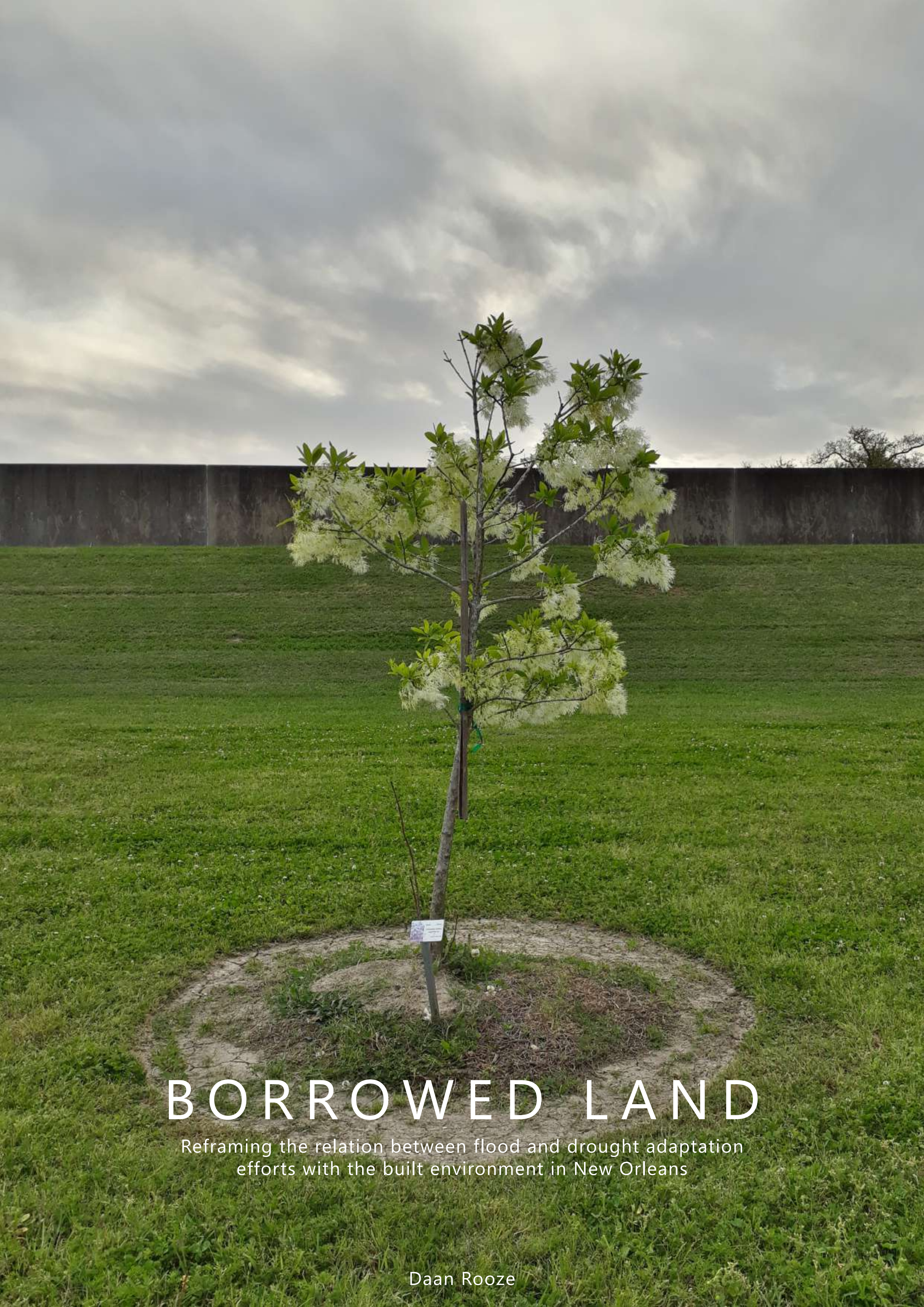

BORROWED LAND

Reframing the relation between flood and drought adaptation efforts with the built environment in New Orleans

Daan Rooze

Colophon

Borrowed Land

Reframing the relation between
flood and drought adaptation efforts
with the built environment in New Orleans.

Master Thesis report
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Figure 1 - Hurricane Katrina (source: NASA, 2005)

Abstract

New Orleans, located in the Mississippi River delta, was hit severely by Hurricane Katrina in 2005 and remains vulnerable to future extreme weather events. The city has persistent socio-spatial issues and is becoming increasingly vulnerable to environmental threats. Along with pressing inequities, stalling repopulation efforts and poor spatial quality, the city faces threats such as rising sea levels, subsidence of low-lying neighborhoods through groundwater pumping, increasing peak precipitation and longer dry spells.

After Hurricane Katrina, the city of New Orleans initiated a workshop series called 'Dutch Dialogues' to produce a strategy for stormwater management inspired by Dutch expertise. This program, coordinated by local architecture firm Waggonner & Ball, yielded an elaborate body of work called the 'Greater New Orleans Urban Water Plan' (GNO UWP), containing an analysis of the water system and urban context, as well as a vision moving forward, supported by a concept design framework. The GNO UWP was completed in 2013. Six years later, few of the proposals in the GNO UWP have been transformed into actual projects. The report remains a source of inspiration for effective stormwater management, but so far it has not gained enough traction to move beyond its advising role.

This research aims to increase the flood and drought resilience of New Orleans by building on existing work through a joint design-engineering approach. There are two fields where this thesis aims to contribute: consideration for extreme weather events in the design framework as well as focusing on the integration of technical adaptation measures with the built environment. The intended end product is an improved design framework with key detailed design interventions, in which the synergy between the engineering and design domains is a primary goal.

The development of a framework and detailed designs follows from a synthesis of existing analyses performed for earlier proposals, supplemented with a vulnerability analysis that focuses on the different capacities of the built environment in dealing with weather events of various magnitudes.

CONTENTS

Manifesto

A place of contrast

Too important and too unique to forsake. Threatened on all fronts but determined to prevail. New Orleans is a place of contrast, a contrast that expresses itself throughout history and space.

Human engineering triumphed the swamps and allowed for sprawl into previously unhabitable land. These extensions of engineering ingenuity are now the most vulnerable parts of the city.

Identity of its deltaic location has diluted; only visible outside of the floodgates. A complete reliance on bigger, better pumps has starved the lower neighborhoods from its geographical location. An identity that only sporadically returns in the form of havoc caused by extreme weather events.

Regarding the city as a work of art, Jane Jacobs (1961) argued, is a mistake of attempting to substitute art for life. New Orleans cannot be made safe by engineering bigger drains and pumps alone. The city must recognize its context and embrace the uncertainty inherent to its location.

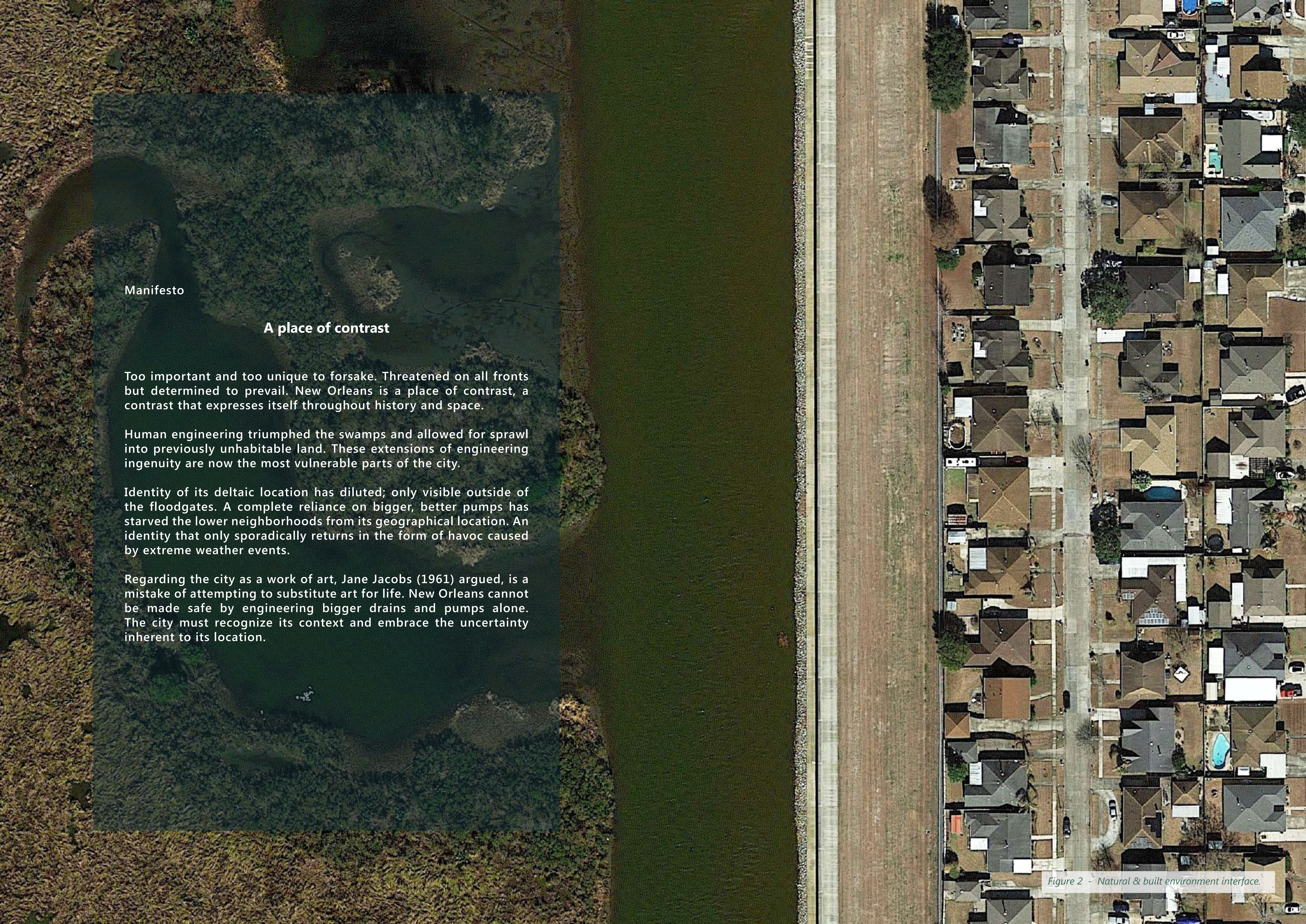


Figure 2 - Natural & built environment interface.

1 EXPLORATION

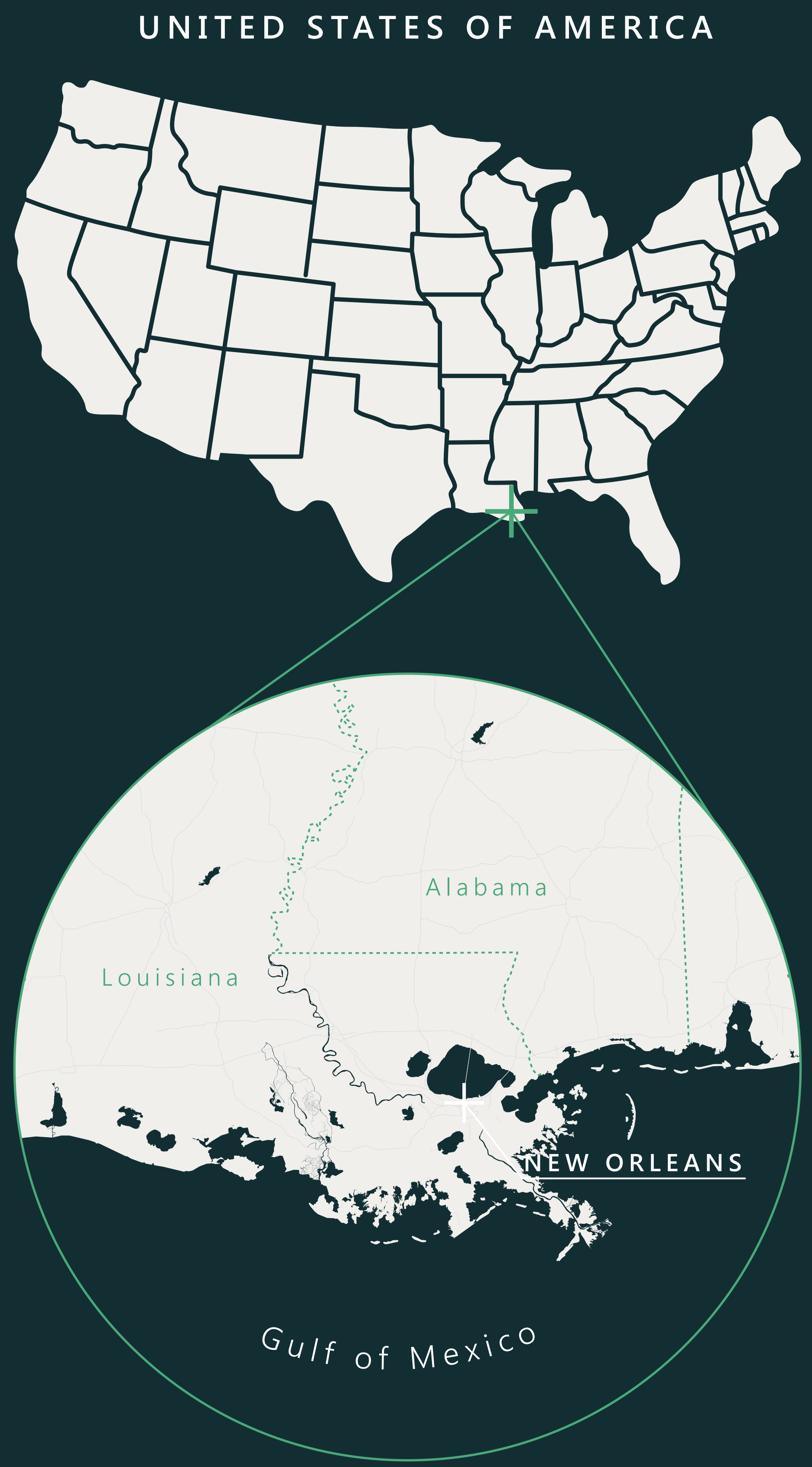


Figure 3 - Local context of New Orleans

1.1 Context

1.1.1 Introduction

The agglomeration of Greater New Orleans, popularly known as New Orleans, is a coastal city, located in the Mississippi Delta in Louisiana, the United States of America. The agglomeration consists of four parishes that together form Greater New Orleans, which are the Jefferson, Orleans, St. Bernard and Plaquemines parishes. The city is bordered by wetlands connected to the Gulf of Mexico on the western, southern and eastern side and Lake Pontchartrain in the north. New Orleans is traversed by the Mississippi River, to which the city owes its rich history and economic and cultural relevance. Figure 3 and Figure 4 show the general surroundings of New Orleans.

New Orleans has frequently been confronted with extreme weather events, with Hurricane Katrina in August of 2005 being the most notable event. An estimated 1833 people lost their lives to Katrina across all affected states, with 1577 reported casualties in Louisiana (Knabb, Rhome, & Brown, 2005). In addition, Hurricane Katrina is estimated to have caused $108 billion worth of damage to property (Knabb et al., 2005). In addition to Atlantic hurricanes, New Orleans also faces pluvial flooding due to high-intensity precipitation on a regular basis. On 5 August 2017, large parts of the city received around 300 mm (10 inches) of rain, causing heavy flooding (Woodward, 2017).

Ever since the early settlement in the 18th century, the population of New Orleans has grown steadily up until the 1960s, when the city saw a sudden decline in population. Fussell (2007) attributes this to a lack of generative power of the oil, port and tourism industries in attracting and retaining population. Hurricane Katrina caused widespread evacuation of the city and large parts of the population did not return after the storm. As of the 2010 census, Greater New Orleans has a total population of 835,320 inhabitants (U.S. Census Bureau, 2010). This is significantly lower than the pre-Katrina census in of 1,034,126 inhabitants in 2000 (U.S. Census Bureau, 2000).

Fussell (2007) identifies three distinctive periods of the population history in New Orleans. The first period is characterized by a migration-driven population of African slaves, which lasted until the end of the 19th century. The second period revolves around the consolidation of the biracial society, during which poor descendants from the enslaved population were spatially segregated from the wealthy white population. The third (and current) period is informed by the influx of largely undocumented Latino migrant workers that helped rebuilding New Orleans in the wake of Hurricane Katrina.

New Orleans has a high degree of climate injustice: low-lying neighborhoods with a majority of low-income black residents were disproportionately hit by the Katrina storm, while wealthier, whiter neighborhoods stayed mostly dry (Fussell, 2007). Many of the poorer residents did not return after the storm, reducing the share of the black population. Instead, Latino migrant workers that helped rebuild New Orleans became a part of New Orleans's society (Fussell, 2007).

Before Katrina in 2005, New Orleans had a notoriously high poverty rate of 24.5 percent of residents living below the poverty level (United States: 13.3 percent) and a median household income of $30,711 (United States: $46,242) (Fussell, 2007).

Parish	2000 census	2010 census
Jefferson	455466	432552
Orleans	484674	343829
St. Bernard	67229	35897
Plaquemines	26757	23042
Total for Greater New Orleans	*1034126*	*835320*

Table 1 - Population before and after Katrina (source: U.S. Census Bureau (2000), U.S. Census Bureau (2010))

Figure 4 - General location of New Orleans.

1.2 Problem Field

The problem field introduces the fundamental boundary conditions that are relevant to this thesis. It discusses the impact of Hurricane Katrina on New Orleans, in addition to currently significant anthropogenic and environmental issues at play.

1.2.1 The Katrina Precedent

On 29 August 2005, the fifth deadliest hurricane ever to strike the United States made landfall in New Orleans. Hurricane Katrina caused widespread damage across the northern Gulf of Mexico coast, with an estimated $108 billion in damage directly related to the storm (Knabb et al., 2005). In addition to the estimated 1,833 casualties, some 445,000 residents were forced to evacuate from New Orleans (Adams, Van Hattum, & English, 2009).

Katrina produced a storm surge that entered the outfall canals of New Orleans via Lake Pontchartrain. According to Knabb et al. (2005), the levee system of New Orleans failed on multiple locations at different times. Some of the levees collapsed due to erosion caused by overtopping of the walls, while some levees gave way before the water reached the top of the walls. Roughly 80% of New Orleans flooded, with varying depth up to 6 meters (20 ft.) (Knabb et al., 2005). Figure 5 shows how the advancing storm surge stroke New Orleans, in addition to all levee breach sites and the recorded flooding across New Orleans.

The recovery of New Orleans in the aftermath of Katrina was slowed by Hurricane Rita, which made landfall in late September the same year and reflooded parts of the city (R. Campanella & Koritz, 2009). It was not until 11 October 2005, 43 days after Katrina made landfall, that all floodwaters were pumped out of the city (Knabb et al., 2005).

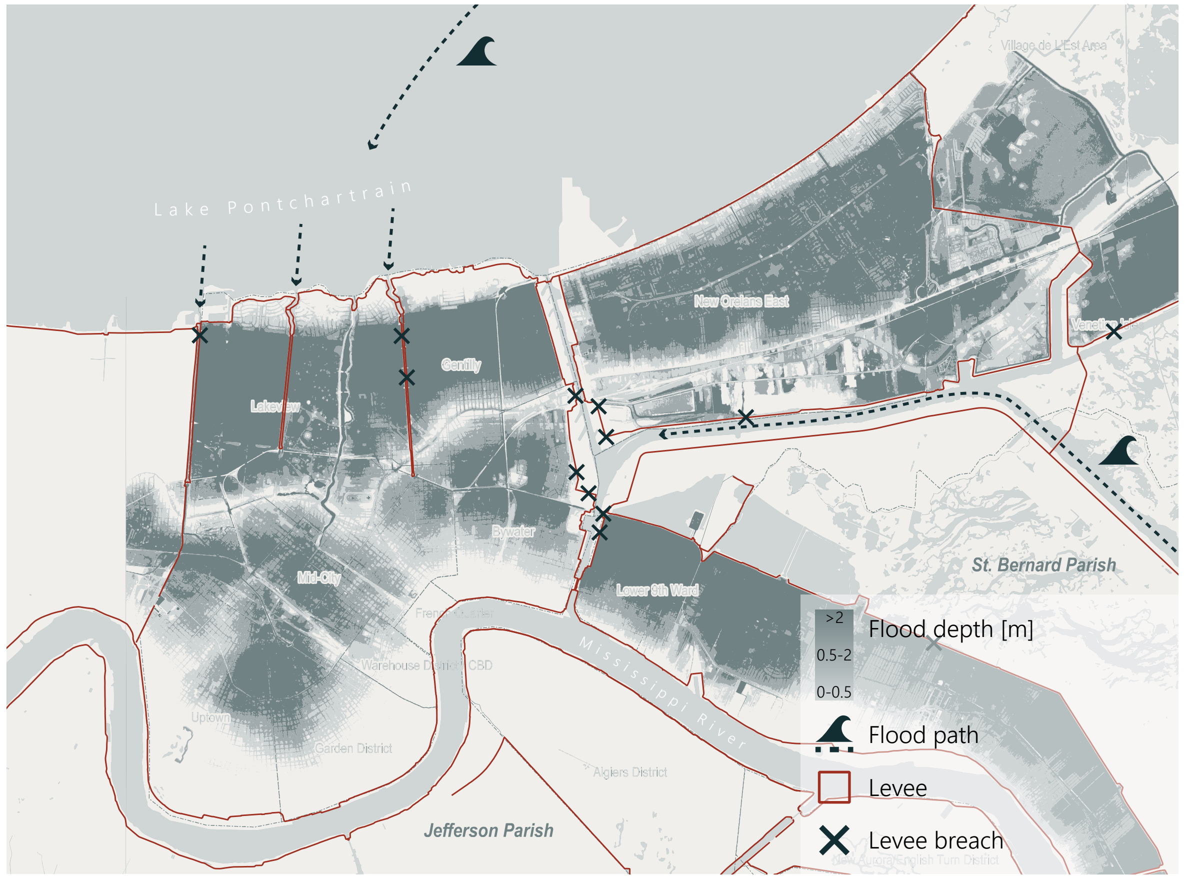


Figure 5 - Development of storm surge through the canals, levee breaches and extent of flooding (source: U.S. Department of Housing and Urban Development (2005), Marshall (2015), elaborated by author).

1.2.2 Socio-Spatial Concerns

1. Inequity

New Orleans suffers from high levels of inequity, in both employment and access to housing (Seicshnaydre, Collins, Hill, & Ciardullo, 2018). Seicshnaydre et al. (2018) conclude that blacks are disproportionately affected, stating "blacks on average remain more physically isolated from jobs than members of any other racial group". Furthermore, housing segregation results in more exposure to environmental hazards and crime.

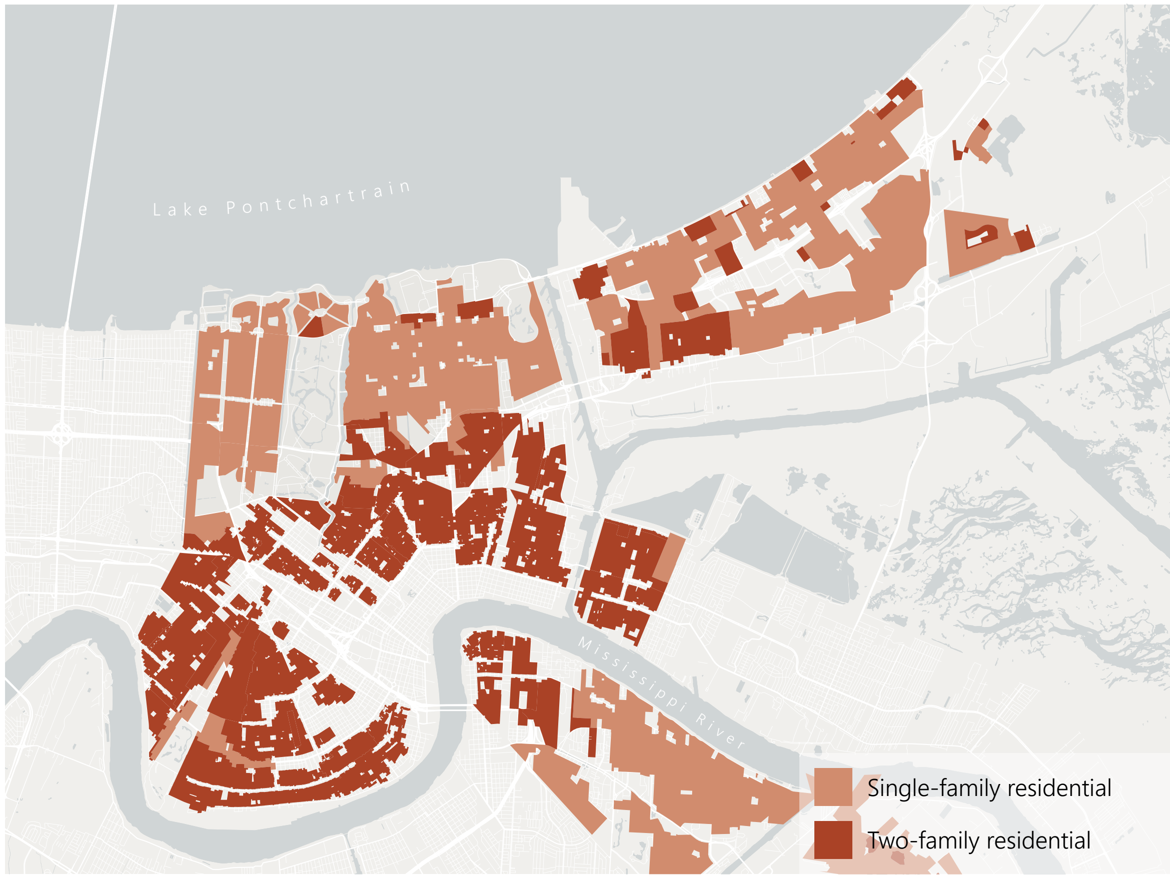
Spatial segregation has roots stemming from the early 20th century, when local governments in Southern states prohibited the integration of races in a neighborhood though so-called "neutral zoning" (Seicshnaydre et al., 2018). Although racial zoning policies were overturned in 1927, state-incentivized development of middle-income single family zoning continued to exclude blacks from desirable and safe neighborhoods, forcing them to settle in more vulnerable places (Seicshnaydre et al., 2018).

Racial segregation resulted in unfair exposure to the Hurricane Katrina disaster, with 68% of African Americans facing displacement, as opposed to 43% of whites (Seicshnaydre et al., 2018). After Katrina, recovery policies only amplified racial segregation instead of reversing the trend. Displacement is currently further reinforced by gentrification processes (Seicshnaydre et al., 2018).

2. Homogenous zoning

New Orleans saw a major expansion of its built footprint in the 20th century with the introduction of the Wood screw pump, which allowed the Sewage and Water Board to drain nearby cypress swamps (Waggonner & Ball Architects, 2013). These expansions have taken shape as classical American suburbs, having a predominant "single family residential" zoning and boasting few other functions. Functional homogeneity and a lack of diversity is often associated with a low resilience to disturbances (Tyler & Moench, 2012).

Figure 6 - Homogenous, single family residential zoning in New Orleans.



3. Vacancy

Vacancy is a persistent problem in New Orleans, which was exacerbated by Hurricane Katrina. According to the City of New Orleans (2018c), New Orleans had around 26,000 vacant dwellings (21.6% of the concurrent housing stock) in 2000, which jumped to 59,000 vacant dwellings in 2009. Although vacancy has dropped in recent years, it remains high. A survey in 2012 found an estimated 35,700 vacant dwellings, while a survey in 2014 concluded 40,901 vacant dwellings (21.4% of the concurrent housing stock).

4. Deteriorated spatial quality

Public space in the suburbs of New Orleans has a poor spatial quality, as shown in Figure 7. Disinvestment over a long period and inadequate repair efforts after Katrina resulted in roads in disrepair and an overall desolated image (City of New Orleans, 2018c).

In regards to water management, water is not available as an amenity in public space. Rather, drainage infrastructure is hidden from view by box culverts and tall floodwalls (Waggonner & Ball Architects, 2013). Figure 8 shows an example of this. By relying on an engineered drainage system of pipes and pumps, New Orleans has lost the connection to its geographical location of wetlands and floodplains.

Figure 7 - Poor spatial quality in the Gentilly neighborhood.

Figure 8 - Open water is hidden behind tall floodwalls.

5. Poor accessibility; dependency on automobiles

Like many American cities, New Orleans is reliant on automobiles for transportation. The city is a regional provider of jobs, but has a severely limited public transport system (City of New Orleans, 2015). The budget for public transport was cut by almost 40% after Katrina, which further crippled its capacity (City of New Orleans, 2015). Figure 9 shows the public transport lines and major job clusters in New Orleans. It shows that there are few lines extending into the suburbs, and a disappointing stop frequency for lines that do. This connects with the earlier made point of inequity, with less affluent neighborhoods having a poor connectivity and accessibility for residents without private transportation.

Figure 9 - Job accessibility and public transport (source: City of New Orleans (2015), elaborated by author).

1.2.3 Environmental concerns

Independent environmental concerns

1. Sea level rise

Across the globe the sea level is expected to rise, but there are spatial variations. Assuming a medium climate scenario, there is a predicted sea level rise on the Louisiana coast of 63 cm (2.07 ft.) over the next 50 years (Coastal Protection and Restoration Authority of Louisiana, 2017).

2. Increasing peak precipitation

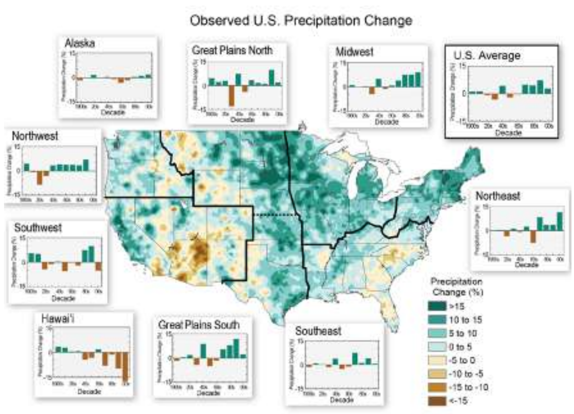
Over the past century, precipitation in New Orleans has increased, although not as significantly as in other parts of the United States (see Figure 10). According to Carter et al. (2014), both daily and five-day rainfall intensities have increased. High-intensity precipitation, a key factor of urban flooding, is expected to increase substantially over the next century (Carter et al., 2014). Figure 11 shows the projected precipitation change by season.

3. Longer dry spells

The length of dry spells is projected to increase across the United States, with the southern part of the country (including New Orleans) having to bear the highest burden (Melillo et al., 2014). Together with an increase in frequency of high-intensity precipitation, this raises the issue of water resources management in the city. In the future, the city will have to deal with more extremes than it is currently capable of managing.

4. Increasing frequency of Atlantic hurricanes

The frequency of Atlantic hurricanes has increased steadily since the 1980s and this trend is projected to continue (Melillo et al., 2014). In addition, measures of intensity, duration and number of strongest storms (Category 4 or 5) have increased since high quality satellite data became available. Melillo et al. (2014) state that models project an increase in number of category 4 or 5 hurricanes by the end of the 21st century.



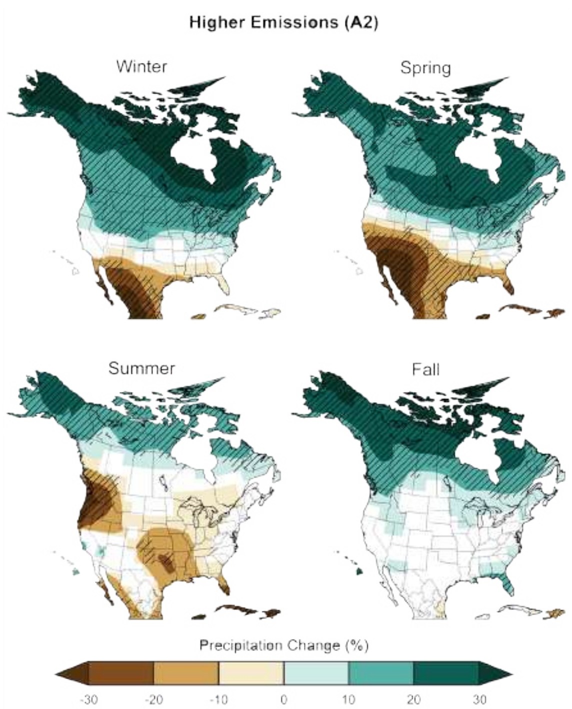


Figure 10 - (left) Observed precipitation changes in the United States (source: Melillo, Richmond, and Yohe (2014)).

