Flood Resistance to Flood Resilience: Mapping our Water Systems Below to Understand how to Shape Our Land Above

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Executive Summary:

It is now abundantly clear that climate change is having a drastic effect on the social and economic well-being of our cities. Global coastal cities are now frequently victim to unprecedented, extreme storms that cause flooding. Numerous studies show that the built-environment in many coastal cities will be irreparably damaged by 2050 if the current climate trend is not reversed. [i] The natural water systems causing these floods; however, can also provide a framework for positive change in our built environment. By exploring the natural water systems below-ground and using the information as a blueprint for the built-environment above-ground, coastal cities can respond to climate change by revealing the natural processes in the built environment and make room for water. This will have a tremendous positive impact on people's well-being as well as the global economy.

This paper will examine current issues in flood management for coastal cities by looking at New York City and Chicago. For the purpose of this paper, a coastal city is defined as a city with a total population exceeding five million with one-fifth of their population or one-sixth of their land located within the vicinity to a major body of water and the land is less than thirty-three feet (ten meters) above sea level.[ii] A case study based in Shanghai will provide an example of a water system implementation plan through the lens of Landscape Architecture. The case study is based on an ongoing exploration of Shanghai's landscape through mapping of the water systems of below the city, to reveal how the landscape above can be reshaped and adapt to constant changes in water levels, frequency and volume.

This paper argues that flood plain management should use a design-oriented water systems mapping plan to effectively reshape coastal cities and better manage water.

Fast Facts:

- Currently 60% of the world's population lives in urban centers - By 2030 this number is expected to increase to 70%.
- In the United States 82% of the population live in urban centers. By 2030 this number is expected to exceed 87%.
- 16% of the Worlds urban population are located in low-elevation zones <30 Feet above sea-level.
- In 2010 30% of the World population was affected by flooding. [iii]

Vulnerability to Flooding:

While extreme weather events are not uncommon in coastal cities, many cities have become vulnerable to flooding. Two major issues contributing to coastal cities vulnerability has been due to outdated flood management systems such as flood plain survey mapping and urban stormwater infrastructure and the percentage of impervious surface that make up a coastal cities built environment. The destruction felt by Hurricane Sandy in New York exemplifies how coastal cities with stormwater systems already working at capacity thus, unable to handle the storm surges associated with flooding can lead to city-wide destruction in extreme storm events. [iv] Hurricane Sandy has been called the most destructive and costliest hurricane in United States history (along with Hurricane Katrina).[v] The total recovery amount has now surpassed 75 billion and it is expected to rise. The storm led to the loss of 75 lives across eight states. It also caused city-wide power loss as well as devastating household neighbourhood damage. The storm destroyed major storm water sewage systems, streets, power plants and public areas. It also led to the closure of major airports, transit, streets, and schools. With regards to economic impact, FEMA, The US main government agency in charge of response to flood disasters, has been called upon to respond with emergency funding that is far beyond what they are able to provide and the closure of major businesses has meant the loss of millions of dollars. Finally, long-term human health and physical damage in the affected areas will be a strain on the economy for years to come.

Another common contributor to a coastal cities' vulnerability to flooding has been through processes set up by urban planning and urban development plans. Many coastal cities such as Chicago have artificially created flood prone areas by building large tracts of impervious areas where stormwater run-off exceeds the areas natural and manufactured ability to manage excess water. Since the birth of the automobile, the City of Chicago has been producing flood plains via mass construction projects for urban living. These impervious spaces now act as conduits for stormwater run-off and, during an extreme weather event they can become so inundated with water that the stormwater management infrastructure is unable to manage the excess water.


NYC outdated flood system

A recent study conducted by Chicago's Center for Neighborhood Technology compared FEMA zoned flood plains to impervious spaces and found no correlation between post- event damage insurance payouts and FEMA zoned flood plains.

The study also stated that the insurance payouts were strongly correlated

with the areas with the highest percentage of impervious paving but many of these areas were not located in the pre-zoned flood plain areas.

