EXPLORING POSSIBILITIES FOR ENCOURAGING FLOOD RESILIENCE IN BINGHAMTON, NEW YORK

by

RENEE DILLON

(Under the Direction of Bruce Ferguson)

ABSTRACT

Binghamton, New York is one of the many cities along the Susquehanna River experiencing increasingly large flood events, causing high levels of damage to the area. This thesis explores the possibilities for encouraging flood resilience and how this resilience would affect urban land use change as well as community amenities. Exploration was conducted through a thorough analysis of the city as a whole followed by projective designs and design analysis. The result of this exploration suggests Binghamton has potential for increasing its flood resilience through floodable areas with limitations.

INDEX WORDS: Landscape Architecture, Resistant, Resilient, Urban, Flood, River, Flood Control, Mitigation, Floodplain, Design

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by

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DEDICATION

I would like to dedicate this work to Patricia Dillon for her constant support and patience.

Thanks Mum!

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS v

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER

1 Introduction 1

River City Flooding 1

Binghamton, NY 2

Methodology 6

2 Flood Resistance vs. Flood Resilience 8

Rivers are Dynamic 8

Floods Happen 9

Flood Infrastructure: Resistance vs. Resilience 13

Using Flood Resilient Infrastructure 18

Flood resilient infrastructure possibilities for Binghamton, NY 24

3 Examining Binghamton’s Flood Infrastructure and Potential for Floodable Space 25

Binghamton’s position along the Susquehanna River 25

Context of City Landforms 26

Context of City Development 27

Flood Zones and Preliminary FEMA Updates 29

Existing Flood Infrastructure 32

Existing Greenspace...33

Low Use Areas...35

4 Identifying Floodable Area 39

Low Use Areas for Potential Study 39

Potential Floodability Treatments 53

Current Flood Protection..56

River Flow Direction 61

Conclusion of Floodable Area Identification..62

5 Flood Resilient Design (Projective Design) 63

Floodable Design 1: MacArthur School Grounds and Pennsylvania Avenue

Ramp 64

Floodable Design 2: Industrial Corridor 82

6 Conclusion 109

REFERENCES 120

LIST OF TABLES

Page

Table 1: Criteria for Classification as “Low Existing Use” 35

Table 2: Potential Floodability Treatment Table 54

Table 3: Potential for Programming Conflict with Uses of MacArthur School Grounds 65

Table 4: Potential for Land Use Conflict with Flood Events of the Industrial Corridor 82

Table 5: Potential Programming Elements and Flooding Conflict 89

Table 6: Percent Inundation before and after Designs 110

Table 7: Floodable Design 1, Change Evaluation Table 114

Table 8: Floodable Design 2, Change Evaluation Table 114

Table 9: Physical Conditions Influencing Floodable design adaptation to flooding 116

LIST OF FIGURES

Page

Figure 1.1: Binghamton, NY 2011 Flood Event..3

Figure 1.2: Vestal, NY Annual Peak Streamflow..4

Figure 1.3: Binghamton, NY: 2011 Flood Event...5

Figure 2.1: The Natural Plumbing System adapted from Rivers : form and process 10

Figure 2.2: Alternative hydrograph illustrating potential effects of detention combined with flows from large watersheds adapted from Bruce Ferguson's Introduction to Stormwater........12

Figure 2.3: Flood Resistance and its Influence on Development as adapted from the paper A Theory on Urban Resilience to Floods 15

Figure 2.4: Flood Resilience and its Influence on Development as adapted from the paper A Theory on Urban Resilience to Floods 17

Figure 2.5: Precipitation movement through the Gowanus Canal Sponge Park during an average rain event adapted from Gowanus Canal Sponge Park...20

Figure 2.6: Precipitation movement through the Gowanus Canal Sponge Park during a heavy rain event adapted from Gowanus Canal Sponge Park...20

Figure 2.7: Illustration of flood patterns of a Watersquare adapted from Florian Boer's Watersquares: the elegant way of buffering rainwater in cities.......................................21

Figure 2.8: Mill Race Park photograph adapted from MVVA website.......................................23

Figure 2.9: Mill Race Park during large flood event photograph adapted from MVVA website .23