Figure 11 - (right) Projected precipitation change by season (source: Melillo et al. (2014).

Human-induced environmental concerns

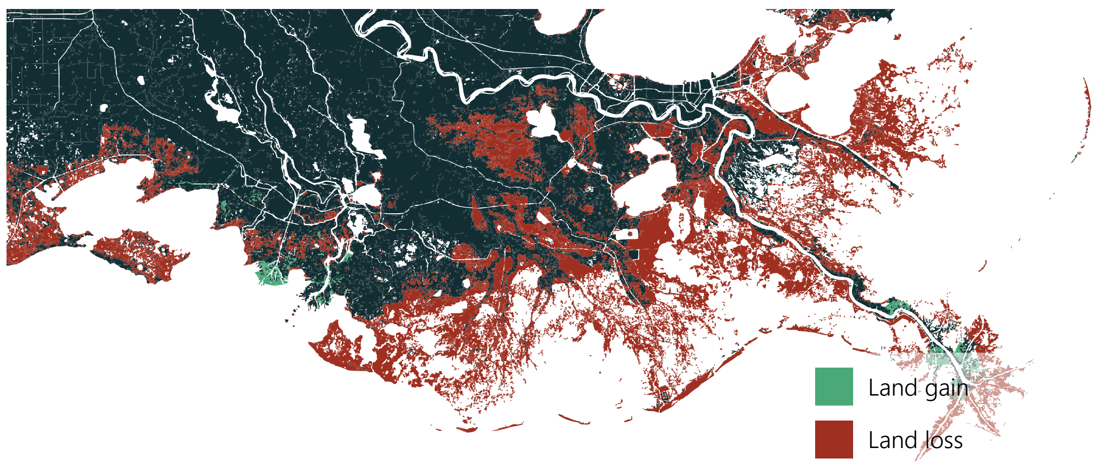
1. Disappearing wetlands

The construction of levees alongside the Mississippi River has disturbed the natural resupply of wetlands with fresh sediments (Coastal Protection and Restoration Authority of Louisiana, 2017). Instead, sediments are now carried to the deep water of the Gulf of Mexico. Combined with subsidence and the sea level rise as discussed earlier, there is a high potential for extensive land loss (see Figure 12). Under the medium climate scenario, inaction would result in an expected land loss of over 5800 km2 (2254 sq. miles). Natural wetlands act as a barrier against storm surge. Therefore, a loss of wetlands makes the city more vulnerable to coastal flooding. In an attempt to save wetlands from completely disappearing, initiatives have started to dredge sediments from the Gulf of Mexico and transport them to sediment-starved wetlands via a pipeline.

2. Crippling infrastructure

The tradition of pumping all stormwater directly out of the city has led to a drop in groundwater level, allowing for shrinkage of the soil and oxidation of organic material. This has resulted in subsidence, which undermines the structural stability of buildings and damages infrastructure (Waggonner & Ball Architects, 2013). As a result, the drainage infrastructure is in a poor state and does not function reliably. Furthermore, Waggonner & Ball Architects (2013) blames decades of deferred maintenance as one of the primary causes of failures in the modern system.

Figure 12 - Extensive land loss is predicted for the Louisiana coast (source: adapted from Coastal Protection and Restoration Authority of Louisiana (2017), elaborated by author).



3. Unsustainable urban development

The deterioration of the wetlands can party be attributed to urban development in vulnerable areas. The administration of George W. Bush abolished a policy that was in place to ensure 'no net loss' of wetlands, encouraging developers to expand the city's footprint (Pelling, 2011).

As Figure 13 shows, large parts of the city's expansions are below sea level; they rely on pumps to get rid of excess water. In addition to having an adverse impact on wetlands, the urbanized areas themselves are at danger of flooding. The city's subdivisions have a poor relation with their geographic location in the swamps. The built environment is surrounded by a concrete levee that forms the primary defense against storm surges.

"Last century's infrastructure enabled widespread urbanization in a wet delta environment, but the principles underlying that infrastructure are no longer adequate to sustain the region" (Waggonner & Ball Architects, 2013, p. 8).

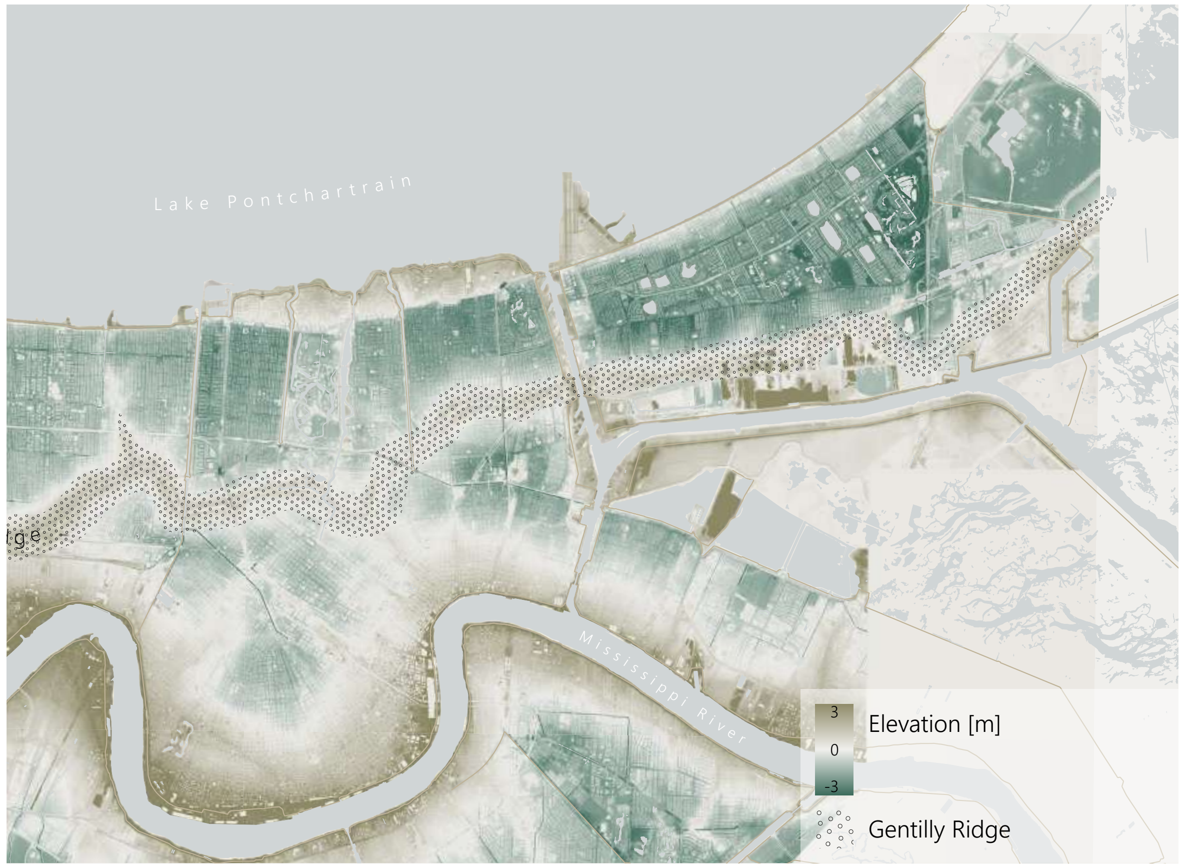
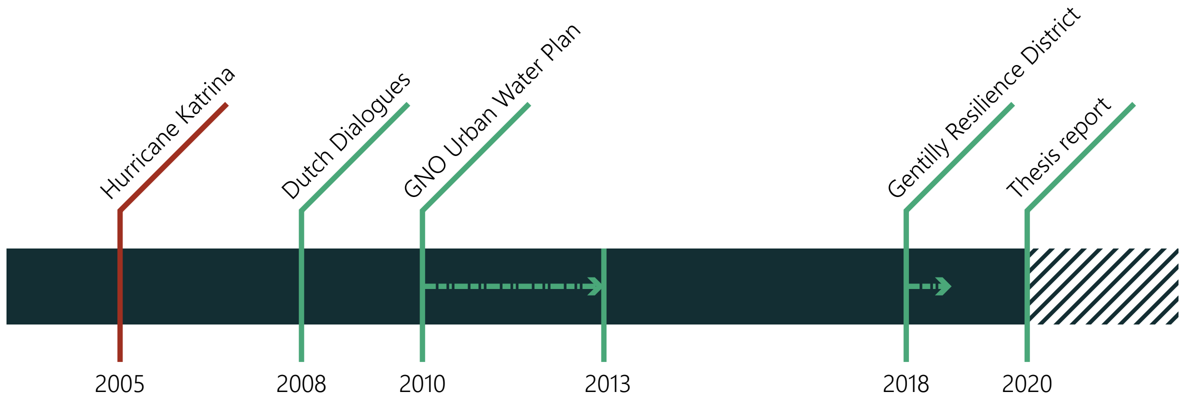


Figure 13 - Elevation map of New Orleans (source: National Oceanic and Atmospheric Administration (2017)).

1.3 Starting Point: After Katrina

Figure 14 - General timeline of events after Katrina.



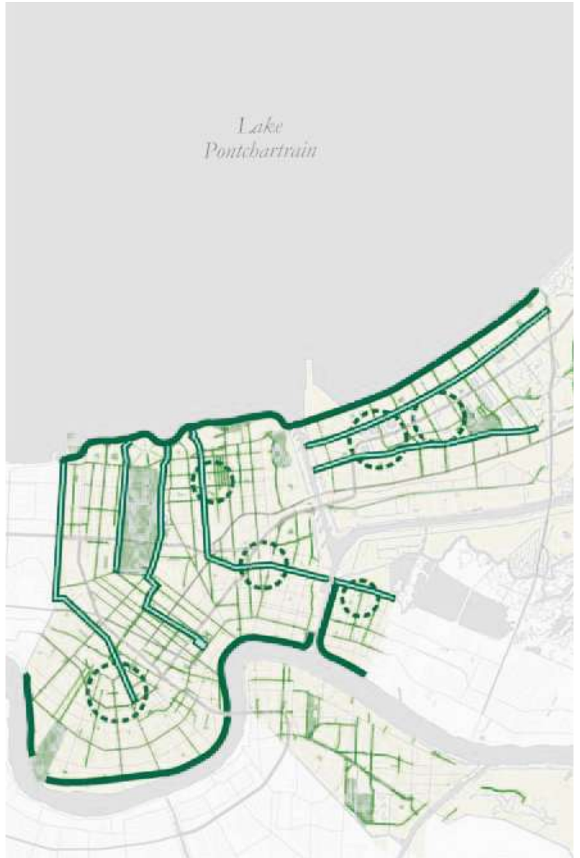
1.3.1 Initial response

The initial response after the Katrina disaster was a unified pledge of rebuilding the city and ensuring that the city would overcome the extensive damage caused by the storm. Speaking to the public on Jackson Square, then-president George W. Bush declared the following:

"I also offer this pledge of the American people: Throughout the area hit by the hurricane, we will do what it takes, we will stay as long as it takes, to help citizens rebuild their communities and their lives. And all who question the future of the Crescent City need to know there is no way to imagine America without New Orleans, and this great city will rise again."
- George W. Bush, September 2005.

However, when the Bring New Orleans Back Commission (BNOB Commission) in 2006 presented their desire to shrink the city's footprint and return many of the geographically low lying neighborhoods to the wetlands, a public outcry followed. While residents living on higher ground argued that New Orleans should return to its early development patterns along the Mississippi river and natural ridges, residents of low lying areas, although underrepresented in public hearings, strongly pleaded for a full recovery of New Orleans (R. Campanella & Koritz, 2009). Eventually, the BNOB Commission proposed a plan as shown in Figure 15, with the green circles indicated as suitable future parkland. The general public interpreted the circles as representing exact geographic boundaries of land that would be turned into wetlands, instead of dimensionless abstractions of parkland (R. Campanella & Koritz, 2009). This made the discussion about the footprint of New Orleans a sensitive topic.

Figure 15 - Greendot plan. The green circles denote the areas destined for future parkland. (source: Bring New Orleans Back Commission (2006)).



1.3.2 Dutch Dialogues and the Urban Water Plan

Early 2006, an American delegation led by U.S. Senator Mary Landrieu was invited by the Dutch government to visit the Netherlands to experience the Dutch approach to urban water management. In 2008, with funding from the Dutch Embassy and American Planning Association, two separate workshops were organized engaging Dutch experts in the development of a new vision on water management in New Orleans.

After receiving funding from the Office of Community Development - Disaster Recovery Unit, architecture firm Waggonner & Ball led a team of local and international experts to produce the Greater New Orleans Urban Water Plan. The Greater New Orleans Urban Water Plan, completed in 2013, proposed a variety of measures and strategies to redefine New Orleans' relation with water and regard water as an opportunity rather than a threat.

Key components of the proposed measures in the Urban Water Plan

This section elaborates on key proposed measures as outlined in the Urban Water Plan that are relevant to this thesis. Rather than an in-depth review of the plans, each aspect is briefly explained. When applicable, this thesis will refer back to the Urban Water Plan more in-depth later in this report.

A restructured water system

In the existing water system, all rainwater is eventually drained to Lake Pontchartrain in the north. The Urban Water Plan proposes a significant change in water system to intercept water flowing from the Mississippi River backslopes and drain it to the river. Furthermore, it proposes to move the pumping stations towards Lake Pontchartrain to reduce the length of the primary flood defense.

Water systems on the neighborhood scale

The Urban Water Plan proposes a network of open canals to allow for more storage capacity and use open water as a public amenity. In addition, the Urban Water Plan advocates for tearing down the canal floodwalls and using the water in the urban fabric. Having flood gates near the lake would disconnect the canals from the Gulf of Mexico in case of a storm surge, making the water level in the canals easier to control. Figure 17 up to and including Figure 21 show designs from the Urban Water Plan. Figure 17 and Figure 18 show a schematic analysis of the urban drainage system and the proposed new system. Figure 19 shows a schematic drawing of how the water system should be integrated in the urban environment. Figure 20 and Figure 21 show more detailed parts of the design, including a design for dry weather conditions.

Figure 16 - Covers of some key Urban Water Plan reports (source: (Waggonner & Ball Architects, 2013).

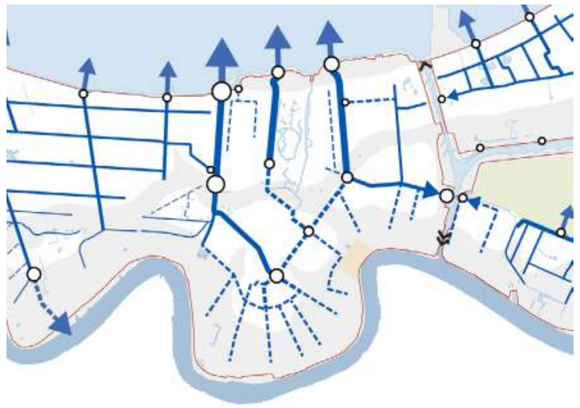


Figure 17 - (left) Existing water system (source: Dolman (2013).

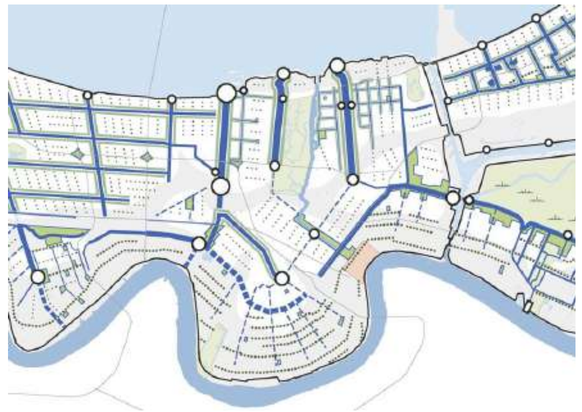


Figure 18 - (right) Proposed water system (source: H+N+S Landscape Architects (2013)).

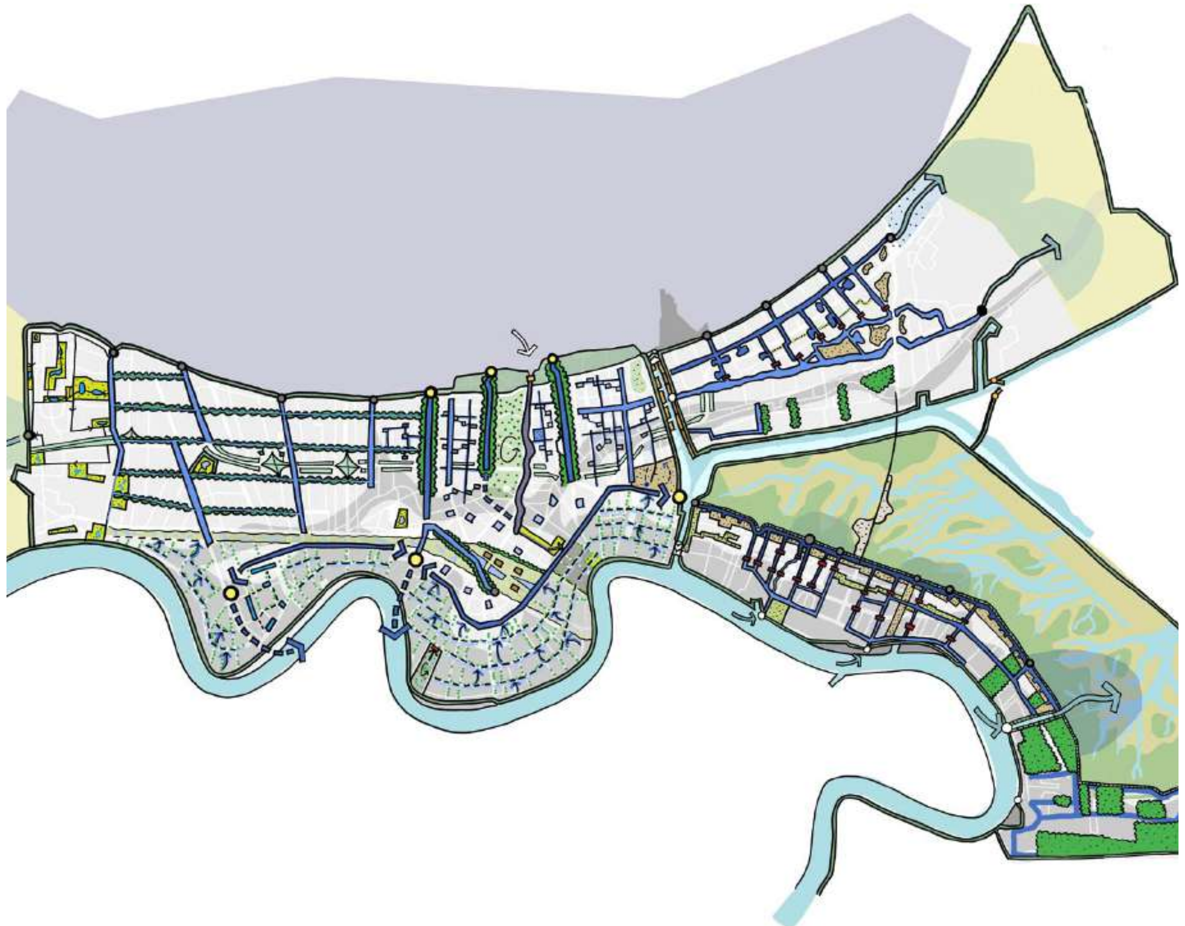


Figure 19 - Water system design (source: H+N+S Landscape Architects (2013)).

Figure 20 - (left) Dry weather flow (source: H+N+S Landscape Architects (2013)).

Figure 21 - (right) Water system design for Orleans Lakeside sub-basin (source: H+N+S Landscape Architects (2013)).

■ 1.3.3 Gentilly Resilience District

The Gentilly Resilience District, the city's first resilience district, constitutes twelve projects in one of the most vulnerable sections of New Orleans. The measures aim at reducing flood risk, slowing subsidence, improving energy reliability and stimulating neighborhood revitalization. None of the projects are yet completed; they are still in the design phase. The National Development and Reform Commission (NDRC) awarded New Orleans $141 million to complete the Gentilly Resilience district projects. Amongst others, the Gentilly Resilience District encompasses a water garden, blue-green corridors and greener neighborhood streets. An overview of the projects is presented in Figure 22.

Figure 22 - Gentilly Resilience District plan (source: (City of New Orleans, 2018))

■ 1.3.4 Taking the Urban Water Plan framework forward

It is clear that since Hurricane Katrina there has been more attention for alternative ways of dealing with stormwater than simply relying on grey infrastructure. The Greater New Orleans Urban Water Plan sets a solid precedent for regarding water infrastructure as a fundamental part of the built form and provides useful analyses and design proposals. The Gentilly Resilience district operates on a smaller scale and considers how blue and green infrastructure would work on a neighborhood scale.

However, there are two fundamental shortcomings in all plans and proposals that have been developed recently. Both shortcomings are individually described below and form the starting point of this thesis.

Shortcoming 1: No consideration for extreme events

The proposals by the Urban Water Plan and Gentilly Resilience District are entirely focused on preventing damage due to moderate precipitation. There is no consideration for making the built environment less vulnerable in case of an extreme event, which could include levee or pump failures. Consequently, merely the "low-hanging fruit" is addressed by the design principles.

Although it is simply not possible (or feasible) to design an urban water system that is capable of dealing with extreme events such as Hurricane Katrina or the 5 August 2017 precipitation, ample opportunities lie in the urban planning and design domain to reduce the vulnerability of the urban environment. The Urban Water Plan does not address these issues, leaving the city still unprepared for extreme storms.

This shortcoming relates to a vulnerability framework developed by de Graaf, van de Giesen, and van de Ven (2009), which is elaborated in section 2.6 (Theoretical Framework). In short, the vulnerability framework identifies four capacities of the built environment in dealing with the consequences of climate change: threshold capacity (preventing damage), coping capacity (minimizing damage in case of failure), recovery capacity (the ability to recover from a traumatic event) and adaptive capacity (reshaping the urban system to future changes).

Shortcoming 2: Poor integration of adaptation measures with the built environment

Many of the current proposals lack detailing on how adaptation measures are integrated in the urban fabric and how they relate to the built environment on different scales. Often, a blue-green corridor is drawn simply as a blue line on a map, without considering what this might mean for the surroundings. Figure 17 up to and including Figure 22 serve as examples for this point. Finished projects in the city, such as rain gardens, are isolated entities and do not adhere to a spatial strategy. Furthermore, the lack of spatial integration of these designs is reflected in improper maintenance and questionable performance.

1.4 Motivation

A critical event such as Hurricane Katrina often triggers an urge for change. There is widespread support for contributing towards a redesigned, safer system. Wagner and Frisch (2009) describe the moment of urgency after a natural disaster or other traumatic event as a 'design moment'. In New Orleans, the design moment after Katrina initiated the development of various plans, including the prominent Greater New Orleans Urban Water Plan.

Regrettably, a design moment loses steam over time and development becomes deadlocked in legislative, cultural and practical objections. In the case of New Orleans, few far-reaching interventions were carried out. Systematic changes that were executed did not take full advantage of their potential to set a solid precedent for change.

The New Orleans case study is not virgin ground; there already is a wide body of reports and articles on how the city has dealt with the fallout of the Katrina disaster. Therefore, this thesis will avoid reiterating general commentaries on which direction the city should take but rather add to established proposals such as the Greater New Orleans Urban Water Plan and Gentilly Resilience District. In fact, the maturity of the plans allows for an interesting analysis of their effectivity and general adoption amongst the public.

The added value this thesis seeks to achieve lies in the combined engineering and urban design approach. The thesis will build on existing proposals and fill knowledge gaps between the urban design and water management disciplines that could lead to more tailored and feasible plans. Therefore, the intended outcome is a design framework with demonstration projects, supported by an engineering perspective.

1.4.1 Motivation for choice of location

This thesis will focus on the Orleans Lakeside sub-basin, wedged in between the Gentilly Ridge, Lake Pontchartrain, 17th Street Canal and the Inner Harbor Navigational Channel. This project area allows for a more spatially focused approach, whilst still dealing with the myriad of issues that New Orleans is dealing with. Below are listed the main arguments for choosing this area over other areas in the city.

- Orleans Lakeside is characterized by homogeneous zoning, mainly consisting of single family residential suburbia. The lack of diversity makes it an economically and socially vulnerable area.
- Much of the land in Orleans Lakeside lies below sea level, making it completely dependent on pumping capacity to get rid of excess water.
- Orleans Lakeside is a sub-basin, meaning it is hydrologically separated from surround parts of the city. This is relevant for water calculations.
- There is a large contrast in income of the population in this projects area. Gentilly, in the eastern part of the project area, is home to predominantly low-income households, while Lakeview, to the west of City Park, has much wealthier households.
- Vacancy is a persistent problem in Orleans Lakeside.
- The Gentilly Resilience District is a pilot program on creating more resilience in the New Orleans suburbs, with multiple projects on green and blue infrastructure underway or planned. It is the first program of its kind in New Orleans. A critical evaluation of the proposed projects results in a thesis that is more connected with the current course of action.

Figure 23 - Project location: Orleans Lakeside sub-basin.

2 Methodology

Chapter roadmap

New Orleans faces a myriad of perils that relate to social, spatial and technical misalignments and sectorial approaches. In order to successfully and sustainably improve the current system, this thesis proposes an integral approach which is elaborated in this methodology chapter.

The spatial delimitation of this thesis, focusing on the Orleans Lakeside sub-basin, allows for a more concentrated and in-depth approach to creating more flood and drought resilience. The choice of this project area does not suggest that other parts of New Orleans do not require attention. It merely is a representative location for further research and exploration of an integral approach to water management.

Section 2.1: Project Backbone

Section 2.1 forms the backbone of the thesis through a thorough analysis of the problem field as laid out earlier. By providing a summary of the project field and identifying the main issues facing Orleans Lakeside sub-basin, a knowledge gap is formulated which this thesis seeks to address. The research gains more focus through the problem statement, which leads to the research aim explaining the wider goals of this thesis. A hypothesis and main research question, supported by sub-questions, formulate the key aspects on which the research should focus to achieve its goal. Finally, the intended research outcomes are explained. The outcomes form the basis to which the research framework is designed to contribute.

Section 2.2: Methodological Framework

In section 2.2, the conceptual framework provides the first insight in how the problem field, aim and theoretical themes relate. The relevant research themes are deducted from the knowledge gap. The conceptual framework is followed by the methodological flowchart, which shows the various phases of this research and how methods are related to each phase.

Section 2.3: Research Approach

Section 2.3 lays out the general research approach using an analytical framework and an explanation of the methods used in this thesis. Furthermore, the analytical framework describes the relation between the (sub) research questions, theoretical research themes and the methods. The interdisciplinary approach taken in this research requires a variety of methods, including modelling and research by design. In addition to an individual explanation of the methods, this section elaborates on the differing perspectives of both disciplines on the proposed methods.

Section 2.4: Research Outcomes

Section 2.4 provides an overview of the expected products and elaborates on the societal and scientific relevance, as well as the ethical dimension of this research. Furthermore, a clarification of the limitations of this thesis describes the awareness that this research project cannot solve all of New Orleans's flood and drought related problems. It, however, seeks to actively contribute to provide a fresh perspective on alternative approaches to creating flood and drought resilience.

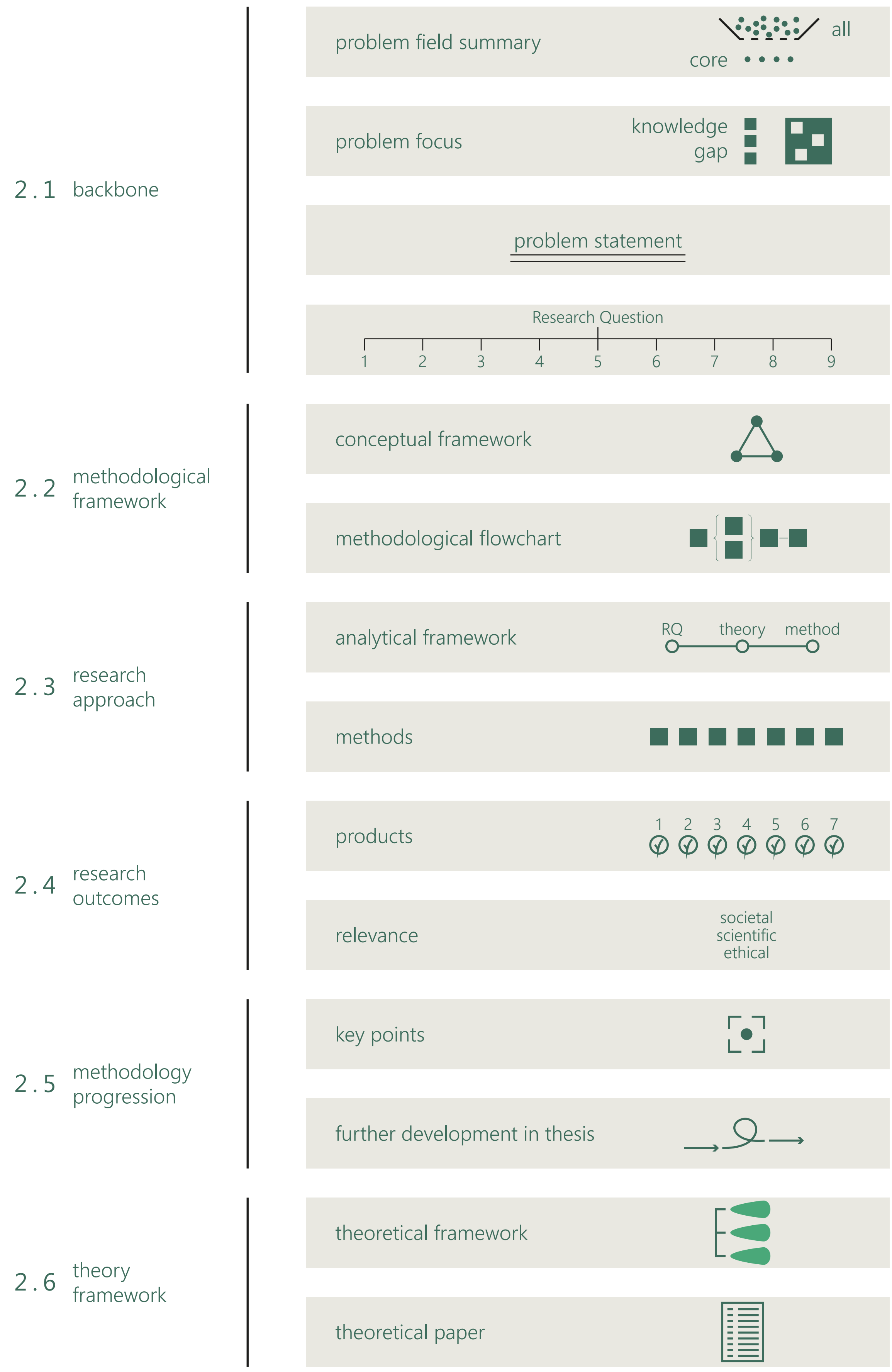
Section 2.5: Methodology progression

Section 2.5 reflects on the key points in the development of the methodology for this thesis and elaborates on how the methodology might develop in the course of the thesis.

Section 2.6: Theoretical Framework

Section 2.6 elaborates on the theoretical framework that forms the general theoretical domain in which this thesis navigates. It explores key themes and relevant authors related to those themes. The theoretical framework concludes with a theory report on the interrelation between two themes, which will be used to gain more in-depth knowledge on innovative approaches.

Figure 24 - Methodology roadmap.



2.1 Project Backbone

2.1.1 Problem Field Summary

This section opens with a distillation of the most pressing issues facing New Orleans, focused on the Orleans Lakeside sub-basin.

