d.).

Tanner Springs Park


Figure 10: Tanner Springs Park perspective (Photo Cred: Land8 and GreenWorks)

Figure 11: Tanner Springs Park hydrograph (Photo Cred: Land8 and Dreiseitl)

Finally, Tanner Springs Park, designed by Atelier Dreiseitl in Portland, Oregan, also 1 acre in size, is a beautiful representation of humans and nature working together to create a functional system within an urban center. Surrounded by tall buildings, Tanner Springs dips down roughly 5 feet below the existing elevation, flooded with rainwater captured on site and from surrounding buildings (See Figure 11). The water, piped into large cisterns underneath the site, is pushed up to ground level through a small bubbling spring, before meandering down the site into the main ponded wetland (See Figure 12). This is not only meant to mimic natural processes, but to use the benefits of those processes to filter the water and create a matrix of habitats based on water saturation levels. The sloping site allows for the higher elevation areas to be used for gathering and recreation while the lower elevation contains the pooling water (See Figure 10). Wide steps on either side of the site allow for visitors to interact with the water level as much or as little as they would prefer. The designs on site mesh curvilinear paths and naturalistic meadow plantings with geometric concrete bridges, steps and walls, creating an intricate balance of humans and nature ("Tanner Springs Park, an Oasis in the Middle of the City," 2015).

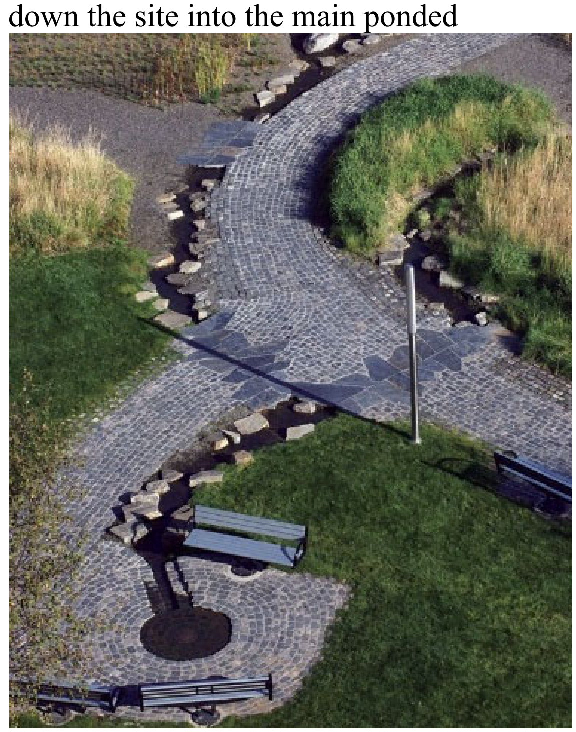
Figure 12: Tanner Springs Park constructed stream (Photo Cred: Land8 and Dreiseitl)

Gaps in Case Studies

While literature about wetlands and urban design is abundant, finding relevant case studies for this paper was challenging. In cases like Xi'an Yannan Park, the wetlands made up a very small portion of a massive park. Few urban areas have 100+ free acres to be repurposed. Additionally, the wetlands in that design, while beautifully designed with a mix of readable geometric borders, were not designed to be interacted with by visitors. On the other end of the spectrum is East Bay Park, which is much smaller in size, but is not designed to fit as neatly within the readable urban fabric. Tanner Spring Park seems one of very few truly urban wetlands, that are smaller in scale and designed to be consistent with the surrounding urban context. However, none of these case studies were located on the eastern half of the United States, which is home to many larger urban centers, including New York City, Washington D.C., Chicago, Atlanta, and Philadelphia, and is also the location of massive wetland loss (Fluet-Chouinard et al., 2023). This makes the eastern half of the United States a very important region to research the implementation of urban wetlands.

Design Program

There are three main design programs formulated from this section of research:

- Use wetland ecosystem services to treat water in urban area and reduce flooding
- Create habitat for wetland flora and fauna
- Combine natural systems with man-made forms to create cues to care

Chapter 3: Methods

This thesis uses a mixed methods approach including LaGro's method for site inventory & analysis, and specific analysis and design tools such as ArcGIS. Initial site selection was done by comparing local flood, soil, and property maps with observed pedestrian foot traffic and existing community attachment. This was done to select a site that allowed for the biological needs of a wetland, while promoting heavy human interaction. Following the site selection, further investigation was done concerning the site's context, features, history, hydrology, and current uses. These will all be expanded on in this section.

__Site Selection and Context__

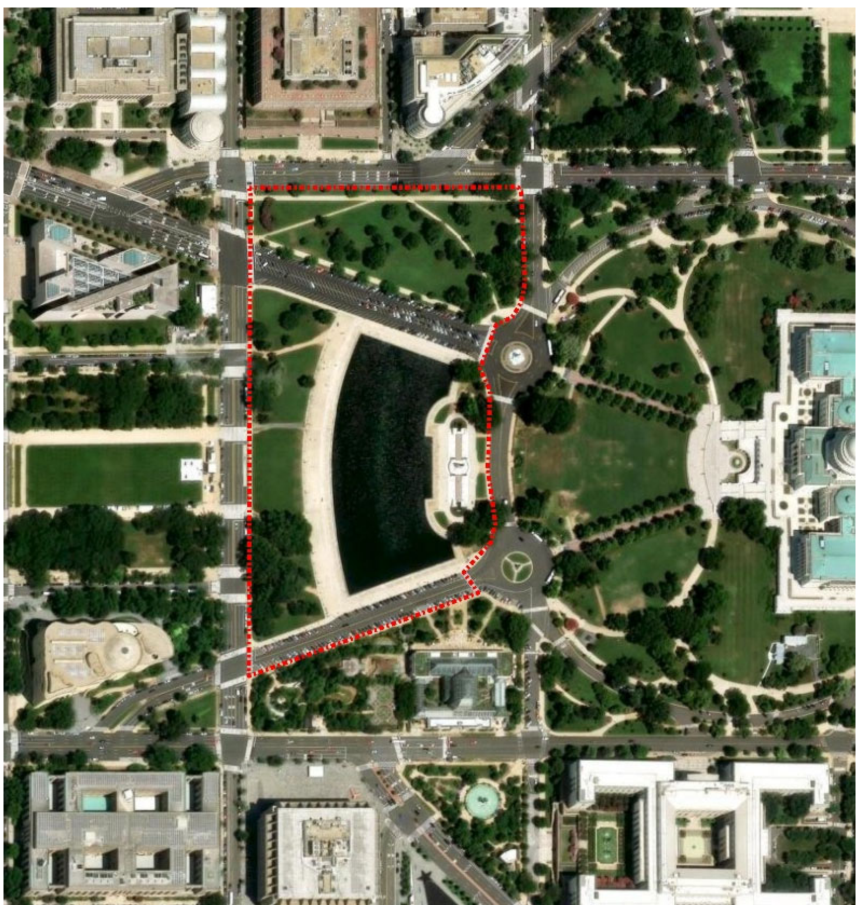

Figure 13: Map of site with boundary

The site chosen for redesign is a 19.56-acre lot named Union Square in Washington D.C., sandwiched between Capitol Hill and the National Mall (See Figure 13). Under the purview of the Architect of the Capitol, the location is more closely linked to the Capitol grounds, however on-site walkability makes the square feel more a part of the National Mall (See Figure 14).

Figure 14: Photo showing connection from site to National Mall during moderate rain event (Photo Cred: Kelly Rasmussen)

The site is within Ward 2 of DC, along with the Capitol, National Mall and the White House. This Ward comes with a number of restrictions on access to public infrastructure information, making some data gathering for this project more difficult. The National Botanical Gardens border the Southern edge of the site, while Constitution Ave and government buildings border the Northern edge. Laying within the roadway that divides the site from the Capitol are two small roundabouts with memorialized statues. Slightly further away from the site lay the White House, Tidal Basin, Union Station, Washington Monument, National Mall and multiple levee systems (See Figure 15).

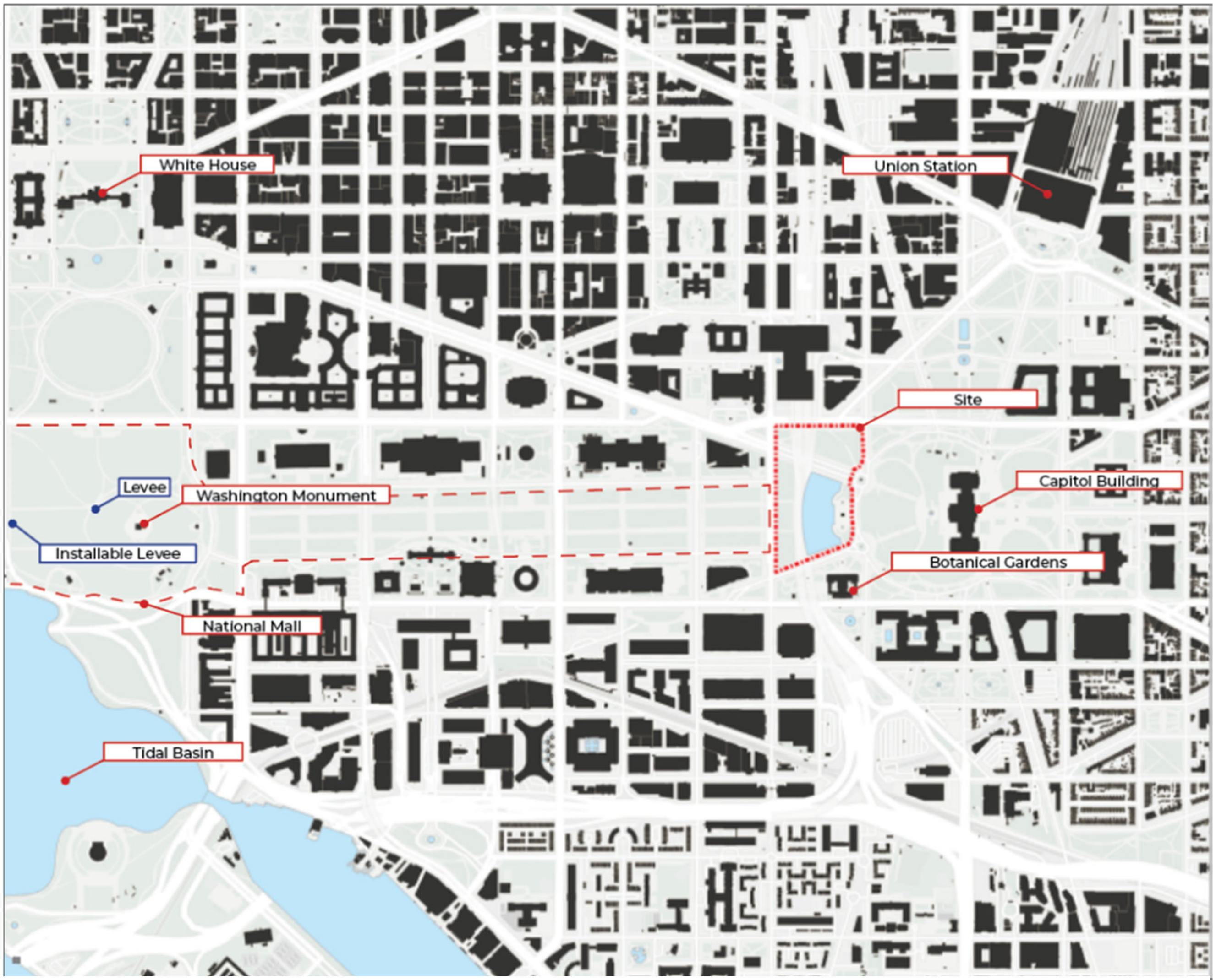

Figure 15: Context map of site showing nearby landmarks

Site History

Washinton D.C. was founded in the 1790's as the Nation's capital; within less than a year plans for the National Mall were being drawn up. In 1791 Thomas Jefferson sketched a basic outline for the National Mall (See Figure 16) and gave the plans to Pierre-Charles L'Enfant who would be the foundational designer for the entire city of Washington D.C. (*National Mall - History of Early American Landscape Design*, n.d.). (See Figure 17)

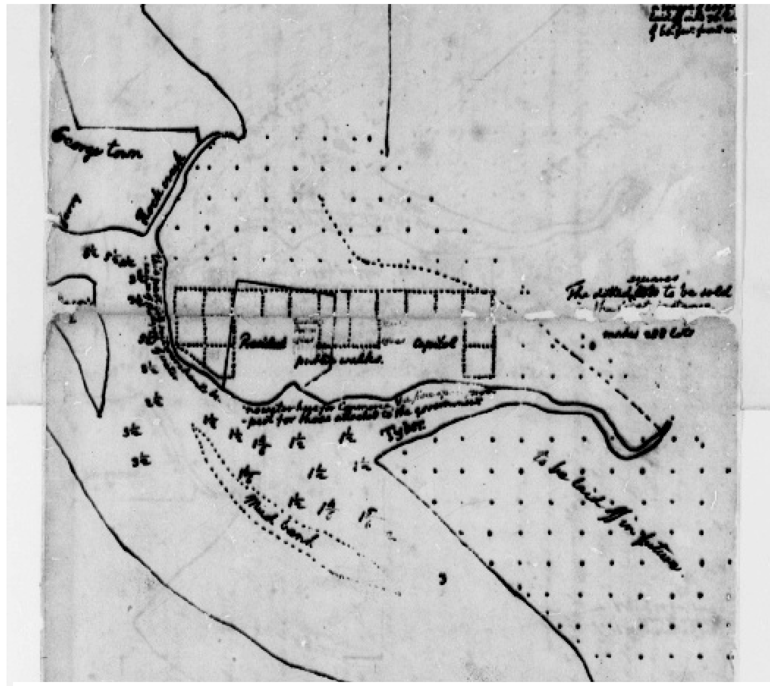

Figure 17:Thomas Jefferson's sketch of early ideas for the National Mall (Photo Cred: National Gallery of Art)

Figure 16: L'Enfant's design for the city of Washington D.C., zoomed in on the National Mall (Photo Cred: National Mall Coalition)

This plan created a large public green avenue with tree lined promenades. On either side of the park, L'Enfant imaged public buildings – including theaters, areas for assembly and academic buildings. At this time the Potomac River came all the way up to the site of the Washington Monument, one of three monumental buildings on site, the others being the Capitol building and the White House. There was also to be a channelized version of the Tiber River running parallel to most of the Mall, before cutting in front of the Capitol building and down to the Anacostia River. Very little of this plan was realized in the next century, instead in 1850, President Fillmore asked designer Andrew Jackson Downing to create a new plan for the National Mall. Downing pulled from more Victorian designs and created smaller, heavily planted, curvilinear gardens (See Figure 18) (*A. J. Downing, Plan Showing Proposed Method of Laying Out the Public Grounds at Washington, 1851 - History of Early American Landscape Design*, n.d.). Only segments of his plan were accomplished and can still be seen today, including Smithsonian Gardens and the Ellipse behind the White House.