Figure 3.1: Map of the Susquehanna River Basin 26

Figure 3.2: Map of Binghamton, NY Landforms 27
Figure 3.3: Binghamton, NY Zoning and Building Locations 28
Figure 3.4: Existing Flood Zone with Proposed Additions and the 2011 Flood 30
Figure 3.5: Proposed Flood Zone with Existing Reductions and the 2011 Flood 31
Figure 3.6: Existing Flood Infrastructure and Steep Slopes 33
Figure 3.7: Existing Green Space in Binghamton 34
Figure 3.8: Map of Proposed Circulation Interventions adapted from Blueprint Binghamton Mini-plan on Transportation 37
Figure 3.9: Map of Area Determined to be Low Use 38
Figure 4.1: Low Use Areas of Potential Study 40
Figure 4.2: MacArthur School Grounds 41
Figure 4.3: Pennsylvania Avenue Traffic Ramp....42
Figure 4.4: Former Crowley Industrial Area 44
Figure 4.5: Pierce Creek Confluence 45
Figure 4.6: Sandy Creek Park 46
Figure 4.7: Northeast Side of the Susquehanna 47
Figure 4.8: Industrial Corridor 48
Figure 4.9: Binghamton Plaza....50
Figure 4.10: Cheri Lindsey Park 51
Figure 4.11: South of Downtown....53
Figure 4.12: Proposed Floodability Treatment Map....55
Figure 4.13: MacArthur School Grounds and Pennsylvania Avenue Traffic Ramp FEMA FIRM map excerpt 57

Figure 4.14: South of Downtown FEMA FIRM map excerpt 58

Figure 4.15: North Industrial Corridor FEMA FIRM map excerpt 59

Figure 4.16: South Industrial Corridor FEMA FIRM map excerpt 60

Figure 4.17: Former Crowley Plant Industrial FEMA FIRM map excerpt 61

Figure 4.18: Hypothesis of Thalweg Patten in the Susquehanna and Chenango Rivers 62

Figure 5.1: School Location Alternative 1: Rebuild at previous location 67

Figure 5.2: School Location Alternative 2: Build on land above the base flood elevation 68

Figure 5.3: School Location Alternative 3: Rebuild toward the road in center of the site 69

Figure 5.4: School Location Alternative 4: Rebuild toward the road on the east edge 70

Figure 5.5: MacArthur School Site Schematic Plan by Appel Osbourne.....................................71

Figure 5.6: Pipe culvert design 72

Figure 5.7: Open bottom culvert design 72

Figure 5.8: Bridge design..73

Figure 5.9: Low Points for Potential Levee Openings..73

Figure 5.10: Cross-section of Levee during times without flooding 75

Figure 5.11: Cross-section of Levee during 12 feet above river Stage flood 75

Figure 5.12: Cross-section of Levee during 100 year flood event..75

Figure 5.13: Floodable Design 1 Conceptual Masterplan 76

Figure 5.14: Floodable Design 1, 4ft above River Stage..77

Figure 5.15: Floodable Design 1, 8 feet above River Stage 78

Figure 5.16: Floodable Design 1, 12 feet above River Stage 79

Figure 5.17: Floodable Design 1, 13 feet above River Stage 80

Figure 5.18: Floodable Design 1, 15 feet above River Stage 81

Figure 5.19: Existing Connectivity between neighborhoods..84

Figure 5.20: Existing connectivity within the corridor..85

Figure 5.21: Excerpt of a 1902 Railway map showing Brandywine Creek..................................88

Figure 5.22: Circulation Alternative 1: Keep Roadways as is..91

Figure 5.23: Circulation Alternative 2: Removing Court Street and Tompkins Street 93

Figure 5.24: Circulation Alternative 3: Conserving Court Street and North Shore Drive Ramps 94

Figure 5.25: Circulation Alternative 4: Removing Court Street and Conserving North Shore.....95

Figure 5.26: Circulation Alternative 5: Implementing Pedestrian Bridge....................................96

Figure 5.27: Floodable Design 2, Conceptual Masterplan 99

Figure 5.28: Floodable Design 2, Site Programming 100

Figure 5.29: Floodable Design 2, Programming Change 101

Figure 5.30: Floodable Design 2, Circulation Plan for Vehicles and Pedestrians.......................102

Figure 5.31: Floodable Design 2, Circulation Plan for Stream Daylighting and Wetland 103

Figure 5.32: Floodable Design 2, 4 Feet above River Bank...105

Figure 5.33: Floodable Design 2, 6 Feet above River Bank...106

Figure 5.34: Floodable Design 2, 100 year flood event..107

Figure 5.35: Floodable Design 2, 500 year flood event..108

CHAPTER 1

Introduction

People rely upon rivers for transportation, water sources, and waste removal; therefore many of our cities have been built directly next to rivers. Because of this river development, many of these cities have been built within the river floodplain. Rivers fluctuate in size within their floodplain, therefore these river cities must deal with the possibility of danger to life and economic loss due to flooding. In the floodplain of the Susquehanna River, located in the northeastern United States, riparian fluctuations result in frequent floods. Many cities along the Susquehanna River are unable to manage the water of these flood events with traditional flood infrastructure, resulting in more damaging flood events.