Socio-spatial Concerns

- New Orleans suffers from high levels of inequity, with racially biased zoning policies from the previous century still contributing to unequal flood risk. Hurricane Katrina displaced a disproportionate part of the black population, with the process of gentrification continuing to displace low-income households.
- New Orleans is struggling with vacancy. While the city already had extensive vacancy issues before Hurricane Katrina, the amount of deserted plots has skyrocketed since the storm.
- The built environment of Orleans Lakeside is homogeneous and ill-suited to dealing with flooding and drought.
- New Orleans has a diluted identity. The city's geographical location in wetlands is not visible in the urban space.
- Orleans Lakeside is reliant on automobiles for transportation, making the suburb poorly accessible by other modes of transportation.

Environmental concerns

Independent environmental concerns

- Exposure to increasing environmental extremes, including hurricanes, peak precipitation & drought.
- Rising sea levels.

Human-induced environmental concerns

- Disrupted sedimentary processes in combination with sea level rise have resulted in extensive loss of wetlands, therefore weakening natural defenses against coastal flooding.
- Sprawling suburbs into the Mississippi floodplains are the most vulnerable parts of the city.
- Decades of mechanical drainage caused severe subsidence of the polder suburbs.
- Poor maintenance of infrastructure has led to a crippling drainage system.

Shortcomings of proposed frameworks

- The strategy proposed by the Greater New Orleans Urban Water Plan (GNO UWP) fails to address the interaction between the built environment and the proposed adaptation measures.
- The GNO UWP is not consistent in translating strategy-level aims into implications for smaller scales of the urban form.
- The GNO UWP does not provide a holistic view on vulnerability of the built environment. The framework only considers a threshold capacity (preventing the problem).

2.1.2 Problem Focus

From the myriad of issues that New Orleans is facing, the knowledge gap, problem statement and research aim narrow down the research field to include both an engineering and spatial task.

Knowledge Gap

The knowledge gap as articulated in the problem field consists of two distinct shortcomings in the current approaches to urban water management in New Orleans. One part of the knowledge gap relates to the lacking consideration of extreme events when prevention of damage is simply impossible and the focus should be to use spatial strategies and design to cope with, recover from and adapt to flooding events. The second part relates to detailing the interaction between adaptation measures with the built environment, as this is currently not a priority. Adaptation measures cannot sustain if they are not integrated in the spatial framework and disregard the local built context. Figure 25 illustrates the knowledge gap this thesis seeks to address, consisting of both a strategical and urban design dimension.

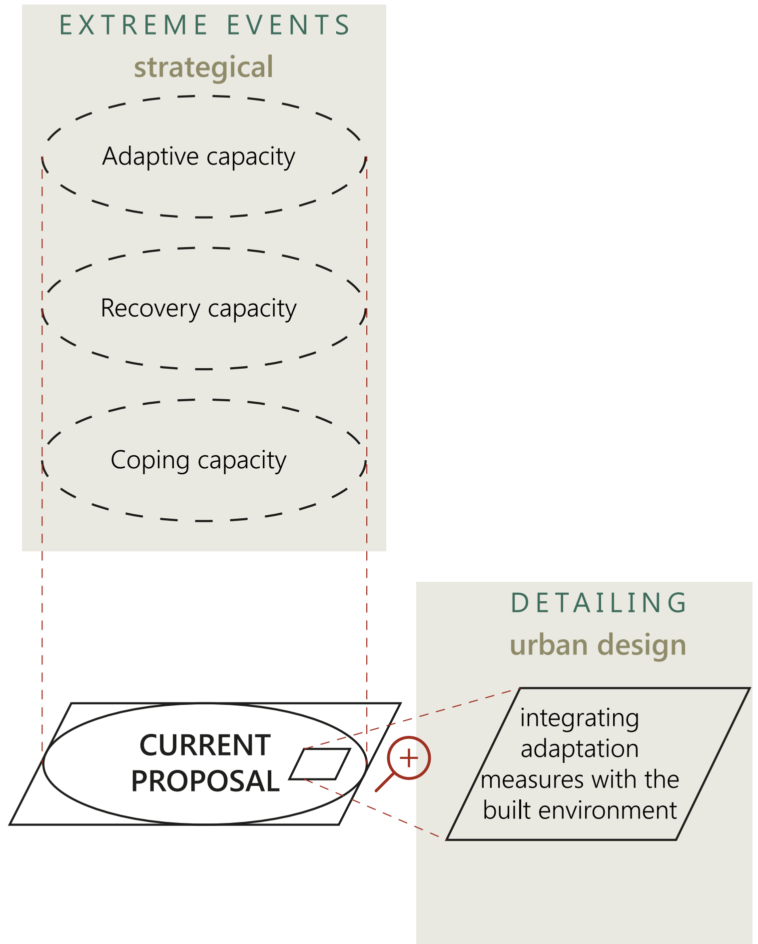


Figure 25 - Knowledge gap.

Problem statement

The aggressive ***expansions of homogeneous, low density suburbia into the wetlands*** of the Mississippi river are now vulnerable and completely rely on pumping efforts to dispose of excess water. ***Changing climatological conditions***, including sea level rise, increasing peak precipitation, longer dry spells and an expected increase of North Atlantic hurricanes demand a ***paradigm shift*** to make the built environment less susceptible to climatological extremes and increase flood and drought resilience. The strategy and measures proposed by the Greater New Orleans Urban Water Plan, while helpful as an indication of desired action, leave out ***key issues concerning the integration of water infrastructure with building typologies and streetscapes***, as well as relating to the stalling rebuilding efforts and pressing inequities across the poorer parts of the city. Furthermore, the performance and effectivity of finished and currently undertaken adaptation projects is poorly understood. Hence, a ***reframing of the interaction between the built environment and adaptation projects*** is required, with consideration for a merger of interests. In addition to the current threshold capacity, a new approach should consider ***multiple capacities of the built environment***, including a coping, recovery and adaptive capacity.

Research Aim

There is a knowledge gap in aligning strategies for integrating adaptation measures with the built environment. The ultimate aim of this project is to improve the flood and drought resilience of the polder suburbs of the Orleans Lakeside basin by aligning strategies and elaborating small scale demonstration projects. This will be pursued from a joint engineering and designing perspective.

Intended research outcome

On a meta level, this thesis aims to initiate a new debate on urban planning and water management practices in New Orleans. More practically, the intended research outcomes are two products that are inherently intertwined:

1. The first product is an alignment of strategies for adaptation efforts in the Orleans Lakeside basin, aiming to advocate a holistic vision for the future of the project area.
2. The second product is a set of demonstration design projects on a smaller scale to solidify the integration of adaptation measures with the built environment.

Section 2.4 provides a more elaborate explanation on the intermediate products to arrive at the desired outcomes.

2.1.3 Research Questions

Hypothesis

Current proposals for climate adaptation in Orleans Lakeside disregard a large potential in making the city more climate resilient. The overall lack of strategic consideration for extreme events leaves the city unprepared for next big storm, whilst the missing detailing and integration of technical adaptation measures in the built environment raise questions about the social, economic and environmental sustainability of the interventions. By considering and integrating all capacities of the built environment and detailing urban interventions across scales, Orleans Lakeside can be made more flood and drought resilient.

The overarching research question to be answered in this report is:

How can Orleans Lakeside be made more flood and drought resilient by integrating multi-layered resilience capacities of the built environment, whilst safeguarding consistent design of technical adaptation measures within the urban space?

The research question touches upon multiple aspects, which are elaborated below:

Aim	Improving the flood and drought resilience
Context	... of Orleans Lakeside
Method	... by integrating multi-layered resilience capacities of the built environment
Condition	... whilst safeguarding consistent design of technical adaptation measures within the urban space.

The main research question is split into two encompassing research focus areas that correspond to both disciplines involved in this project. Both focus areas contain research sub questions that elaborate on the discipline-specific challenges.

Urbanism

1. How can Orleans Lakeside be restructured in a way that reduces vulnerability to flooding and drought?
2. How can flood and drought adaptation measures be consistently integrated with the built environment through all scales?
3. How to deal with uncertainty regarding the rebuilding and repopulation efforts in New Orleans?
4. How can a design framework of improved integration of adaptation measures with the built environment be transferred to other delta cities in a similar context?

Water Management

1. Which areas of Orleans Lakeside are the most vulnerable to flooding and drought?
2. How can the existing urban features such as city parks be used in managing the water supply?
3. What is the performance of finished and currently implemented green infrastructure projects such as rain gardens?
4. How can green infrastructure be deployed in managing water surplus and shortage on a small scale?

2.2 Methodological Framework

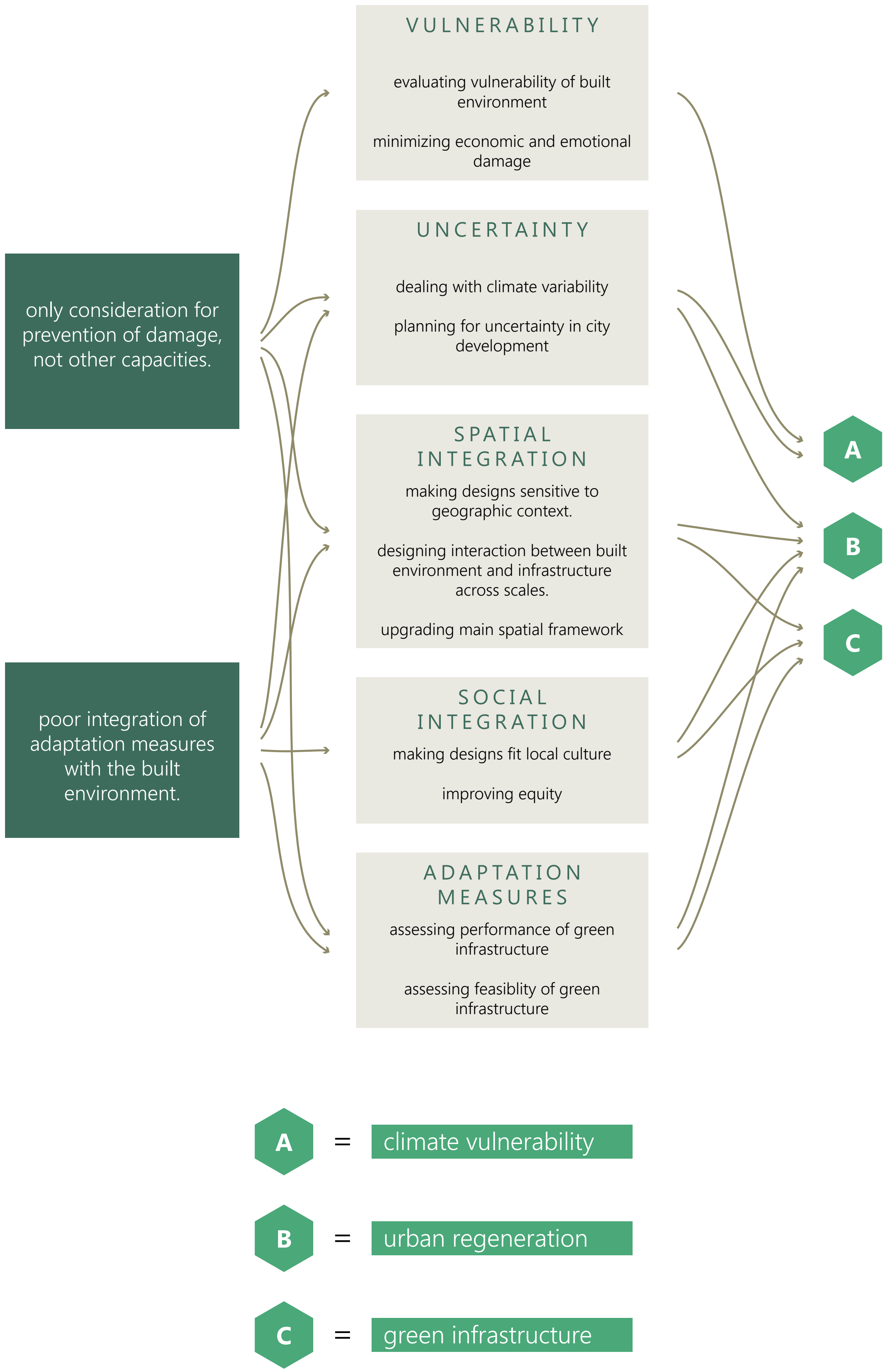
An integrated interdisciplinary approach at the intersection of urban design and water management provides a challenging methodological basis for the thesis. The methodological framework forms the most fundamental structure of the thesis, describing the main themes, point of departure and general sequence of research.

The water management and urbanism disciplines both delivered domain-specific research questions, as outlined in the previous section. This thesis aims to provide an interdisciplinary outcome, making the integration of the domain-specific research questions from a methodological standpoint a vital concern. In this thesis, the integration of the two domains and their respective research questions takes shape through a synthesis of the leading research themes. As a result, these research themes are a mix of both disciplines and cover the entire spectrum. Reflection moments include a domain-specific reflection, in which the answers to the domain-specific research questions are evaluated, as well as an integrated reflection to assess the success of the interdisciplinary integration.

The knowledge gap brings forth a set of connected topics that form the basis of the main theoretical underpinning of this project. These topics connect a wide variety of related issues and are not well-defined research themes themselves. Through an exploration and synthesis of the most important connected topics, three relevant research themes are derived, with their interrelations capturing the essence of the knowledge gap. This process is schematized in Figure 26.

Climate vulnerability relates to the relative vulnerability of residents and the built environment to different magnitudes of extreme weather. Urban regeneration refers to the premise that any spatial intervention should have beneficial effects for the economic, social and environmental sustainability of the city. The green infrastructure theme encompasses research on the performance of green infrastructure in urban environments, in addition to their integration in the urban fabric. The three leading themes converge into the theoretical framework (section 2.6) by expanding their range and listing relevant authors.

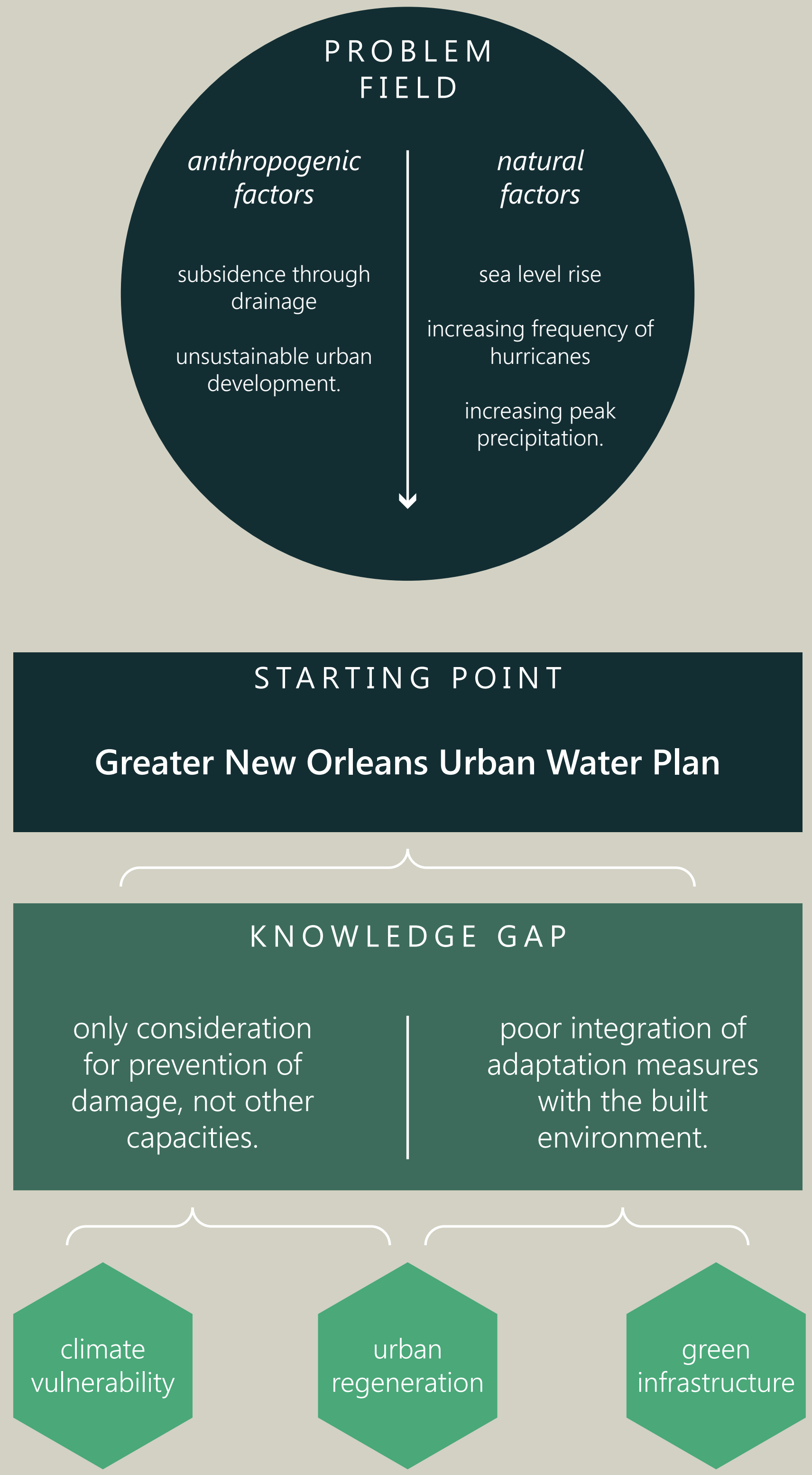
Figure 26 - Process of determining three main research themes from the knowledge gap.



2.2.1 Conceptual Framework

The conceptual framework as depicted in Figure 27 describes the interrelations between the problem field, point of departure, connected theories and the aim of the thesis. It recognizes the anthropogenic and natural parts of the problem field and illustrates the shortcomings of the Greater New Orleans Urban Water Plan (GNO UWP) as the starting point for this thesis. As identified earlier, there are two main instances where the Urban Water Plan fails to contribute to a more flood and drought resilient New Orleans: the lack of consideration of extreme events and the poor integration of green infrastructure with the built environment. The three primary themes, being climate vulnerability, urban regeneration and green infrastructure are associated with the aforementioned shortcomings and are substantiated by multiple key authors. The three themes, to be further explored in this thesis, combine into the aim of improving the flood and drought resilience of the lower lakefront neighborhoods of New Orleans.

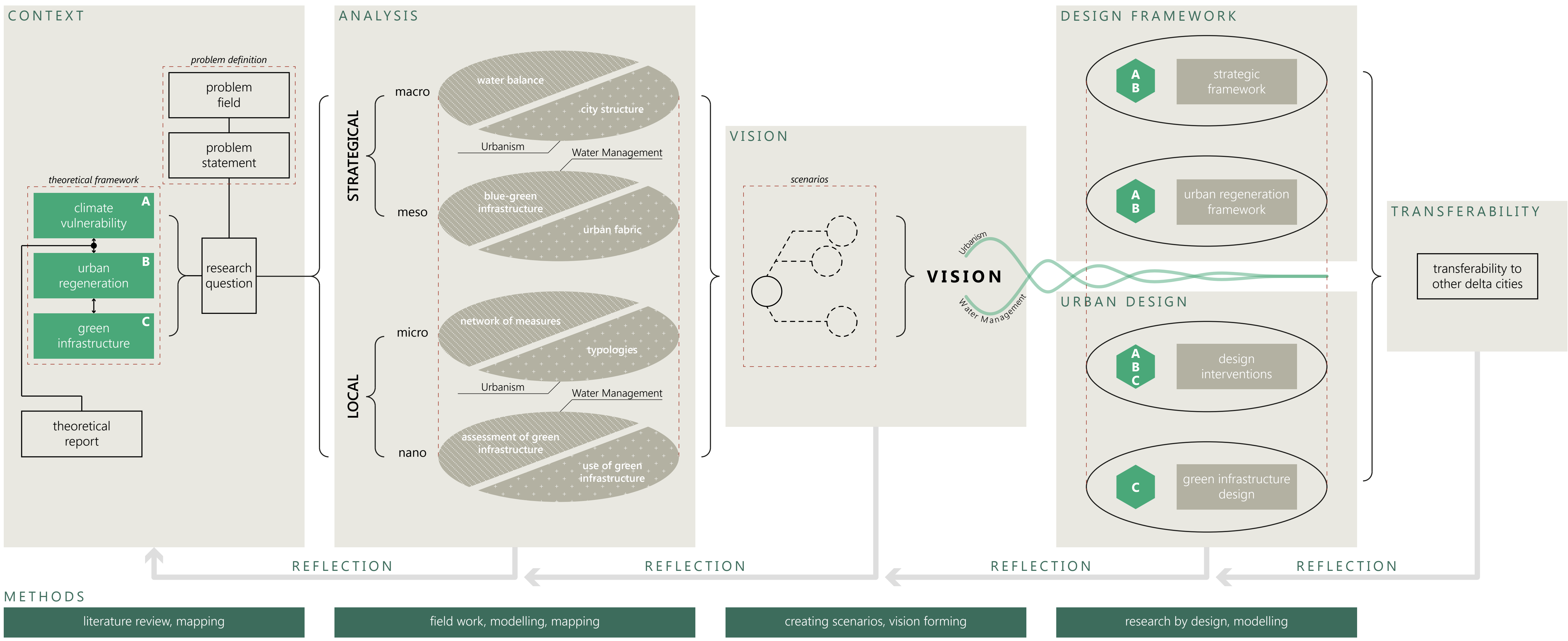
Figure 27 - Conceptual framework.



2.2.2 Methodological Flowchart

As much of the problem field relates to inconsistencies and deficiencies across scales, the scalar approach remains central to the thesis's methodological flowchart (see Figure 28). The thesis consists of four main phases. The first phase is concerned with contextualizing the problem field and formulating the research foundation. In the second phase, the built environment of New Orleans is analyzed on topics that are relevant to urban design and water management. Phase three draws from the analysis and leads to scenarios and a vision. Phase four consists of research by design on multiple scales. Figure 28 shows that each phase has a reflection back, which indicates the iterative character of the approach. A final reflection at the end considers the transferability of the results to other delta cities facing similar problems.

Figure 28 - Methodological Flowchart.



2.3 Research Approach

This subsection elaborates on the methods used in this thesis and how they relate to each other. The careful selection of methods ensures a fruitful combination of design and engineering. The thesis uses a total of 6 methods, which are used at different times throughout the thesis:

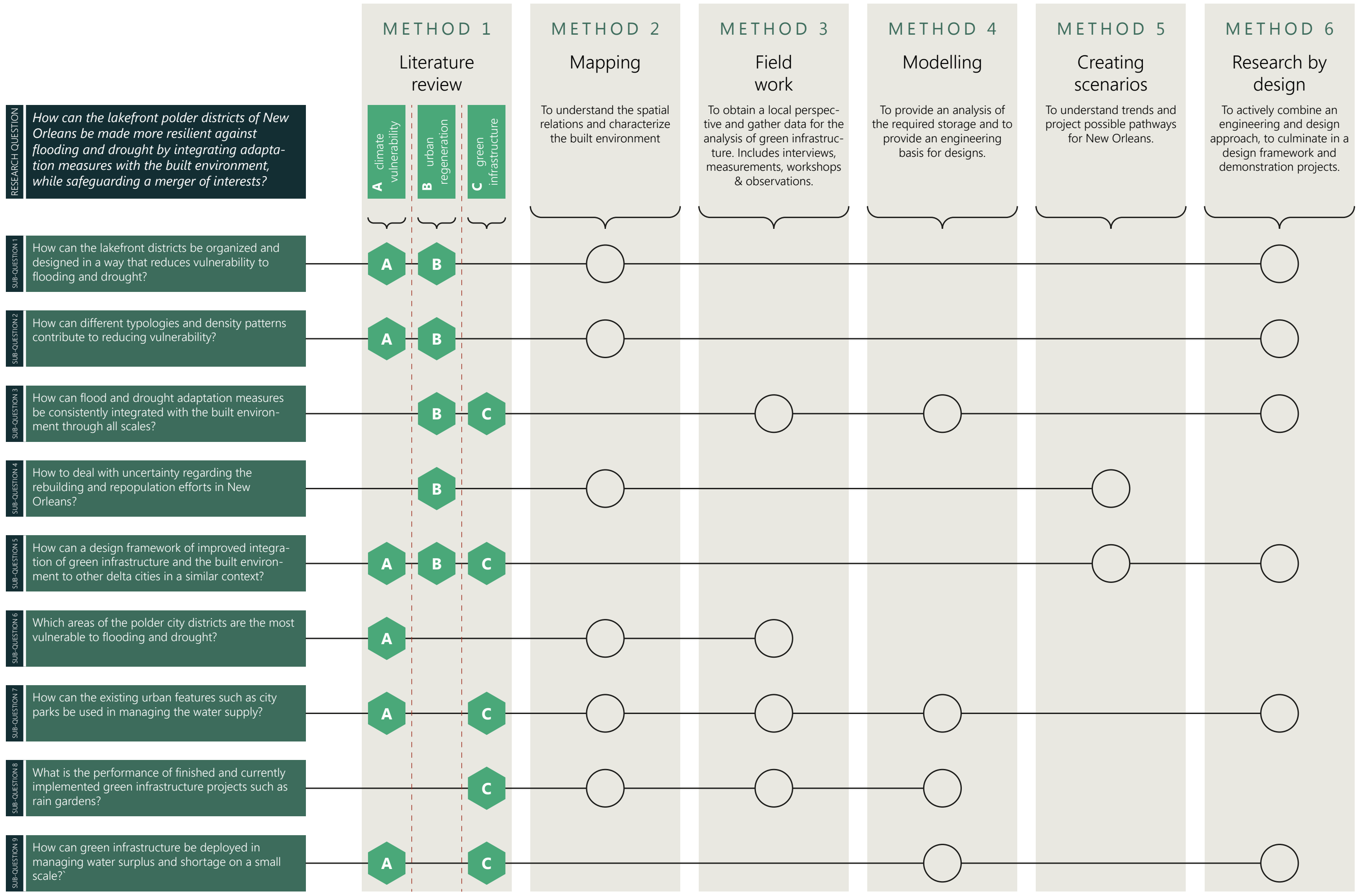
1. Literature review
2. Mapping
3. Field work
4. Modelling
5. Creating scenarios
6. Research by design

As described in the methodological framework, the concept of scales is pivotal for this research. This concept is also related to the use of methods throughout the thesis, as certain methods are more prominent on a particular scale than others.

2.3.1 Analytical Framework

The analytical framework, depicted in Figure 29, shows the relations between the research questions, connected theories and proposed methods for this thesis. Literature review forms the basis for the report, as it identifies the current state of the art an the most pressing knowledge gaps. It also provides a fundamental theoretical underpinning of the thesis.
Mapping, in its broadest sense, is used to understand the spatial relations and characterize the built environment. An important part of the thesis is field work, where a variety of activities are performed. This includes interviews, measurements and observations. Modelling adds an engineering backing to the proposed interventions and helps understanding the most critical parts of the system. Scenarios are useful for understanding trends and project possible pathways for New Orleans. Finally, research by design combines the engineering and design approach into a design framework with demonstration projects. The following segment elaborates on each method, describing the purpose and procedure in detail.

Figure 29 - Analytical Framework.



01: Literature review

Purpose of method

To collect and synthesize theories and concepts relevant to the thesis.
Literature, ranging from conceptual theories to practical reports, forms the theoretical basis for the thesis. This culminates in a theoretical framework, consisting of the three main research themes: climate vulnerability, urban regeneration, green infrastructure. In addition to sharpening the problem focus, it provides an understanding of the state of the art and builds a frame of reference for interventions. A deepening theoretical research is conducted through a theory paper, which explores the relation between the topics of climate vulnerability and urban regeneration in more depth.

Key words

Thesis general:
New Orleans, flooding, drought, climate vulnerability, urban regeneration, green infrastructure, climate adaptation, adaptation measures, urban water management

Theory paper:
New Urbanism, New Orleans, urban sprawl, flood resilience, climate vulnerability

Search engines

JSTOR, Google Scholar, WorldCat Discovery

Document types

Books, book reviews, peer-reviewed journals, (government) reports, newspaper articles.

Procedure

The central research themes as deducted from the knowledge gap (Figure 25) are explored and synthesized into a theoretical framework. The relevant keywords as described above are entered in scientific search engines to retrieve relevant literature connected to the three main themes. Section 2.6 (Theoretical Framework) elaborates further on the content and associated authors of each theme.

02: Mapping

Purpose of method

To understand spatial relations and characterize the built environment.
Mapping and overlaying forms a powerful tool to grasp spatial challenges and identify opportunities for interventions.

Relevant scales

Macro (system)
Meso (neighborhood)
Micro (block)
Nano (unit)

Procedure

The maturity of the flooding issues in New Orleans means a large body of maps already exist on this topic. This thesis draws from previous reports to use those maps, but presents own maps where existing products fall short. Furthermore, relating back to the core goal of this thesis to combine engineering with design, maps will be overlaid to expose core issues and identify novel opportunities. Mapping takes place throughout the project, as elaborated below.

Problem definition
Mapping is the most prevalent at the macro and meso scale in the problem definition phase. Maps contribute to an understanding of general climatological issues and define the spatial boundaries of the thesis.

Analysis
In the analysis phase, mapping occurs at all scales: macro, meso, micro and nano. On the macro and meso scale, mapping is used to fathom the complex system of water flows and the spatial framework of the city. Using tools such as GIS, floods and water shortages are mapped. An analyses of the urban fabric identifies the main challenges and opportunities for interventions. Mapping on the micro and nano scales is used to determine deficiencies and opportunities at the transition from system scale to actual building scale.

Vision
The creation of scenarios and forming of a spatial vision is supported by maps on multiple scales.

Research by design
The design phase sports all mapping scales, building on input from the multi-scalar analysis and vision. This project phase is supported by other ways of visualization, as outlined in ‘method 06: research by design’.

03: Field work

Purpose of method

To obtain a local perspective and gather measurement data for the analysis of adaptation measures.
It is essential to visit the location in order to fully understand the context and locality of the project area. Furthermore, engaging with local residents and practitioners provides valuable insight that is unobtainable through literature review. The complex nature of the problem requires a broad view on the issues at play, drawing from multiple perspectives. In addition to discussing with and interviewing the local residents and practitioners, the field trip is used for data gathering. Essential data for the assessment of adaptation measures is not being made public in the United States due to copyright and liability issues. This requires independent data gathering.

Field work period

Visit 1: 27-03-2019 – 07-04-2019
Visit 2: 05-2019 – 05-2019

Procedure

<u>Visit 1</u>
Colleagues:
- Roelof Stuurman - urban water and soil expert, Deltares
- Rik van den Oever - graduate student, Deltares

Activities:
1. Walking tours with community project groups (Saint Anthony Events)
2. Community workshop on green infrastructure
3. Interviews with local architects Dana Brown & David Waggonner
4. Interviews with representative of Sewerage & Water Board of New Orleans
5. Observing, photographing

The first visit is meant to get acquainted with the city and project area, as well as ongoing community projects. Throughout the field work period, multiple site visits and interviews take place. A complete list of all interviewed people is displayed in Table 2.

<u>Visit 2</u>
Colleagues:
- Roelof Stuurman - urban water and soil expert, Deltares
- Rik van den Oever - graduate student, Deltares
- Floris Boogaard - expert green infrastructure, Hanzehogeschool Groningen

Activities:
6. Assessing performance of green infrastructure

The second visit revolves around gathering data and performing field tests on adaptation measures. This is to provide an elaborate review of current adaptation efforts in New Orleans and provide a substantiated conclusion on their effectivity.

Table 2 - Interviewees in New Orleans.