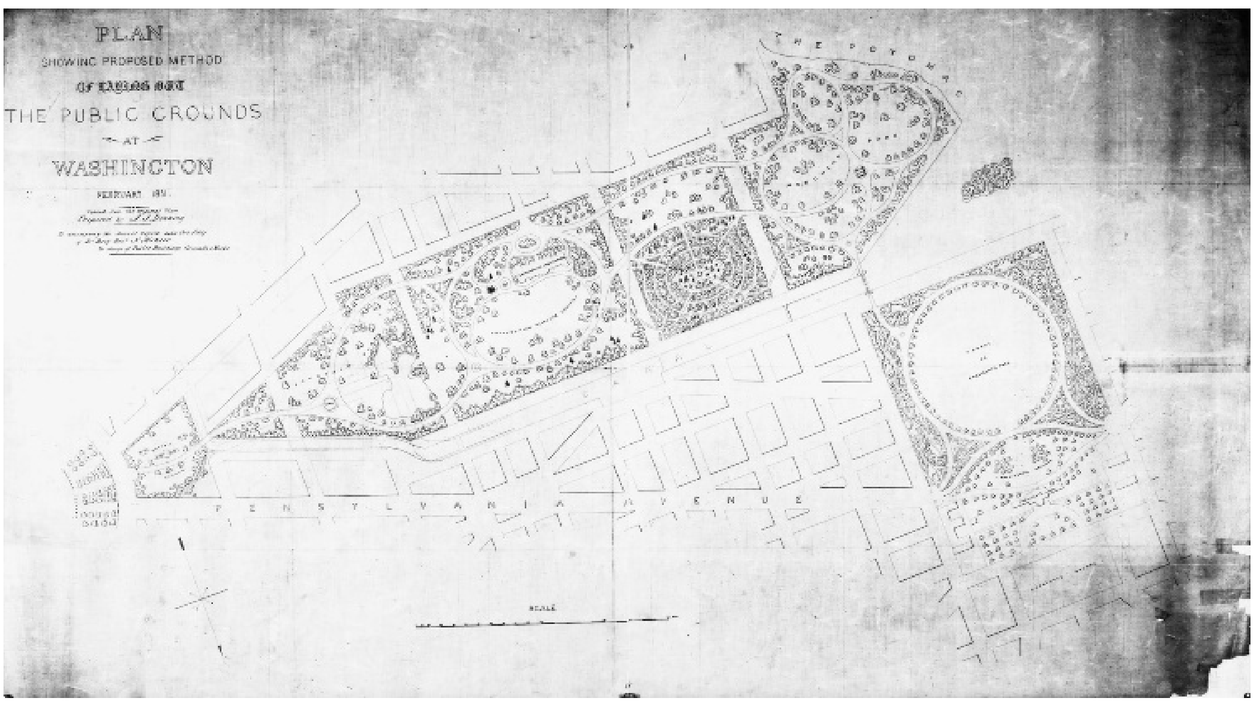

Figure 18: Andrew Jackson Downing's proposed redesign for the National Mall (Photo Cred: National Gallery of Art)

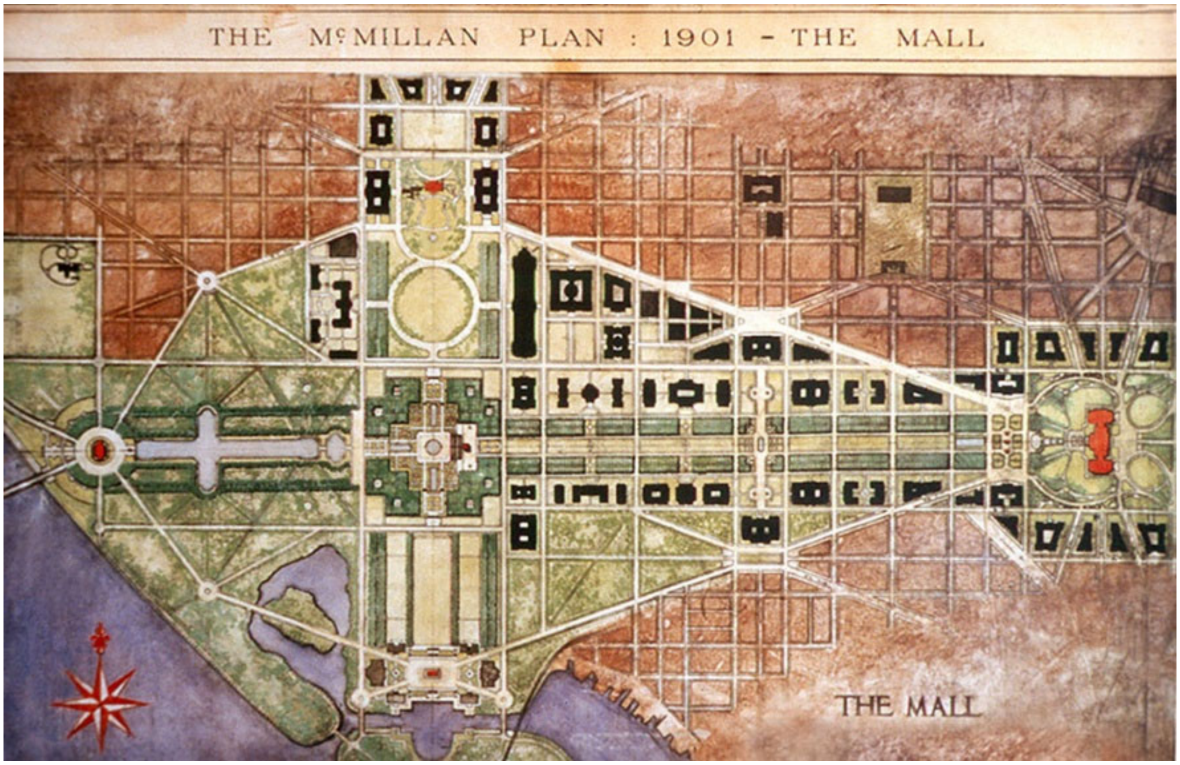

Figure 19: McMillian Commission's proposed redesign for the National Mall (Photo Cred: National Endowment for the Humanities)

By the 20th century the National Mall had become overgrown with trees, industrial buildings, impermanent settlements, and sewer from the channelized Tiber River. At the beginning of the 20th century, the McMillian Commission was formed with architects Daniel Burnham, Charles McKim, landscape architect Frederick Law Olmsted, and sculptor Augustus St. Gaudens, among others, to create another plan for the National Mall. The Commission took inspiration from the original L'Enfant plan with large open axis and tree lined promenades (See Figure 19). They were also able to expand the existing Mall due to newly formed land from the Army Corp of Engineers dredging of the Potomac River – giving the rivers boundary that is seen today. This new land gave a location for the final bookend of the National Mall, the Lincoln Memorial (*National Mall History | National Mall Coalition*, 2014). The plans created by the McMillian Commission are largely the plans visitors would experience today with some small changes. These changes were predominantly made by Skidmore, Owings, and Merrill in 1976 to prepare for larger visitor numbers during the Bicentennial Celebrations (See Figure 20). One of these changes included the creation of Union Square as seen today. The design was meant to reduce automobile traffic while creating a pair to the Lincoln reflecting pool on the other end of the Mall.

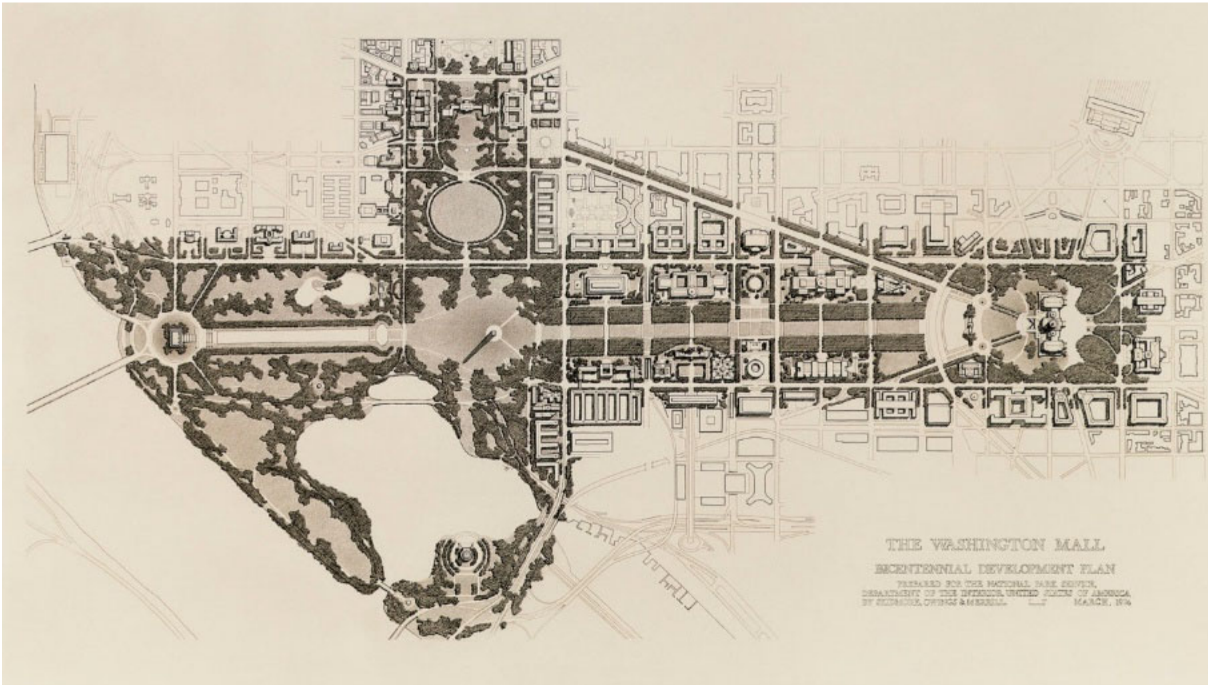

Figure 20: SOM's proposed redesign for the National Mall (Photo Cred: SOM)

Capitol Redesign Project

In 2012 the Capitol Redesign Project was announced, in which three locations along the Mall were selected to be re-imaged. Each location was given to four different teams. The Union Square location had the following teams: GGN, Snohetta & AECOM, Ken Smith & Pei Cobb, and Diller Scofidio + Renfro & Hood Design. Each team's design took different approaches to address the given design prompt:

"The Ulysses S. Grant Memorial, one of the five presidential memorials on the national mall, will be the focal point of a symmetrical and formally laid out civic square based on historic precedents. This highly symbolic foreground to the U.S. Capitol will be redesigned as an attractive flexible stage for democracy that can accommodate more people and divert use from the mall. It will be a popular, active, and dignified day and evening destination that is easily transformed into a larger venue for first amendment demonstrations, national celebrations, and events. A smaller reflecting pool or interactive water features, highlighting sustainable water management practices, will be considered to make the space more suited to various uses and reduce water use. The sound of water will be used to muffle the noise of urban traffic. Grade changes will be eliminated to improve pedestrian access and circulation for all. Union square will include flexible, indoor/outdoor, multipurpose facilities with shaded spaces and seating from which to enjoy views of the grant memorial and the U.S. Capitol, along with outdoor exhibits or displays. High-capacity restrooms will be designed so that more stalls can be opened during

high-use periods, and nearby drinking water and recreation equipment rentals will be provided. The redesigned area will also consider connections to adjacent capitol complex grounds and transitions with the national mall. The union square redesign is intended to fulfill the McMillan plan goal of connecting the U.S. Capitol grounds with the national mall, as well as providing more convenient and flexible land use at the foot of the west side of the capitol" (*National Mall & Memorial Parks, National Mall Plan: Summary - November 2010*, n.d. p.13).

Figure 21: GGN's rendered perspective site design (Photo Cred: GGN)

GGN's design is focused around a central, shallow reflecting pool with paths crisscrossing through the pool (See Figure 21). The pool, shaped to mimic the rectangular design of the National Mall, can be drained to create a large area for which to gather. The design also utilizes topographical changes and plantings to create specific rooms across the site. Finally, the design includes a grouping of buildings in the NW corner of the site to address the desired built component. GGN's design is the most consistent of the four with the existing geometry surrounding the site but is also the most simplistic design. This makes the spaces versatile but may not speak to the grandeur of the site as much as other designs. Despite this, GGN did win the design competition, although no plan was ever made to move forward with their design.

Figure 22: Snohetta and AECOM's site plan for Union Square (Photo Cred: Snohetta)

Snohetta and AECOM's design went in a distinctly different direction. Their design combined the geometric shapes of the National Mall with the curvilinear paths of the Capitol grounds into a radiating circular pattern (See Figure 22). Their pool spans the middle of the site, across a raised platform in the center of the side, to the outside edges with paths crossing over top. Sustainability goals onsite are addressed by vegetated areas around the raised platform, including a constructed wetland, as well as the new pool with is designed to capture stormwater.

Ken Smith and Pei Cobb's design focuses on "few and simple" key features. The largest being an expanded pool that incorporates interactive fountains (See Figure 23). They also added more gardens and expanded on seating options on site. Their goal was to make the site more welcoming to visitors. The design fell short of project requests including flexible space and buildings for recreational uses.