River City Flooding

Flood damage in river cities may be increasing due to continued land development and inadequate existing flood infrastructure. Some cities, such as New York City, and countries, such as the Netherlands and United Kingdom, have begun competitions and national campaigns to develop new adaptations to flooding problems (Bergdoll 2011, Hannan 2011) . Many small cities, such as the city studied in this thesis, and towns experience severe flooding as well and should also be addressed.

Flood events are not uncommon along the Susquehanna River. This 464 mile long river is known for its floods, which occur an average of every 14 years according to the Susquehanna River Basin Commission (Susquehanna River Basin Commission 2007). The Susquehanna River Basin contains over 1,400 municipalities and a large percentage of these areas are prone to flooding. This arrangement of cities within the floodplain is not uncommon. As Gilbert White stated in his 1958 dissertation, Human Adjustment to Floods, " Although most of the densely settled flood plains are in the Northeastern Manufacturing Belt and along the Lower Mississippi River, economically important encroachments have been made upon floodplain in all sections of the United States (White 1958)."

Binghamton, NY

Binghamton, New York is one of the many cities along the Susquehanna River experiencing large flood events. It is located at the confluence of the Susquehanna and Chenango Rivers. The Susquehanna River is the largest contributing river to the Chesapeake Bay, draining approximately half of Pennsylvania as well as portions of New York and Maryland (Susquehanna River Basin Commission 2013). The Chenango River empties into the Susquehanna in Downtown Binghamton, the heart of the city. Floodwalls, levees, and dams have been protecting Binghamton since the 1930s (Montz and Gruntfest 1986), but recently these floodwalls have been overtopped twice. Emergency spillways for the city have been used, (Masters 2011) public and private property damaged, and the city dweller's relationship with the river has become increasingly negative.

The following table provides a list of major floods of record, based on flood crests, recorded for Binghamton, NY (National Weather Service N.D.). It is important to note that a vertical datum, the starting point for flood level measurements, changed within the below measurements. Early vertical datums used are unknown. The National Geodetic Vertical Datum of 1929 (NGVD 29) was then used, followed by the North American Vertical Datum of 1988 (NAVD 88) used today (Federal Emergency Management Agency 2010).