Name	Company	Function	Date
Andy Sternad	Waggonner & Ball Architects	Architect	3-4-2019
Aron Chang	Blue House (formerly: Waggonner & Ball Architects)	Community group leader (formerly: architect)	29-3-2019
Dana Brown	Dana Brown & Associates	Landscape architect	5-4-2019
David Waggonner	Waggonner & Ball Architects	Architect, CEO	4-4-2019
Delaney McGuinness	Dana Brown & Associates	Junior landscape architect	5-4-2019
Edwin Welles	Deltares USA	Hydrologist/ Director	1-4-2019
John Taylor	-	Local resident	2-4-2019
Joshua Lewis	Tulane Universtiy; ByWater Institute	Research Assistant Professor, ecologist	5-4-2019
Julia Kumari Drapkin	Iseechange	CEO	4-4-2019
Maggie Hermann	Blue House	Community worker	29-3-2019
Ramiro Diaz	Waggonner & Ball Architects	Architect	28-3-2019
Sarah Olivier	New Orleans City Park	Director of Planning	1-4-2019
Thorbjörn Törnqvist	Tulane University	Vokes Geology Professor in the Department of Earth and Environmental Sciences	31-3-2019
Todd D. Reynolds	Groundwork	Executive Director	28-3-2019
Tyler Antrup	City planning department	City officer urban planner + resilience	29-3-2019

04: Modelling

Purpose of method

To quantify current flooding and drought issues and testing design interventions for their effectivity.
With this thesis' intention of joining design and engineering disciplines, modelling provides an engineering backing to proposed interventions. From a designer's perspective, modelling can provide insight in the overall effectivity of interventions, while an engineering point of view is more focused on the dimensions and performance of measures. This thesis uses both hydrological and hydro-dynamic models.

Procedure

The procedure for both hydrological and hydro-dynamic modelling is elaborated below.

<u>Hydrological modelling</u>
A hydrological model is used to identify general water management issues concerning flood and drought. Modelling software provided by Deltares will be used for this analysis. Modelling the flow of groundwater is part of the hydrological scope, which can provide insight in groundwater levels, as well as salinization of groundwater.

<u>Hydro-dynamic modelling</u>
The Storm Water Management Model (SWMM) computes real-time stormwater dynamics and provides insight in both the quality and quantity of runoff. This modelling software, developed by the United States Environmental Protection Agency, simulates the flow through a simplification of the drainage system into catchments, nodes, conduits and outflow points. A SWMM model was already set up for the Greater New Orleans Urban Water Plan and will be expanded in this thesis. For modelling runoff it is essential to use relevant design storms. This thesis will use the design storm with a return period of 10 years (T10) as determined in the Urban Water Plan, accounting for a peak precipitation increase due to climate change.

In the analysis phase, the model is used to identify weak links in the system and determine the most vulnerable parts of Orleans Lakeside. Combined with demographic data, this provides insight in the relative vulnerability of areas. In the design phase, the SWMM model is used to test proposed interventions.

05: Creating scenarios

Purpose of method

To identify possible paths for the development of the city as a basis for interventions.
The future is unpredictable and depends on a multitude of factors. Instead of extrapolating the current city developments as the starting point for design interventions, this thesis recognizes the most relevant and pressing uncertainties by providing a scenario analysis.

Procedure

Although an extensive scenario review falls outside the scope of this thesis, there are several key factors that can greatly influence the future development of New Orleans. Based on a literature review, this thesis identifies the following uncertain aspects:

<u>Climate projections</u>
Accounting for the effects of climate change is pivotal in developing a solid proposal for Orleans Lakeside. This thesis considers the projected changes in precipitation, length of dry spells and the frequency of Atlantic hurricanes.

<u>Municipal policies and desired development</u>
The municipality can exert influence on the development of the city through policies and incentives. Desired improvements in the drainage system and planned projects have to be taken into account.

<u>Actual demographic trends</u>
New Orleans has had a slow recovery from Hurricane Katrina, with the population count stagnating (U.S. Census Bureau, 2010). Independent of the goals and ambitions of the municipality it is relevant to consider the actual and projected demographic trends. A persistent reluctance of evacuees to return in combination with a low net migration could result in a city whose footprint is too big for its population. Stagnating growth could lead to a removal of a tax base for future interventions.

06: Research by design

Purpose of method

To propose a holistic design framework and location specific designs, supported by engineering evidence.
Research by design is to address the knowledge gap: proposing a holistic design framework, building on existing frameworks, and detailing the interaction of adaptation measures with the built environment.

Procedure

This method combines the design and engineering disciplines through an iterative approach and operates in two phases. The first phase produces a design framework that expands and improves on existing frameworks such as the Urban Water Plan. The second phase is location-specific design, where a couple of representative locations are chosen for further detailing.

Phase 1: design framework
Building on the Urban Water Plan and other frameworks, the first phase proposes a design framework that tackles the strategic part of the design challenge. This phase is mainly concerned with the macro & meso scales. Major implications for the water system are modelled with SWMM and the hydrological model as defined earlier. Several representative locations for further detailing are chosen, which are elaborated in the second phase.

Phase 2: urban design
Phase 2 consists of a series of urban design projects on the meso, micro & nano scales. These projects focus on detailing the interaction of the built environment with adaptation measures, while considering their implications on larger scales. Urban designs are tested in SWMM for their effectivity.

2.3.2 Methods and disciplines

Water management and Urbanism deploy methods in different ways. Although both disciplines benefit from all methods described in this section, the interpretation is different. To clarify these differences, Figure 30 elaborates on both discipline's perspective on the methods.

Figure 30 - Differing perspectives on methods.

	URBANISM	WATER MANAGEMENT
METHOD 1 literature review	• Studying US planning culture. • Determining boundary conditions for urban regeneration.	• Defining the technical state of the art. • Investigating ways to analyze adaptation measures. • Defining possible technical solutions.
METHOD 2 Mapping	• Overlaying maps for spatial analyses. • Combining socio-spatial and technical data. • Uncovering the scales of the system and their interrelations	• Simplifying to understand the water system.
METHOD 3 Fieldwork	• Grasping socio-spatial processes. • Studying spatial quality. • Interviewing designers & residents.	• Gathering data. • Understanding the water system through field measurements. • Interviewing engineering experts.
METHOD 4 Modelling	• Determining the relative climate vulnerability. • Testing urban designs.	• Determining dimensions. • Producing a hydraulic & hydrological design.
METHOD 5 Creating scenarios	• Evaluating socio-economic development. • Developing a vision for the future.	• Determining hydraulic & hydrological boundary conditions.
METHOD 6 Research by design	• Deploying urban design in iterative design loops to explore socio-spatial interventions.	• Intensive design process to design effective systems.

2.4 Research Outcomes

2.4.1 Products

The thesis proposes a total of seven intermediate products that together lead to the two main research outcomes as described earlier: an alignment of strategies resulting in a design framework and set of demonstration design projects at smaller scales. Figure 31 shows the seven intermediate products in a logical succession. The first two products are domain-specific, while the products in the following phases join to explore their synergies.

Product 1

The first intermediate product is a synthesis of the analysis done for the Greater New Orleans Urban Water Plan. A synthesis of the most relevant conclusions from the readily available body of morphological and technical analyses forms the starting point of further elaboration.

Product 2

The second product is a vulnerability analysis of Orleans Lakeside by using the vulnerability framework as described by de Graaf et al. (2009). This analysis is designed to build upon existing analyses and contribute to a more in-depth analysis of the situation. All three main research themes are assimilated in this analysis.

Product 3

The products of the first phase, with their primarily domain-oriented approach, combine into the development of scenarios for the Orleans Lakeside project area. These scenarios contain a projection of possible future trends such as demographics, urban development and hydrology.

Product 4

The fourth product is a vision for Orleans Lakeside, based on a synergistic consolidation of both technical and socio-spatial scenarios.

Product 5

Building on the Urban Water Plan and ongoing adaptation plans, the fifth product is a design framework that aligns strategies and proposes improvements on existing programs. This product is largely tied to the larger scales of the project (macro & meso).

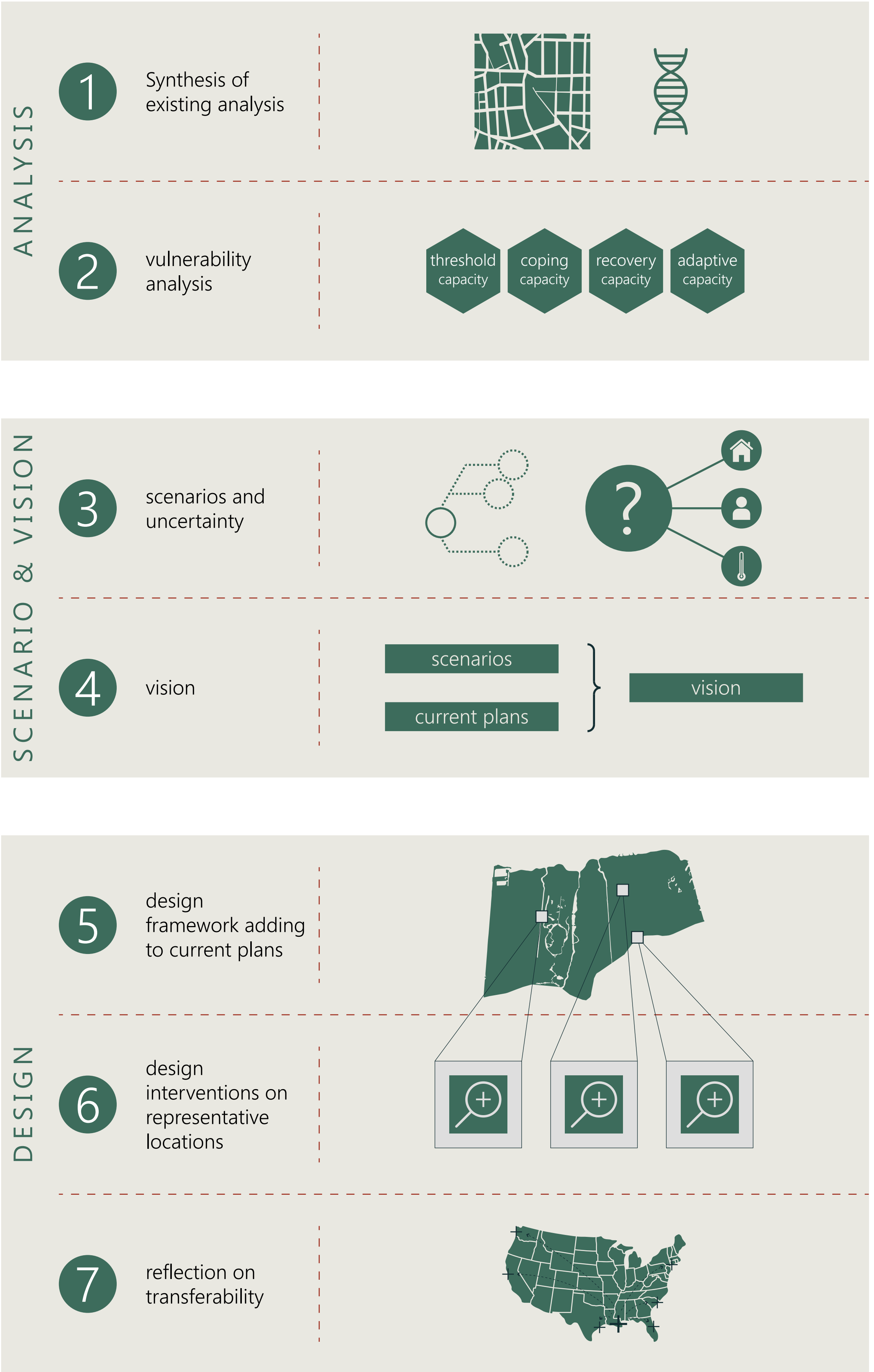
Product 6

The sixth product is an elaboration of the fifth product. From the design framework, several representative design locations are selected for further detailing. The detailed urban design ties together all scales of the project with the aim of successfully integrating adaptation measures with the built environment.

Product 7

The seventh intermediate product takes shape as a reflection on the transferability of the findings in this thesis to delta cities facing similar issues. This product is to expand the societal relevance of this thesis, although an in-depth review of possible transfer locations falls outside the scope of this project.

Figure 31 - Research outcomes.



2.4.2 Limitations

In order to provide sufficient depth in this research, the thesis is spatially limited to the Orleans Lakeside basin, confined by Lake Pontchartrain, the Gentilly Ridge, 17th Street Canal and the Inner Harbor Navigational Channel. This basin holds some of the most vulnerable neighborhoods, as well as City Park. The low lying Gentilly neighborhood is home to many community initiatives on green infrastructure, making it a suitable location for further research.

This thesis recognizes the pressing social-racial issues in the city, but will not elaborate on these issues due to time constraints. The strategies and designs proposed in this thesis will be sensitive to their surroundings, but will not consider an elaborate analysis on racial issues in the city. This thesis will have a predominantly technical character, in which the focus on combining designing with engineering is key.

2.4.3 Societal relevance

Urban flood and drought resilience in deltas is a pressing matter. For the New Orleans case, a reinterpretation of the built environment in flood and drought resilience is required to make the city capable of dealing with future climate extremes. In contrast to current policies and practice, the water system and the built environment cannot be considered separately, but rather should be regarded as an intertwined system. In New Orleans, and the United States in general, there is a lack of strategy in policies, therefore ignoring the existence of other actors and their autonomy. The individualistic approach of agencies and residents leaves out great opportunities for synergies that would provide a greater result than the sum of their parts.

A fresh perspective on a synergistic relation between adaptation efforts and the built environment can open new pathways for governmental and non-governmental actors in dealing with an uncertain future. This thesis aims to research the opportunities of a more holistic approach of stormwater and drought management in New Orleans, enabling the city to truly adapt to a rapidly changing environment. Such a novel approach can contribute positively to reduce the vulnerability of residents and minimize the economical and emotional stress of rebuilding time and time again to the pre-disaster state. This thesis aims to add to the existing Urban Water Plan and ongoing adaptation efforts rather than rehashing the same conclusions. Therefore, this thesis has the potential to bring the discourse further by addressing previously untouched subjects.

2.4.4 Scientific relevance

The scientific relevance of this research project lies within the power of actively combining an engineering and design approach. There is a growing body of research available on how to deal with urban stormwater, as well as on adaptive urban planning. However, the potential of combining these two fields and creating a strong synergy is largely unexplored. This thesis project seeks an intensive circular relation between both disciplines, where they are combined into a design exercise. If successful, this model has a potential transferability to other American delta cities that are facing similar problems.

2.4.5 Ethical considerations

The process of rebuilding efforts in New Orleans after Hurricane Katrina was heavily influenced by politized decisions. For instance, international help from Venezuela and Cuba was declined (Pelling, 2011) and the heavily damaged public housing stock was replaced with middle-class condominiums (Adams et al., 2009). Furthermore, rather than looking at the city in a holistic way, many of the city's agencies have their own agenda and time horizon and are reluctant to compromise on their goals. This thesis is free from political interference and therefore has the potential to address issues that otherwise be untouched due to the fear of a political backlash. On a more practical level, this thesis tries to combine the often conflicting agendas of designers and engineers. Whilst designers often look for a holistic approach, engineers are generally more interested in the specifics. The alignment of these agendas will be a major challenge in this thesis.

2.5 Methodology Progression

2.5.1 Summary

This chapter presented the overall methodology that forms the fundamental framework in which the thesis operates. A logical succession of steps was presented that leads from a general problem field to concrete steps in the methodological process.

The main knowledge gap this thesis addresses relates to the failure of current proposals in considering extreme weather events, as well as the lack of detailing the relation between adaptation measures and the built environment. The sub-basin Orleans Lakeside was found to be a suitable location for further research. From the knowledge gap, three main research themes are introduced (climate vulnerability, urban regeneration, and green infrastructure) which form the theoretical framework. A set of six methods is deployed to tackle research questions, designed to contribute towards the two explicit end products: an improved design framework and urban design interventions.

The chapter acknowledges the limitations of the thesis related to institutional rigidness and the extent of socio-economical issues in New Orleans. However, being an independent research project, this thesis has the liberty to propose what would otherwise be provocative measures.

2.5.2 Further development in thesis

As a research project is a dynamic process, the methodology will undoubtedly evolve and be refined in the course of the thesis. The current proposal provides a solid basis to proceed with the thesis.

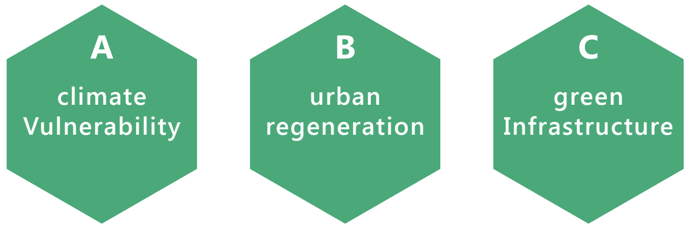
2.6 Theoretical Framework

2.6.1 Theoretical Framework Elaboration

The main research themes introduced in section 2.2 (Methodological Framework), presented in Figure 32, form the basis for the theoretical framework. The relevance of a solid theoretical framework lies within a theoretical underpinning the problem focus and proposed interventions. This section elaborates on the main research themes and relevant associated authors.

Although the leading research themes are used throughout the thesis, a separate, more in-depth theory paper is included as part of the theoretical framework. The theory report explores the relation between the climate vulnerability and urban regeneration themes to investigate how different forms of urbanization could positively affect the vulnerability of the low-lying New Orleans neighborhoods, whilst creating conditions for urban regeneration.

Figure 32 - Theoretical themes relevant to this thesis.



Climate Vulnerability

Climate vulnerability refers to the relative vulnerability of residents and the built environment to different magnitudes of extreme weather. Central to this research theme is the work by de Graaf et al. (2009), who developed a vulnerability framework to describe the capacities of the built environment in dealing with extreme weather events. de Graaf et al. (2009) identify four capacities of the built environment: threshold capacity (preventing damage), coping capacity (using spatial planning to minimize damage and optimize evacuation), recovery capacity (recovering), and adaptive capacity (adapting to future changes). This approach relates to the Multi-layer Safety Framework, developed by the Dutch Government in 2015 to actively use spatial planning in reducing flood risk. This theme includes work by Adams et al. (2009), who consider climate injustice issues and the eviction of the poor from New Orleans.

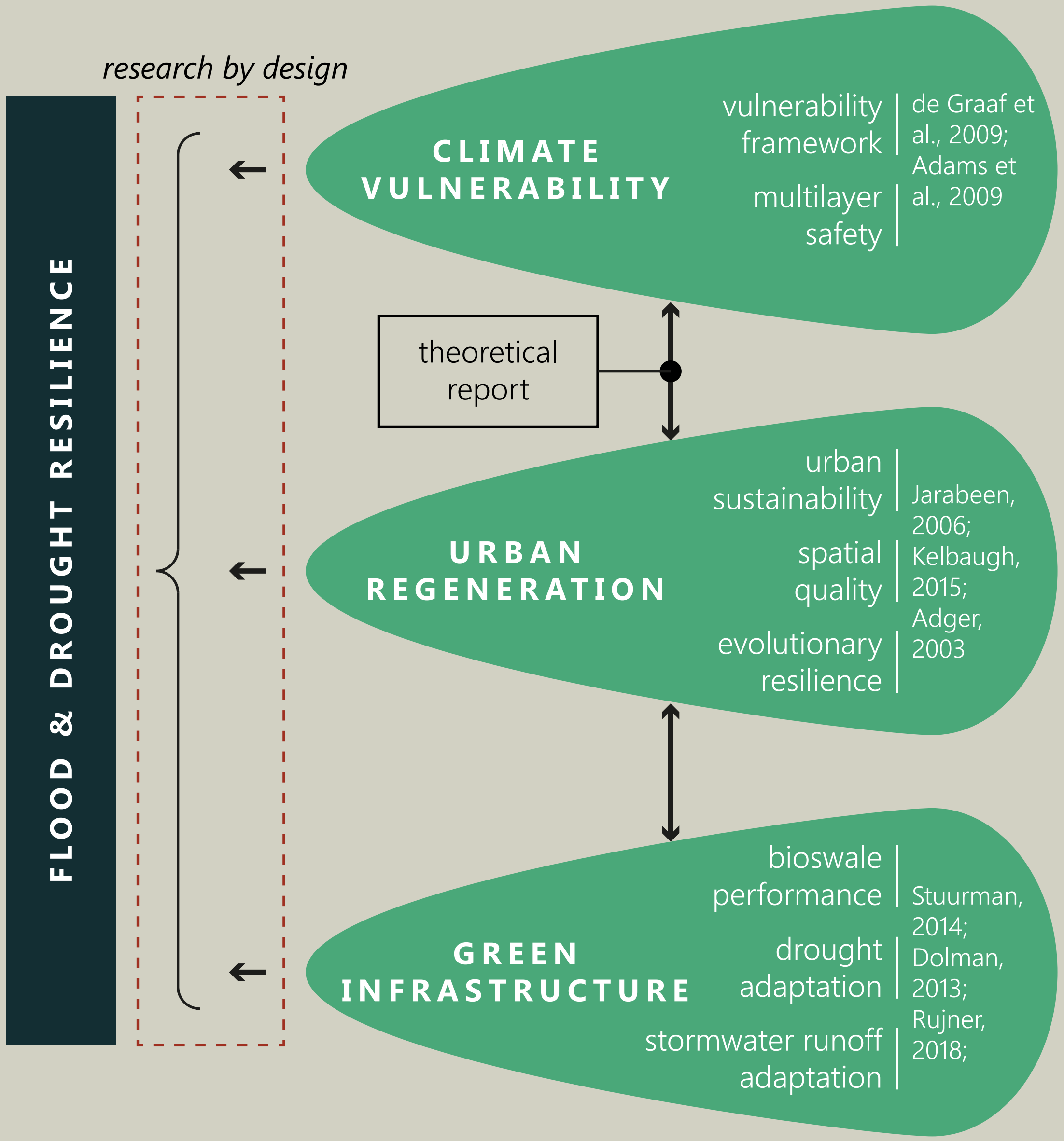
Urban Regeneration

Urban regeneration refers to the premise that any spatial intervention should have beneficial effects for the economic, social and environmental sustainability of the city. This theme covers a range of literature, including theory on alternative urban typologies (Jabareen (2006); Kelbaugh (2015)), evolutionary resilience (Adger (2003); T. J. Campanella (2006);) and the role of public space (Jacobs (1961)). Part of the urban regeneration theme is dedicated to a review of the American urban grid design, with Busquets, Yang, and Keller (2018) providing relevant literature on this aspect. As this thesis builds on the Greater New Orleans Urban Water Plan, the book Dutch Dialogues written by Meyer and Waggonner (2013) is used to guide general strategies in making the water system beneficial to upgrade the main spatial framework. Governmental reports and policies are part of this framework as well, as they are used in defining scenarios for New Orleans.

Green Infrastructure

The green infrastructure theme encompasses research on the performance of green infrastructure in urban environments, in addition to their integration in the urban fabric. For the evaluation of small scale adaptation measures (rain gardens), literature by Warnaars, Larsen, Jacobsen, and Mikkelsen (1999), van Seters, Smith, and MacMillan (2006) and Rujner (2018). For the integration of green infrastructure with the built environment this thesis refers to the book Green-blue Grids by Hiltrud Pötz (2016).

Figure 33 - Theoretical framework.



2.6.2 Theory paper

The potential of New Urbanism in making New Orleans more flood resilient.

Abstract - This paper addresses the potential of New Urbanism development in creating more flood-resilient communities in New Orleans suburbs. It seeks to evaluate the potential benefits, on multiple layers, of flood-risk management and provide arguments against conventional suburb planning. As a grounds for comparison, a vulnerability framework is used which identifies four capacities of the built environment on dealing with extreme weather events: threshold, coping, recovery, and adaptive capacity. For each capacity the paper identifies multiple aspects where New Urbanism performs better than conventional suburb planning, although some capacities are benefitted more than others. For the threshold capacity, a denser city fabric results in a smaller footprint, which reduces the required dike-length and therefore reduces vulnerability to failure. In addition, a more efficient evacuation facilitated by New Urbanism increases the coping capacity of the built environment. New Urbanism advocates a denser built environment, which reduces evacuation travel time and allows for vertical evacuation in taller buildings. Furthermore, the higher diversity of functions encouraged by New Urbanism creates more suitable conditions for recovery, although communal institutions and social networks are found to play a more significant role. Finally, New Urbanism increases the adaptive capacity by proposing a finer grained urban fabric containing a larger mix of functions. This type of urban environment is better able to adapt to future changes than rigid, homogenous suburbia. The limitations to New Urbanism found in this research mainly relate to a planning approach that caused resistance amongst the residents. Hence, New Urbanism design principles hold a strong potential in making New Orleans more flood resilient, although an integration towards a context-sensitive design with regards for local perception is essential.

Key words – New Urbanism, New Orleans, urban sprawl, flood resilience, climate vulnerability

1. Introduction

This paper addresses the potential of New Urbanism development in creating more flood-resilient communities in New Orleans suburbs. It seeks to evaluate the potential benefits on multiple layers of flood-risk management and provide arguments against conventional suburb planning.

After Hurricane Katrina struck New Orleans on 25 August 2005, urban planners seized the opportunity provided by the extensive destruction to put forth their design agenda and use the city as a clean slate for experiments (Wagner & Frisch, 2009). The New Urbanism movement was a prominent player involved from the early stages of rebuilding New Orleans (Michna, 2006). New Urbanism's design principles, cemented by the Congress for the New Urbanism (CNU), can be classified as neo-traditional development, aimed at limiting urban sprawl and inner-city decline by focusing on density and diversity (Jabareen, 2006). These design proposals encountered fierce resistance among New Orleans residents, largely due to the lack of regard to local context and the superimposed, top-down character of the plans. Subsection 4 (Urban flood resilience and the role of New Urbanism in New Orleans) deals with these issues in greater detail.

Generally, it is argued that urban development based on New Urbanism fundamentals is more sustainable than conventional suburb development (Berke et al., 2003). Brody, Gunn, Peacock, and Highfield (2011) found that high-density development patterns, including those prevalent in New Urbanism planning, show significantly less reported property damage than low-density development. This is echoed by Stevens, Berke, and Song (2010), who argue that New Urbanist designs have a potential to reduce losses due to natural hazards. However, all previous studies only considered the influence of New Urbanism development on the causes of flooding with regards to basin-wide implications. The potential of New Urbanism principles in making the built environment more flood resilient is not fully understood.

This paper appraises the potential of New Urbanism in making New Orleans more flood resilient by focusing on the design principles that affect the vulnerability of the built environment. Hence, this paper is not seeking to enter a debate on the aesthetics of New Urbanism, but rather discusses the aspects of compact development that directly influence the spatial vulnerability. The abundance of New Urbanism precedents in New Orleans greatly helps to identify the potential of these design principles in making the city more flood resilient.

This paper provides a comparative research on the differences in flood resilience between conventional suburb development and design guidelines dictated by New Urbanism. For the definition of resilience, theories by Liao (2012) and Davoudi, Brooks, and Mehmood (2013) are used. The potential of New Urbanism in creating flood resilient communities is evaluated on the basis of the vulnerability framework as defined by de Graaf, van de Giesen, and van de Ven (2009). This framework identifies four capacities which determine the vulnerability of the built environment: threshold, coping, recovery, and adaptive capacity. These four capacities provide a representative basis for comparison.

Reading guide
The appraisal of New Urbanism and the argument against conventional suburbia is built up by formulating the context and research question. Then follows an explanation of the methodology used for the comparative analysis. A theoretical framework introduces the main concepts used in this paper, after which the comparative analysis forms the main argument. The paper concludes with a reflection on the potential of New Urbanism in making New Orleans more flood resilient.

2. Context & Problem statement

Suburbs are ubiquitous in the United States; major city expansions often take shape as extensive subdivisions filled with detached dwellings. Large greenfield development, resulting in urban sprawl, converts vast areas of natural landscape to residential districts (Berke et al., 2003). Generally, scholars agree that suburbia creates an environment that is less than ideal and starves the city cores of investment (Kelbaugh, 1997; MacBurnie, 1995). However, suburbia remains immensely popular with investors and residents alike, as this is a typology that is associated with the "good life" (MacBurnie, 1995).

The catastrophic damage caused by Hurricane Katrina triggered a design moment, defined by

Wagner and Frisch (2009) as a period of time in which particular events occur that result in a process of urban restructuring. A design moment, Wagner argues, can result from (natural) disasters or other traumatic experiences. The role of New Urbanism in New Orleans in the design moment after Hurricane Katrina is elaborated in subsection 4 (Urban flood resilience and the role of New Urbanism in New Orleans).

The proposed urban designs were criticized for having little regard to the local context and being too overzealous in their approach to completely reimagine the city of New Orleans (Michna, 2006). However, with the rejection of these plans, interesting ideas and concepts that would increase the flood resilience of New Orleans were discarded as well.

Reconsidering the potential of compact development and New Urbanism principles holds potential in making the lower lying New Orleans more flood resilient. New Urbanism designs have the capacity to reduce losses due to natural hazards and offer a much more promising future than business as usual (Kelbaugh, 1997; Stevens et al., 2010).

This paper aims to answer the following research question:
To what extent can New Urbanism increase flood resilience in New Orleans suburbs?

3. Methodology: Comping New Urbanism with conventional suburbia

Firstly, when assessing the flood resilience of New Urbanism development, a definition of (flood) resilience is required. In this paper, flood resilience is defined by the framework and theory set forth by Liao (2012), complemented by the notion of evolutionary resilience by Davoudi et al. (2013).

An introduction to New Urbanism and its basic principles and concepts follows. Special attention is paid to the properties linked to environmental sustainability and flood resilience. This paper drafts from multiple authors on this issue to compile a holistic view on New Urbanism design ideals.

In order to provide a thorough assessment of the potential of New Urbanism in increasing flood resilience, the vulnerability framework as defined by de de Graaf et al. (2009) is used. This framework identifies four capacities of the built environment in dealing with (natural) disasters: a threshold, coping, recovery and adaptive capacity. The main characteristics of this framework and criteria for evaluation are briefly explained in subsection 4.

The main body of this paper is a comparative analysis between conventional suburbia and New Urbanism on all four layers of the vulnerability framework.

4. Theoretical Framework: Urban flood resilience and the role of New Urbanism in New Orleans

Resilience theory

Despite the increasing prevalence of the term "urban flood resilience", it remains ambiguous (Liao, 2012). Liao (2012) identifies two distinctive interpretations of resilience: ecological and engineering resilience. Engineering resilience is defined as the ability of a system to maintain stability and the capacity to return to the pre-disaster state as quickly as possible. Ecological resilience, on the other hand, describes the ability of a system to survive a disturbance and return to a stable state, not specifically being the pre-disaster state. Davoudi et al. (2013) introduces the concept of evolutionary resilience, which recognizes the ability of a system to change, adapt or transform in response to stresses and strains. Thus, a system does not necessarily have a stable state (Davoudi et al., 2013). This paper draws from both Liao and Davoudi and defines urban flood resilience as the capacity of the built environment to prevent flooding, and to reorganize should physical damage and socioeconomic disruption occur, so as to prevent deaths and injuries (Davoudi et al., 2013; Liao, 2012).

New Urbanism

New Urbanism opposes to conventional suburb development and focuses on reviving traditional typologies and urban patterns (Kelbaugh, 1997). It views the explosive sprawl of low density residential subdivisions in the natural landscape as undesirable and rather sees investment in more traditional, denser urban forms. Kelbaugh (1997) identifies seven principles of New Urbanism that cover the primary goals

of the movement: denser communities, fine-grained and diverse land use, priority to 'slow' traffic, conserving existing urban cores, a sense of identity, increased citizen participation and making day-to-day life more energy-efficient and sustainable. Jabareen (2006) describes New Urbanism as an approach to urban planning and design that relies on historical precedents to blend a variety of housing types in the form of communities, rather than superblocks or suburbs. Stevens et al. (2010) underline compactness and walkability as core principles of New Urbanism.

The destruction caused by Hurricane Katrina triggered the development of different rebuilding and design proposals, with New Urbanism playing a key role in the immediate aftermath of the hurricane (Michna, 2006). Wagner and Frisch (2009) argue that the extent of destruction was exaggerated by urban planners to justify using New Orleans as a clean slate to facilitate their own agenda. A wide variety of designs were proposed for the city, including a relocation of the city, constructing super levees and creating an 'American Venice' (Wagner & Frisch, 2009). Most plans had two aspects in common: the rejection of homogenous urban sprawl and limiting the city's footprint. New Urbanism was widely involved in reconstruction efforts along the Gulf Coast, as the Congress for the New Urbanism (CNU) was invited by the then-Mississippi Governor Haley Barbour to develop plans for the rebuilding of the communities damaged by Hurricane Katrina (Talen, 2008).