Figure 23: Ken Smith and Pei Cobb's perspective rendering of Union Square (Photo Cred: Politico and Pei Cobb Freed & Partners & Workshop: Ken Smith Landscape Architect)

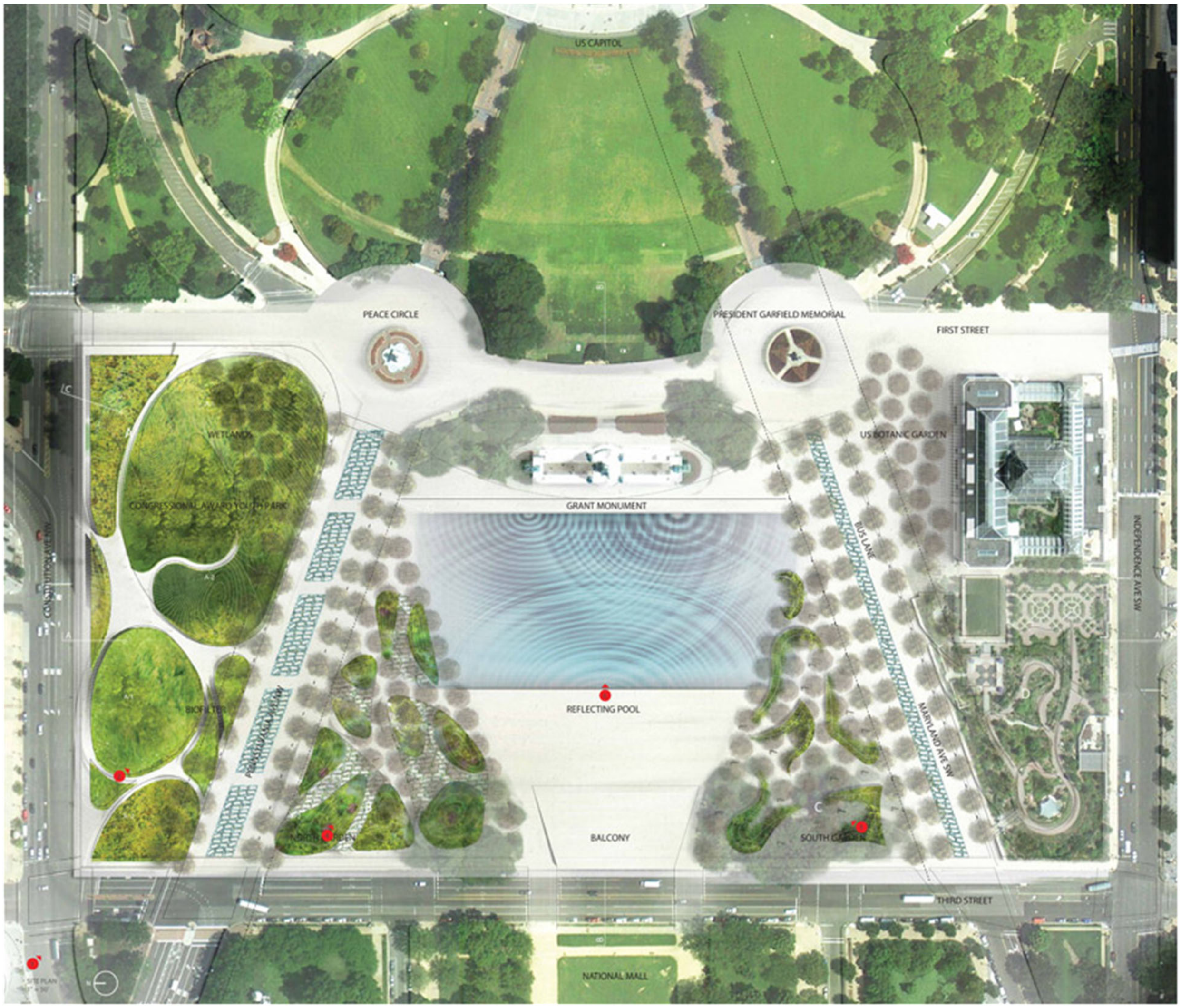

Figure 24: Diller Scofidio + Renfro & Hood Design's rendered site plan of Union Square (Photo Cred: DesignBoom and Diller Scofidio + Renfro & Hood Design)

Finally, Diller Scofidio + Renfro & Hood Design created a site that leaves the basic shape of the existing reflecting pool, while adding new naturalistic gardens surrounding (See Figure 24). With winding pathways, the expanded gardens include multiple sustainability features including a green roofed structure, biofiltering, and a constructed wetland to deal with flooding. This design strays the farthest from the surrounding typologies but addresses many of the environmental and sustainability concerns.

Design Program

There are three main design programs formulated from the historical research section:

- Use design choices that accent and pull from the iconic location and it's long history
- Design with 10 year storm volume or more in mind
- Invite more human occupation of site

Site Hydrology and Landforms

The Union Square resides in one of three main watersheds within the District of Columbia, specifically the Anacostia River Watershed (See Figure 25). Sitting at the juncture between two higher elevation areas, the site not only accumulates significant pooling from onsite rainfall but also receives significant runoff from the surrounding areas.

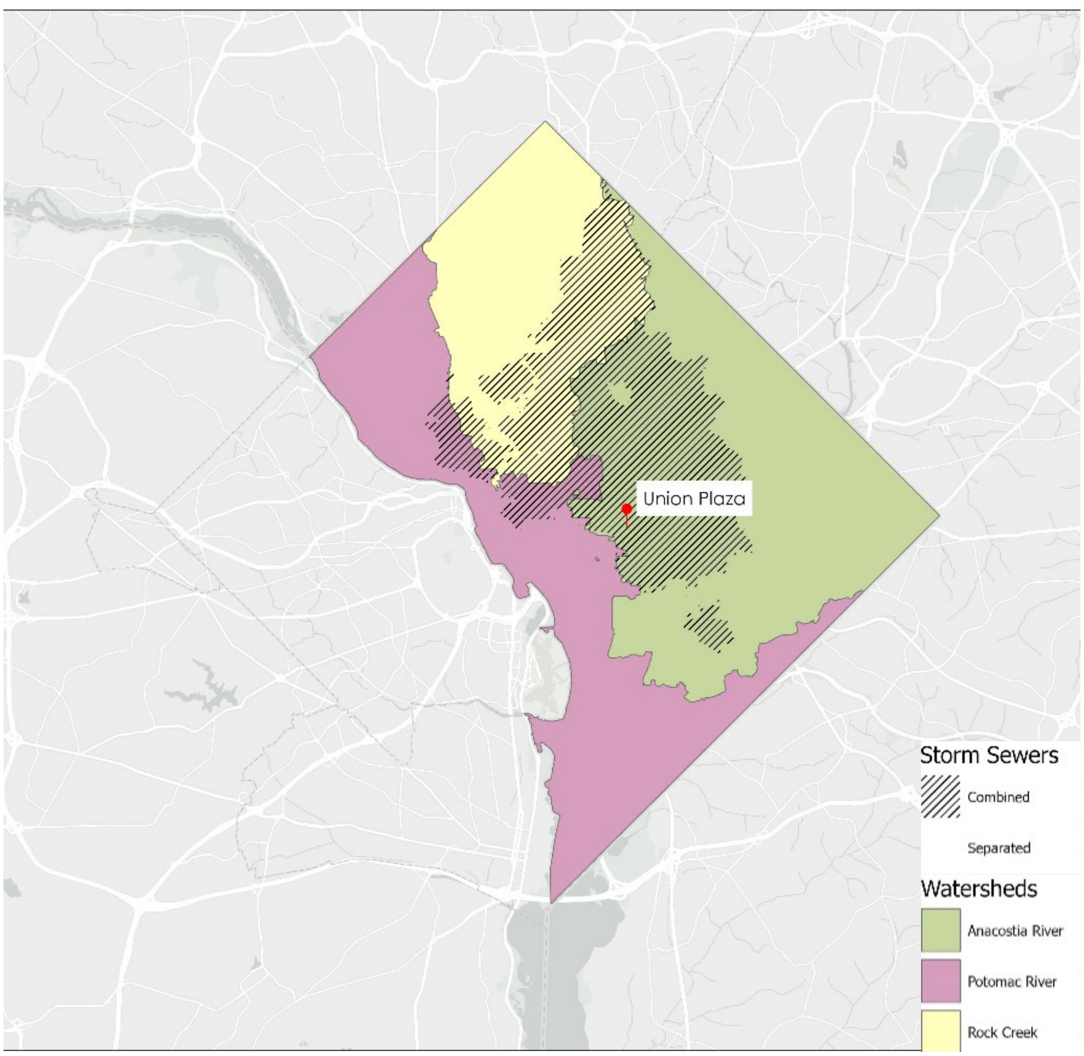

Figure 25: Map showing an intersection of watersheds with CSS's in Washington D.C., indicating the site lies within the Anacostia River watershed and in a combined sewer system area

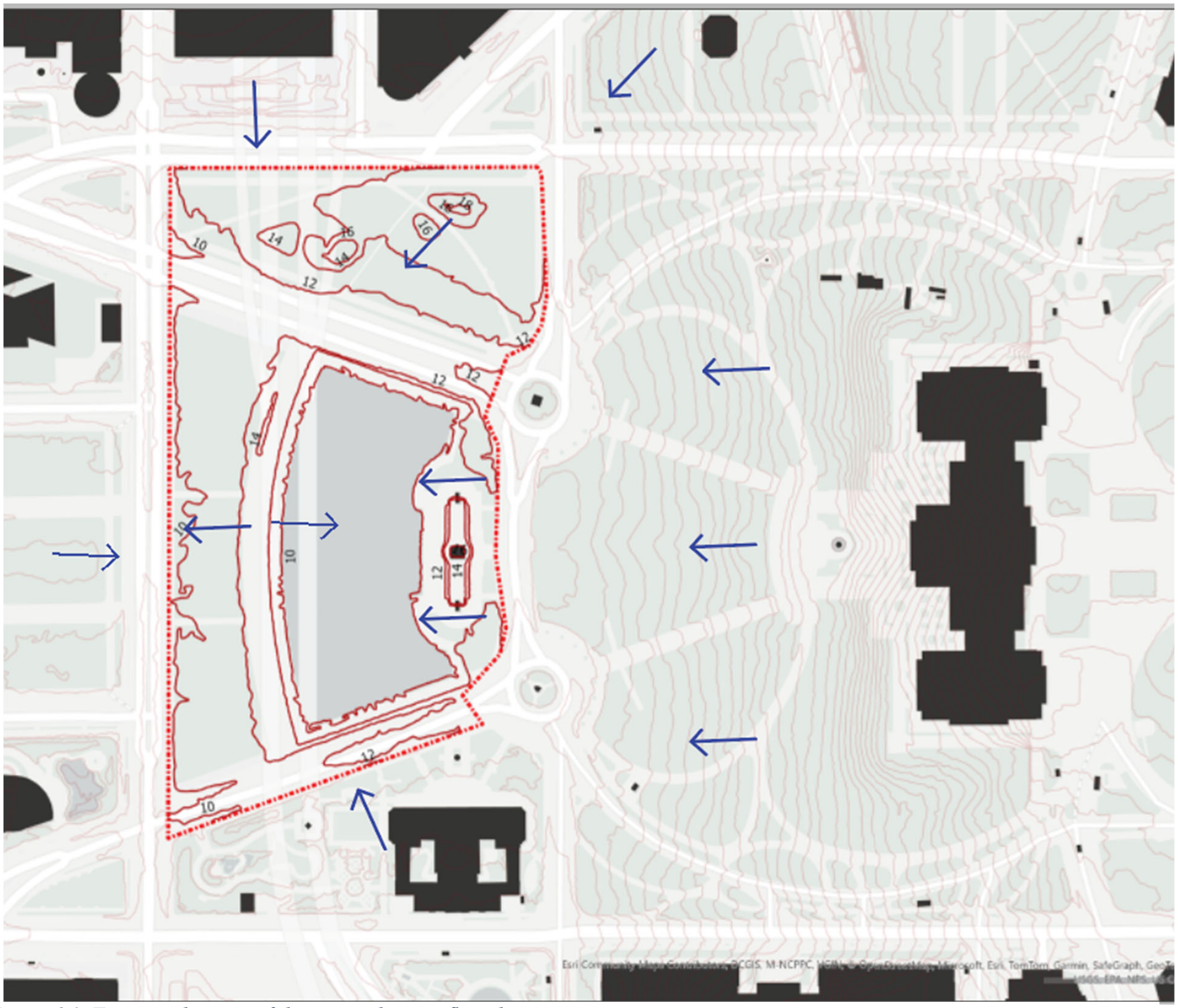

Figure 26: Topography map of the site with waterflow directions

The northern lawn section of the site has a few small hills, with most runoff flowing towards the inside of the site (See Figure 26). The main section of the site has more controlled grading, pushing most of the water towards to reflecting pool, with the exception being the western lawn section, which slopes out towards the road. While digital mapping shows sufficient sloping to accommodate rain, onsite observations show erosion and dense soils that create pools of rainwater onsite during even the smallest of rainfalls. Furthermore, the entire site lays within the 100-year storm flood zone along with much of the northern edge of the National Mall (See Figure 28). The current map indicates everything on site under 12’ of elevation will be affected; this includes almost the entirety of the main site, with most the northern lawn section affected as well.