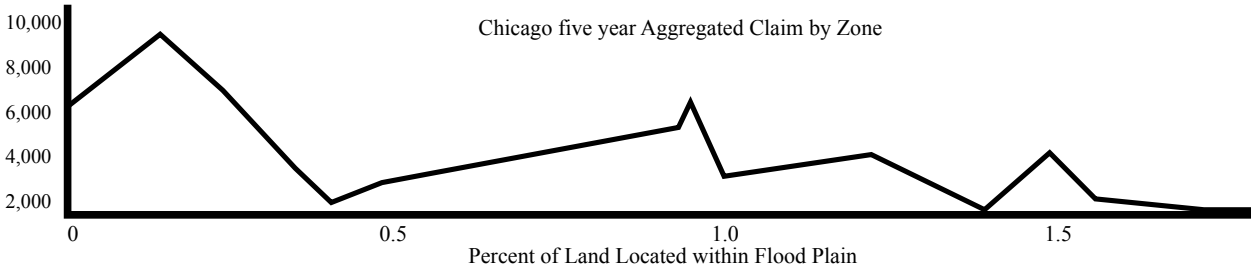
There are innovative methods being implemented in coastal cities to combat stormwater run-off; however, the influence felt from these methods are local and not able to take on city-wide flooding. One example of these methods is New York's Green Infrastructure Plan. In 2012, New York City announced a major commitment to the use of green infrastructure to manage stormwater run-off and support the outdated centralized stormwater management systems. This is known as the NYC Green Infrastructure Plan. The NRDC's recent report, *Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows*, also supports this strategy to manage stormwater run-off. In their report the NRDC states, "Green infrastructure holds tremendous potential to augment over-stressed sources of municipal water supply, and can even be a driver for private investment in urban revitalization efforts." [vi]


impervious surface
Source: NYC Green Infrastructure Plan

Example of NYC new infrastructure
Source: Peter Lehner Executive Director, Natural Resources Defense Council New York City Commits to Green Solution for Sewage Overflows

The use of green infrastructure to manage stormwater run-off is a tremendous development in the field of stormwater management.

These methods will have many environmental benefits, manage our urban pollution levels, and mitigate our urban heat island effect. The use of green infrastructure as proposed in the NYC Green Infrastructure Plan; however, does not have the capacity to withstand the volume and intensity of water during extreme storm events. [vii] By examining stormwater influence from a city-wide scale a comprehensive flood-oriented design plan can be implemented. An example of a city-side flood-oriented design plan will be shown in the proceeding section. *Note: NYC and Chicago are representative in terms of age, state and design of infrastructure in many coastal cities.*

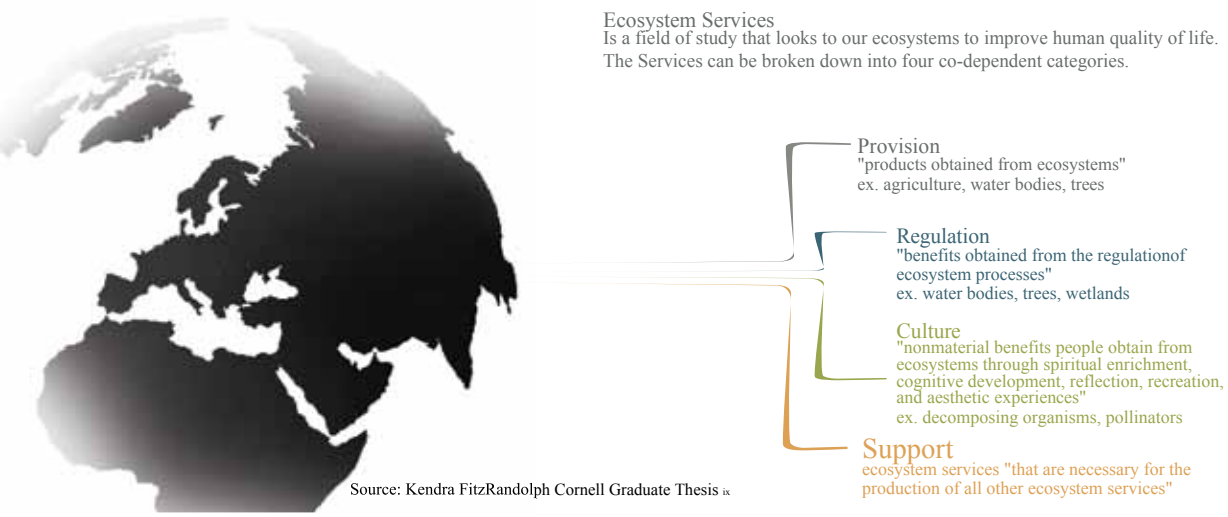


Source: Kendra FitzRandolph Cornell University Graduate Thesis [viii]