There was fierce resistance against New Urbanist plans from both professionals and the public. Professionals argue that New Urbanism developments do not live up to their promise of social improvement, but rather provide nostalgic urban communities for the upper-middle class that actually contradicts social improvement and perpetuate an old social order (Michna, 2006; Talen, 2008). Especially in the context of New Orleans, where many vulnerable and poor residents were severely hit, this seems unethical (Michna, 2006). Furthermore, local architects criticize the vastness and top-down character of the plan, which contrasts with the incremental growth and development of the city. New Orleans residents, Michna (2006) argues, do not identify with the New Urbanism plans as they have little consideration of local stories and do not connect with the New Orleans identity.

Despite the backlash, the New Urbanism agenda has achieved some successes in the rebuilding of New Orleans. Talen (2008) describes the design of a small affordable housing unit and new types of zoning as the major contributions of New Urbanism. The "Katrina Cottage", a more permanent alternative to FEMA's emergency trailers, was hailed nationally and received the Cooper-Hewitt National Design Museum's People's Design Award (Talen, 2008). The second significant contribution is the development of the "SmartCode", a zoning plan that thoroughly considers social diversity by allowing a range of dwelling types and price segments for each zone (Talen, 2008).

Vulnerability framework

A framework was developed by de Graaf et al. (2009) that identifies four capacities of the built environment in dealing with (natural) hazards. This framework acknowledges the traditional threshold capacity (1), which is focused on prevention of damage caused by extreme events. This takes shape in building dikes, pumping stations and other infrastructure. In addition, the framework identifies a coping capacity (2), a recovery capacity (3) and an adaptive capacity (4). The coping capacity is defined as the ability to minimize impact on society when the damage threshold is exceeded (de Graaf et al., 2009). The recovery capacity concerns the capability of society to return to a pre-disaster situation. The adaptive capacity describes the ability of society to change over time to a state that is better equipped to dealing with extreme events.

The four capacities of the vulnerability framework operate on different time horizons. The threshold capacity relies on past events, such as using extreme-value statistics based on historic water levels to determine the necessary height of a dike (de Graaf et al., 2009). The coping and recovery capacities are focused on the instant. In contrast, the adaptive capacity is relevant on a long time horizon and involves a high degree of uncertainty (de Graaf et al., 2009). This capacity requires the built environment to have a sufficient flexibility to respond to all possible future trends.

The different time horizons can be represented in three different domains and have a direct relation with the damage involved. In the threshold domain, no damage is perceived. The coping and recovery domain relate to low return periods and relatively limited damage. The adaptive domain, on the other hand, is relevant to extreme events

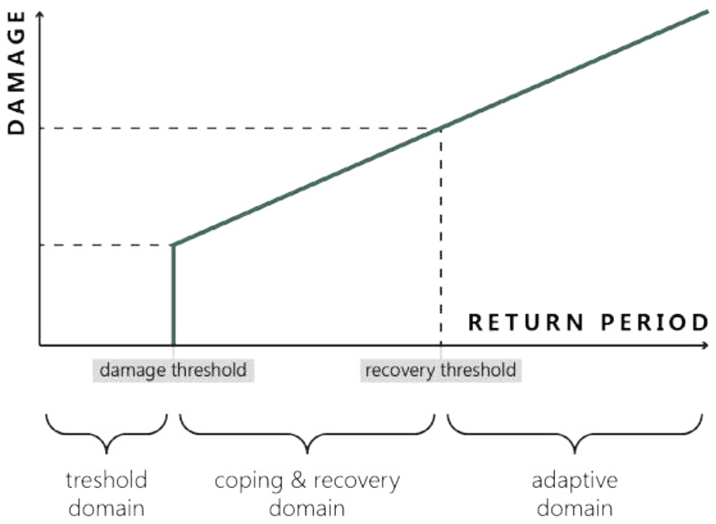
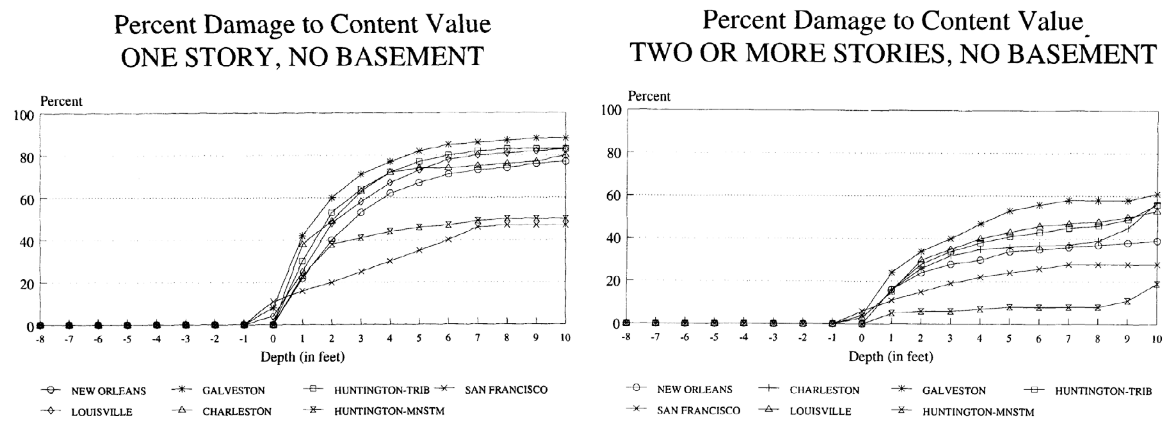


Figure 34 - Vulnerability framework (source: adapted from De Graaf, van de Giesen & van de Ven, 2007).

Figure 35 - Depth-Damage curves for single-story and multiple-story dwellings (souce: US Army Corps of Engineers, 1992).



and a corresponding high potential damage. Figure 34 shows the relation between the return period and potential damage.

5. Discussion: Comparative analysis

With the main theories underpinning this paper explained, this section continues with a comparative analysis between conventional suburbia and New Urbanism development in terms of flood resilience based on the four capacities of the vulnerability framework.

Threshold capacity

There is a variety of literature claiming that New Urbanism development is less likely to contribute to natural hazards than conventional suburbia. High-density development patterns show significantly less reported property damage than low density development (Brody et al., 2011). This is attributed to the alteration of the flow regime by conversion of open space to housing divisions, resulting in more extensive flooding. Furthermore, Stevens et al. (2010) found that New Urbanist designs have a potential to reduce losses due to natural hazards. However, if development takes place in areas prone to natural hazards or when insufficient hazard mitigation techniques are implemented, the risk of damage to natural hazards is exacerbated. For New Orleans, the main detrimental effect of urban expansions on the natural water system concerns the disappearing wetlands. Channelization and confinement of the Mississippi river has disrupted sedimentary processes, threatening the health of the wetlands separating New Orleans from the Gulf of Mexico (Coastal Protection and Restoration Authority of Louisiana, 2017). Wetlands act as a natural barrier during storm surges, and a retreat of the wetland system would put a greater strain on the federal flood defenses in case of a hurricane.

New Urbanism development is inherently more compact than traditional suburb development. By clustering housing demand into a denser typology, the effective footprint of the city shrinks. This implies that a New Urbanism subdivision would be cheaper to protect with a dike than a conventional suburb subdivision. After Hurricane Katrina struck New Orleans, arguments arose in favor of abandoning the most vulnerable parts of the city and limiting the city's extents (Ford, 2007). Such a move would reduce the length of dikes and make the city less vulnerable. However, this proposal was met with intense criticism by residents who were forced to flee the rising waters but insisted on returning (Ford, 2007).

Coping capacity

An important consideration for building in areas that are exposed to extreme weather events is that it is not feasible to make the built environment completely resistant to flooding. When the threshold capacity is exceeded, the city should be well-equipped and designed to minimize damage and facilitate a proper evacuation.

Conventional suburbia has an inherent but limited capacity to dealing with moderate flooding, which is due to the typical architecture in these subdivisions. A small elevation allows the typical urban dwelling to cope with a few feet of water, however, remains extremely vulnerable to severe inundation due to the single-story architecture. New Urbanism typologies, often sporting multiple stories, is less prone to inundation as not the entire property's value is amassed on the ground floor. Depth damage curves, developed by the US Army Corps of Engineers (1992), show damage per feet of water, per building typology. The curves, displayed in Figure 35 for different typologies, give the damage as a percentage of the building's content value. The curves show that denser typologies (40% damage at 10 ft. of flooding) cope better with moderate flooding than single-story dwellings (80% damage at 10 ft. of flooding).

An individualistic approach in American property management focuses on preventing flood damage to private structures. By raising individual parcel, private property is saved from moderate flooding, while runoff from the storm floods the streets and disrupts processes in the city. Those who can afford it save their property, while putting a greater strain on the overall system.

In addition to mitigating damage in case of flooding, evacuation is an important aspect of the coping capacity. Evacuation from conventional suburbia is completely reliant on automobiles due to the vast sprawl of the built environment. During Hurricane Katrina, impoverished residents were unable to leave due to a lack of private transportation (Colten, 2006). New Urbanism can provide vertical evacuation in local shelters as an alternative, as upper floors of buildings would remain dry during floods. Furthermore, concentrating development on naturally higher ridges would reduce the vulnerability in an effective way.

Recovery capacity

The capacity of an urban environment to recover from extreme events depends on a multitude of factors. While urban planning definitely plays a role in the recovery of cities, Campanella (2006) argues urban resilience largely depends on people. Campanella (2006) explains that communal institutions and social networks tend to survive the destruction of their physical environment, recalling the determination of residents of the devastated Lower Ninth Ward to rebuild their living environment. Increasing citizen participation by strengthening the public realm and discouraging to spend time in privatized spaces are one of the prime objectives of New Urbanism (Kelbaugh, 1997). While these principles are significant contributors to social networks, the case of the Lower Ninth Ward shows that social networks can also thrive in urban environments that do not meet these demands. Thus, the potential of New Urbanism is less clear in the aspect of recovery.

In terms of economic damage, the recovery capacity relates back to the threshold and coping capacity, as these capacities determine the amount of damage the built environment sustains in the event of a disaster. If, for instance, the extent of flooded area is limited by a more compact built form, it takes less resources to rebuild flood defenses and inundated infrastructure. However, a higher value of the affected buildings might lead to more expensive reconstruction.

Adaptive capacity

Conventional suburbia falls into a trap that inhibits the adaptive capacity. Carpenter and Brock (2008) identify two types of traps, of which one is applicable to the New Orleans suburbs. The rigidity trap is described by Carpenter and Brock (2008) as a system where institutions become highly connected, self-reinforcing and inflexible. Furthermore, the lack of diversity is a predisposing factor for a rigidity trap, with Carpenter and Brock (2008) providing an ecological example where only a few shade-tolerant species can survive in an old-growth forest and the entire system is vulnerable to external disturbances such as wild fires. The rigid, top-down planning nature of conventional suburbia with inflexible land uses and segregated zoning matches the features of such a system and falls in the rigidity trap. Turner (2017) elaborates on why the rigidity trap persists in American planning culture, arguing that particularities of land development and finance inhibit other ways of urbanization. Current institutional characteristics and connectivity create a system where there is little incentive to explore alternatives; exposure to stress has led to entrenchment rather than experimentation (Turner, 2017).

As the adaptive capacity operates on a longer time scale with associated uncertainties, flexibility is key. By laying out homogeneous subdivisions across the landscape, suburbia does not take into account possible uncertainties in vacancy, demographic trends and potential urban development along its fringes. New Urbanism has an inherent better adaptive capacity, as its diversity enhances the collective flexibility (Pelling, 2011). In addition to a diverse urban environment, Kelbaugh (1997) describes New Urbanism's aim to achieve a small grain size, making adjustments over time easier. Flexibility can be further increased at the building scale. By integrating attributes such as high ceilings, buildings can more easily change function over time.

6. Conclusions

This paper aimed to appraise to what extent New Urbanism can contribute to an increased flood resilience in New Orleans. A comparative analysis with conventional suburbia on the basis of a vulnerability framework showed that New Urbanism holds potential on multiple capacities, underlining the argument of this paper in favor of alternative urban planning.

The core design principles of New Urbanism developments hold merits on all layers of the vulnerability framework, although some capacities are enhanced more than others. For the threshold capacity, a more dense city fabric results in a smaller footprint, which reduces the required dike length and therefore reduces vulnerability to failure. In addition, a more efficient evacuation increases the coping capacity of the built environment. New Urbanism advocates for a denser built environment, which reduces the evacuation travel time and allows for vertical evacuation in taller buildings. Furthermore, a higher diversity of functions encouraged by New Urbanism creates more suitable conditions for recovery, although communal institutions and social networks play a more significant role (Campanella, 2006). These social networks are also found to exist in a conventional suburban environment. Finally, New Urbanism increases the adaptive capacity by proposing a finer grained urban fabric containing a larger mix of functions. This type of urban environment is better able to adapt to future changes than rigid, homogenous suburbia (Pelling, 2011).

The limitations to New Urbanism found in this research mainly relate to a planning approach that caused resistance amongst the residents. The opportunistic behavior of New Urbanism planners after Katrina was widely denounced, making some promising proposals such as reducing the city's footprint now unnegotiable. New Urbanism design principles hold a strong potential to making New Orleans more flood resilient, although an integration towards a context sensitive design with regards for local perception is essential.

3 Analysis synthesis

This chapter aims to provide insight into the state of the art of current urban analyses and distill the most relevant aspects for this thesis. Rather than rehashing general engineering and morphological analyses, this chapter draws from conclusions made in the GNO Urban Water Plan.

This analysis synthesis chapter provides a general background and precedes the more project-focused vulnerability analysis in Chapter 4.

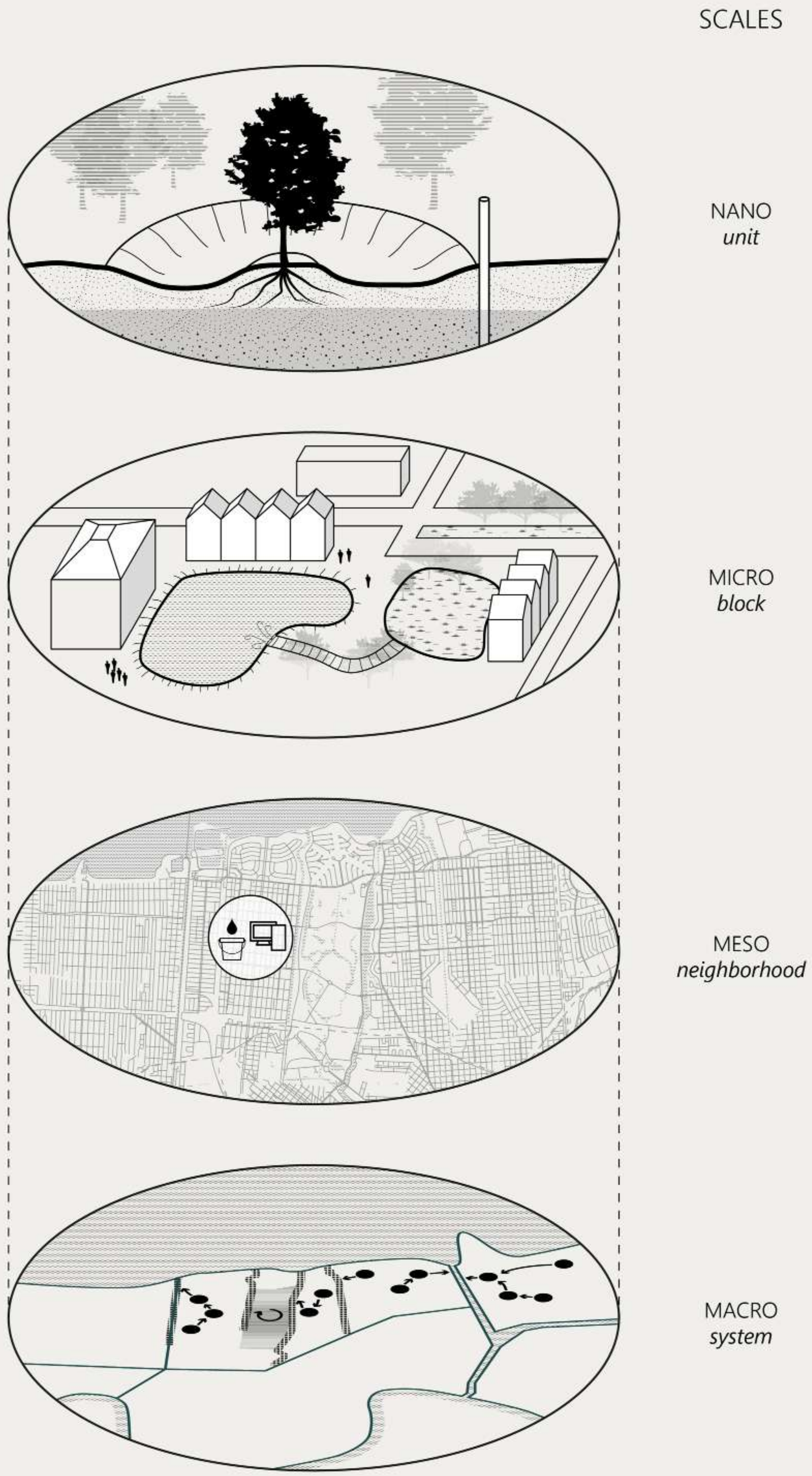
The analysis synthesis is structured with a set of topics that tie together a series of related analyses. For each topic, the analyses are sorted by scale (macro-meso-micro-nano). Figure 36 shows the relevant scales in this thesis; this classification of scales is valid for the entire report.

This chapter consists of the following topics:

3.1 Climate boundary conditions
3.2 Topography & flood susceptibility
3.3 Urban structure
3.4 Drainage infrastructure

NOTE: this chapter is not yet complete; several analyses are missing.

Figure 36 - Scales considered in this thesis.



3.1 Climate Boundary Conditions

New Orleans has a subtropical climate, resulting in the occurrence of extreme precipitation. South-east continental US has a high annual precipitation (Figure 37), with a large seasonal variability in precipitation intensity (Figure 38).

The Mississippi River drains 40% of the landmass of the lower forty-eight states (Waggonner & Ball Architects, 2013). The extent of its watershed is displayed in Figure 39.

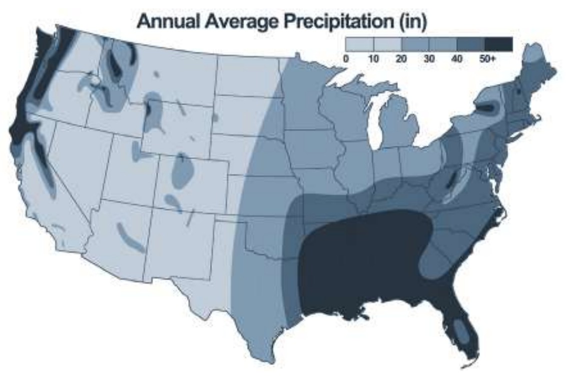


Figure 37 - Annual Average Precipitation in inches (Waggonner & Ball Architects, 2013).

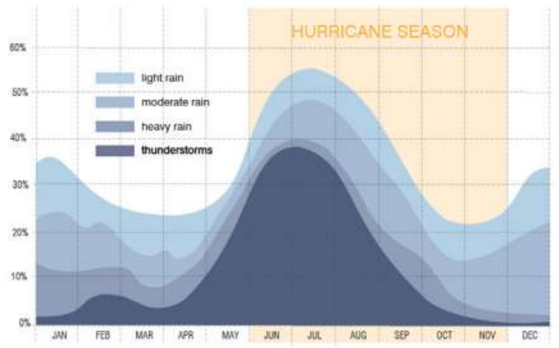


Figure 38 - Seasonal distribution of precipitation (Waggonner & Ball Architects, 2013).

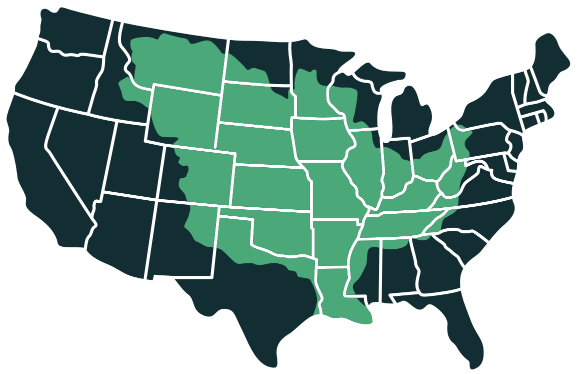


Figure 39 - Mississippi watershed.

2.3 Topograhy & Flood Susceptibility

■ 3.2.1 Land elevation

Much of New Orleans lies below sea level; only the current river banks and old alluvial deposits are above mean sea level. Gentilly Ridge, traversing the city from east to west, separates the northern and southern parts of New Orleans' hydrological system. Furthermore, these elevated areas have a relatively low flood vulnerability.

The federal levee system of New Orleans is designed to withstand a storm surge with a return period of 100 years (US Army Corps of Engineers, 2012). Figure 40 provides insight in the potential flooding depth across New Orleans in the case of levee failure. The maximum potential flooding depth reaches almost 3 meters (10 ft.) in the lowest parts of the city.

Figure 40 - Digital elevation model of New Orleans with levee system and Gentilly Ridge.

■ 3.2.2 Lithology

The top layers of the soil New Orleans is built on have a predominantly silty and organic composition, reflecting the alluvial character of the Mississippi River delta. As Figure 43 shows, the current river banks and the Gentilly Ridge have silty soils, while the parts of New Orleans below sea level mainly consist of clay and muck soils.

Sections of the subsoil are given in Figure 42. These sections show that the top soil primarily consists of silt, clay and muck, while deeper layers also contain more permeable sands. The sand layer originates from the Pine Barrier Island, which dates back prior to the formation of the Mississippi River delta (Waggonner & Ball Architects, 2013).

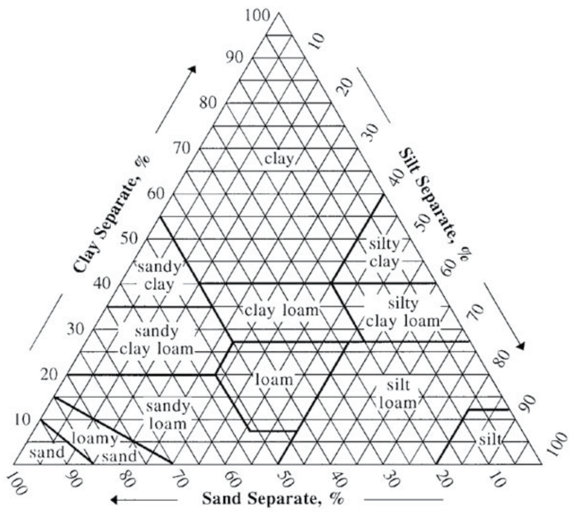


Figure 41 - (left) Soil texture classification (Source: Natural Resources Conservation Service (N.D.))

The soil texture class in Figure 41 provides insight in different soil classifications. As the share of sand is low in the top soils of New Orleans, the classifications on the right side of the graph are applicable.

Figure 42 - (right) Soil section A-A' through Lakeview, soil section B-B' through City Park, soil section C-C' through Gentilly (source: van Asselen, Jaimerena, and Stuurman (2019), elaborated by author).

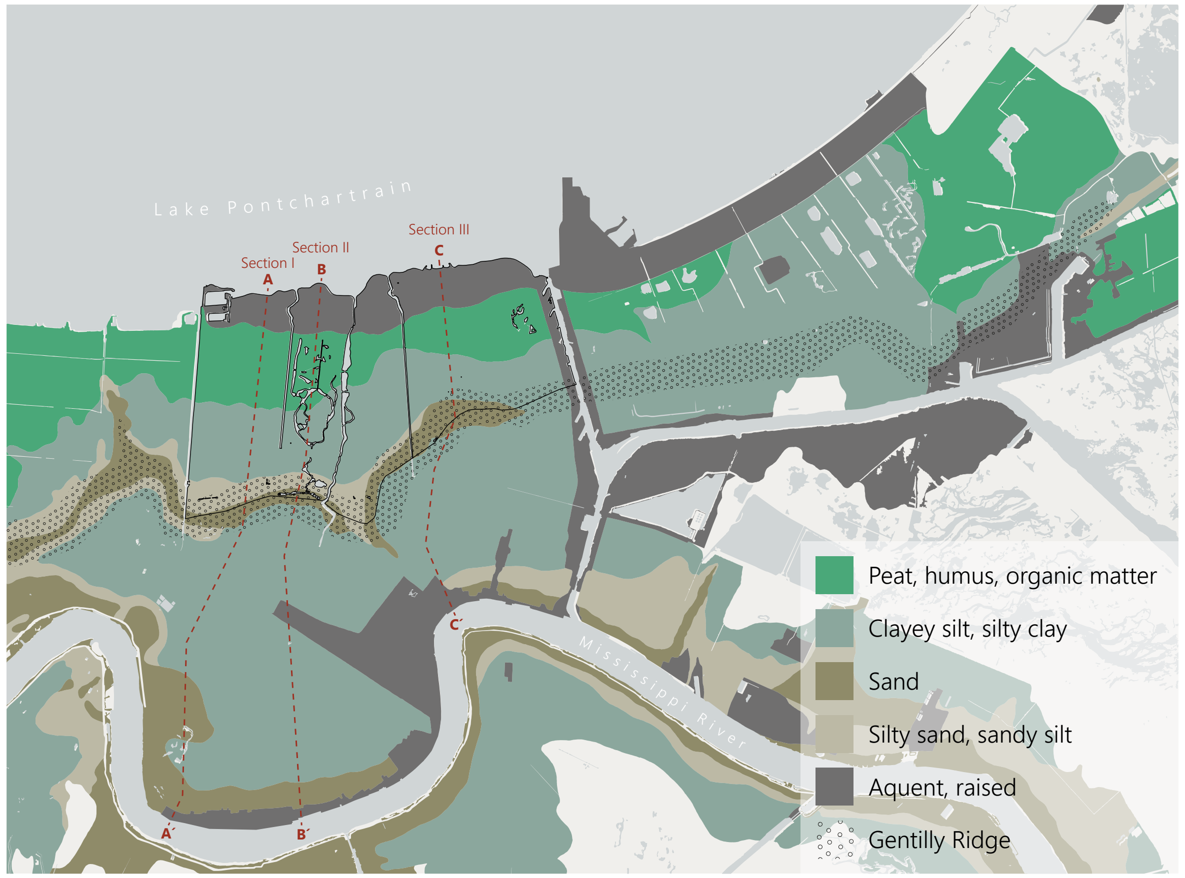
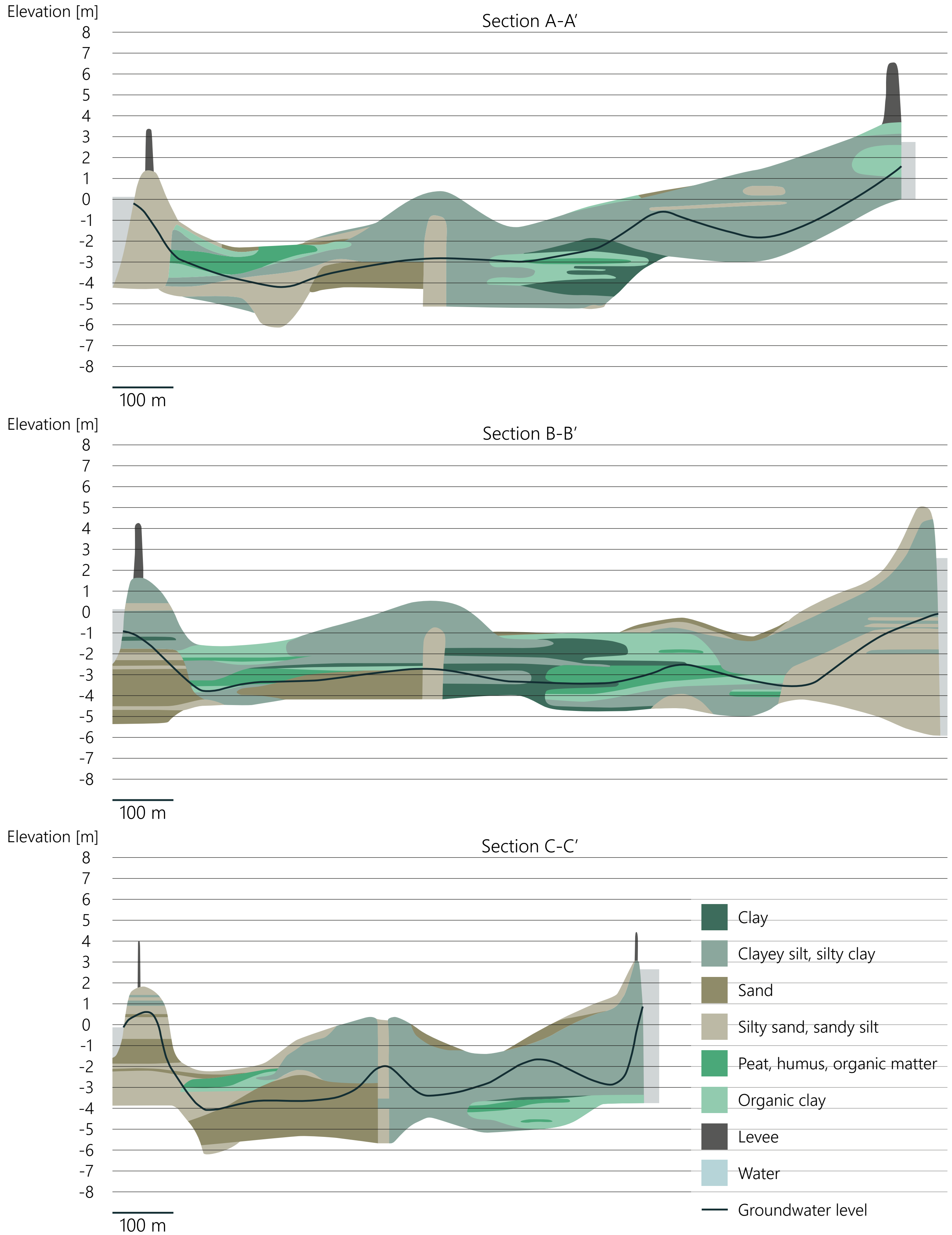


Figure 43 - Lithology with Gentilly Ridge as natural river deposit (source: Natural Resources Conservation Service (2013), elaborated by author).



3.3 Urban Structure

This section presents an overview of the most relevant urban characteristics of Orleans Lakeside, focusing on the relation to water management.

■ 3.3.1 Neighborhood profiles

Figure 44 shows an overview of administrative districts within Orleans Lakeside, along with key statistics regarding population and density.

A comparison of neighborhoods brings to light several striking differences within Orleans Lakeside. With a total population of nearly 70,000 inhabitants, Orleans Lakeside contains a major part of the total city's population of 340,000. Neighborhoods differ greatly in terms of population density, vacancy and percentage of owner/renter, although there seems to be a strong east-west pattern. In short, most differences come forward with City Park being a dividing line between values.

Population density

Neighborhoods west of City Park generally have a lower population density than those to the east of City Park. While Lakeview, Navarre and West End generally have densities of around 180 inhabitants per square kilometer, Gentilly Terrace, Milneburg and St. Anthony have densities closer to 300 inhabitants per square kilometer.

Vacancy

Vacancy largely follows patterns of income; affluent neighborhoods such as Lakeview and Lake Shore – Lake Vista have a low vacancy, while less affluent neighborhoods such as Gentilly Woods and Filmore have a higher vacancy.

Land ownership

Similar to vacancy, the percentage of land owners follows income patterns. Affluent western neighborhoods see ownership rates of up to 90%, while east of City Park this figure is much lower with 40% to 60%.

Figure 44 - Administrative districts (source: The Data Center (2017), elaborated by author).