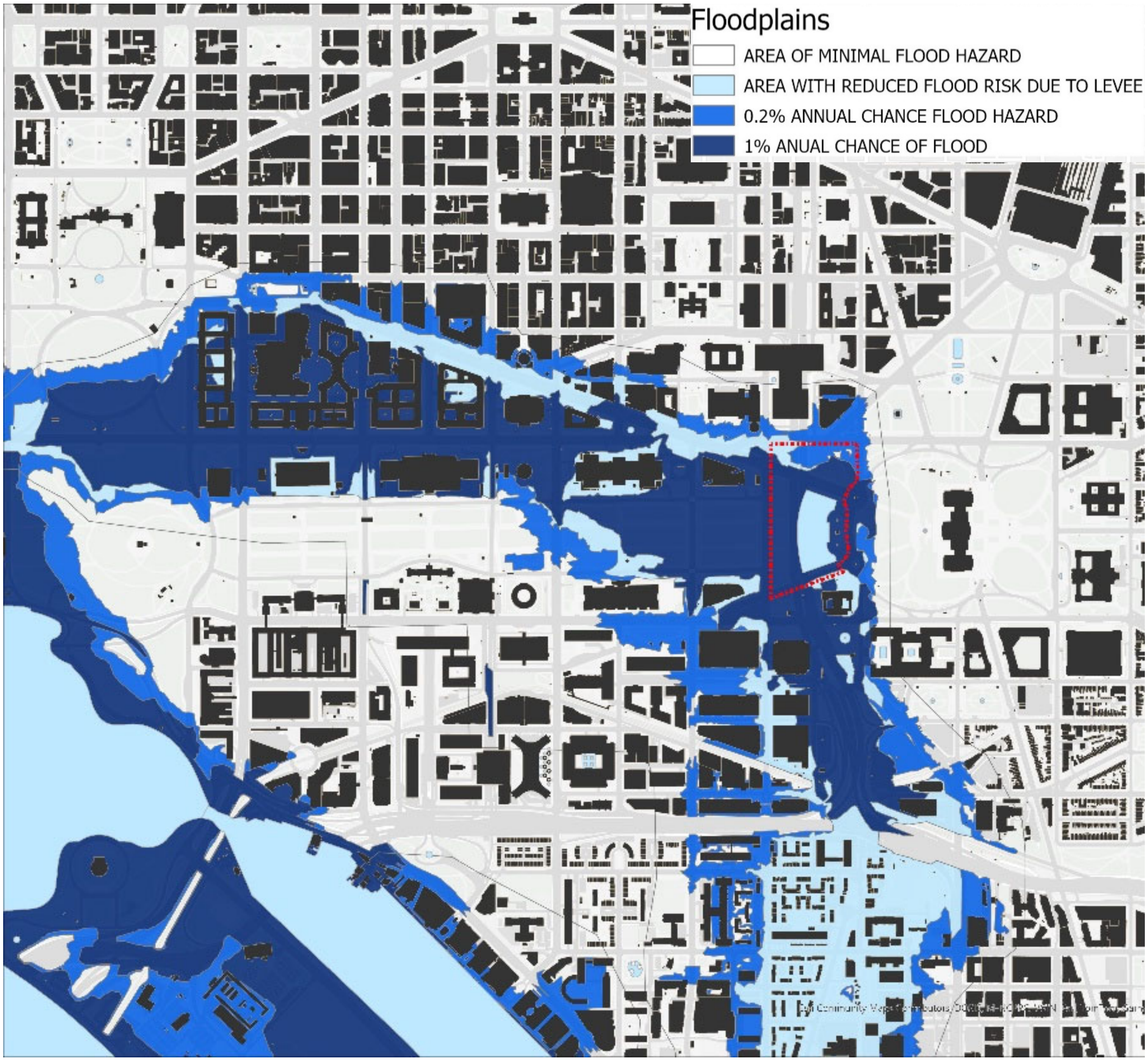

Figure 28: Map showing different flood levels in Washington DC, with the darkest blue representing a 100-year storm

Onsite hydrologic features include standard street drains surrounding the site as well as overflow drainage around the perimeter of the reflecting pool. The majority of the overflow drains are significantly clogged, which causes pooling around the reflecting pool (See Figure 27). All the drains on site are connected to the D.C. Combined Sewer System. Information regarding underground systems is largely unavailable in this area. While it is known that Highway 395 passes underneath, the depth to structure is unavailable. Based on construction photos, an estimated 5' to structural roof is being used for this project's purposes.

Figure 27: Photo showing clogged on site drain (Photo Cred: Kelly Rasmussen)

Sitting at one of the lowest points in the general vicinity, the site could potentially catch runoff from a large area, roughly 2,096 acres (See Figure 29).

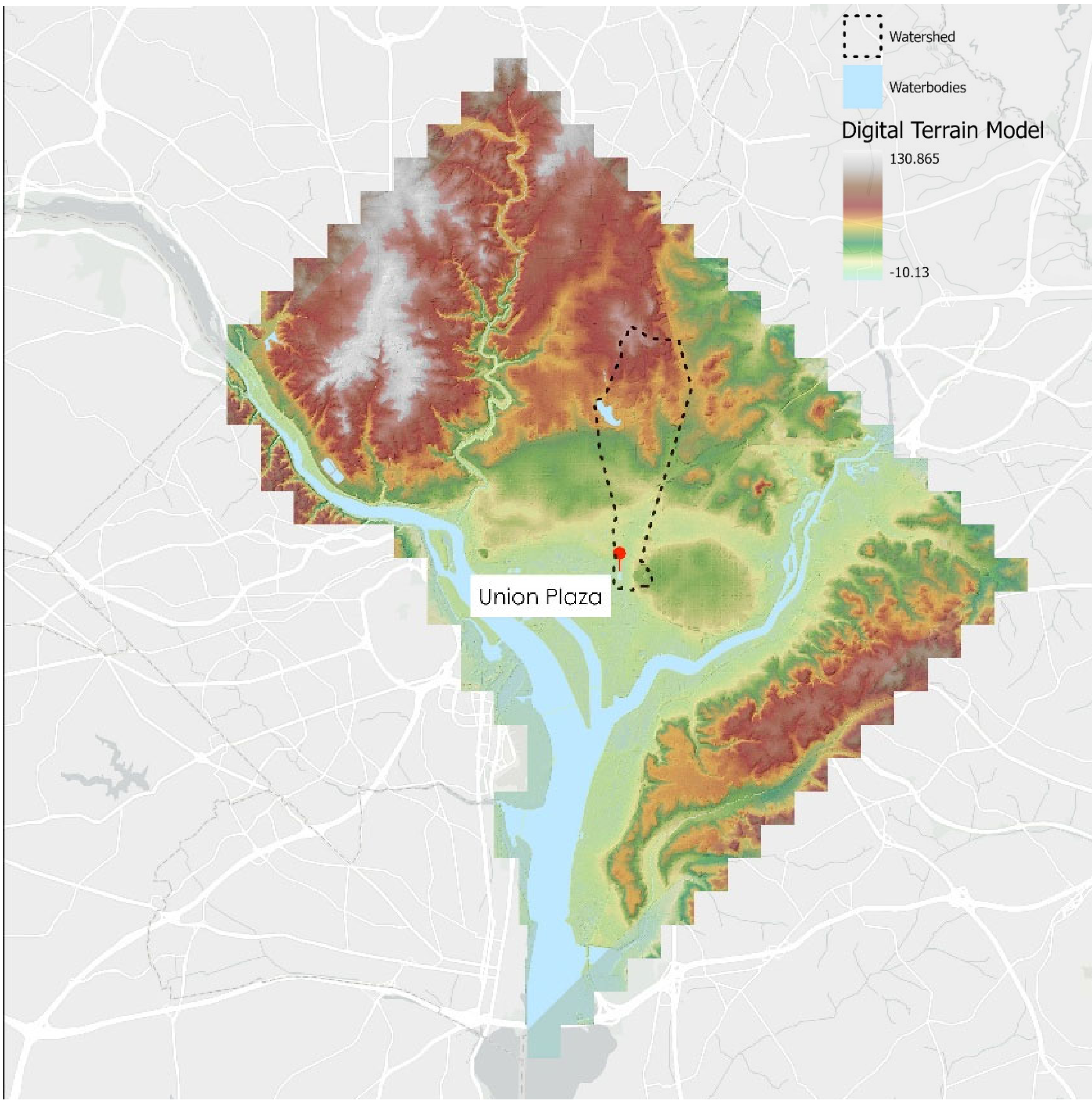

Figure 29: Hillshade and DTM map of Washington D.C. showing the potential water basin flowing into the site from the dashed line outline

Given that most of that water would flow into the combined sewer systems prior to reaching the site, a much smaller section of that area was chosen to actively collect water around the site (See Figure 31). This area, roughly 161 acres, will divert water into separate pipes directed onto the site. Main soil types within the designated water catchment area are Udorthents and Urban Land, based on information from the National Soil Survey (See Figure 30). No information was available on the Hydrologic Soil Groups found on site, nor the depth to water table. Udorthents and Urban land are both indicative of little to no infiltration, high runoff rates, and restrictive features higher in the soil column.

Based on observed hard, compacted soil and a lack of infiltration, the existing hydrologic soil will be assumed to be within the C/D levels. The main existing zoning uses are Commercial, Open Space or Other (See Figure 32). The majority of the Open Space is dominated by manicured lawns and large trees, similar to those seen on the north parcel of the design site.

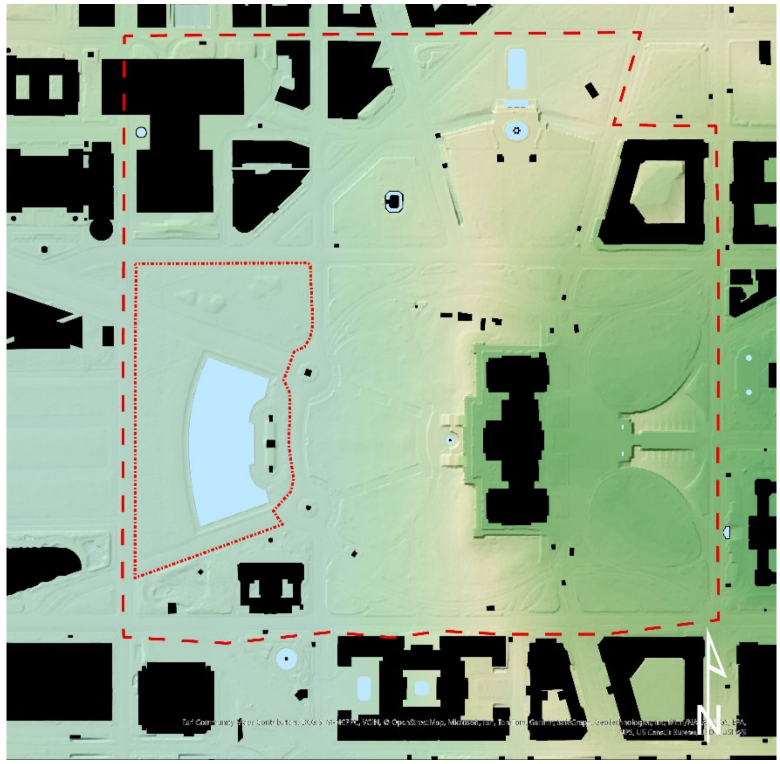

Figure 30: Hillshade and DTM map showing the decided catchment area surrounding the site

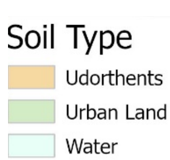

Figure 31: Soil type map of the catchment area

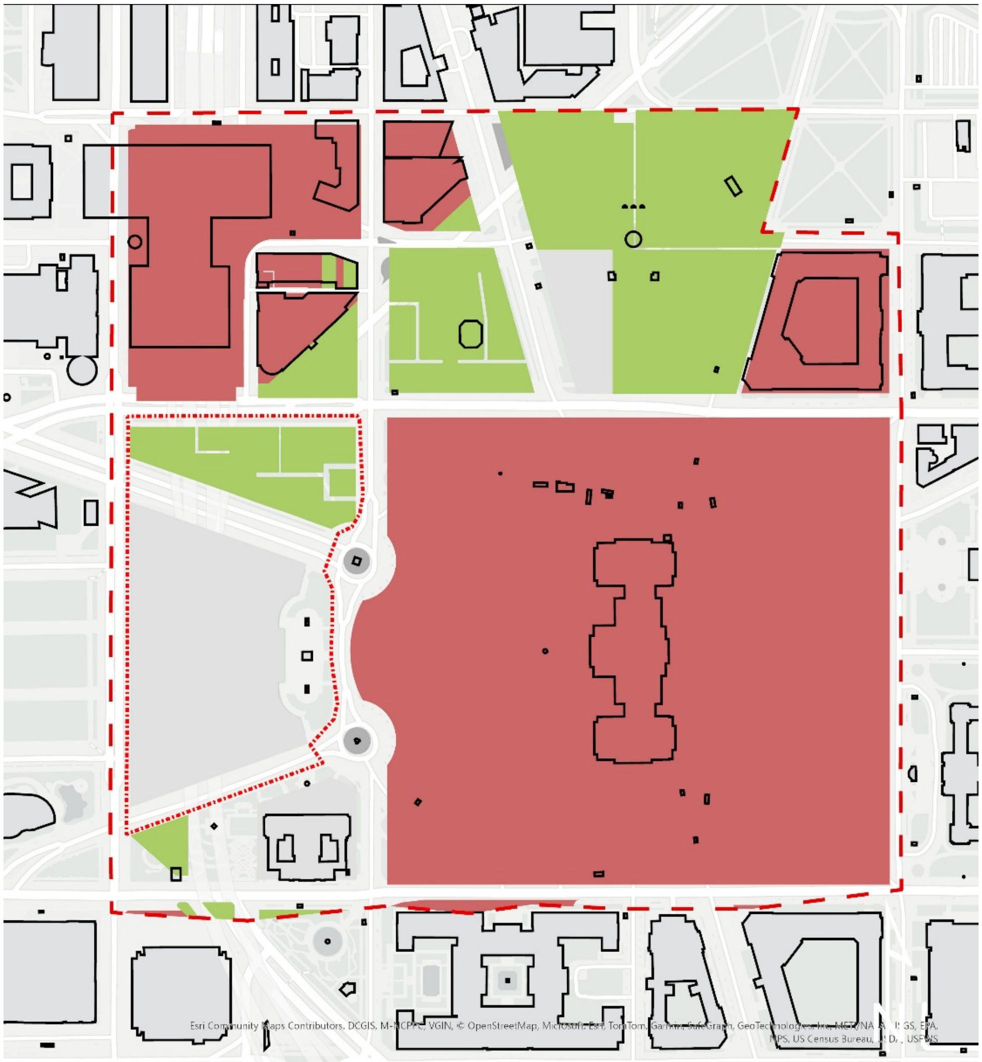

Figure 32: Zoning land use map of catchment area

<u>*Site Uses*</u>

Union Square is largely a location for passing through rather than presiding in for any length of time. No seating of any kind is currently found on site, and even the edge of the reflecting pool is curved, limiting the desire to sit. Everyday activities seen on site predominantly consist of two groups: tourists and runners. Due to its central location and obvious photographic appeal, the reflecting pool is a regular stop for tourists getting photos of the Capitol or the Washington Monument. Additionally, a significant number of runners use the reflecting pool as part of their loop (See Figure 33). There are rarely people using the green space on site for recreational activities, favoring the neighboring lawn of the National Mall.