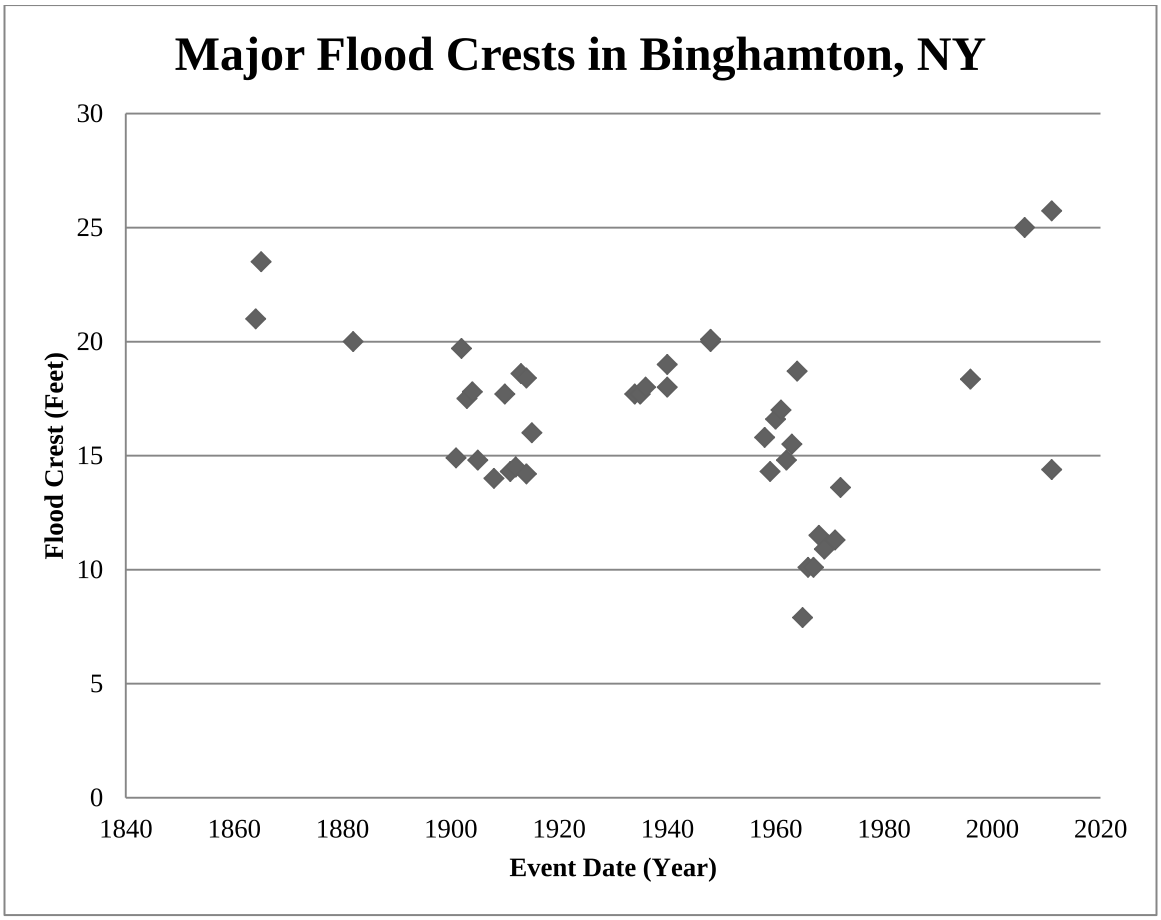

Figure 1.1: Binghamton, NY Major Flood Events (National Weather Service Eastern Region Headquarters. N.D. , National Weather Service N.D.)

Recording of flood events in Binghamton began in the mid-1800s with observations of high water marks and later profile calculations (Brewster 2014). The first major flood on record for Binghamton occurred March 18, 1864. Records continued to be kept through observation and later a manual staff gauge, read occasionally by Binghamton Fire Department staff and only when water was particularly high, until 5-10 years ago when and automated gauge was installed. Because of the variety of flood measurement techniques used, a representative of the National Oceanic and Atmospheric Administration has advised that this thesis focus on flood crest data. A flood crest is the highest point reached by the flood water.

Because the data provided for Binghamton's river fluctuation is sporadic, below I have also included the annual peak streamflow of the Susquehanna River at a gauge downstream of Binghamton. This has been included to provide a more complete picture of the Susquehanna River fluctuations in the region.

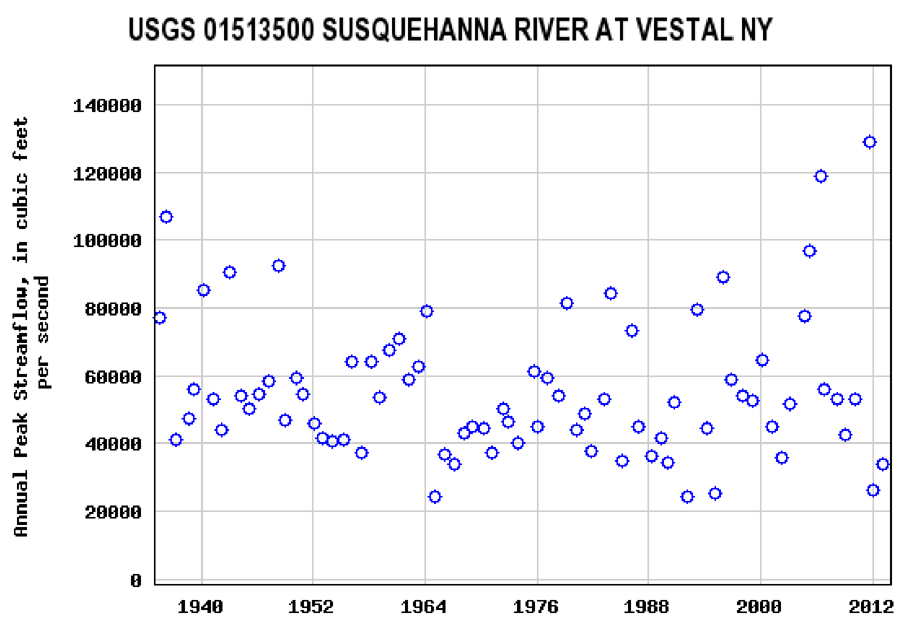

Figure 1.2: Vestal, NY Annual Peak Streamflow (U.S. Geological Survey, 2015)

The worst flood in Binghamton's recorded history occurred in September 2011 (NOAA N.D.), just 4 years after the last record breaking flood in 2006 (Susquehanna River Basin Commission 2007). During this flood, as reported by Dr. Jeff Masters, the Susquehanna crested at 25.71', topping floodwalls by 8.5" in some areas (Masters 2011). The below map illustrates the extent of the 2011 flood in Binghamton utilizing data compiled by New York State Electric and Gas Corporation, NYSEG.