District	Population	Density [inh/km2]	% Vacant	% Owner	% Renter
City Park	2842	41	13.9	43.8	56.2
Dillard	5181	196	17.9	51.6	48.4
Fairgrounds	5612	231	17	42.6	57.4
Filmore	5649	166	19.4	77.5	22.5
Gentilly Terrace	10169	300	15.4	61.8	38.2
Gentilly Woods	3170	154	18	61	39
Lake Shore - Lake Vista	3872	123	10	87.1	12.9
Lake Terrace & Oaks	2098	50	22	77.5	22.5
Lakeview	8043	179	11.8	72	28
Lakewood	1818	72	11.4	92.4	7.6
Milneburg	4659	226	13.9	58.5	41.5
Navarre	2914	159	10.6	60.3	39.7
Pontchartrain Park	2186	78	19	73.8	26.2
St. Anthony	4754	266	12.4	40.8	59.2
St. Bernard Area	2518	256	14	17.5	82.5
West End	4128	186	16.7	54.1	45.9

■ 3.3.2 Character of water infrastructure

Figure 45 shows an overview of administrative The central part of New Orleans can be divided into six hydrological sub basins, which all have a different approach to water management in the urban environment. Based on an analysis by Palmbout Urban Landscapes (2013), the following brief descriptions of each sub basin are given:

Jefferson Lakeside

Contains a network of open canals in both east-west and north-south direction.

Jefferson Riverside

Main infrastructural connections run parallel to the river; secondary lines run perpendicular to the primary connections.

Orleans Lakeside

Contains the primary outfall canals and a set of box culverts that drain stormwater to pumping stations. Open water is barely visible in this sub basin.

Orleans Riverside

Green boulevards run perpendicular to the Mississippi River towards Gentilly Ridge.

Orleans East

Contains a set of open canals that run parallel to Lake Pontchartrain.

Lower Ninth / Upper St. Bernard

Contains open canals that run perpendicularly to the river and drain to the Forty Arpent Canal.

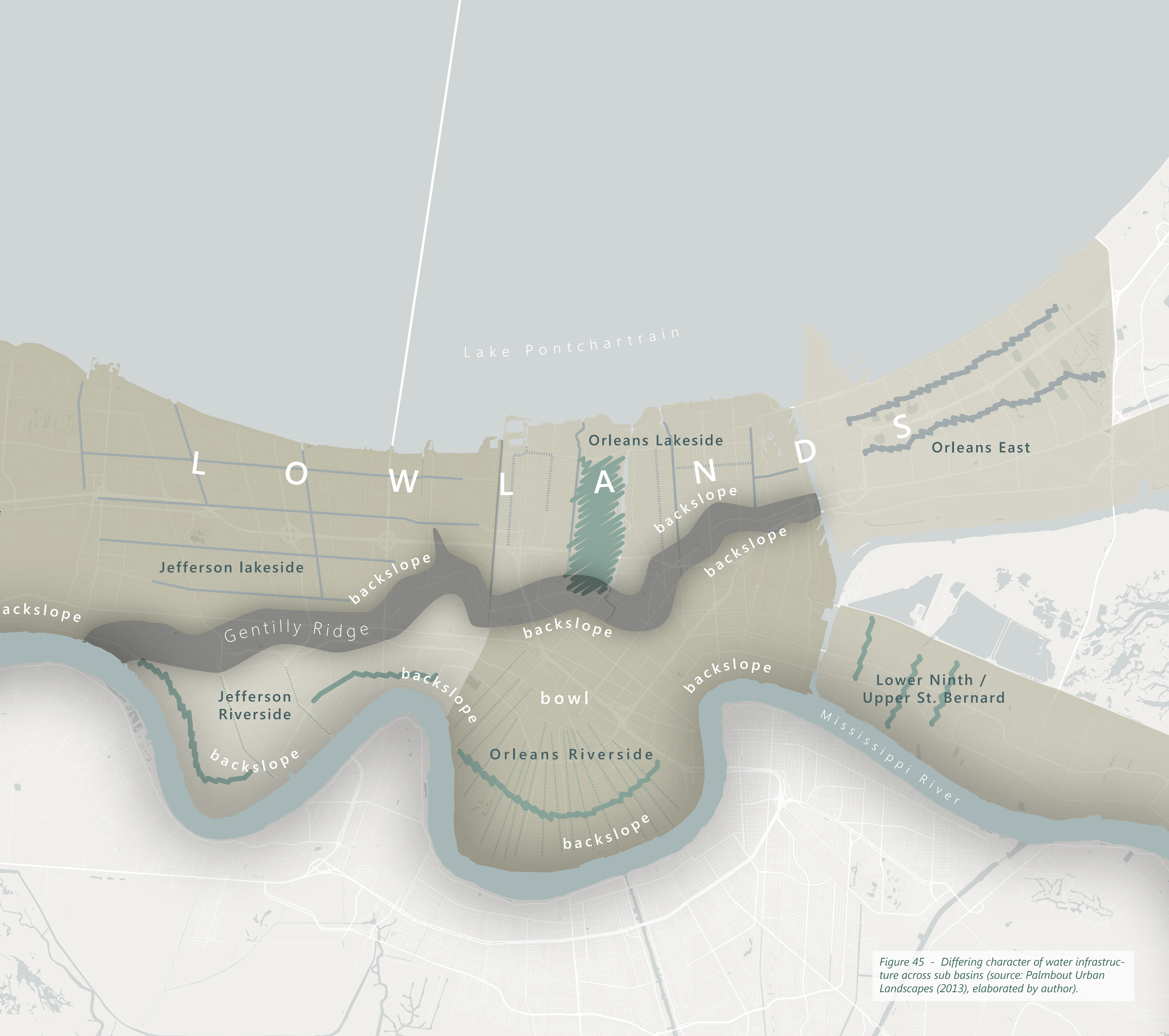


Figure 45 - Differing character of water infrastructure across sub basins (source: Palmbout Urban Landscapes (2013), elaborated by author).

■ 3.3.3 Character of coastal flood protection system

The coastal flood protection system within Orleans Lakeside can be categorized in four typologies, each with a different interface. Figure 46 shows the location of the various types, accompanied by a sketch.

1. *Floodwall on earthen levee*

This type mainly occurs alongside the outfall canals; during Hurricane Katrina, several sections of this type collapsed. A concrete wall on top of an earthen elevation prevents open water access. Although this type of flood protection does not allow for open water to be used as amenity, it does provide a sense of security to residents living in Orleans Lakeside. Conversations with residents during fieldwork showed that a lowering of the walls would not be preferred, even if conditions would allow it.

2. *Earthen levee*

The primary flood defense with the interface of Lake Pontchartrain takes shape as an earthen levee, which cars and pedestrians can cross. The earthen levees are not spatially integrated to be used as open space, although access on top of the levee is not restricted.

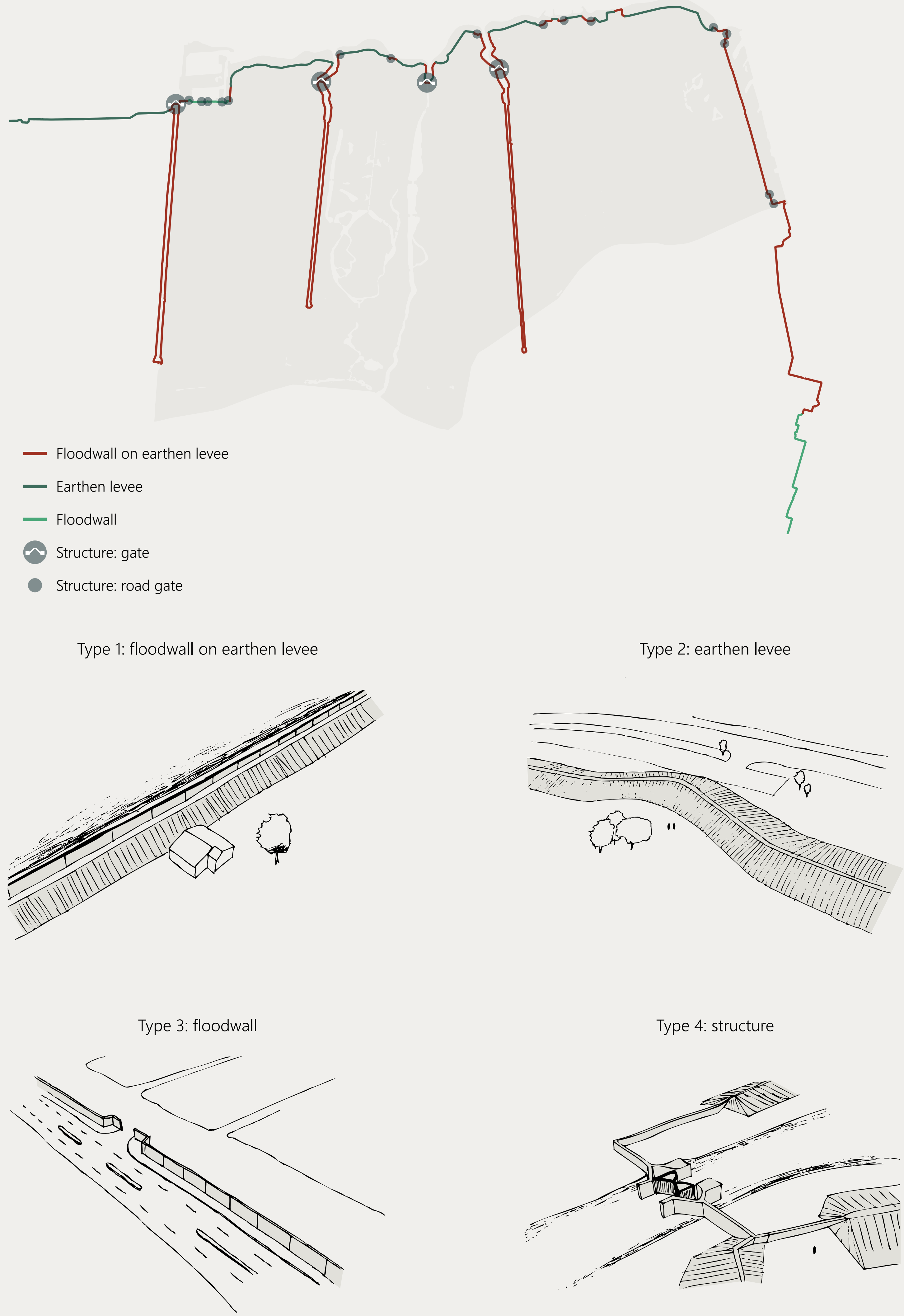
3. *Floodwall*

A solid concrete floodwall is used near the Orleans Marina, where space is limited. Design standards for a storm with a return period of 100 years result in a significant height of the required wall. There are few passageways.

4. *Structure*

There are several structures in place along the interface with Lake Pontchartrain and the Inner Harbor Navigational Channel. Bayou St. John can be closed with a gate and each outfall canal can be closed with a gate at the pumping stations near the lake. The levees and floodwalls have gates that are usually open for traffic but can be closed in case of high water. Gates of floodwalls, such as the ones near the Orleans Marina, are the full height of the flood protection system. In contrast, gates on earthen levees have a limited height.

Figure 46 - Various types of flood barriers in the project area.



■ 3.3.4 Urban Fabric

Although Orleans Lakeside is traversed by the I-610 interstate highway in an east-west direction, primary access points to the project area are through several north-south oriented roads (see Figure 48). An important east-west connection is Lakeshore Drive, which runs parallel to Lake Pontchartrain. As Figure 49 shows, a more fine-grained grid pattern fills the area in between primary access roads.

Orleans Lakeside contains various public parks and open space, although these assets are not evenly distributed across the area. With a size comparable to New York City's Central Park, City Park functions as a dividing element between Lakeview and Gentilly. Other major open spaces are Pontchartrain Park and Lakeshore Park.

Figure 47 - Open space in Orleans Lakeside (source: City of New Orleans (2019), elaborated by author). Scale 1:75,000.

Figure 48 - Major access roads. Scale 1:75,000.

Figure 49 - Street pattern. Scale 1:75,000.

■ 3.3.5 Block typologies

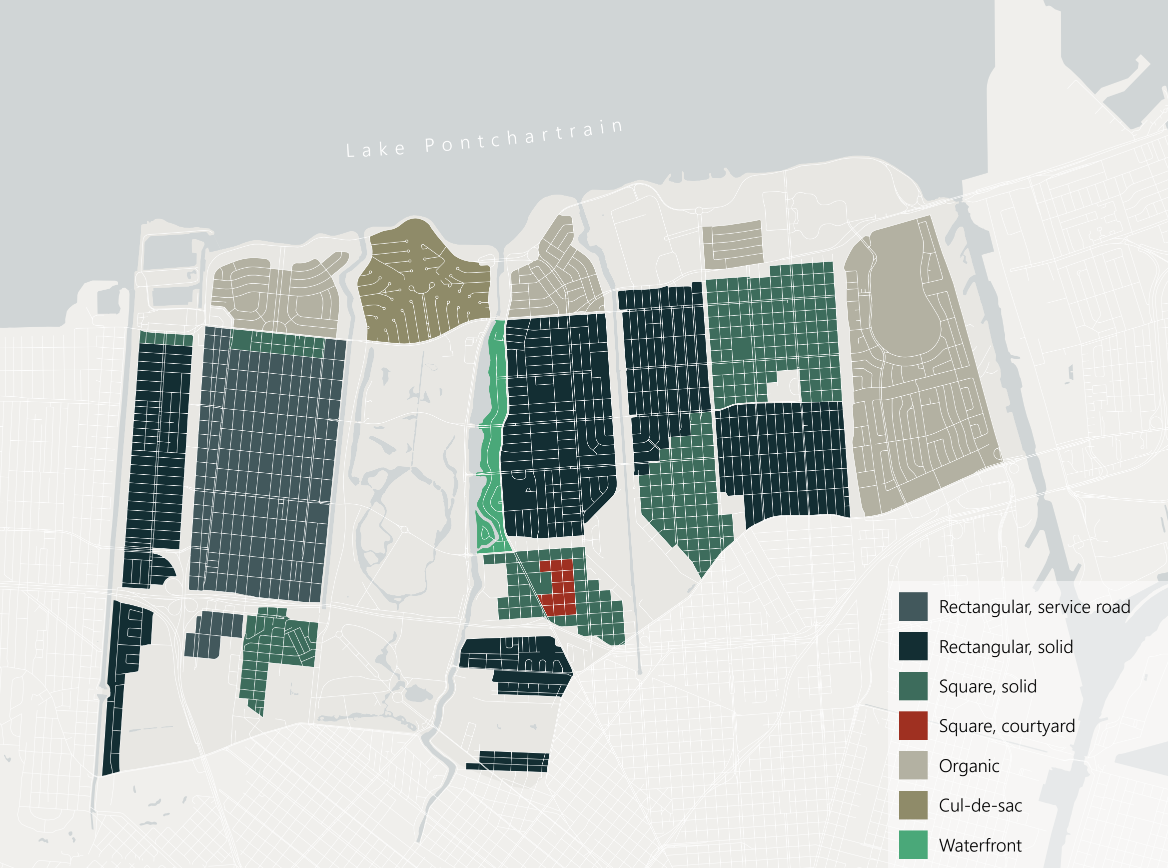


Figure 50 - Distribution of block typologies. Scale 1:75,000.

Type A - Rectangular, service road

Building types:
ranch home, 1-story bungalow, 2-story bungalow

Type B - Rectangular, solid

Building types:
2-bay shotgun home, 4-bay shotgun home, ranch home, 1-story bungalow, 2-story bungalow

Figure 51 - Predominant block typologies in Orleans Lakeside with their most common building types. Scale 1:5000.

Type C - Square, solid

Building types:
ranch home, 1-story bungalow, 2-story bungalow

Type D - Square, courtyard

Building types:
garden-style apartments, townhomes

Type E - Organic

Building types:
ranch home, 1-story bungalow, 2-story bungalow

Type F - Cul-de-sac

Building types:
ranch home, 1-story bungalow, 2-story bungalow

Type G - Waterfront

Building types:
ranch home, 1-story bungalow, 2-story bungalow

■ 3.3.5 Building typologies

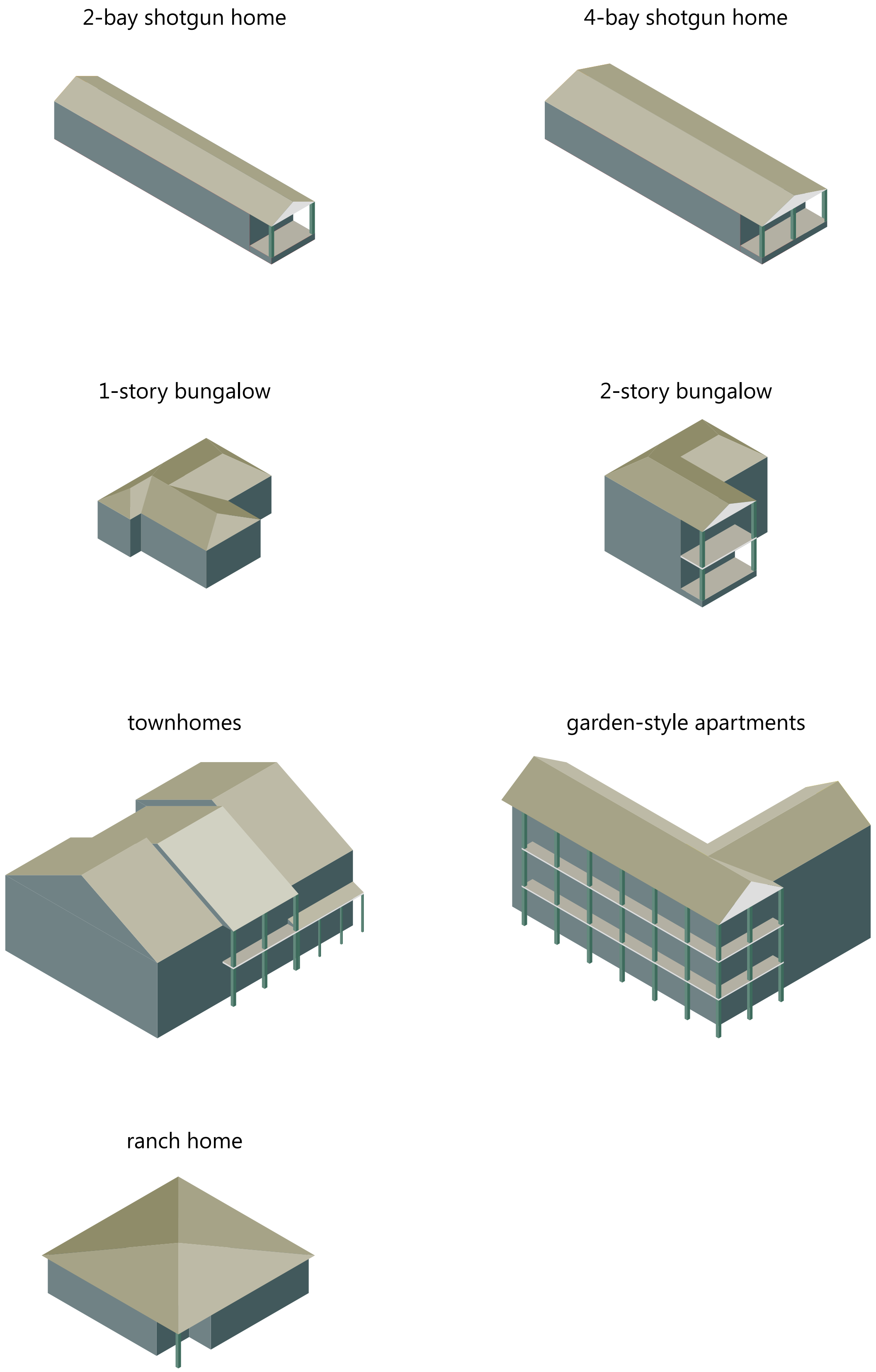


Figure 52 - Predominant building typologies in Orleans Lakeside.

3.4 Drainage Infrastructure

Drainage of stormwater in New Orleans has a strong engineered character; powerful pumping stations discharge stormwater towards Lake Pontchartrain through a network of open and closed concrete canals. This network disregards local topography, meaning that even precipitation falling near the Mississippi River is transported northwards. Figure 53 shows the drainage of the Jefferson/Orleans basin.

Figure 54 shows a more detailed schematization of the drainage infrastructure in the Orleans Lakeside sub basin. Striking is the double configuration of pumping stations near Lake Pontchartrain; new pumping stations are being built to replace the temporary system put in place after Hurricane Katrina. These new pumping stations will reduce the dependence on other pumping stations, turning the outfall canals into boezems (see glossary) and shortening the required length of the primary coastal flood defense system.

Almost every public road in Orleans Lakeside has one or more underground drainage pipes, with a few minor exceptions. A set of sizable box culverts connect the conduits to the pumping stations. These box culverts were originally designed as open canals, but are now covered due to fears of a mosquito plague.

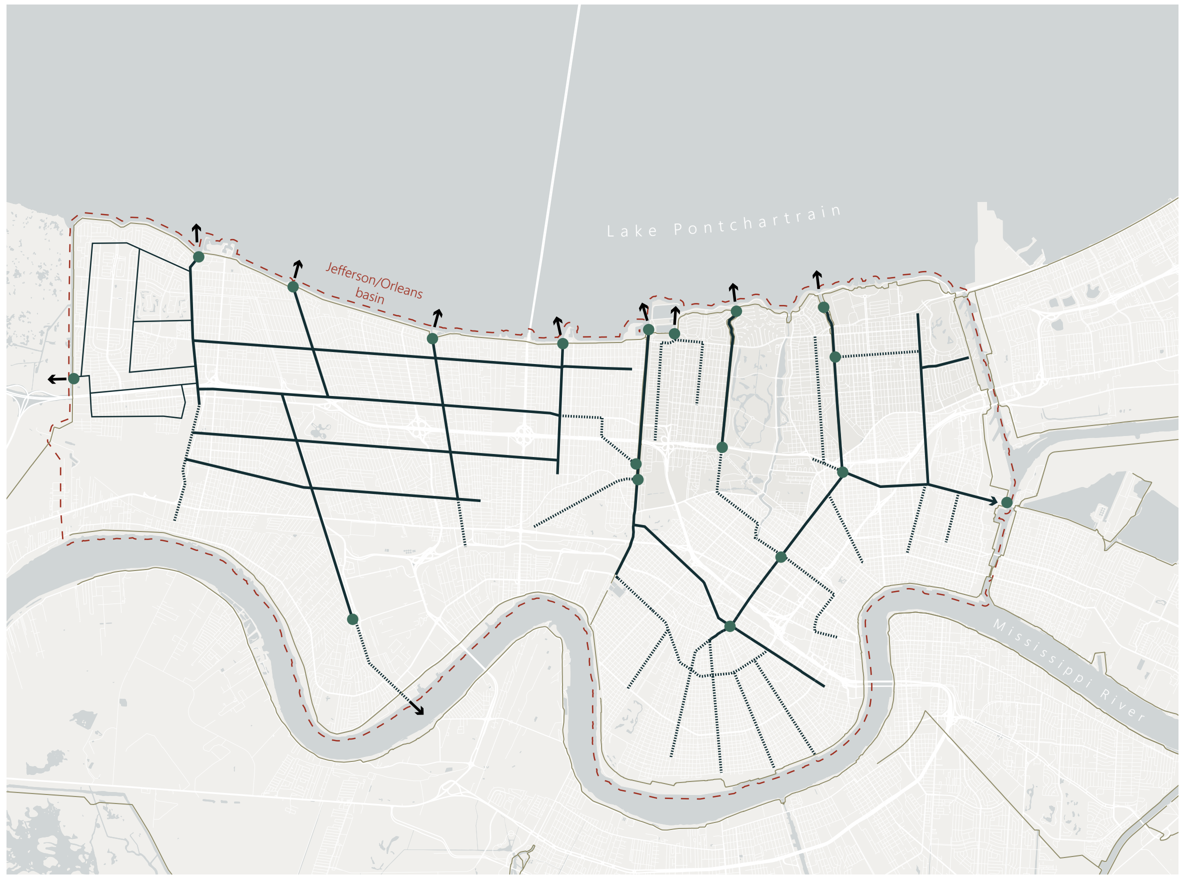


Figure 53 - Drainage infrastructure in New Orleans. Scale 1:200,000.

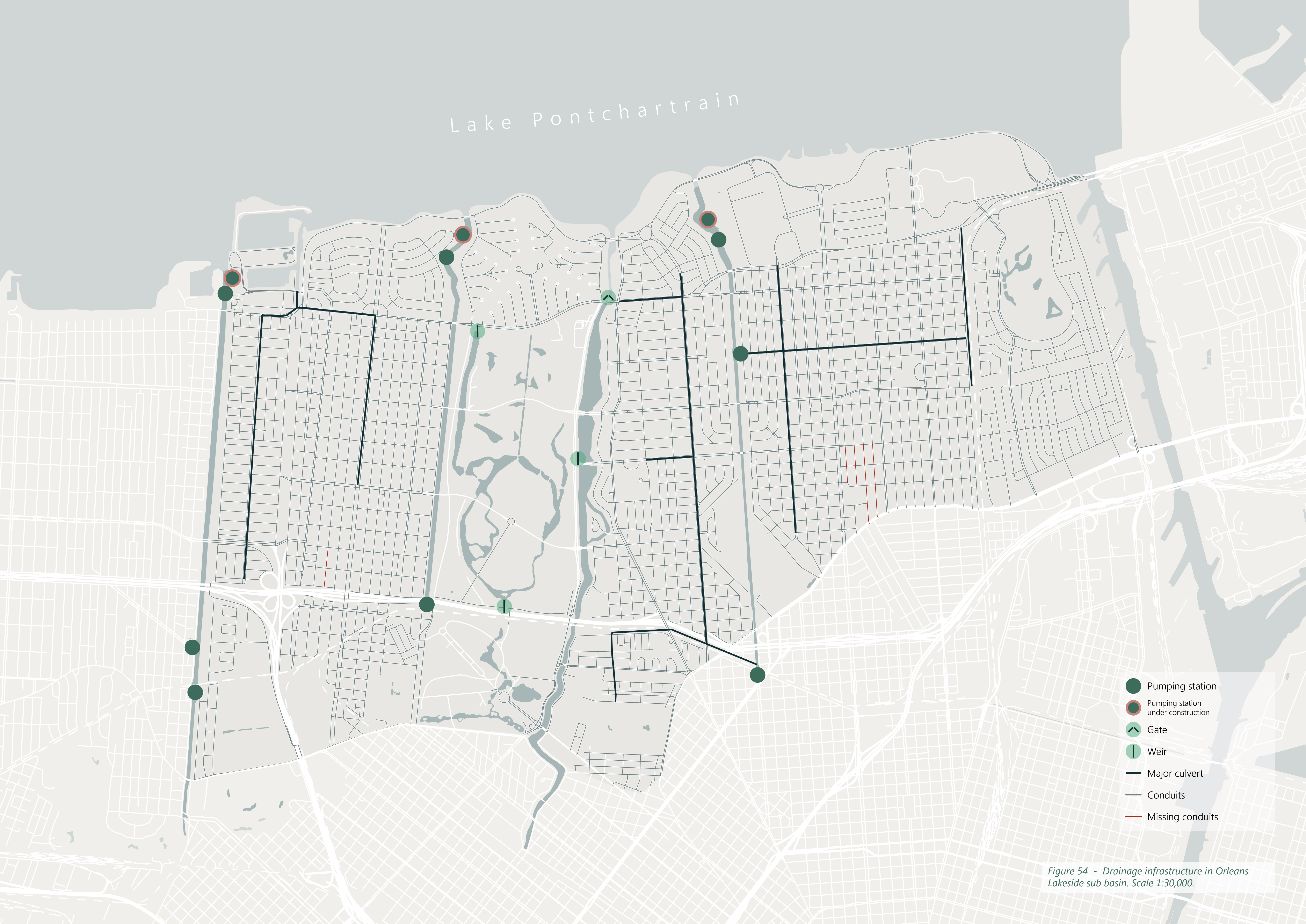


Figure 54 - Drainage infrastructure in Orleans Lakeside sub basin. Scale 1:30,000.

4 Vulnerability Analysis

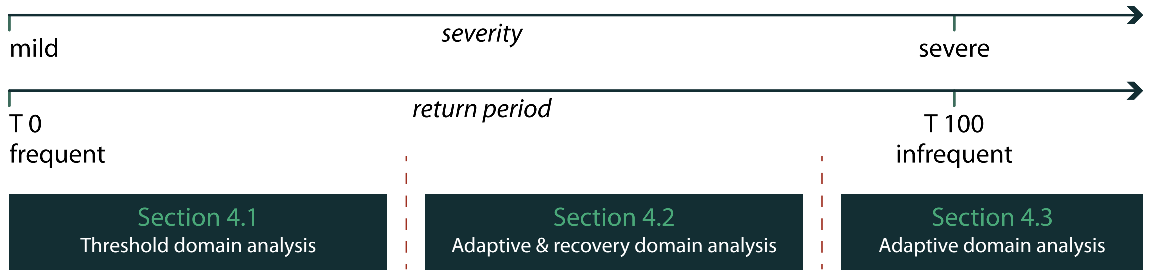


Figure 55 - Schematic narrative for vulnerability analysis.

Figure 56 - Structure of the vulnerability analysis.

This chapter connects to one of the primary knowledge gaps identified earlier in Chapter 2. The lack of consideration of extreme events, by focusing merely on moderate weather events, leaves out the pressing matter of how the urban water system would perform during extreme weather events.

The analysis presented in this chapter relate to the previous, more general synthesis of existing analyses.

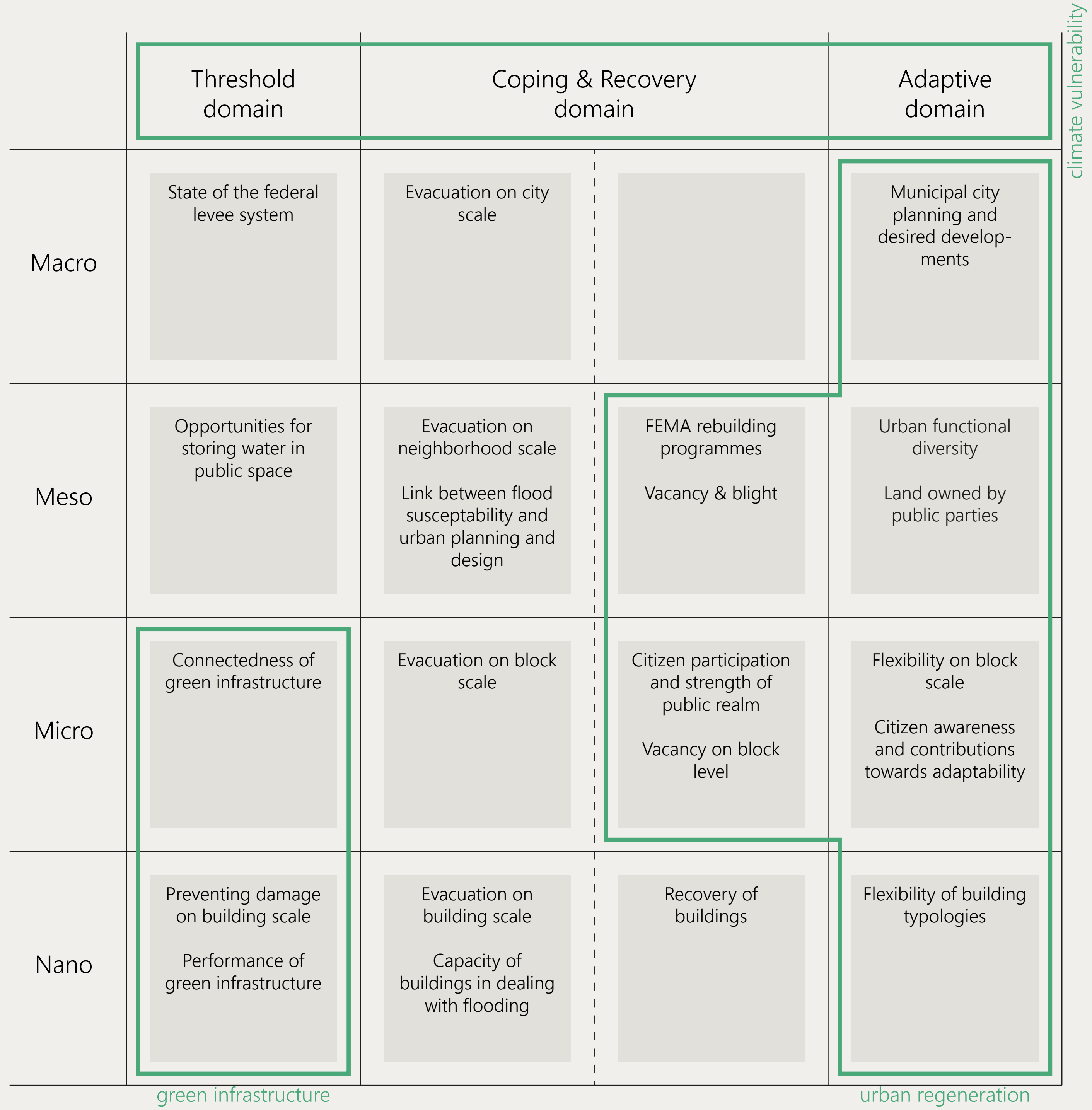
This chapter's narrative for analysis is based on the vulnerability framework by de Graaf et al. (2009), defining three main domains related to time: threshold domain (frequent, mild events), coping & recovery domain (relatively infrequent, limited severity events) and the adaptive domain (infrequent, severe events). A schematic representation of this chapter's narrative is given in Figure 55, which shows the interdependence of return period and severity of the storm. Similar to the previous chapter, each section is internally sorted by scale (macro-meso-micro-nano).