Integrating Ecosystem Services into Design and Flood Management:

This paper summarizes two major issues in coastal cities that are increasing vulnerability to flooding; outdated stormwater management systems such as infrastructure as well as survey maps, and manufactured flood plains. Rather than referencing the current flood plain maps in new plans and building more or repairing old stormwater infrastructure and flood walls to prevent water from entering these designated areas, this paper proposes examining the issue of vulnerability and flooding from a city -wide scale, by mapping the natural water systems below ground and using that information to inform the built environment above-ground. Integrating the study of ecosystem services within the field of Landscape Architecture and Urban Design is a unique opportunity to conduct this mapping and examine the flow and patterns of a city's water systems.

The concept of ecosystem services in coastal cities is still in its infancy however, in the last ten years, there has been a growing understanding of how ecosystem services can be used to decrease a city's vulnerability and increase resilience. One particular area is in the integration of ecosystem services in green infrastructure plans. New York's Green Infrastructure Plan is one example utilizing ecosystem services in urban design.



Source: Kendra FitzRandolph Cornell Graduate Thesis [ix]

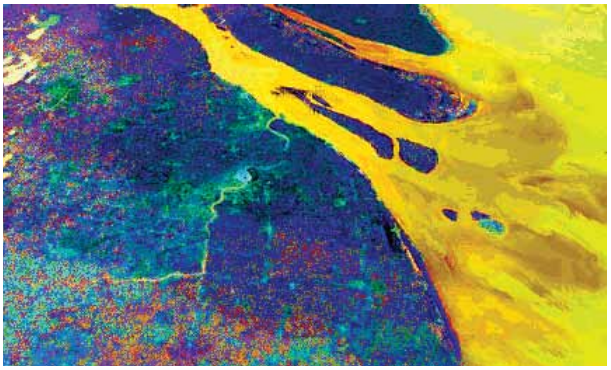
The goal for this paper is to explore ecosystem services that will help decrease vulnerability levels to extreme weather events in coastal cities. In this paper, the ecosystem that is focused on is 'water systems' running coastal cities.

The case study to follow exemplifies how designers can explore the relationships between urban ecosystems and site development processes to determine how a landscape can provide long-term resilience against the changes in water-systems.

This case study explores climate change and flooding in Shanghai, China. Shanghai is a city with similar infrastructure issues to many other coastal cities, therefore, this paper argues that the implantation plan used in this case study can be contextualized and implemented in other coastal cities.

Case Study - Shanghai:

Shanghai is the largest city by population in Mainland China with over 23 million people.



Shanghai water system Source: Kendra FitzRandolph Cornell Graduate Thesis

Much of this population resides along the coastal area of the city. It is located on the mouth of the Yangtze River in East China.[x] The 2012 Coastal City Flood Vulnerability Index has named Shanghai the world's most vulnerable city. The study suggests that this is largely due to its geographic terrain and limited investment in flood management.[xi] The city is built on an alluvial plain and the topography is very flat. Shanghai is also a city in subsidence and since the growth of industry and urban density; the city's subsidence has been expanding at an alarming rate. Currently, the city is 15 feet (4.5 meters) above sea level with an average annual decrease of 0.3 inches (6.2mm).[xii]

Prior to 1949, there was no infrastructure or plan in place to manage flooding. In the 1940's Shanghai underwent massive industrial development and extraction of a huge volume of ground water which resulted in further subsiding. Following a devastating 1949 typhoon (water levels reaching 15 feet [4.77 meters]) that submerged the whole city area, Shanghai began constructing flood-prevention walls and soil dikes 31 miles (50 km) long and 15 feet (4.8 meters). Since then, Shanghai has had a series of annual typhoons and extreme storms and with each storm the city has been increasing the height and breadth