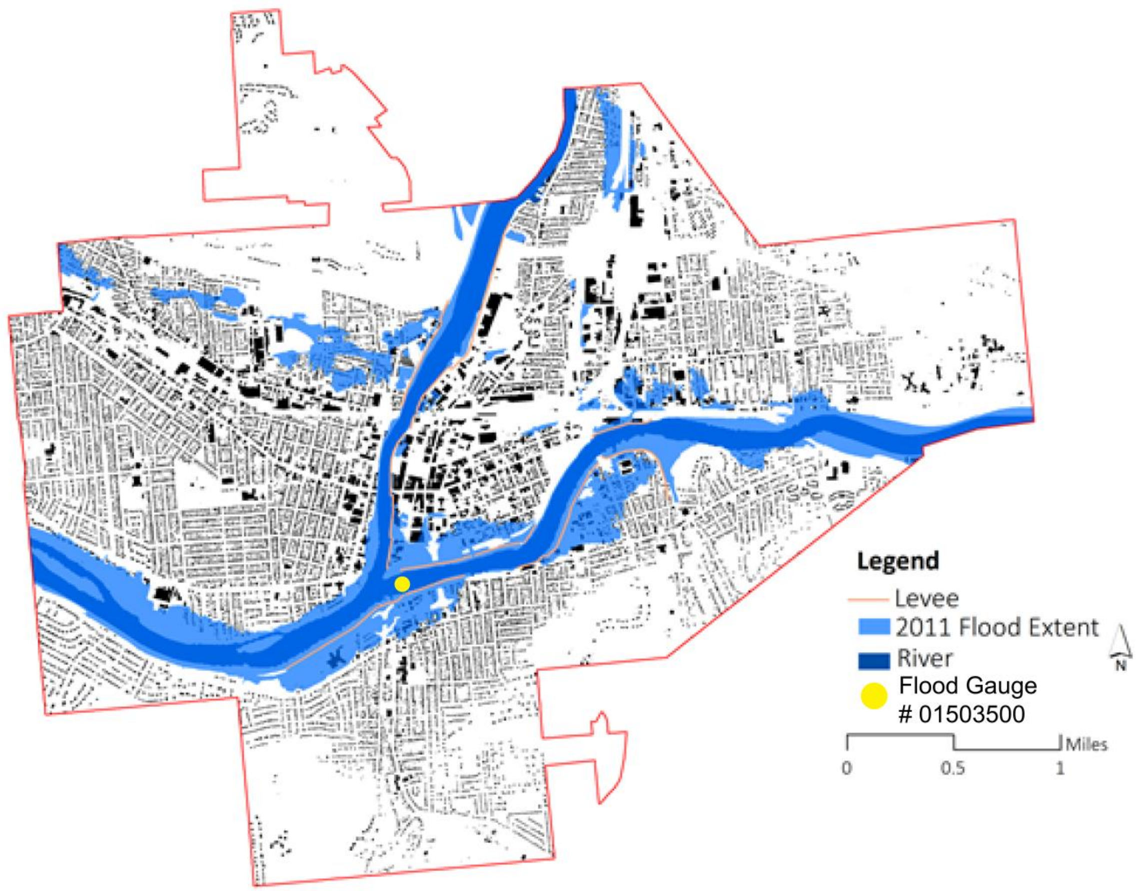

Figure 1.3: Binghamton, NY: 2011 Flood Event

The standard approach to riparian flood events has changed very little in the past 50 years, focusing on engineering solutions to holding back water, repair after flood events, and a reliance on flood event prediction (White 1958). Since the 2011 flood of the Susquehanna River more communities are petitioning for floodwalls and levees , and flood warning systems have been improved (Jacobson 2012, Susquehanna River Basin Commission 2007). This may increase a community's sense of security living within the floodplain, but is it the right direction? Binghamton has had floodwalls, levees, and a flood warning system in place long before the 2011 flood. Damage was still substantial in spite of this infrastructure (Jacobson 2012, Masters 2011).

Cities along rivers experience flooding as a sort of domino effect. Whatever happens upstream influences the risk of flooding in the cities downstream. Binghamton is in a position of being both a contributor to problems downstream and as well as a receiver of problems originating upstream. These conditions make Binghamton an appropriate test city for new flood infrastructure techniques.

Methodology

This study aims to examine how new floodable infrastructure can be implemented within an existing city to increase flood resilience to riparian flood events while also creating public amenities and limiting conflict with existing land uses. It will attempt to address the following questions: What type/s of flood resilient infrastructure would work best in Binghamton? Is there room for floodable space in Binghamton? Where could these floodable spaces be located? What services could these spaces provide and how could they be designed to increase public amenities with minimal urban land use conflict?