Figure 56 shows the structure of the chapter, including the integration of theories.

The vulnerability analysis is undertaken from a socio-spatial standpoint. This implies that the focus is on issues that can be solved in the spatial domain,, and that governance and legislation issues are not addressed in detail.

Casting forward, the goal of this vulnerability analysis chapter is to provide insight in the current vulnerability of Orleans Lakeside to ultimately provide leads for the design phase.

NOTE: this chapter is not yet complete; several analyses are missing.



4.1 Threshold Domain Analysis

The threshold domain comprises measures that prevent damage to the built environment (de Graaf et al., 2009). Focusing on flood and drought resilience, relevant topics to analyze are the state of federal levees, the capacity of the current drainage system and measures that could improve the drainage system. Furthermore, building-scale design choices that help preventing damage due to moderate flooding is a relevant topic.

MACRO	MESO	MICRO	NANO

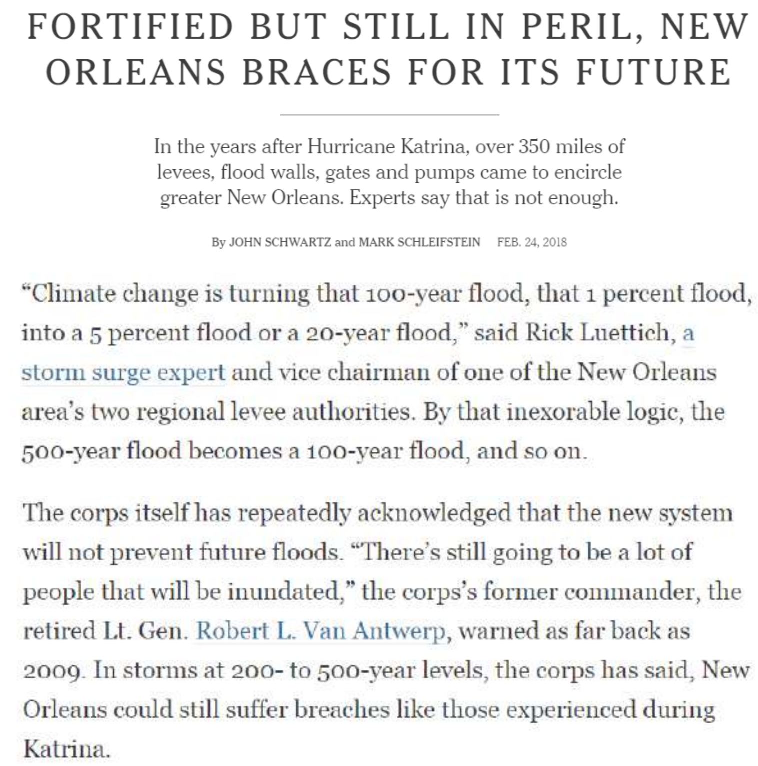
4.1.1 Federal levee

As discussed earlier, the federal levee system surrounding New Orleans is designed for a storm with a return period of 100 years (US Army Corps of Engineers, 2012).

However, there are serious concerns whether the current system is able to adequately protect the city from future hurricanes. In recent years, several newspapers reported on doubts amongst experts of the current system's capacities.

Figure 57 - Childs (2019).

Figure 58 - Schwartz and Schleifstein (2018).



FORTIFIED BUT STILL IN PERIL, NEW ORLEANS BRACES FOR ITS FUTURE

In the years after Hurricane Katrina, over 350 miles of levees, flood walls, gates and pumps came to encircle greater New Orleans. Experts say that is not enough.

By JOHN SCHWARTZ and MARK SCHLEIFSTEIN FEB. 24, 2018

"Climate change is turning that 100-year flood, that 1 percent flood, into a 5 percent flood or a 20-year flood," said Rick Luettich, a storm surge expert and vice chairman of one of the New Orleans area's two regional levee authorities. By that inexorable logic, the 500-year flood becomes a 100-year flood, and so on.

The corps itself has repeatedly acknowledged that the new system will not prevent future floods. "There's still going to be a lot of people that will be inundated," the corps's former commander, the retired Lt. Gen. Robert L. Van Antwerp, warned as far back as 2009. In storms at 200- to 500-year levels, the corps has said, New Orleans could still suffer breaches like those experienced during Katrina.

Figure 59 - Schleifstein (2019).

Figure 60 - Levee breach during Hurricane Katrina (source: Laforet (2005)).

MACRO | MESO | MICRO | NANO

■ 4.1.2 Storing water in public space

Analysis still missing.

MACRO | MESO | MICRO | NANO

■ 4.1.3 Connectedness of drainage infrastructure

Analysis still missing.

MACRO | MESO | MICRO | NANO

■ 4.1.4 Measuring performance of green infrastructure

Introduction

In recent years, several green infrastructure projects have been finished across New Orleans. These installations come from different designers and their diversity is reflected in the detailing of the designs. The finished rain gardens are scattered across the city and do not adhere to a central scheme or strategy. Their performance and efficiency is unknown and a more detailed analysis is required to understand their contribution to mitigating stormwater runoff.

Research goal

The following questions will be researched in this subsection:

- What are the costs of 1 cubic feet (meter) of rain water storage?
- What is the actual % of rain water storage (per urban catchment)? At what amount does this become significant?
- How can we optimize green infrastructure design?

Methodology

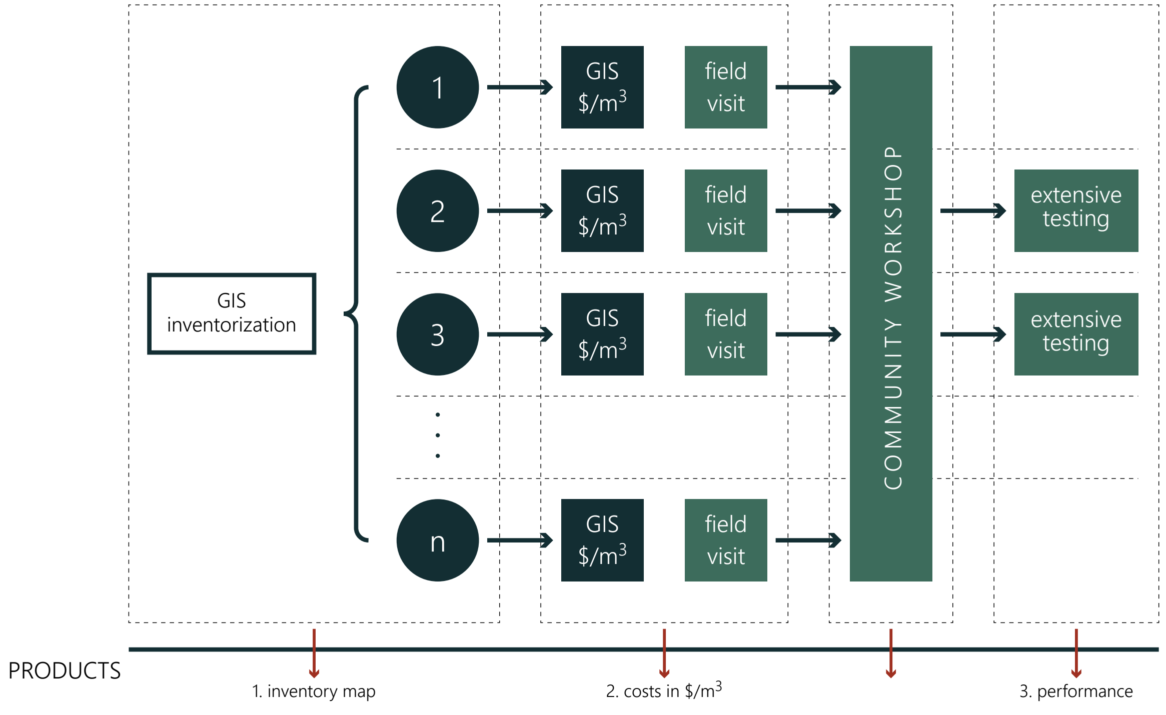
Assessing the performance of green infrastructure involves both desk research and field research. As part of the desk research, an inventorization is made of completed green infrastructure projects in New Orleans, as well as an overview of terminology of different types of green infrastructure. This inventorization draws from municipal documents, community initiative groups and landscape architecture firm portfolios. Green infrastructure projects gardens are mapped in a GIS environment. Furthermore, design, construction and maintenance costs of diverse projects is collected to provide insight in the cost effectivity of green infrastructure. Fieldwork involves testing green infrastructure by monitoring the performance. In addition, a community workshop is organized to gain more insight in issues and opportunities regarding green infrastructure.

The following methods are used in this part of the research:

- Collecting major green infrastructure locations and general data
- Collecting and estimating costs
- Visiting sites
- Meeting stakeholders, individually and in a workshop setting

The general procedure is displayed in Figure 61. Relevant information regarding the methods is given below.

Figure 61 - Chronological flowchart for assessing green infrastructure.



Collecting green infrastructure locations and general data

In order to provide a standardized way of describing green infrastructure, a description form is developed to map all green infrastructure projects and list general data. This form is given in Appendix B.

The quick scan assessment is carried using publicly available data, supplemented with and verified by estimations done on site visits.

For the indication of capacity, design capacities provided by landscape architecture firms are compared with estimations based on a digital elevation model. Two general shapes of green infrastructure are identified to which most projects can be assigned: bowl-shaped and meander-shaped. Both types of rain garden and their estimated initial storage volume is elaborated below.

<u>Bowl-shaped green infrastructure</u>
Displayed in Figure 62. The sloping sides are simplified to a straight slope; hence the initial depression storage of this type is estimated by:

$$V = \int_0^{0.65} \pi \left(\frac{80}{13} y + (r-4)\right)^2 dy$$

With:
V = volume [m3]
r = radius of the bowl [m]

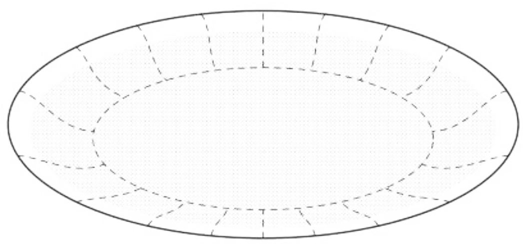


Figure 62 - Bowl-shaped rain garden.

<u>Meander-shaped green infrastructure</u>
Displayed in Figure 63. The sloping sides are simplified to a straight slope; hence the initial depression storage of this type is estimated by:

$$V = \frac{1}{2} l * b * d$$

With:
V = volume [m3]
l = length of meander [m]
b = width of meander [m]
d = depth of meander [m]

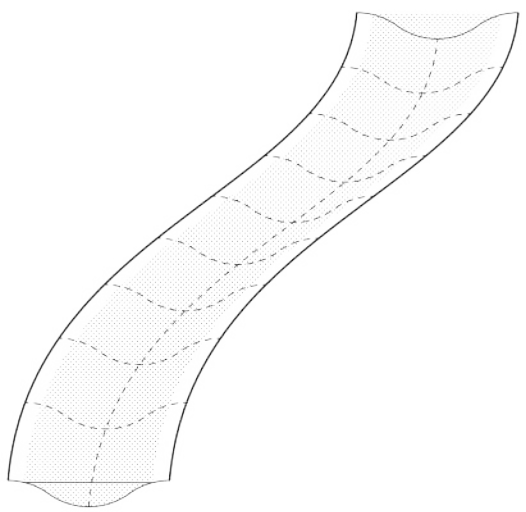


Figure 63 - Meander-shaped rain garden.

Field tests

Several representative green infrastructure projects are tested by filling them with water and monitoring the behavior of both groundwater and surface water. Divers are deployed to provide accurate timeseries of measurement data. Figure 64 shows the procedure of calculating the groundwater level from diver pressure data.

Estimating costs

The costs of storage is calculated for each green infrastructure project evaluated in this assessment. This calculation considers initial costs (design & construction) and returning costs (annual maintenance). The goal of this part is to obtain insight in which types of green infrastructure with a certain set of features has the lowest cost (expressed in $/m3 of storage).

Meeting stakeholders

Individual stakeholders in green infrastructure projects are approached through several meetings. In addition, a community workshop serves to engage the public and provide external insight into the operation of finished projects. Independent input can provide a unique insight in challenges and opportunities for the improvement of green infrastructure.

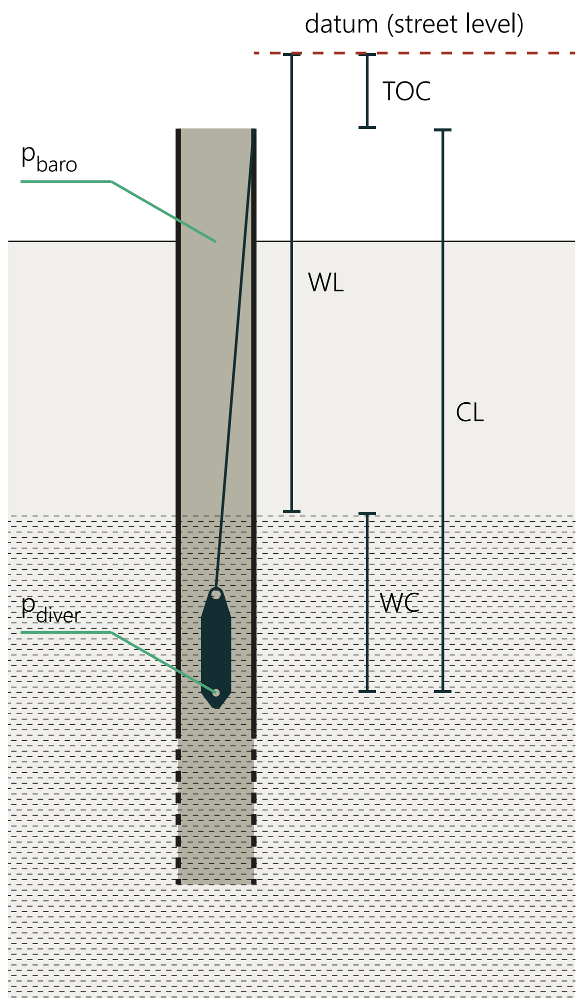


Figure 64 - Calculating groundwater level from diver pressure data. p(baro) = barometric pressure, p(diver) = pressure at diver, TOC = distance between the top of the standpipe and the reference level, CL = diver cable length, WC = water column, WL = water level.

Results

Stakeholders

<u>Design</u>
Landscape architecture firms, architecture firms, private landowners.

<u>Maintenance</u>
Contractors, community groups, private landowners.

Description of green infrastructure

<u>Bioswale</u>
Shallow channels with wide side slopes that use suitable plant to stormwater and filter out pollutants. A bioswale differs from a bioretention cell in that the bioswale functions as a conveyance of stormwater while also storing and infiltrating flow.

<u>Infiltration trench</u>
Small and constrained by hard edges, stormwater planters are typically above ground or partially above ground and receive inflow from roofs or canopies through downspouts.

<u>Rain garden</u>
Relatively small depressions in the ground that can act as infiltration points for roof water and other clean surface water. Normally planted with native vegetation.

Inventorization of green infrastructure

An overview of all major green infrastructure projects in New Orleans is shown in Figure 67. An overview of the master file containing all green infrastructure projects is included in Appendix A.

Cost-benefit analysis

(missing)

Monitoring results

Hourly groundwater levels were recorded for a rain garden in the Lower Ninth Ward over a period of three years. The results of this monitoring are shown in Figure 65, while Figure 66 highlights the 5 August 2017 heavy precipitation event.

Conclusions for green infrastructure design

(missing)

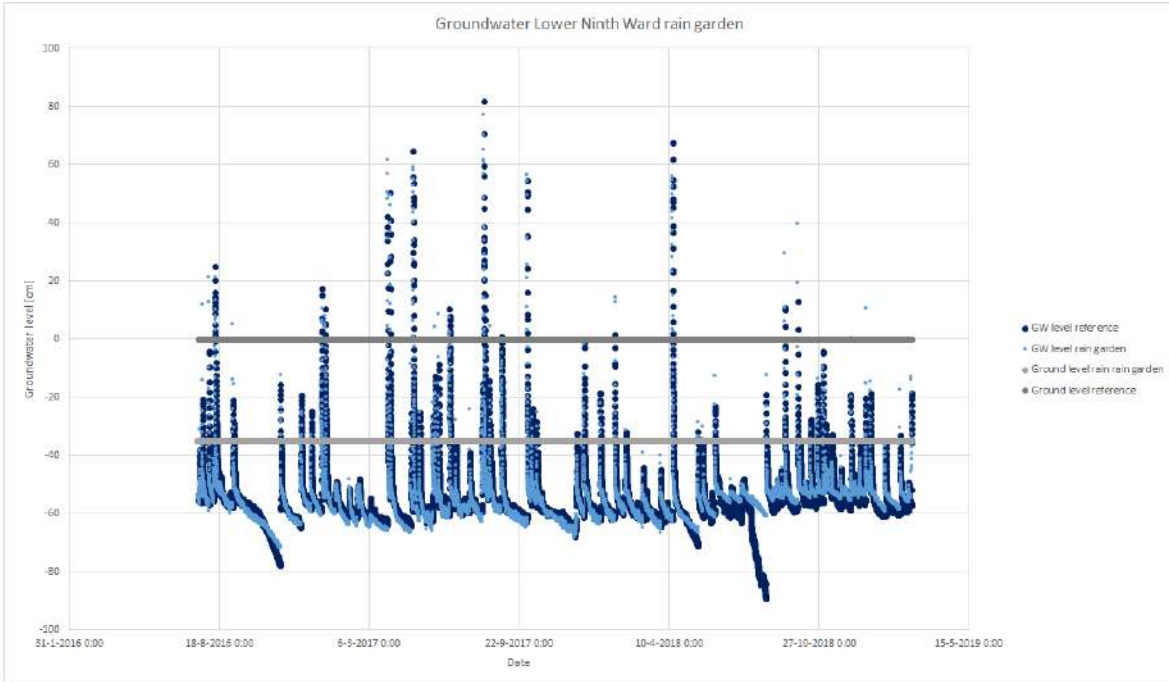


Figure 65 - Groundwater levels at the rain garden in the Lower Ninth Ward.

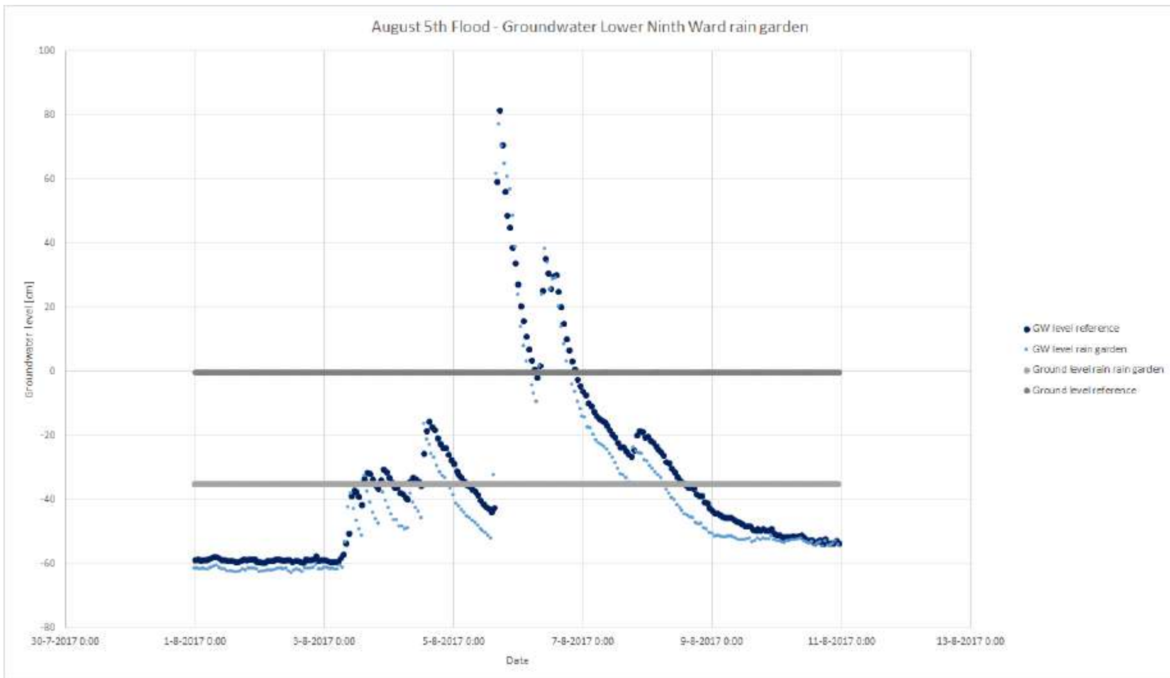


Figure 66 - 5 August 2017 precipitation event.

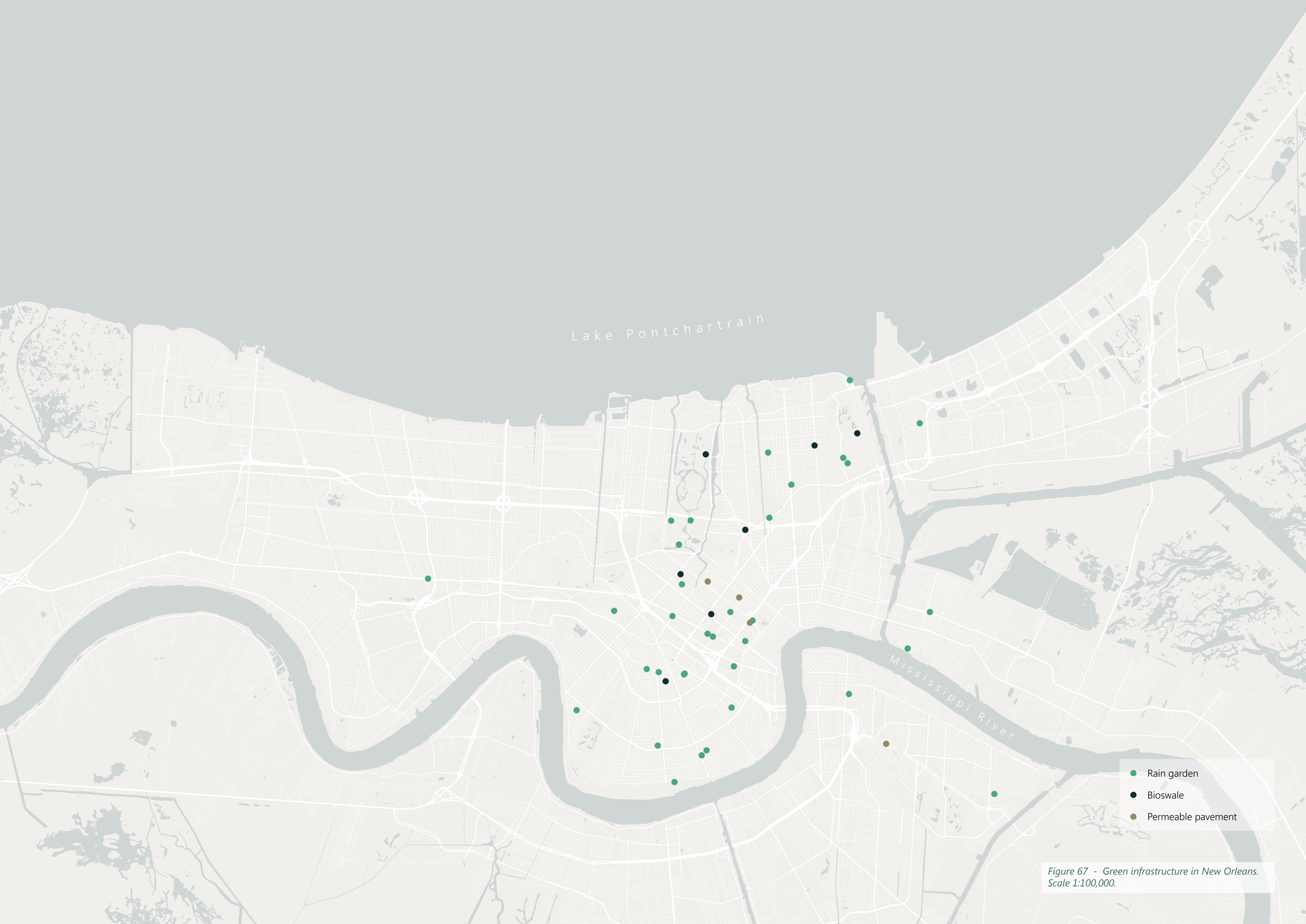


Figure 67 - Green infrastructure in New Orleans. Scale 1:100,000.

4.2 Coping & Recovery Domain Analysis

The analysis of the Coping & Recovery domain revolves around characteristics and features of the urban environment that are relevant for less frequent and more intense weather events, during which damage prevention is the prime goal.

4.2.1 Flood Susceptibility & Urban Planning

The Orleans Lakeside project area is bordered by the Gentilly Ridge, artificially raised land and open water. There is a large variation in elevation throughout the project area, which directly influence the flood and drought vulnerability of the built environment. It is relevant to research whether the urban environment is designed with the flood susceptibility in mind.

Two profiles of representative streets on both sides of City Park provide insight in the relation between the building typologies and elevation. Figure 68 shows the longitudinal profile of Canal Boulevard in the Lakeview neighborhood, while Figure 69 shows the longitudinal profile of Elysian Fields Avenue in Gentilly.

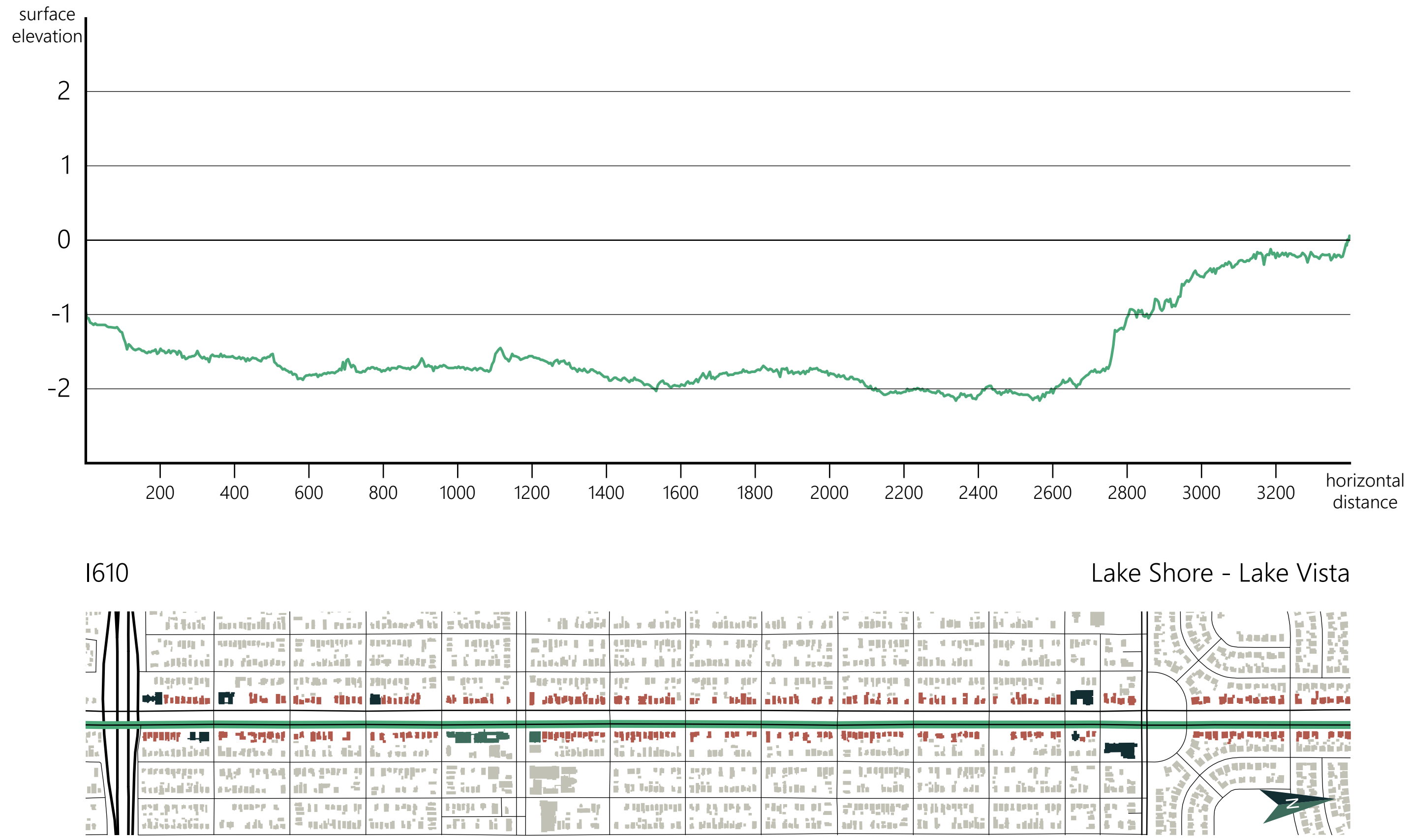


Figure 68 - Relation between topography and building typology on longitudinal profile of Canal Boulevard.

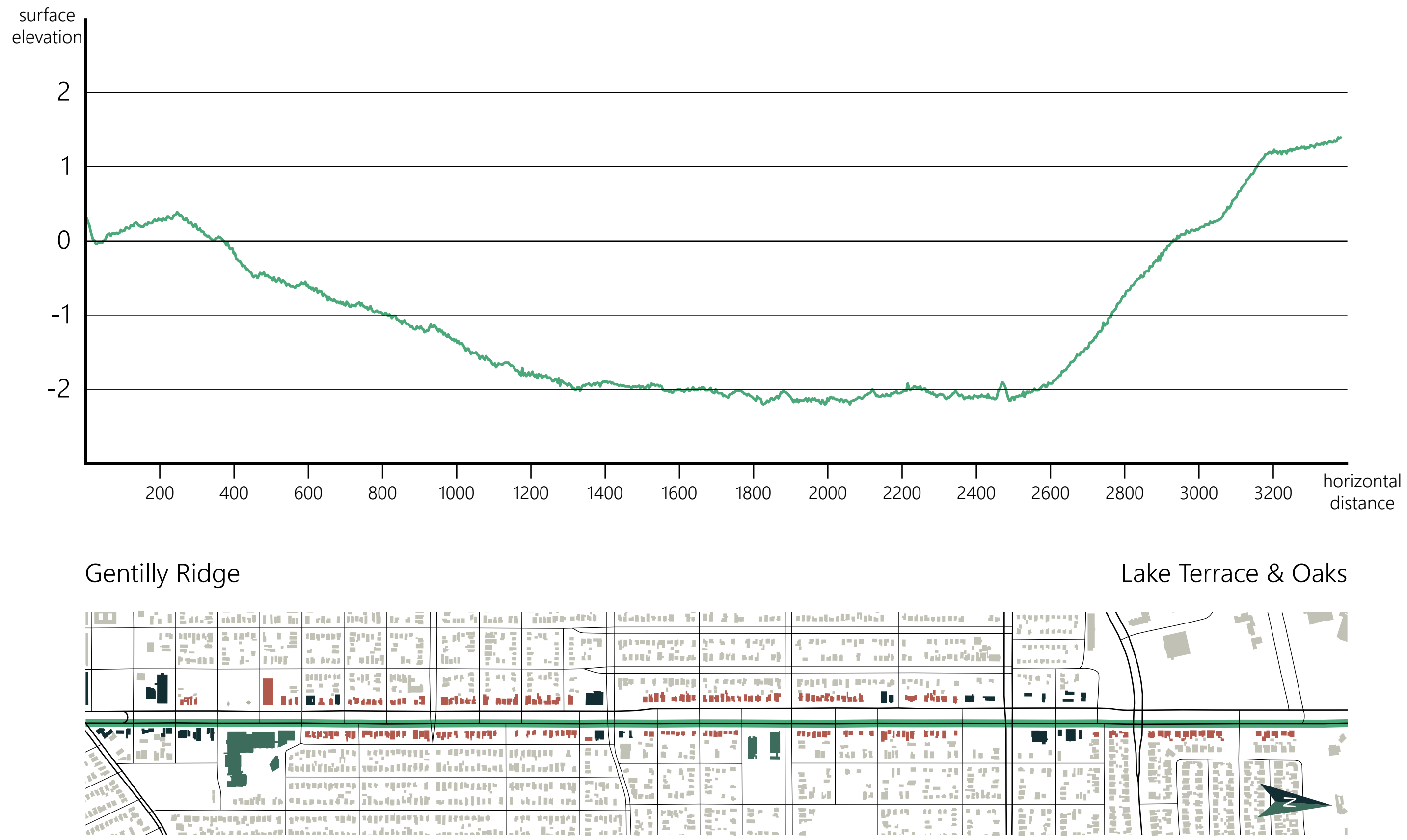


Figure 69 - Relation between topography and building typology on longitudinal profile of Elysian Fields Avenue.