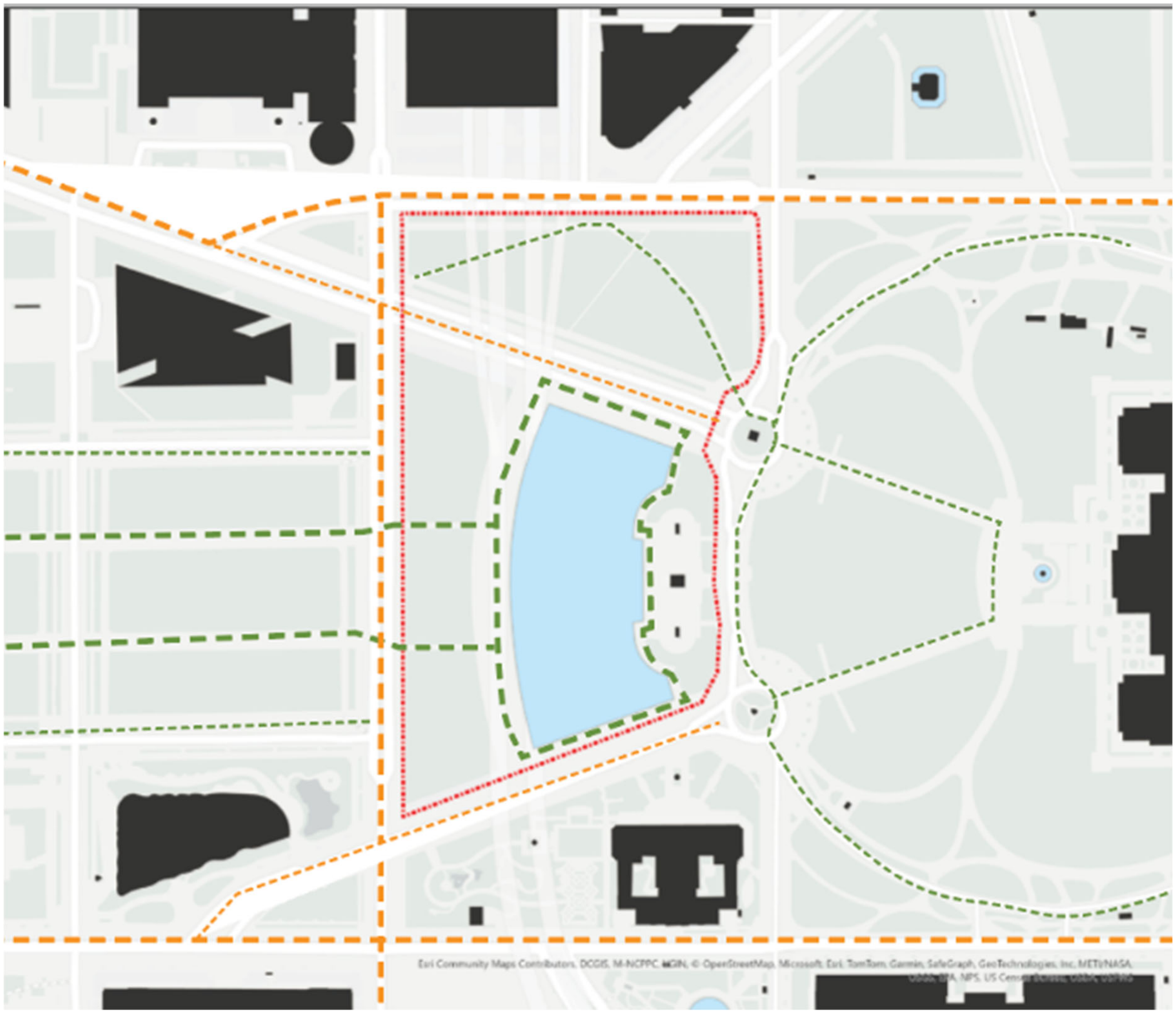

Figure 33: Circulation map showing pedestrian circulation in green and automotive circulation in orange

More formal uses of Union Square include Inauguration Day crowds. Thousands of Americans flock to the National Mall, Capitol Hill and Union Square to witness the inauguration of a new president. Currently, the reflecting pool creates a large gap, reducing the number of people capable of occupying the space.

Design Programs and Goals

There are three main design programs formulated from the site features, hydrology and usage section:

- Use plant palette to address bioremediation on site
- Capture stormwater from on site and surroundings prior to entry into combined sewer system
- Design site for multiple forms of circulation

The overall design goals encompass all gathered research, from existing literature, historical analysis, and site inventory:

1. Capture, treat, and recycle stormwater
2. Implement features on site to foster care
3. Interweave the design within the context of the site
4. Connect site with natural systems

Chapter 4: Results

This section will give an overview of the final design created based on earlier research and analysis. The design started with preliminary conceptual plans and will end in a full theoretical design with visualization.

Concept Design

Based off the design goals and programs devised from the obtained information, three conceptual plans were formed, The Grassland, The Plaza, and The Ha-Ha. While each has different organizations of areas, they all shared similarities including the focus on maintaining sight lines across the East-West axis, highlighting a constructed wetland on site to treat stormwater, and a central plaza that can be flexible in usage. They all also convert the axial parking lots to permeable allées. These main similarities come from not only the design goals created for the new design, but also from the design program provided for the 2012 Redesign Competition.

The first design, the Grassland, (See Figure 34) brings the wetlands toward the center of the site, creating a meadowy border surrounding the central plaza. These grasslands are the starting point for water to percolate down into two separate wetland pools on the western edge of the site. On the outside both systems are additional smaller plazas and tiered steps allowing for access down to the ponded wetland. This design leaves the northern segment mostly undisturbed as it is in good condition.

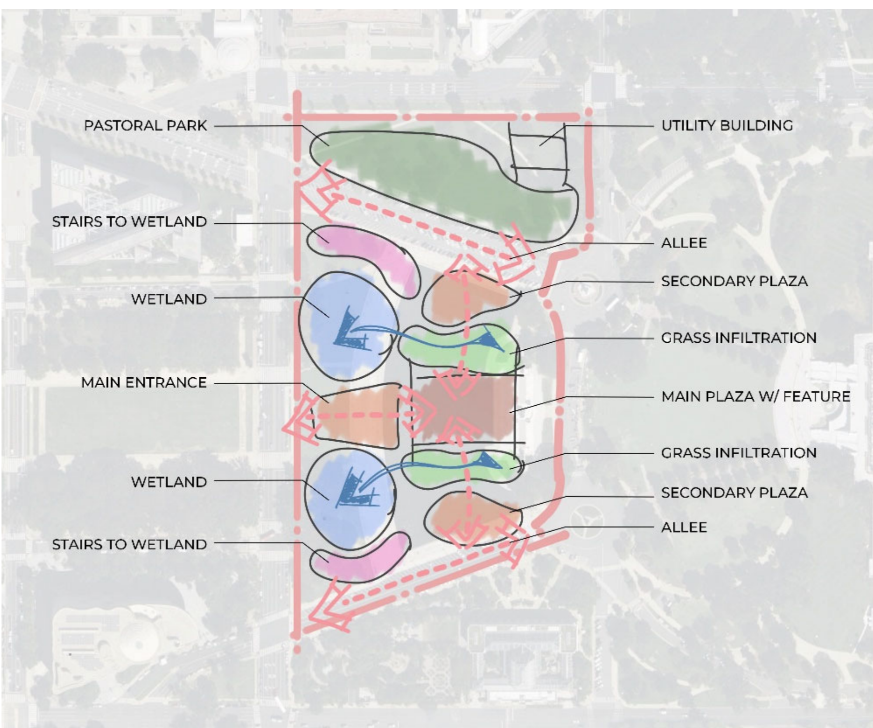

Figure 34: Grassland concept diagram

The second design, the Plaza, (See Figure 35) moves the majority of the wetland system to the northern segment of the site. This design has a more extensive wetland filtration system with a smaller ponded wetland area on the western side of the site. This allows the water to be pipped to the southwestern corner of the site for an interactive fountain. The majority of the center of the site is taken up by a large plaza, bordered by some park land.

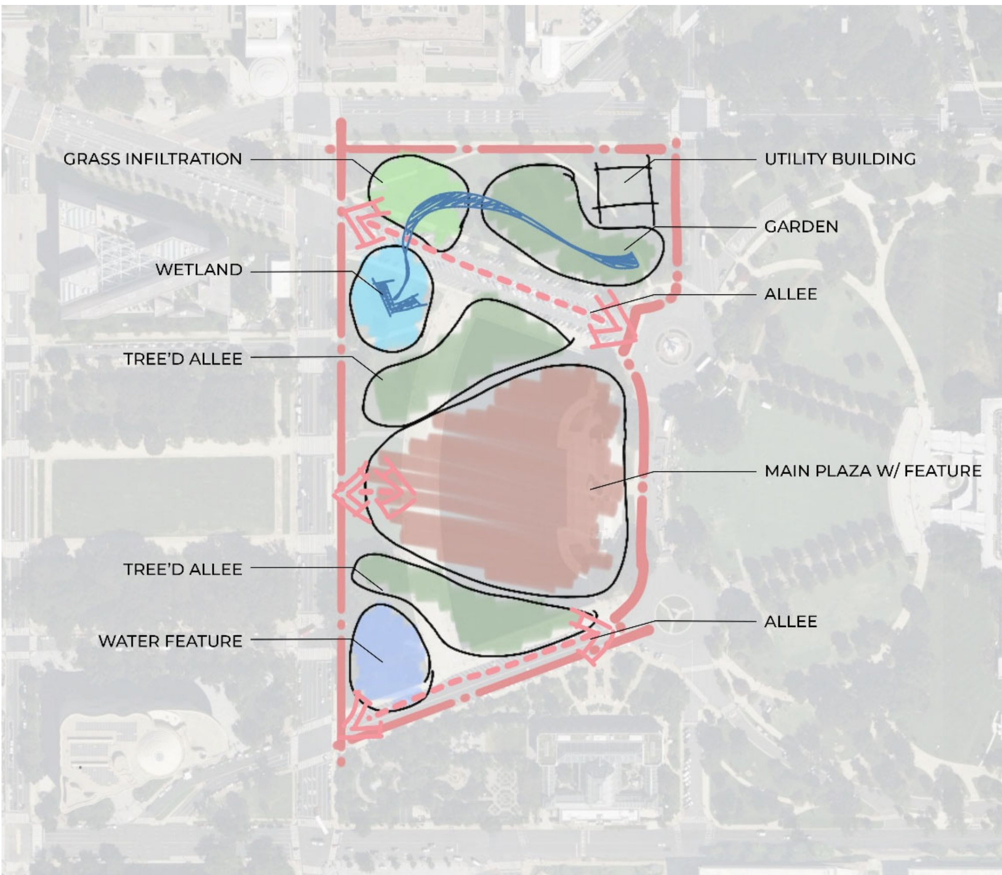

Figure 35: Plaza concept diagram

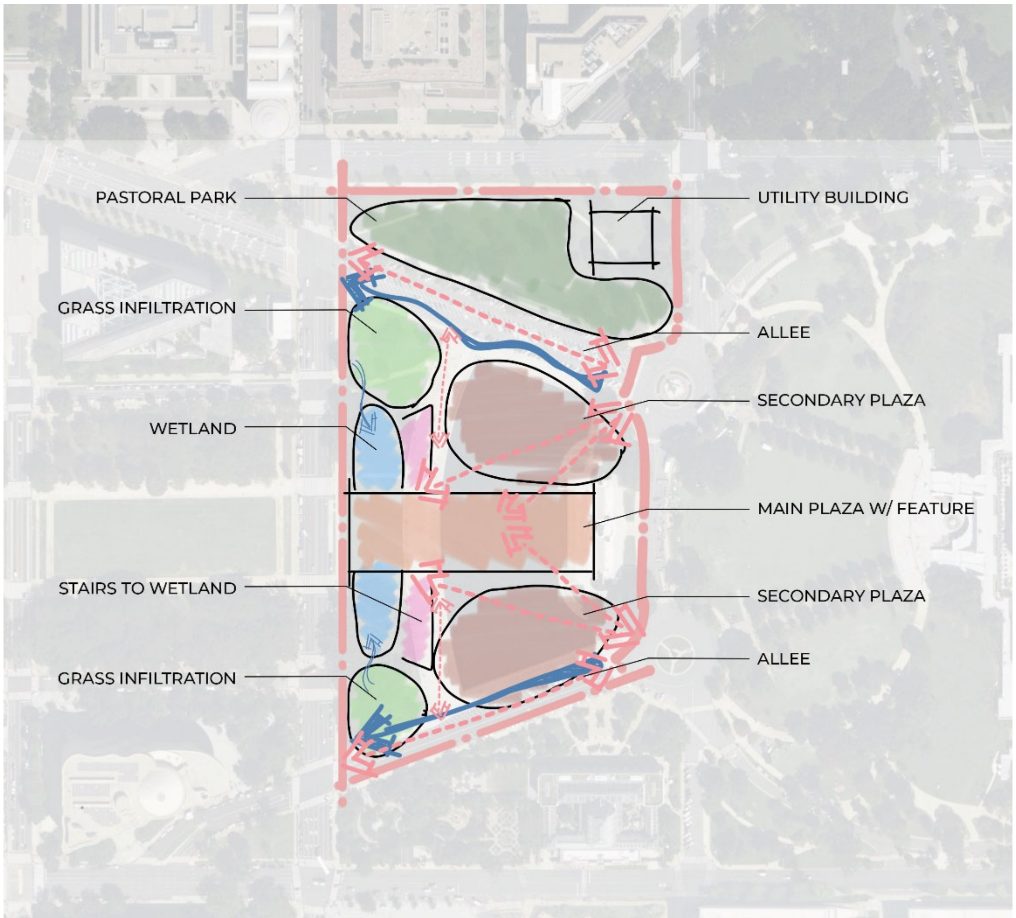

Figure 37: Ha-Ha concept diagram

The final design, the Ha-Ha, (See Figure 36) (See Figure 37). Designed to best continue sight lines from the National Mall up to the Capitol, while centering the wetland on site, the ha ha landform depresses the wetland against a wall along the western edge. This allows the water to still be contained along one edge, while letting it flow up along a more natural floodplain on the other. The rest of the design is focused on a central plaza designed to mimic the geometry of the National Mall, with secondary plazas on either side. This design also leaves the northern section of the site mostly undisturbed. This concept was the most favorable and is leading the next design phase.