This thesis aims to address this topic through the use of projective design. Chapter 2 includes an overview of existing and new flood infrastructure technologies. Chapter 3 contains an analysis of the existing context of Binghamton as it relates to flood events and areas of potential for new flood infrastructure. Chapter 4 examines the areas of potential in greater detail for their potential for floodable spaces. Chapter 5 examines two areas deemed appropriate as floodable zones through projective design. Chapter 6 contains a design analysis to determine the extent to which flooding is increased, how this flooding would occur, the conflicts between the proposed design and existing land use, and how the design functions as a public amenity.

CHAPTER 2

Flood Resistance vs. Flood Resilience

In order to examine Binghamton's potential for new flood infrastructure technology, it is important to first examine how and why flood events occur, what is typically done to protect cities from flood events, what Binghamton currently plans to do to prevent damage during future flood events, and what alternative solutions may exist. This chapter will inform what flood infrastructure solutions exist and what solutions may be most appropriate for Binghamton.

Rivers are Dynamic

Rivers are dynamic systems meant to rise, expand, and shift over time (Prominski 2012). Morisawa and Clayton describe these river dynamics as a "process/response system", which adjusts in accordance with changes within the river's watershed (Morisawa and Clayton 1985). These changes in the watershed include climatic effects, such as rainfall and temperature, land use, and geologic influences (Morisawa and Clayton 1985). The climate effects, rainfall and temperature, influence the amount and frequency of precipitation. Land use effects, such as vegetation and development, and geology effects, including topography and soil character, influence river dynamics. Despite the negative effects flooding can cause to human development, it is an essential river process, slowing velocity and decreasing water height (Prominski 2012).

Floods Happen

River rise and fall, vertical fluctuations, occur daily in rivers and are primarily influenced by the pathways of precipitation flows (Prominski 2012). Precipitation, both rainfall and snowfall, is the key element of flood events. This precipitation moves through pathways involving infiltration, groundwater storage, and runoff.

Precipitation that enters into the ground is infiltrated (Ferguson 1998). When moving through the soil, water also moves much slower than in other paths, highly influencing the speed at which precipitation enters a water way (Dunne and Leopold 1978). Infiltration is dependent on land cover, vegetation, characteristics of precipitation, and the characteristics of the soil (Dunne and Leopold 1978). When infiltrated, water may eventually reach the layer of groundwater. Groundwater is a water saturated subsurface zone where water moves slowly, supplying water to streams long after precipitation has ended (Dunne and Leopold 1978).

Runoff is precipitation that reaches the ground surface but does not infiltrate. This water will usually reach a stream channel within a day of a precipitation event, raising water levels in streams (Dunne and Leopold 1978). In a natural system, runoff occurs on surfaces that have reached their absorption capacity (Dunne and Leopold 1978). For soils this is called the "infiltration capacity of the soil" and it decreases as storm duration increases (Dunne and Leopold 1978). When precipitation fails to infiltrate into the soil it begins to puddle in depressions. This is known as depression storage. Once these depressions are filled, water then spills out and runs downslope, filling downhill depressions or into nearby water bodies.

Marie Morisawa, a geomorphologist, equates the precipitation pathway to a "natural plumbing system". The longer the pathway of the precipitation, the longer the time the water is moving through this "plumbing system". The following diagram by Morisawa and Clayton, lays out the path of precipitation through this system illustrating the relationships of infiltration, groundwater storage, and runoff over time (Morisawa and Clayton 1985).