4.2.2 Evacuation

Evacuation is a major part of natural hazard mitigation planning in the United States. There is an elaborate network of government-selected roads that together form an evacuation system. For those without private transportation there are central pick-up points from where the government evacuates residents.

Figure 70 shows the evacuation network in New Orleans. There are two major routes via which local residents can leave the city: either west- or eastwards via the I10, or northwards via the Lake Pontchartrain Causeway. Data from the U.S. Department of Housing and Urban Development (2005) shows that several key links in the evacuation system flooded during Hurricane Katrina, making it difficult for residents to leave once the event started. Although local pick-up points in the central city remained largely dry, pick-up points in the lower neighborhoods of New Orleans flooded severely.

Committee on Homeland Security and Governmental Affairs (2006) indicates a problematic pre-storm evacuation of New Orleans, citing few evacuation routes and long waiting times for more northern parishes to wait for southern perishes to complete their evacuation. An estimated 100,000 people stayed behind, part of which was unable to evacuate.

Post-landfall evacuation in 2005 was heavily criticized due to a lack of effort by multiple levels of government. According to the Committee on Homeland Security and Governmental Affairs (2006), some 10,000 to 15,000 residents sheltered at the Superdome, which was designated as a "refuge of last resort". A lack of buses prevented a large part of the population to leave; it took several days for the city to designate buses and drivers for post-landfall evacuations (Committee on Homeland Security and Governmental Affairs, 2006).

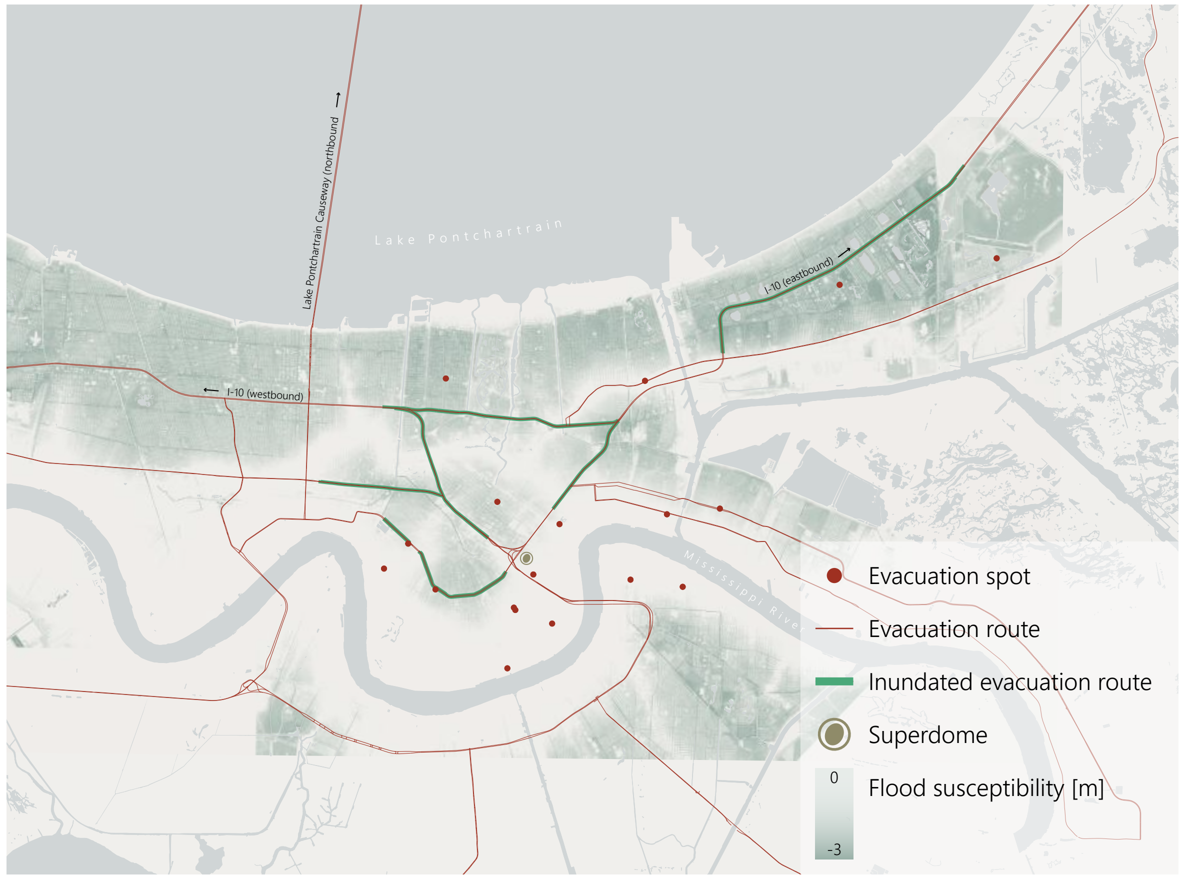


Figure 70 - Evacuation spots and primary evacuation routes. Parts of the evacuation road system was severely inundated during Hurricane Katrina (source: U.S. Department of Housing and Urban Development (2005), City of New Orleans (2018a), elaborated by author). Scale 1:250,000.

Evacuation on building scale

The Hurricane Katrina disaster showed shortcomings in the capacity of local and higher governments to safely evacuate New Orleanians before and short after a storm. This makes it relevant to study evacuation possibilities on building scale. Certain housing typologies might offer the opportunity to shelter in place, reducing the necessity of mass evacuation.

Analysis still missing.

4.2.3 Dealing with flooding on building scale

Analysis still missing.

Figure 71 - Evacuation shortly after Hurricane Katrina made landfall (source: The Times-Picayun Publishing Co. (2005)).

MACRO | MESO | MICRO | NANO

4.2.3 Recovery & Vacancy

The most recent survey concluded an estimated 40,901 vacant parcels across New Orleans (City of New Orleans, 2018c). Orleans Lakeside is estimated to have 2600 vacant parcels, most of which are located east of City Park. This subsection investigates whether there is a relation between the flood susceptibility and vacancy in order to provide an image on how the physical location influences recovery.

Figure 72 shows that there seems to be a relation between the elevation and amount of vacancy in Orleans Lakeside. Higher parts of the area generally suffer less from flooding and are therefore not quickly destroyed and abandoned. However, while Gentilly shows a clear relation between elevation and vacancy, this relation is not as clear in the wealthier Lakeview neighborhood. Lakeview experienced similar flooding as Gentilly during Hurricane Katrina, but its quicker reconstruction can be attributed to more financial means and often better flood insurance of building owners.

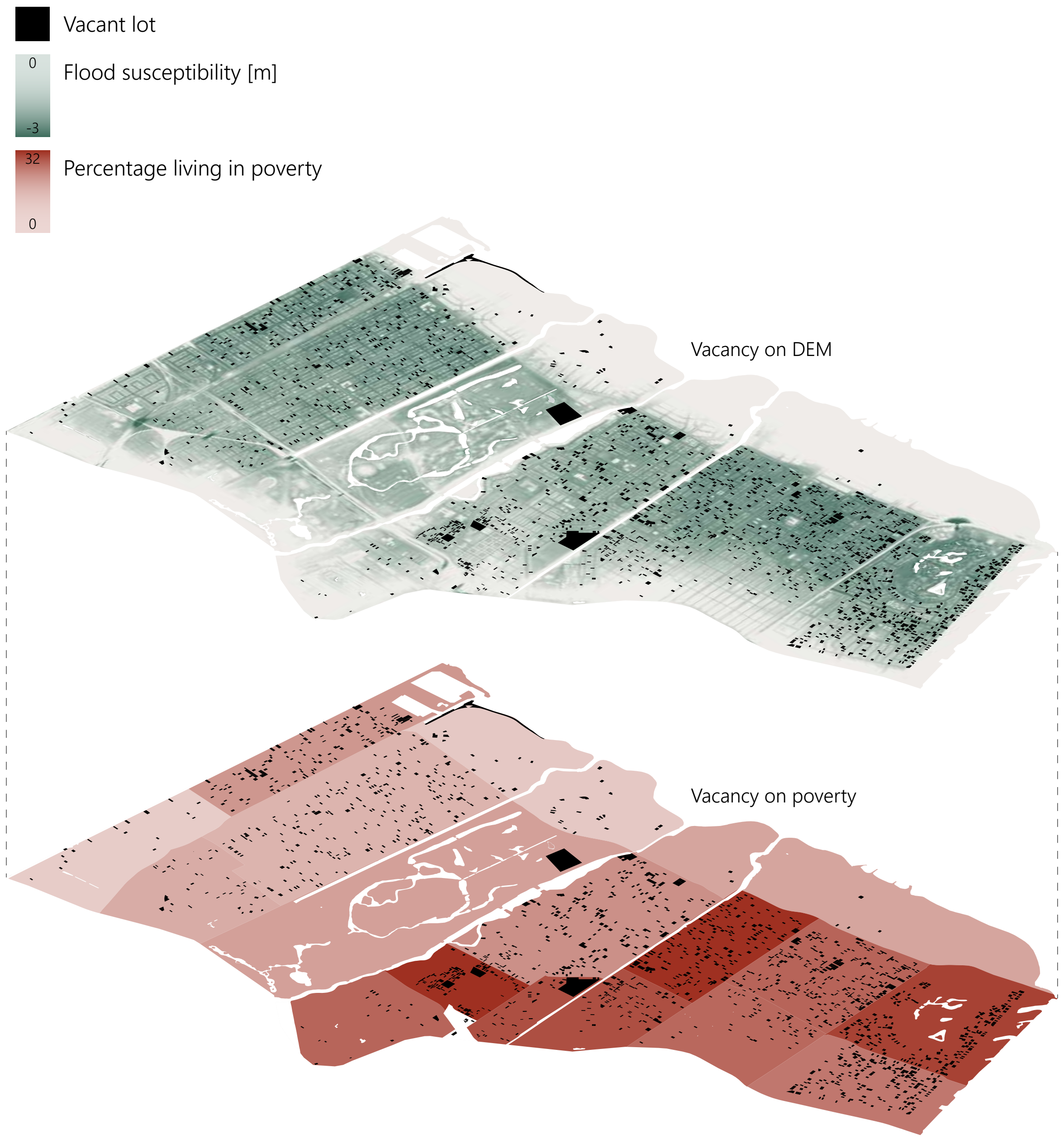


Figure 72 - Vacancy in relation to elevation and poverty level. This map highlights the relation between flood susceptibility and vacancy, especially prominent in less affluent neighborhoods.

Role of business in recovery

Analysis still missing.

4.3 Adaptive Domain Analysis

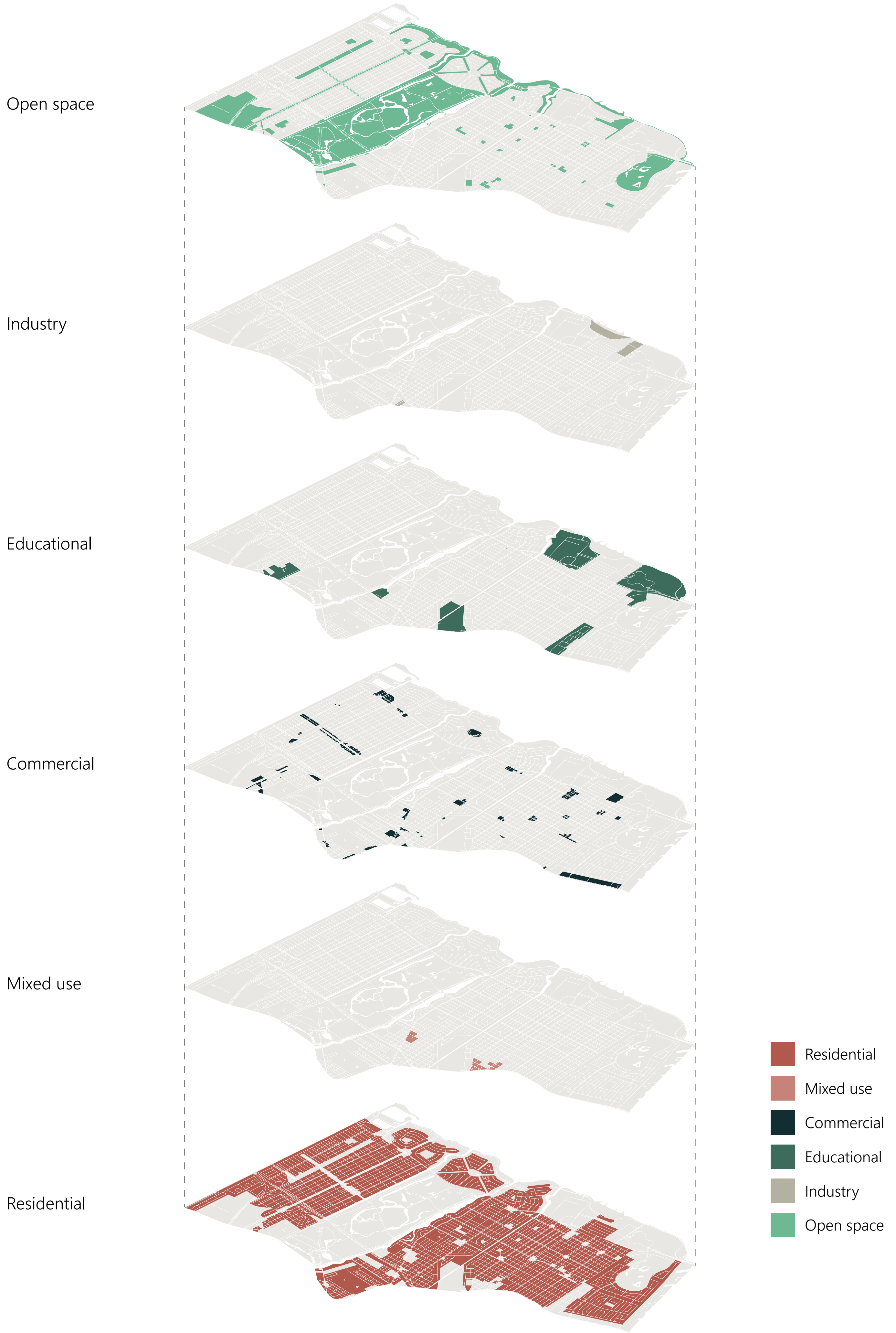
The adaptive domain analysis appraises the capacity of the existing built environment to change and adapt to future developments. A major determinant of adaptive capacity is flexibility of the urban environment, which takes shape on multiple levels of scale. On the largest scale, this section analyzes municipal city planning and desired future developments that might influence the adaptive capacity. On a smaller scale, features such as functional diversity are major determinants of adaptive capacity. Flexibility of individual buildings provides insight in adaptive capacity on the smallest scale.

MACRO | MESO | MICRO | NANO

4.3.1 Functional Diversity

Functional homogeneity and a lack of diversity is often associated with a low resilience to disturbances (Tyler & Moench, 2012). An analysis of the spatial diversity of functions provides insight in the adaptive capacity of the urban environment. Figure 73 shows an axonometry of functional zoning in Orleans Lakeside. It highlights problematic homogeneous zoning and strong spatial segregation of functions. Pure residential zoning is ubiquitous in Orleans Lakeside; commercial activity is limited to concentrated spots of either car-oriented or pedestrian-oriented retail. Mixed use zoning is rare. Access of open space is unevenly distributed across the project area. City Park and Pontchartrain Park provide massive open spaces, although the amount of high quality public space within residential districts is minimal.

Figure 73 - Zoning analysis of Orleans Lakeside.



MACRO | MESO | MICRO | NANO

4.3.2 Municipal city planning and desired developments

Analysis still missing.

MACRO | MESO | MICRO | NANO

4.3.3 Land owned by public parties

Analysis still missing.

MACRO | MESO | MICRO | NANO

4.3.4 Land owned by public parties

Analysis still missing.

MACRO | MESO | MICRO | NANO

4.3.5 Flexibility on block and building scale

Analysis still missing.

5 Scenario & Vision

This chapter provides a projection for the future as a basis for designs, as well as a vision for Orleans Lakeside that the final product contributes towards.

Instead of providing an elaborate scenario analysis with a myriad of variables and outcomes, this chapter constructs a projection of the "autonomous situation". This projection considers current and planned developments, as well as uncertain factors that could influence the development of Orleans Lakeside. This "autonomous situation" sketch is not inherently negative; it might contain positive developments that contribute towards a better flood and drought resilience. However, given the extensive problem field, this autonomous situation will be far from ideal.

This reduced scenario considers some key variables regarding demographics and climate change, which are plotted against each other. Furthermore, the scenario offers a time horizon.

Deviations from the autonomous situation, the "desired situation", solidifies as a vision for Orleans Lakeside. The vision provides a course of action for the ideal situation for the project area. It describes the outcome if the design framework and design interventions are implemented in the best possible way.

The deviation from the autonomous situation towards the desired situation by means of design interventions is schematically shown in Figure 74.

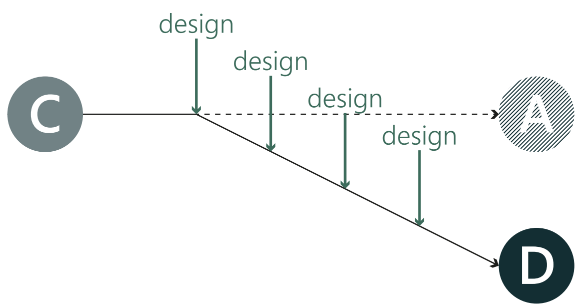


Figure 74 - Autonomous vs. desired situation (C=current situation, A=autonomous situation, D=desired situation).

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Green infrastructure element 12

Basic characteristics

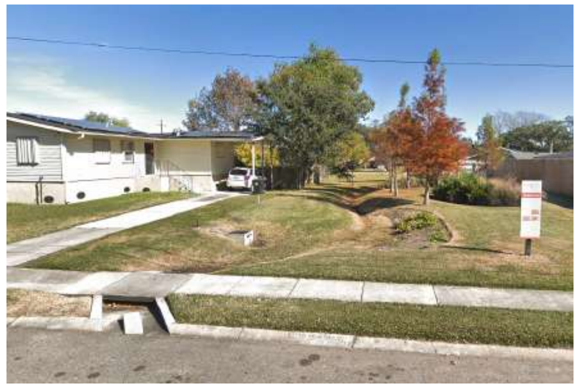
Category
Rain garden

ID
i.12

Location
Address
5019 Press Drive

Coordinates
-90.04187, 30.01076

Pumping Station Catchment
4



Phyiscal properties

Basic dimensions
Shape
Linear

Surface area [m2]
117

Depression
Maximum depression volume [m3]
???

Depression volume till overflow [m3]
133

Maximum depression depth [m]
0.6

Catch basin source water
site runoff and adjacent street

Material finishing
Grass, native vegetation

Subsoil conditions
muck

Design & costs

Design
Designer
Dana Brown & Associates

Maintenance
NORA

Owner
???

Costs
Design [$]
???

Construction [$]
2520

Maintenance [$/yr]
683

APPENDIX B - INVENTARIZATION GREEN INFRASTRUCTURE

Cat.	Item	Designer	Name	Address	Longitude	Latitude	Shape	Material	Subsoil	Description	Catchment	Size surface area [thousand ft2?]	Size surface area [sf2]	Size surface area [m2]	Capacity [cf]	Capacity [m3]	Calculated capacity [m3]	Deepest depression [m]
C	i.1	Eskew+Dumez+Ripple	Rosa F. Keller library	4300 S Broad Ave, New Orleans, LA 70125	-90.10354	29.94879	Other	Grass, Louisiana Iris		Rain garden	building roof					0		
C	i.10	Dana Brown & Associates	Tri-Centennial Place parking lot	53 Dreyfous Dr, New Orleans, LA 70119	-90.096773	29.985687	Other	Native vegetation		Rain garden	adjacent parking	2.25	2250	1881.28656	4680	133		
A	i.11	Dana Brown & Associates	Milne Municipal Boys Home	5420 Franklin Ave, New Orleans, LA 70122	-90.05145	30.01433	Linear	Grass, shrubs		Bioswale	adjacent parking	1.3	1300	1086.965568	7214	204		
C	i.12	Dana Brown & Associates	NORA stormwater detention lot	5019 Press Drive	-90.04187	30.01076	Linear	Grass, native vegetatio	muck	Rain garden	site runoff and adjacent street	0.14	140	117.0578304	4694	133		0.60
C	i.13	Dana Brown & Associates	NORA stormwater detention lot	5302 Wildair Drive	-90.06698	30.01228	Linear	Grass, native vegetatio	clay	Rain garden	site runoff and adjacent street	0.29	290	242.4769344	11898	337		0.60
C	i.14	Dana Brown & Associates	NORA stormwater detention lot	8641 Forshey Street	-90.11841	29.96651	Bowl	Grass, native vegetatio	clay	Rain garden	site runoff and adjacent street	0.09	90	75.2514624	855	24		0.40
C	i.15	Eskew+Dumez+Ripple, Daly-Sublette Landscape Architects	L. B. Landry high school	1200 L. B. Landry Avenue	-90.03996	29.94245	Other			Retention ponds, stormwater detention, irrigation tanks,	building roof					0		
C	i.16	Mathes Brierre Architects	Muses apartment homes	1720 Baronne Street	-90.079182	29.938535				Rain garden, bioswales, curb cuts, pervious concrete	adjacent parking					0		
C	i.17	Eskew+Dumez+Ripple	Bioinnovation Centey	1441 Canal Street	-90.07462	29.95776		Gravel		Bioswales, pervious concrete, water recycling air conditioning unit, underground retention systems	building roof					0		
C	i.18		Community Development and Climate Action Center	5400 Douglas St., New Orleans, LA	-90.02034	29.95562				Bioswales, Permeable pavers, Raised catch basins for infiltration, Raingardens, Cistern storage						0		
A	i.19	FutureProof	Medard Nelson school	3121 St. Bernard Avenue	-90.0746	29.98994	Linear	Gravel		Bioswales, rain gardens, bioretention cells	site runoff					0		
A	i.2	Linfield, Hunter & Junius, inc.	Carrolton Shopping Center	510-550 N. Carrollton Avenue	-90.09623	29.97711	Linear	Gravel		Rain garden, Ditch garden, Pervious pavement	adjacent parking				12268	347		
C	i.20	Dana Brown & Associates	Dillard University	2601 Gentilly Boulevard	-90.066541	29.99344				Bioswales, pervious concrete, pervious pavers, biorentention basins, green roof, rainwater harvesting	building roof	19	19000		245349	6948		
C	i.21	Dana Brown & Associates	Central City GI Project	2415 South Galvez Street	-90.09488	29.94835				Stormwater Lot	site runoff and adjacent street				2769	78		
A	i.22		The WEB	3601 General Taylor Street	-90.10122	29.94615				Stormwater Lot	site runoff and adjacent street					0		
C	i.23	Gaea Engineering Consultants, LLC	Aurora Raingardens	6000 Carlisle Ct.	-89.99136	29.91355	Bowl	Small planting		Rain garden	site runoff and adjacent street					0		
C	i.24		EPA Urban Waters Small Grant	4834 Feliciana Dr	-90.04039	30.009196				Stormwater lot rain garden site						0		
A	i.25		EPA Urban Waters Small Grant	4718 Prentiss Ave	-90.03718	30.01785				Large bioswale to gather runnoff from north Pontilly						0		
C	i.27	Waggonner & Ball Architects, FutureProof	Sacred Heart Arts & Athletics Center	4529 Carondelet St., New Orleans, LA	-90.103837	29.927547	Linear	Gravel		Rain garden	building roof					0		
C	i.28	Waggonner & Ball Architects, FutureProof	Brother Martin Chapel	4401 Elysian Fields Ave, New Orleans, LA	-90.05921	30.00302	Bowl	Grass		Rain garden	building roof					0		
C	i.29	Waggonner & Ball Architects, Avegno Bailey Engineers	City Park Administration Building	1 Palm Drive, New Orleans, LA	-90.09938	29.99259	Bowl	Grass		Bioswale, rain garden, pervious concrete	building roof					0		
D	i.3	Spackman Mossop & Michaels	The Rendon, historic renovation	800 N Rendon St, New Orleans, LA	-90.08715	29.97499				Permeable pavers	adjacent parking				4106	116		
C	i.30	Dana Brown & Associates	Capital One Bank	4625 Airline Dr., Metairie, LA	-90.18061	29.97582	Linear	Gravel		Rain garden	adjacent parking					0		
A	i.31	Mathes Brierre Architects	Blood Center parking lot	2609 Canal St, New Orleans, LA	-90.08598	29.96555	Linear	Lush green		Bioswales	adjacent parking					0		
C	i.32	Evans + Lighter Landscape Architecture	Carlson residence	2137 South Lopez St., New Orleans, LA	-90.10753	29.94968	Other	Native vegetation		Constructed wetlands, for more consistent soil moisture and groundwater recharge	building roof					0		
C	i.33	Evans + Lighter Landscape Architecture	Klingman residence	1309 Harmony St., New Orleans, LA	-90.08755	29.92618	Other	Native vegetation		Constructed wetlands, detention ponds	building roof					0		
C	i.34	Dana Brown & Associates	Abrams Elementary	6519 Virgilian St, New Orleans, LA 70126	-90.016288	30.020745				Bioretention Cells, Bioretention planter		4.6	4600		1272	36		
C	i.35	Dana Brown & Associates	Campus Federal - Tulane Avenue	2200 Tulane Ave., New Orleans, LA 70119	-90.085427	29.959052				Bioretenı on Cells, pervious concrete		3	3000		966	27		
C	i.36	Dana Brown & Associates	Cherokee Street	Cherokee Street from Benjamin to Pearl St	-90.130974	29.937769				Bioretenı on Cells					183	5		
C	i.37	Dana Brown & Associates	City Hall Bioswales, WEF 2016 Service Project	1400 block of Poydras Street, corner of Lasalle St	-90.078408	29.950459				Bioswale, rain garden		0.02	20		800	23		
C	i.38	Dana Brown & Associates	City Park Wetlands	4 Golf Drive, New Orleans, LA 70124	-90.092874	29.992668				wetland		2	2000		134667	3813		
C	i.39	Dana Brown & Associates	Lafitte Greenway Implementation	2200 Lafiı e Ave., New Orleans, LA 70119	-90.079578	29.966165				bioswales, bioretention cells, pervious concrete, street basins (not completed)		32.6	32600		153765	4354		
D	i.4	HCI Architect	Mondy Apartments	2327 St. Philip Street, New Orleans LA 70119	-90.07664	29.97037				Permeable pavers with overflow in gravel swales					1185	34		
C	i.40	Dana Brown & Associates	Mid City Townhouses	3701 Bienville Street, New Orleans, LA 70119	-90.095769	29.974191				Bioretention Cells and Pervious pavers		0.98	980		6308	179		
C	i.41	Dana Brown & Associates	Nick's Bar	2400 Tulane Avenue, New Orleans, LA 70119	-90.087206	29.959892				Bioretenı on Cells, pervious pavers		0.29	290			0		
C	i.42	Dana Brown & Associates	NO DPW Multi-Purpose Site	755 South Jefferson Davis Parkway	-90.098943	29.964999				Bioretention Cell, aggregate parking with pervious pavers, retenı on		1.23	1230		7315	207		
C	i.43	Dana Brown & Associates	NORA Lot - N. Claiborne Avenue	5703 N. Claiborne Avenue	-90.012908	29.966175				detention basin		0.1	100		2455	70		
C	i.44	Dana Brown & Associates	Pontilly	Ponchartrain Park	-90.039654	30.033209				SW Parks, SW lots, Canal		79.5	79500		245349	6948		
C	i.45	Dana Brown & Associates	Port Orleans Brewery	4124 Tchoupitoulas Street, New Orleans, LA 70115	-90.098262	29.917004				Bioretenı on Cells		0.39	390		1617	46		
C	i.5	Trapolin Peer Architects	Good Counsel Apartments	1215 Louisiana Ave, New Orleans, LA 70115	-90.08915	29.92473				Rain garden					2221	63		
C	i.6	Daly Sublette Landscape Architects Inc.	1508 & 1524 Orleans Avenue	1508 Orleans Ave, New Orleans, LA 70116	-90.07217	29.96371				Rain garden with multiple elements.					1589	45		
D	i.7	Williams Architects	1601 Lafitte Avenue	1601 Lafitte Avenue, New Orleans, Louisiana	-90.07306	29.96306				Pervious pavement leads to catch basins and public storm system.					3444	98		
D	i.8	Christopher Kidd & Associates, LLC	2908 Gen. De Gaulle Dr.	2908 General De Gaulle Drive, New Orleans, Louisiana	-90.027515	29.928055				Pervious pavement						0		
A	i.9	Dana Brown & Associates	City Park Golf Course Maintenance Facility	1059 Filmore Ave, New Orleans, LA 70124	-90.087803	30.011772	Linear	Grass, shrubs		Bioswale	adjacent grass	3.2	3200		5205	147		
C	i.46	Dana Brown & Associates	S&WB Galvez Lot	2423 & 2427 S. Galvez Street, New Orleans, LA 70125	-90.095087	29.948141				Rain garden		0.12	120		20768	588		

Construction Cost per sf [$/sf]	Maintenance cost per sf [$/sf/yr]	Costs: design [$]	Costs: construction [$]	Costs: annual maintenance [$]	Costs per cubic meter [$/m3]	Costs: annual costs per cubic meter [$/m3]
18.00	4.88		40500.00	10980.00		
69.00	6.60		117873.00	8580.00	577.02	
18.00	4.88		2520.00	683.20		
18.00	4.88		5220.00	1415.20		
18.00	4.88		1620.00	439.20		
			46317715.00	36900.00	133330.18	106.22
18.00	4.88		342000.00	92720.00		
18.00	4.88					
18.00	4.88		82800.00	22448.00		
18.00	4.88		54000.00	14640.00		
18.00	4.88		0.00	0.00		
18.00	4.88		360.00	97.60		
18.00	4.88		36000.00	9760.00		
18.00	4.88		586800.00	159088.00		
		5000.00	73525.00	5000.00	2340.02	149.00
18.00	4.88		17640.00	4782.40		
18.00	4.88		5220.00	1415.20		
18.00	4.88		22140.00	6002.40		
18.00	4.88		1800.00	488.00		
18.00	4.88		1431000.00	387960.00		
18.00	4.88		7020.00	1903.20		
18.00	4.88		0.00	0.00		
18.00	4.88		68020.00	10200.00	1511.71	226.69
			88960.00	7100.00	912.19	72.80
69.00	6.60		220800.00	21120.00		
18.00	4.88		2160.00	585.60		