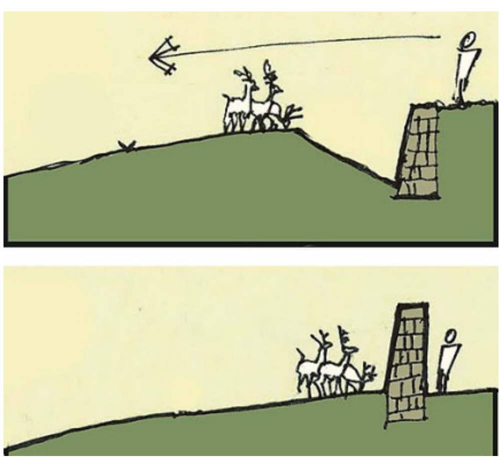

Figure 36: Cartoon displaying what a ha ha is and why it can be used (Photo Cred: Wikipedia)

Site Design

The new design for Union Square, has several new notable features (See Figure 38). The central gathering place is broken into three sections, each inspired by branches of government. The middle plaza is the Legislative Plaza with the Executive and Judiciary Plazas on either side. Each section has its own fountain reflecting its name. Rectangular garden and lawn areas are spread out across the plazas, breaking up the expanse of paving. A large, constructed wetland runs across the Western edge of the site and is made up of a ponded wetland with grassy floodplains on three sides. The exterior Northern and Southern wings of the site are predominantly park lands. The park land is made up of low-cut lawn and a variety of trees with various curvilinear paths meandering through the site and two new axial tree lined allées.

Figure 38: New Union Square Site Plan with Main Features Key

Goal 1: Capture, Treat, and Recycle Stormwater

In order to capture and treat water on site, the design uses a three-tiered system (See Figure 39). First, water captured from across the site and around the catchment area is re-routed from the standard sewer pipes with a splitter at the top of the inlet drain. This will direct the initial flow of water into the site to be treated but will also have an overflow outlet at the top of the splitter to let any excess water flow back into the normal sewer system.

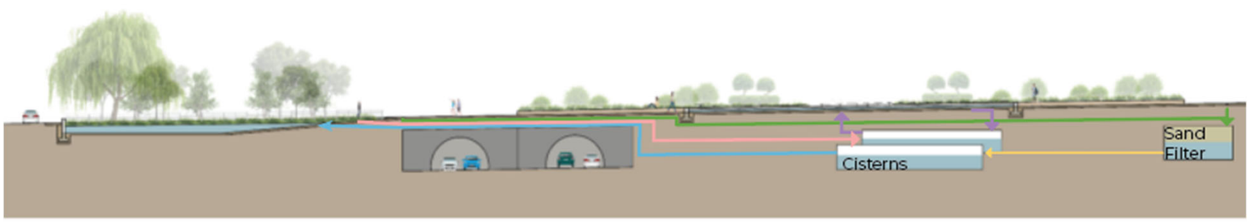

Figure 39: Water System diagram showing movement of water across site within the new design

Key:
Green Rainwater inflow
Yellow Post Filter to Cistern
Blue Wetland Water Supply
Pink Wetland Overflow
Purple Fountain Water

Once directed into the site, the collected water is combined with water collected on site and treated through an initial sand filter before being stored in the first twenty-five cisterns under the plaza. The rainwater falling on site either permeates into the majority permeable areas or is directed to the edges of impermeable areas to drain into pipes that connect back to the aforementioned sand filter. The water from the cisterns is then pushed up to the spouts on either side of the floodplains where it is then allowed to flow down through the grasses. This process further cleans the water as it combs through the filter-like materials of the grasses, before draining into the main ponded wetland at the center of the site. Along the floodplain, the water can also begin to infiltrate into the soil or be soaked up into the plants. Initial overflow water from the wetland, one foot above the standard level, will flow into the second set of five cisterns which will use the cleaned water to supply the three fountains on site, where it will be continuously recycled. This will also allow for some level of control regarding the ponded water level. Both groups of cisterns will also have overflow drains to release excess water back into the sewer system in the case of too much rain, but only after the wetland has reached max capacity, two feet above the standard level.

Within the wetland there will be two small fountain structures that can be turned on when necessary. While this will be an aesthetic feature, the primary purpose of the fountains will be to aerate the water in cases of high nutrient loads. This will help reduce the likelihood of intense algal blooms.

The water captured and treated through this process is gathered from onsite and the decided catchment area. There are a number of unknowns regarding water capture as well. The first and foremost is if the building and lot owners would agree to retrofit their drainage to allow for new pipes. Another unknown is regarding potential other sources of water to inundate the wetland. It is fundamentally important to the health of a wetland to have a continual source of water for inundation. Most natural wetlands get this water from the continued connection to existing ground water. Due to existing surrounding structures, such as the adjacent roads and underground highway, this ground water connection is inadvisable. Finding another reliable source of water is paramount, in the unlikely event of a long-term drought that would dry up the stormwater cisterns. Given that there is an existing reflecting pool on site, it is reasonable to assume there is an existing supply of potable water on site. This will be used to supply water to the wetland as a last resort, if the cisterns and wetland run dry.

In addition to a backup supply of potable water, additional recycled water could also be used to feed the wetland. The first option is from the underground highway on site. It has been noted that water pumps are used underground to drain groundwater from the tunnel, although the amounts of water and location of the tunnels are unknown. If those numbers and locations could be learned, the water pumped from the tunnel could potentially also be used to inundate the wetland. Another source of water could be from distinctly urban sources, such as air conditioning units in the surrounding buildings.

Goal 2: Implement Features On Site to Foster Care

Mixing the naturalistic state of the wetland with an urban park and plaza relies on a number of design principles. The first is a reliance on historical and surrounding influences, this will be discussed in the following section. The second is "cues to care" (Nassauer, 1995). This design uses those cues in a number of ways. Spreading signage throughout the wetland and even into the rest of the site creates a cohesive display of human intentionality (See Figure 40). These also work to educate visitors on what a carefully tended wetland habitat can look like and offer.

Figure 40: Rendered image of new design from northern overlook deck, looking towards the central plaza

Additionally, using distinctly man-made features act to remind viewers of the intentionality and safety of the otherwise "wilder" area. This design uses a variety of these including several large bridges made from concrete, pavers and steel. These cut up the wetland so that from any viewpoint visitors are reminded they are not far from more formally designed human spaces. The bridges also allow visitors to closely interact with the wetland, moving visitors through, around, and over the wetland. Other than handrails where needed, the wetland is entirely accessible with no large walls or barriers. This accessibility and interaction allow visitors to feel more comfortable and confident in the new space.

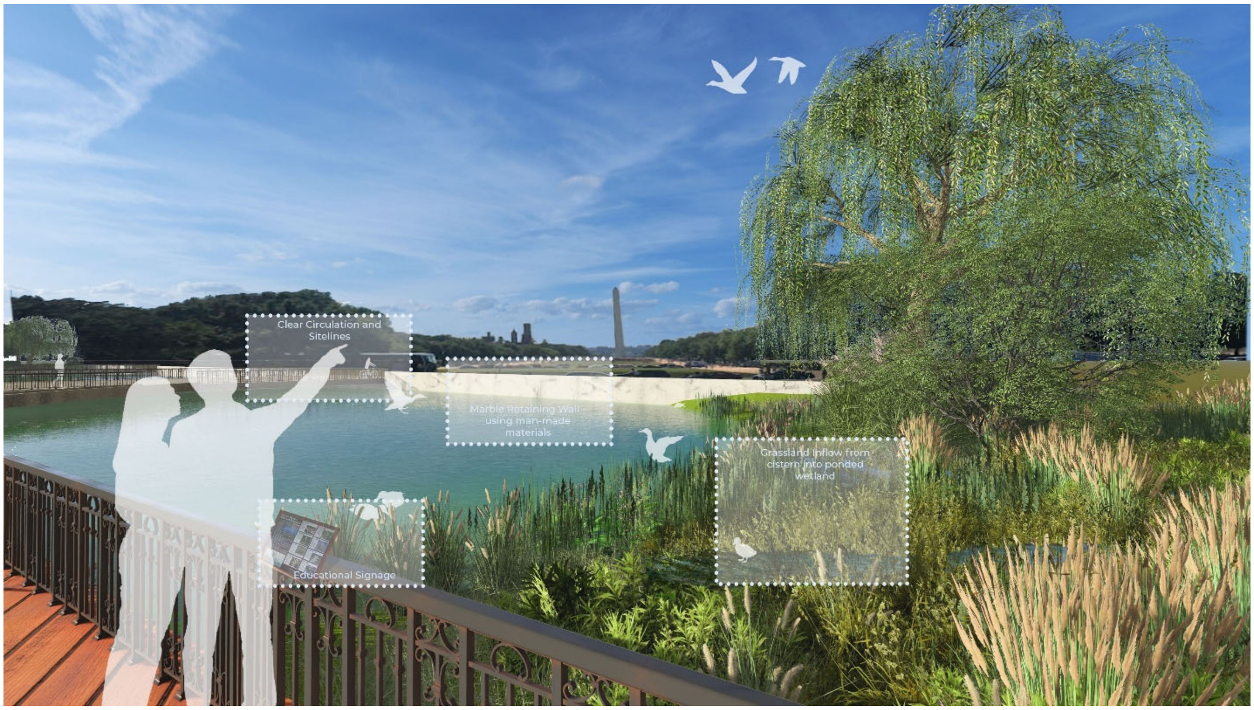

Figure 41: Rendered image of new design, showing the view from the northern overlook deck across the National Mall

Another reminder of human intervention is the marble wall across the entire Western edge of the ponded wetland (See Figure 41). While the wall is a practical necessity to keep the water from spilling into the nearby road, the materiality was chosen to reinforce the urban nature of the wetland in addition to its durability. Marble is often used as a hallmark of human achievement, seen on buildings such as the United States Capitol Building, the Lincoln Memorial, and the Washington Monument, as well as the Parthenon in Greece, Pantheon in Italy and the Taj Mahal in India.

Circulation is another essential element of urban design. With a site that demands flexibility, the designed circulation must accommodate not only varying levels of circulation, but varying types of circulation as well. Standard sidewalks surrounding the site connect existing circulation routes to proposed routes. Two main access routes on the Western edge of the site, bridging across the wetland, are roughly 50 feet across (See Figure 42). These are the main entry points to the site which come from the National Mall and must accommodate large groups of people crossing onto the site at once. They are also a very formal entrance; thus they are paved with the same stones as the larger plazas.

Second level access points and circulation routes accommodate medium sized groups moving from one area to another. They are roughly 20 feet wide and are meant as main routes of circulation on site. These secondary circulation routes are between two main features on site including between large entry points and the plazas, between the plaza and the allées, or between an allée and the multi-use building. These routes are generally standard concrete sidewalks, with the exceptions of areas crossing over the wetland where the paths are raised or when they transition into the allées.

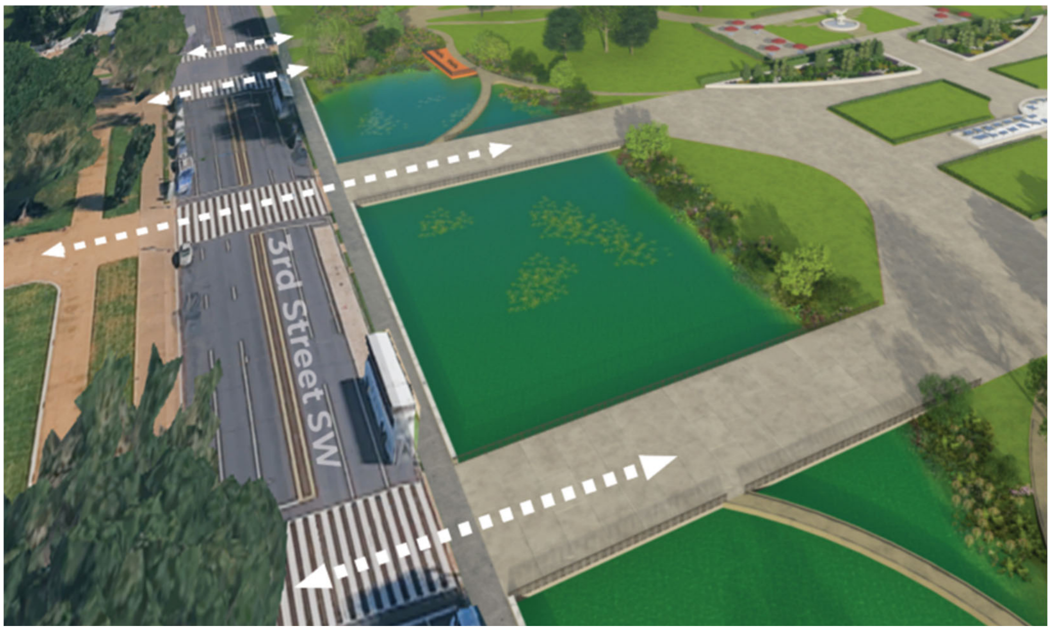

Figure 42: Rendered image of the new design showing circulation routes from the National Mall onto the site.

Finally, the third level of access points and circulation routes are designed to accommodate small groups only. These routes are generally meant for slower meandering through the site, connecting one path to another, instead of quick movement from one destination to another. These routes could be ideal for runners' intent on staying off the main plaza during their circuit or for pedestrians taking a more scenic route.

In a similar vein, designing for varying levels of occupation of the site is also important when designing an active urban park (Whyte, 2001). The new design implements several different seating types in a variety of locations. Tables with movable chairs occupy the side plazas to invite visitors to sit and enjoy the site for longer periods of time. This may include workers from surrounding buildings coming out for lunch, tourists stopping for a meal, or large groups meeting up before/after their activities. These seats are protected by hedges surrounding most of the plaza, appeasing the prospect-refuge instincts, while allowing guarded views into the park areas on the outskirts and the large plaza on the inside. For shorter term occupation, ledges and benches can be found throughout the design.