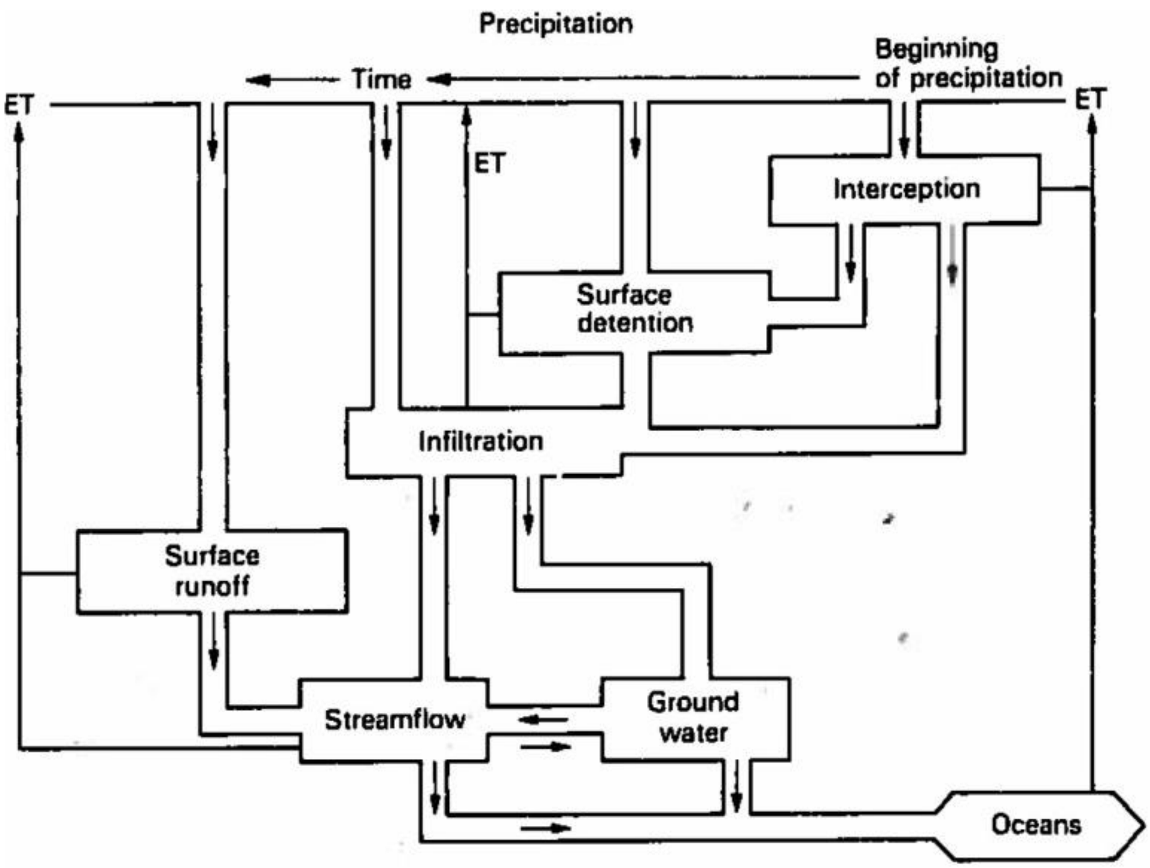

Figure 2.1: The Natural Plumbing System adapted from Rivers : form and process (Morisawa and Clayton 1985)

Morisawa and Clayton explained that maintaining this “natural plumbing system” may reduce water fluctuations of the river which often result in severe flooding (Morisawa and Clayton 1985). Large floods are often caused by intense storm events which exceed the infiltration potential of a watershed and watersheds upstream, generating high volumes of runoff (Dunne and Leopold 1978). When a watershed exceeds infiltration potential depends on the structure of the soil in the area and the duration of the storm (Dunne and Leopold 1978). Flood events are believed to be intensified in developed areas, or areas downstream of developed areas, due to a decrease in infiltration and river channel adjustments, limiting storage and increasing runoff speed (Morisawa and Clayton 1985). Decreasing infiltration in urban areas is primarily due high volumes of impermeable groundcover, in the form of roofs and paved surfaces, and rapid runoff conveyance to rivers through gutters, drains, and sewers (Dunne and Leopold 1978). Morisawa and Clayton suggest mitigating flooding by lengthening the time precipitation is in the “natural plumbing system”, by maintaining forested areas and detaining storm water, reducing and slowing runoff and encouraging infiltration (Morisawa and Clayton 1985).

Detention of runoff is one method of slowing water to encourage later infiltration, but must be carefully considered when attempting to address riparian flooding. The location of the area of concern within the watershed of the river in question is a necessary consideration in determining the effectiveness of detention for flood mitigation. Detaining precipitation far upstream on a river can be quite effective, slowing the arrival of water from distant parts of the watershed to the river. However, detaining precipitation further downstream on a river may actually contribute to flood events, by delaying discharge of runoff from the area of concern and causing it to be combined with the later arrival of discharge from the larger watershed (Ferguson 1998). The illustration below, developed by Bruce Ferguson, illustrates this phenomenon using a hydrograph.