Shanghai 19th Century

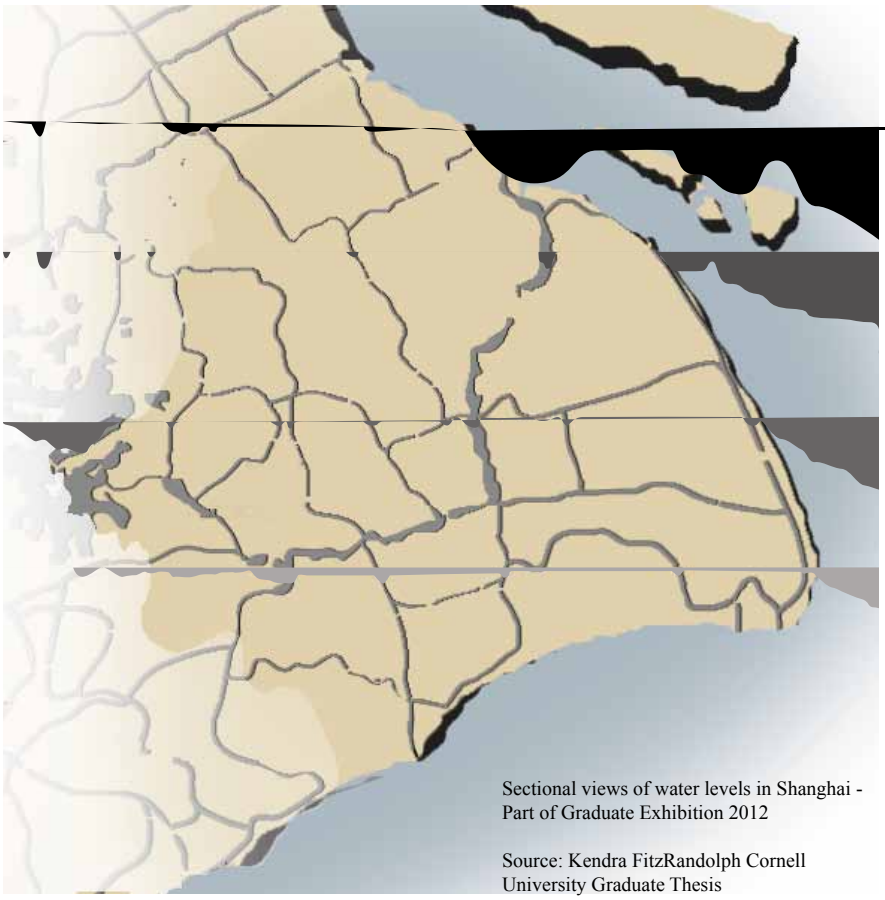
Shanghai 1950s

Shanghai 2001

Shanghai flood wall development - Part of Graduate Exhibition 2012
Source: Kendra FitzRandolph Cornell University Graduate Thesis

of the flood walls. Currently, 337.2 miles (542.8 km) of the City's edges of water bodies are controlled by walls at times exceeding 17 feet (5.2 meters) in height.[xii]

The physical geography of Shanghai and limited flood management plan makes the city an interesting case study to explore a new method for flood management where water systems below-ground become the blueprint for resilient urban redevelopment above-ground. In order to understand the water systems, various aspects of the city have been mapped including; the topographic changes of the city, human use and movement across the city, the water systems underneath (as shown in the sectional mapping system below) and around the city as well as the designated flood-prone areas.



It is about finding common ground with out water systems and designing to follow the shape of our water

We cannot be defined by our walls. We must negotiate with our landscapes

Sectional views of water levels in Shanghai - Part of Graduate Exhibition 2012

Source: Kendra FitzRandolph Cornell University Graduate Thesis

Explorations from the information gathered help to predict where water will likely cumulate on the surface and this information can be used to develop city-wide urban development design plans that allow for a relationship between human use and water-systems movement. By providing a space for water to travel through the city above, as it does below, we will be able to decrease the potential for flooding.

Note: Images shown in this paper are taken from the Graduate Thesis of Kendra FitzRandolph. Proposed completion date: May 2014

Conclusion:

Flooding in coastal cities is chronic and systemic. Coastal cities are plagued with outdated and insufficient stormwater management plans and infrastructure. Although green infrastructure plans such as NYC's Green Infrastructure Plan will be important steps towards more resilient city planning and design, these plans are often small scale and unable to handle the volume of water a coastal city could be inundated with during an extreme storm. This paper argues the necessity for a plan that will decrease the vulnerability of coastal cities when they are inundated with water in extreme weather events. This paper suggests one method for flood plain management. This method calls for a comprehensive city-wide plan that focuses on mapping the natural movement, path and patterns of the water below the ground and then using that information to establish a blueprint for urban development of the built environment above ground.

In Short: explore alternative ways to design a coastal city by looking at the landscape as an aqueous space.

Collage mapping of impervious spaces as conduits for water in Shanghai - Part of Graduate Exhibition 2012
Source: Kendra FitzRandolph Cornell University Graduate Thesis

Works Cited:

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