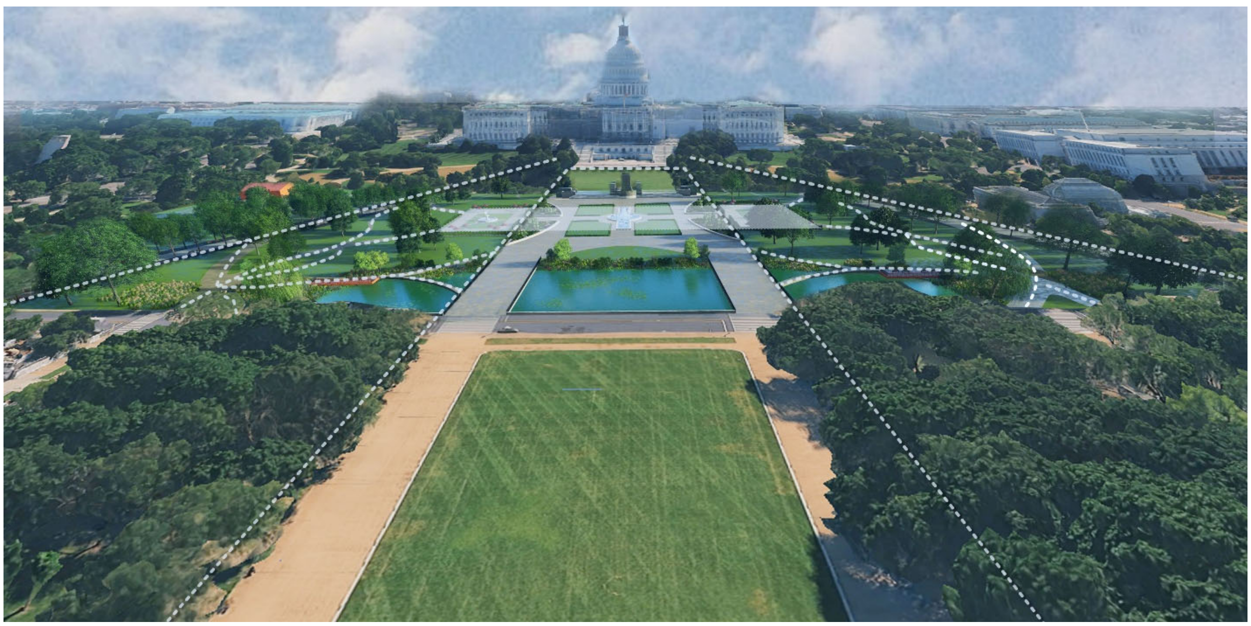

Figure 43: Rendered image of new design showing the bridged entries walking into the central plaza, and its connection to the Capitol Grounds, with the circulation illustrated with dashed lines

<u>*Goal 3: Interweave the Design Within the Context of the Site*</u>

In order to fully mesh the wetland design with the surrounding urban environment, the design relies heavily on the historical and surrounding influences. The first use of this method is through the materials used on site. The large marble wall along the western edge of the wetland along with the fountains built from marble blocks are a reflection of the marble structures across the National Mall. Crushed granite paths down the axial allées are also continuations of expressions seen on the National Mall. Finally, brick edging is seen throughout the design to connect back to the more mundane structures around the site. Brick is seen occasionally along the Capitol grounds in places that are seen as less formal and bringing that material into the design continues the message of creating a place for people of all kinds to gather.

The shapes and geometry of the design are also specific references to the surrounding sites (See Figure 43). The edges of the design continue the curvilinear pathways seen on the Capitol grounds to the east of the site, while the interior of the design pulls the rectilinear axial design from the National Mall. This strategy also works to create a hierarchy to the design, creating more formal gathering places towards the center of the site, with informal and small gathering places towards the outside. These two geometries merge in areas like the secondary plazas, where curved stepping blocks meet with linear blocks at the centered fountain, or in the main plaza where two curved paths become partially curved garden beds (See Figure 44). The areas where the two geometries meet allow for the design to feel cohesive, while still creating a distinct hierarchy.

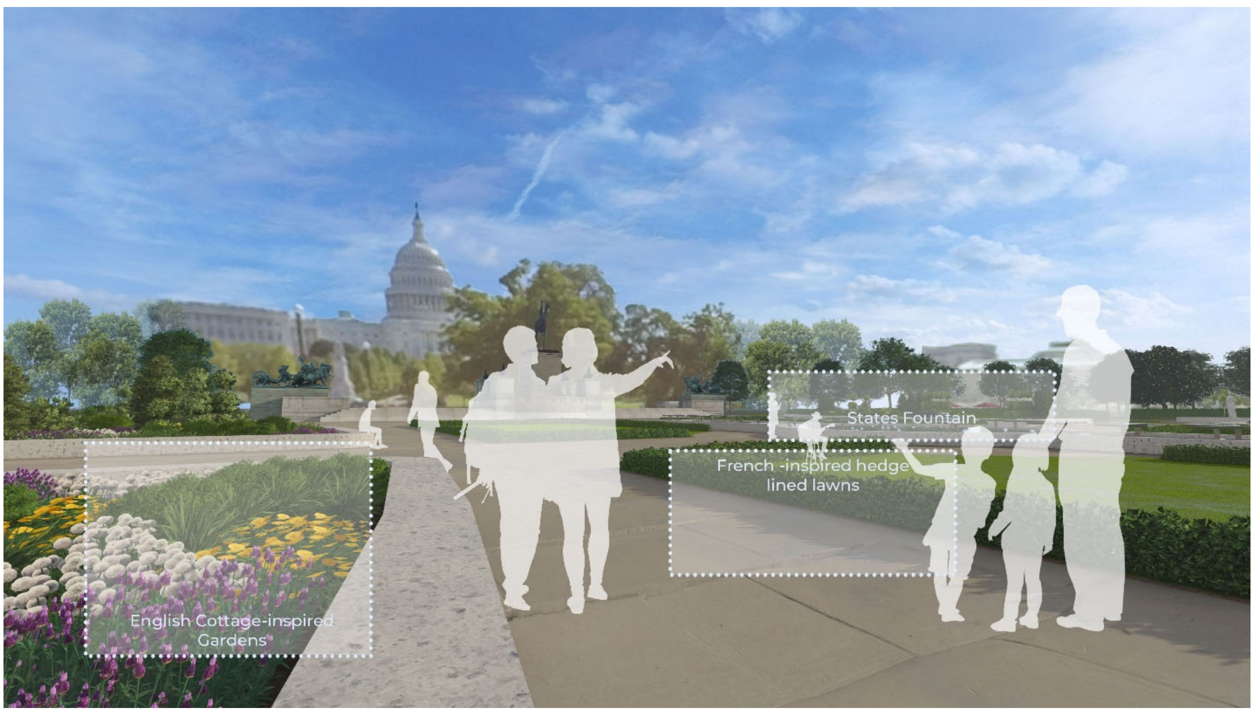

Figure 44: Rendered image of new design, looking across the Legislative Plaza up to the Capitol building

The important geometry onsite was not limited to those isolated-on site. Some of the most important lines in the design are continuations of long-standing axis created by L'Enfant's design in 1791. The existing axial parking lots will retain the shape, maintaining the connection, but will be changed in tree lined allées, similar to those seem walking up Capitol Hill. Additionally, the straight site-line across the center of the National Mall, from the Washington Monument up to the Capitol building, will be maintained. This site line is accomplished by keeping all structures and plantings low in the middle of the design, building higher up as the design moved to the North or South.

Finally, the prominent location in front of the United States Capitol building called for a plaza that embodied that position. Entitled Union Square, the design for the plazas was inspired by the location at the foot of a building meant to reflect the opinion, desires, and votes of the American public (See Figure 43). Made up of three parts, each representing a branch of government, the plaza represents how the core of the American democracy is supposed to be the representation of the people. The central Legislative Plaza is the largest of the three plazas and is centered on the Capitol building. Its central feature is the State's fountain which is a large pool with all 50 states raised up and spread around the perimeter. This fountain is meant to symbolize how the government is meant to be by- and for- the people, represented by the states. Ideally it will also be a draw for tourists, who can now come to their nation's capital and find their home and toss a coin onto their state.

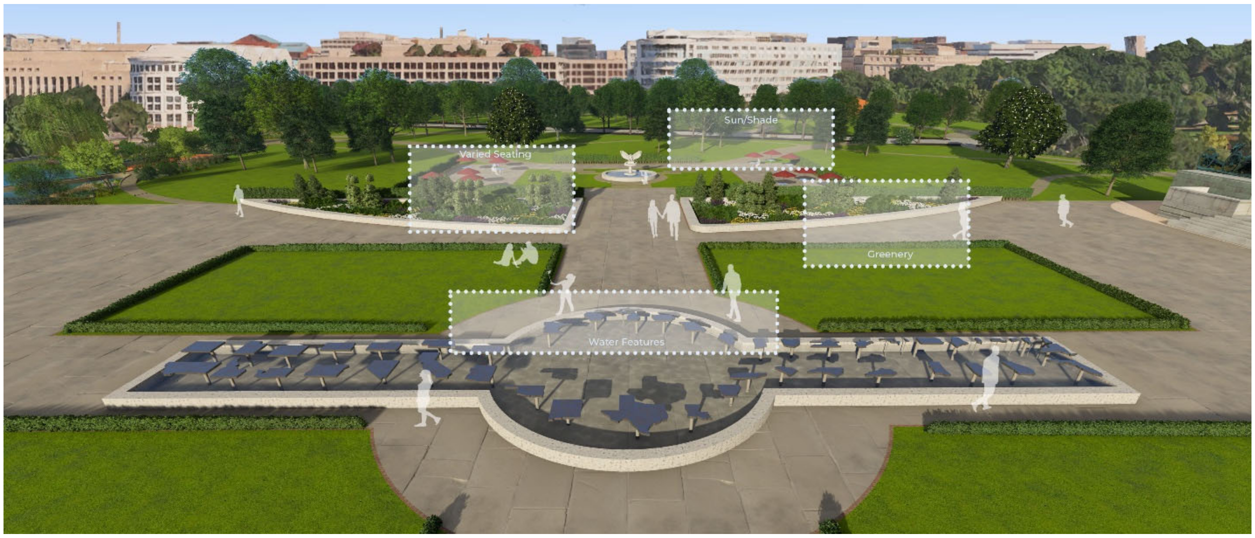

Figure 45: Rendered photo of the new design showing the Legislative and Executive Plazas

On either side of the Legislative Plaza are smaller plazas, representing the Judiciary and Executive branches of government. They each also have a fountain representing their branch of government. The Judiciary Plaza has a fountain with Lady Justice, while the Executive Plaza's fountain boasts an eagle taking off (See Figure 45). The hedge-lined rectangular lawns across the plazas are inspired by traditional French designs, also seen across Washington D.C., due to L'Enfant's designs.

Goal 4: Connect Site with Natural Systems

The goal of re-connecting the site to natural systems was less successful. While the wetland created significantly more habitat, the underground structures prevented the connection of the wetland to the natural water table.

The new design greatly increases the number of species on site. The wetland section itself has a range of plants, from higher on the flood plain with the canopy and shrub layers to the deeper water with the saturated soil and emergent layers (See Figure 46).

Figure 46: Rendered diagram showing levels of plant species according to inundation levels

- Canopy Layer
    - *Betula nigra* (River Birch)
    - *Salix nigra* (Black Willow)
- Shrub Edge
    - *Cephalanthus occidentalis* (Buttonbush)
    - *Itea virginica* (Virginia Sweetspire)
    - *Cornus amomum* (Silky Dogwood)
- Wet Meadow/Transition
    - *Asclepias incarnata* (Swamp Milkweed)
    - *Panicum virgatum* (Switchgrass)
- Saturated Soil
    - *Carex stricta* (Tussock Sedge)
    - *Juncus effusus* (Soft Rush)
- Shallow Emergent
    - *Pontederia cordata* (Pickerelweed)
    - *Iris versicolor* (Blue Flag Iris)
- Deeper Emergent
    - *Nymphaea odorata* (American White Water-lily)

The Park section will be filled with lowcut lawn with some larger shrubs and trees. It also has less defined differences in sub-habitats.

- Primary Canopy Trees
    - *Quercus bicolor* (Swamp White Oak)
    - *Quercus rubra* (Northern Red Oak)
    - *Liriodendron tulipifera* (Tulip Poplar)
    - *Platanus x acerifolia* (London Plane Tree)
- Moist or Low Park Areas
    - *Taxodium distichum* (Bald Cypress)
    - *Acer rubrum* (Red Maple)
- Flowering Small Trees / Transitional Layer
    - *Magnolia virginia* (Sweetbay Magnolia)

    - *Amelanchier canadensis* (Serviceberry)
    - *Cornus florida* (Dogwood)
- Shrub Massing
    - *Viburnum dentatum* (Arrowwood Viburnum)
    - *Ilex verticillata* (Winterberry Holly)

The final subset of plants in the design is in the four planter beds on the Legislative Plaza. These plants must be able to grow in almost full sun and should bring a variety of colors and textures, paying homage to the traditional English cottage style.

- Structural Shrubs
    - *Hydrangea paniculata* (Panicle Hydrangea)
    - *Rosa* (Roses)
- Evergreen Structure
    - *Buxus sempervirens* (English Boxwood)
- Flowering Perennials
    - *Lavandula angustifolia* (Lavender)
    - *Nepeta x faassenii* (Catmint)
    - *Salvia nemorosa* (Salvia)
    - *Echinacea purpurea* (Coneflower)
    - *Achillea millefolium* (Yarrow)
- Texture Layer
    - *Carex pensylvanica* (Pennsylvania Sedge)
    - *Carex flacca* (Blue Sedge)
    - *Carex oshimensis* (Oshima Sedge)
- Groundcover
    - *Phlox subulata* (Creeping Phlox)
    - *Thymus serpyllum* (Creeping Thyme)
    - *Geranium sanguineum* (Hardy Geranium)

The added plants, spread across almost 20 acres, make it easier for animals to traverse the site, due to the site having fewer areas with no protection. It will also increase habitat and food availability for a variety of animals. More toads, frogs and fish will be able to live in the wetland habitat, which can then support a number of birds like the Blue Heron. Other birds finding food and habitat across the site include hummingbirds, cardinals, goldfinches, and brown thrashers. Finally, insect populations, like the monarch butterfly, honey bee, clearwig moth, and hoverflys will be able to pollinate, inhabit, and protect the plantings on site.

While habitat has increased, reconnecting the water table in that area was not possible. Due to the underground highway and its infrastructure, keeping the wetland open to surrounding soil and water table was irresponsible. As flooding onto the highway is already a problem, adding more water into the soil to be pumped out would have been problematic. Additionally, on the other side of the wetland is 3rd Street SW. Making the soil underneath that road wet would also be damaging to the structural stability of the road.

Site Analytics

This section will provide some analysis of the new design of Union Square, including new water capture abilities and permeability numbers.

Water Catchment

The Contour-Area Method will be used to calculate the volume of water that can be stored in the new wetland.

$$Volume = \left[\left\{ \frac{(A^1 + A^2)}{2} \right\} + \left\{ \frac{(A^2 + A^3)}{2} \right\} + \left\{ \frac{(A^3 + A^4)}{2} \right\} + \left\{ \frac{A^4}{3} \right\} \right] * h$$

This method uses the area of each contour to average the volume in between, where A = a given area from a certain contour and h = the height between these contours (the contour interval). The equation must also take into consideration the bottom contour which has zero area and thus creates a conical shape for the last volume. The individual contour areas and volumes can been seen below (See Figure 47). Based off these calculations, the new wetland has been designed to store approximately 275,704.62 cubic feet at standard pond elevation of 8’ above sea level, and 462,219.95 cubic feet at full capacity. Additionally, the site has thirty 50,000 gallon cisterns stored beneath the plazas on site, 25 used to supply the wetland, the remaining five used to supply the fountains. This is roughly an additional 200,534.76 cubic feet of water storage. The total capacity of the site is 662,754.71 cubic feet, almost 5 million gallons.

Contour	Area (sq ft)	Volume (cubic ft)	
8' Contour	69,749.87	65,160.07	Volume between 6' and 8' Contour
6' Contour	60,570.26	55,729.40	Volume between 4' and 6' Contour
4' Contour	50,888.54	16,962.85	Volume between 2' base and 4' Contour
275,704.62			**Total Volume at 8' Contour**
10' Contour	116,765.46	93,257.67	Volume between 8' and 10' Contour
462,219.95			**Total Volume at 10' Contour**

Figure 47: Table used to calculate volume capacity of pond at standard capacity and max capacity

In order to determine the amount of water running onto the site, the Q=CIA equation was implemented. Where:

Q = Total Runoff Flow

C = Dimensionless Coefficient (representing permeability)

I = Rainfall Intensity

A = Area

The "C" (See Figure 48) and "I" (See Figure 49) numbers come from documentation from the Department of Energy and Environment of District of Columbia, while area numbers come from digital mapping of the site and desired catchment area.

runoff coefficient for natural cover (0.00)
area of post-development natural cover (ft^2)
runoff coefficient for compacted cover (0.25)

area of post-development compacted cover (ft^2)
runoff coefficient for impervious cover (0.95)

Figure 48: Section of text from document showing the DC dimensionless runoff coefficients (Photo Cred: DOEE DC)

Table A.2 Depth-Duration-Intensity-Frequency Rainfall Values for the District of Columbia

	1 Year		2 Year		5 Year		10 Year		15 Year		20 Year		25 Year		50 Year		100 Year	
Time (min)	d	i	d	i	d	i	d	i	d	i	d	i	d	i	d	i	d	i
5	0.38	4.60	0.44	5.28	0.54	6.42	0.61	7.34	0.63	7.56	0.64	7.63	0.66	7.93	0.72	8.61	0.74	8.89
10	0.65	3.88	0.74	4.44	0.89	5.34	1.02	6.11	1.05	6.30	1.06	6.36	1.10	6.64	1.20	7.20	1.25	7.90
15	0.83	3.32	0.96	3.83	1.15	4.59	1.32	5.27	1.36	5.44	1.38	5.50	1.43	5.72	1.54	6.14	1.61	6.42
20	0.97	2.91	1.12	3.36	1.35	4.04	1.55	4.65	1.61	4.82	1.63	4.88	1.69	5.08	1.78	5.35	1.86	5.59
30	1.13	2.26	1.35	2.70	1.64	3.27	1.90	3.79	1.97	3.95	2.02	4.03	2.10	4.19	2.24	4.49	2.32	4.65
45	1.29	1.72	1.57	2.09	1.93	2.57	2.25	3.01	2.37	3.16	2.44	3.25	2.54	3.38	2.83	3.77	2.96	3.94
60	1.38	1.38	1.70	1.70	2.13	2.13	2.51	2.51	2.66	2.66	2.76	2.76	2.87	2.87	3.22	3.22	3.39	3.39
80	1.49	1.12	1.81	1.36	2.33	1.75	2.77	2.08	2.96	2.22	3.10	2.32	3.22	2.42				
100	1.55	0.93	1.89	1.13	2.48	1.49	2.98	1.79	3.20	1.92	3.37	2.02	3.51	2.10				
120	1.58	0.79	1.94	0.97	2.60	1.30	3.14	1.57	3.40	1.70	3.61	1.80	3.75	1.87				
150	1.65	0.66	2.00	0.80	2.75	1.10	3.34	1.34	3.65	1.46	3.90	1.56	4.06	1.62				
180	1.68	0.56	2.04	0.68	2.86	0.95	3.50	1.17	3.87	1.29	4.16	1.39	4.32	1.44				
360			2.13	0.35	3.29	0.55	4.15	0.69	4.68	0.78	5.23	0.87	5.43	0.91				
720			2.16	0.18	3.73	0.31	4.84	0.40	5.64	0.47	6.49	0.54	6.75	0.56				
1440			2.17	0.09	4.18	0.17	5.62	0.23	6.79	0.28	8.04	0.34	8.35	0.35				

Notes: t = time in minutes
d = rainfall depth in inches
i = rainfall intensity in inches per hour
In general, i = (60 * d) / t

Figure 49: Depth-Duration-Intensity-Frequency Chart (Photo Cred: DOEE DC)

Permeability Type	Site Area (Acres)	Runoff Coefficient
Natural	3.01	0
Compacted	5.42	0.25
Impervious	4.95	0.95

Figure 50: Chart showing on site areas based on permeability levels

Permeability Type	Catchment Area (Acres)	Runoff Coefficient
Natural	3.01	0
Compacted	178.96	0.25
Impervious	87.69	0.95

Figure 51: Chart showing entire catchment areas based on permeability levels

Based off these numbers, using the Q = CIA equation, the site can hold a 2-year, 1 hour storm, which would produce roughly 648,540 cubic feet of water from the entire catchment area, with almost 20,000 cubic feet of remaining volume (See Figures 50 and 51).

Permeability

The existing site is made up of 11.13 acres of impermeable surfaces and only 8.43 acres of permeable surfaces (See Figure 53). The new design has 15.8 acres permeable surfaces, and only 4.94 acres of impermeable surfaces (See Figure 52).

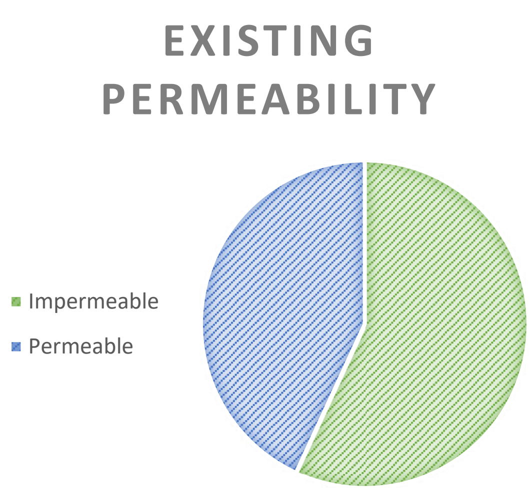

Figure 53: Pie Chart showing existing permeability percentages on site

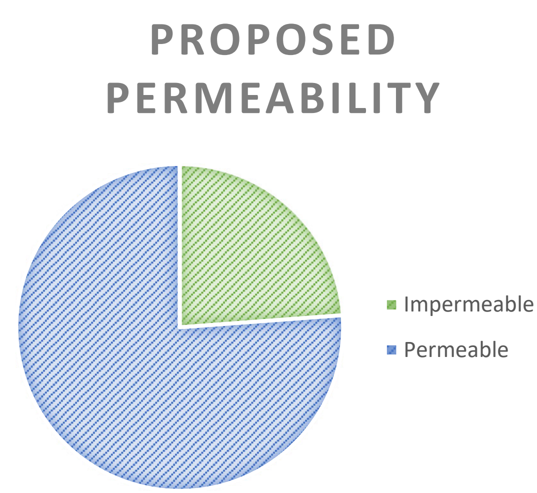

Figure 52: Pie Chart showing proposed permeability percentages on site

Chapter 5: Discussion and Conclusion

This section will address the main two research questions; in what ways can wetlands be used to address a plethora of issues facing urban environments, and how can wetlands be designed to better fit within the urban fabric? These will be answered by providing general methods that were specifically demonstrated in Union Square design.

Research Question 1: In What Ways Can Wetlands Be Used to Address a Plethora of Issues Facing Urban Environments?

Green Space

Green space in many urban areas is severely limited, as is space in general. Not only are wetlands capable of acting as these green spaces, they are also able to defend their existence in these heavily sought after locations through a multitude of ecosystem benefits. As previously noted, they can provide cheaper water filtration systems than existing grey infrastructure systems, which will be further discussed in the next section. Additionally, urban wetlands can provide recreational opportunities, cooling effects, and carbon sequestration, based on various design choices. In the Union Square design, recreational opportunities are provided through educational signage, gathering areas, and wetland overlooks. Additionally, the addition of varying tree species across the site provide increased shade during warm months and increase carbon uptake.

Water Systems

Flooding is becoming increasingly impactful in urban areas across the world. In Washington D.C. alone, flooding comes from two directions, one coming up from the surrounding rivers, and the other flowing down from overwhelmed sewer systems. Wetlands are uniquely capable of assisting in both respects. Not only can wetlands act as buffers between waterbodies and land, protecting the land from flooding, but urban wetlands can also help reduce the volume that existing pipes need to accommodate by providing an alternative location for surface runoff. The placement and design of the wetland can determine which of the two flooding scenarios any given urban wetland will address. In the Union Square design, the capture of stormwater is furthered by underground systems that clean, store, and recycle the water prior to, and following its use within the wetland.

Additionally, like many older cities, Washington D.C. has a large network of CSS. Using urban wetlands throughout the city to reduce the volume of stormwater flowing into these systems can greatly reduce the likelihood of further sewage spills contaminating local waterbodies. Using splitters in existing sewer grates, like those in the Union Square design, to redirect water into the wetland system, can further spread the beneficial reach.

Research Question 2: How Can Wetlands Be Designed to Better Fit Within the Urban Fabric?

Defined Interaction

One of the defining characteristics of wetlands is the lack of a clear border. However, standard urban environments are almost the exact opposite. Cities are made up of defined borders and defined interactions; doors and walls that restrict access, sidewalks that define where people are welcome, and even streetlights that dictate when one is supposed to move. Finding ways to accomplish both the flexibility that wetlands require and the structure that urban areas desire, could be a potential answer. This relies distinctly on the ideas of Nassauer, providing some readable, orderly frames to the internal messy wetland. One example of how this shows up in the Union Square design is by having some floodable, flexible boundaries to the wetland, and some rigid, strict boundaries. Additionally, clear pathways and crossings create an understanding in where human interaction in the wetland is accepted and where it is prohibited. This can ease the uncertainty that visitors may otherwise experience when traversing the wetland ecosystem.

Materiality

Another resource that can be used in the merging of wetlands and urban ecosystems is the materials chosen on site, and where they are located. By using materials that are often associated with human dominance, such as marble in the case of Union Square, and locating them within the boundaries of the wetland, the design is signifying the intentionality of the otherwise “wild” environment. This can also be seen in the plants chosen for the wetland. While they must be selected from natural wetland plants, that have evolved to thrive in varying inundated habitats, the design may rely on specifically chosen plants, such as Blue Flag Iris or Sweetspire, that often appeal to the flowering, garden aesthetic that people often gravitate towards.

Education

Educational efforts can assist in allowing humans to feel more comfortable in wetland environments. Educational signage can be used to inform visitors on what types of plants and animals they are seeing within the wetland, what a healthy wetland looks like, how wetlands function, and even ways in which they can better tend to the wetland environment. All of this information makes the wetland a more understood entity, simultaneously making it a more comfortable environment for humans.

Controlled Systems

Finally, creating systems within the urban wetland that can allow for more control of the environment assists in the wetland better functioning within cities. This system is demonstrated in the Union Square design a number of ways. First and foremost, using underground cisterns to regulate the inundation levels of the wetland allows for more stability in the aesthetics of the site. Natural wetlands go through large fluctuations of inundation levels based on rainy or dry seasons, creating significant changes in the appearance of the flora on site. Regulating this inundation allows for better control of the health of the plants on site. Another example of greater control of the wetland is the fountain mechanisms. Dictating when these fountains are activated means managing the oxidation levels within the wetland, thus potentially preventing algal blooms.

Future Opportunities

While the design is largely successful by achieving the stated goals, there were areas that could use further investigation or probing for answers. One such area is the opportunity to use water being pumped out of the underground highway on site. This opportunity would require collaboration with DC Water, which wasn't able to be achieved during this thesis. Further information in general would be necessary to further this design and any future in being actually developed. This information would include more information regarding soil quality, water table depth, and other underground structures.

Final Thoughts

The research and design of Union Square demonstrate how wetlands can be designed to fit within an urban fabric, while benefiting both the wetland and the city. Heavy reliance on urban design theories promotes the community development of a sense of place. This connection to the site will help protect and preserve the health of the wetland. On the other hand, the wetland can provide numerous ecosystem benefits to the city, protecting it from flooding, cleaning water supplies, and providing necessary green spaces. The wetland is acting as green infrastructure to benefit the city, and the city providing care, funding, and resources to the wetland. This creates a beautiful balance between a historical urban city and an environmentally beneficial natural landscape.

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