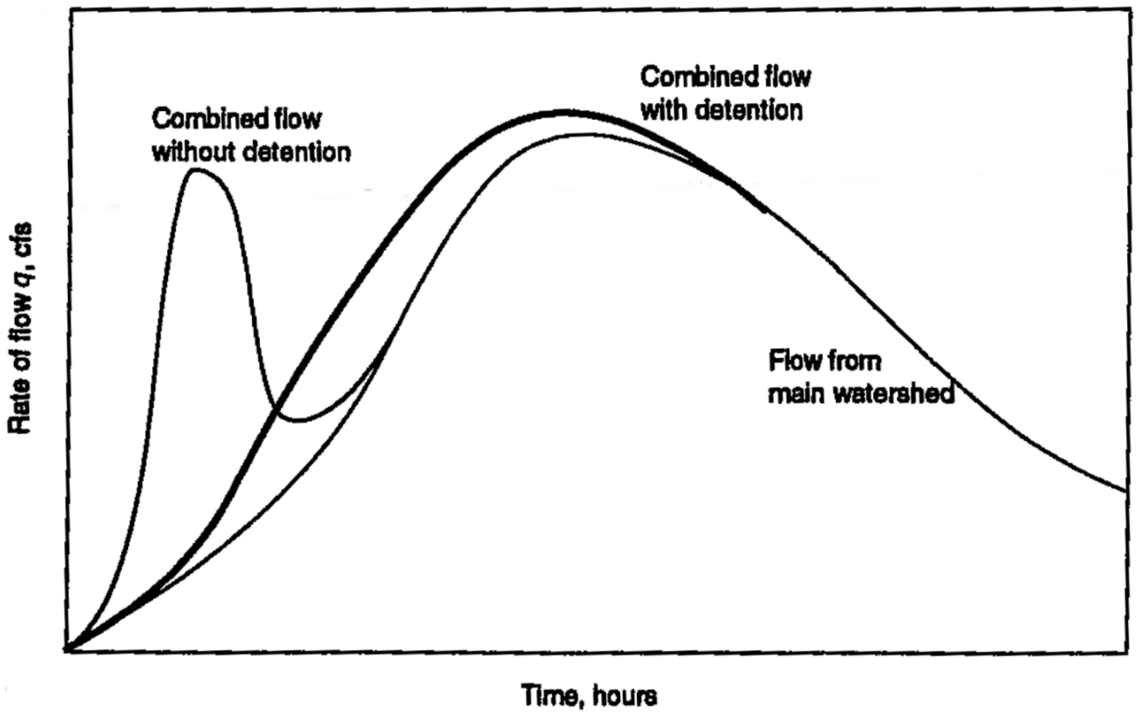

Figure 2.2: Alternative hydrograph illustrating potential effects of detention combined with flows from large watersheds adapted from Bruce Ferguson's Introduction to Stormwater (Ferguson 1998)

Being located below the headwaters of the Susquehanna River watershed, the floodwaters of Binghamton come from runoff in its own smaller watersheds, as well as runoff from the larger upstream watershed conveyed by the Susquehanna River and Chenango River. Because of the large size of the Susquehanna River watershed, the volumes of flood water affecting Binghamton are likely to be caused primarily due to discharge of the larger river watershed than from local discharge. For this reason, detention of stormwater may contribute to increased flood peaks as in the hydrograph above.

Flood Infrastructure: Resistance and Resilience

Urban infrastructure is often hidden from view, conveying water and electricity, moving away waste, and directing our paths of transportation. Urban infrastructure affects the flow of water, sometimes intentionally and sometimes unintentionally. Storm water infrastructure controls the path of precipitation in our cities, as runoff and river overflow. Runoff, as was previously mentioned, is usually funneled into stream channels via storm drains, gutters, and pipes. It is important to note that in some flooding situations this infrastructure can have a reverse impact, backflow, allowing stream overflow to flood through pipe systems. Impervious pavements, intended for pedestrian and vehicular circulation, influence the flow of water as well, increasing runoff volumes and decreasing groundwater storage potential (Ferguson, 1998). River overflow is usually managed by way of “flood protection”: levees, floodwalls, channel diversions, dams, and reservoirs (White 1945).

Some flood infrastructure could be best described as flood resistant. Flood resistance focuses on holding off flood events by preventing river water from expanding beyond its banks (Prominski 2012). Flood control features such as levees, dams, and channelized rivers are some examples of flood resistant infrastructure (Liao 2012). Though these alterations are done to reduce flooding, it has been found that these alterations may increase the intensity of flooding, increasing velocity and height of events by blocking river water from accessing its floodplain (Prominski 2012).

When a river expands beyond its banks it typically overflows to a floodplain, a flat area directly adjacent to a river channel (Dunne and Leopold 1978). Floodplains, space provided for water to spill over during times of high flow, are considered by many professionals to be part of the river itself (Liao 2012). When floodplains are urbanized, as in many river cities, flood resistant infrastructure becomes a possible solution to protect these areas from flood events.

Along with its potential for increasing the height and velocity of flood events, preventing flow into a floodplain through flood resistant infrastructure creates a system of two potential flood event conditions dependent on the effectiveness of the flood protection (Liao 2012). If the flood event does not rise above the flood protection the former floodplain is kept dry; damage to development is prevented and the developed area can continue to function as usual. If flood resistant protection fails, damage is incurred and regular use is disrupted (Liao 2012). The division between these two conditions is expressed by Liao as the flooding threshold, distinguishing a regime of regular city functioning from one of reduced function. The below diagram by Liao illustrates this threshold and its effect on the ability of a developed area to function (expressed as the “Degree of socioeconomic state change”).

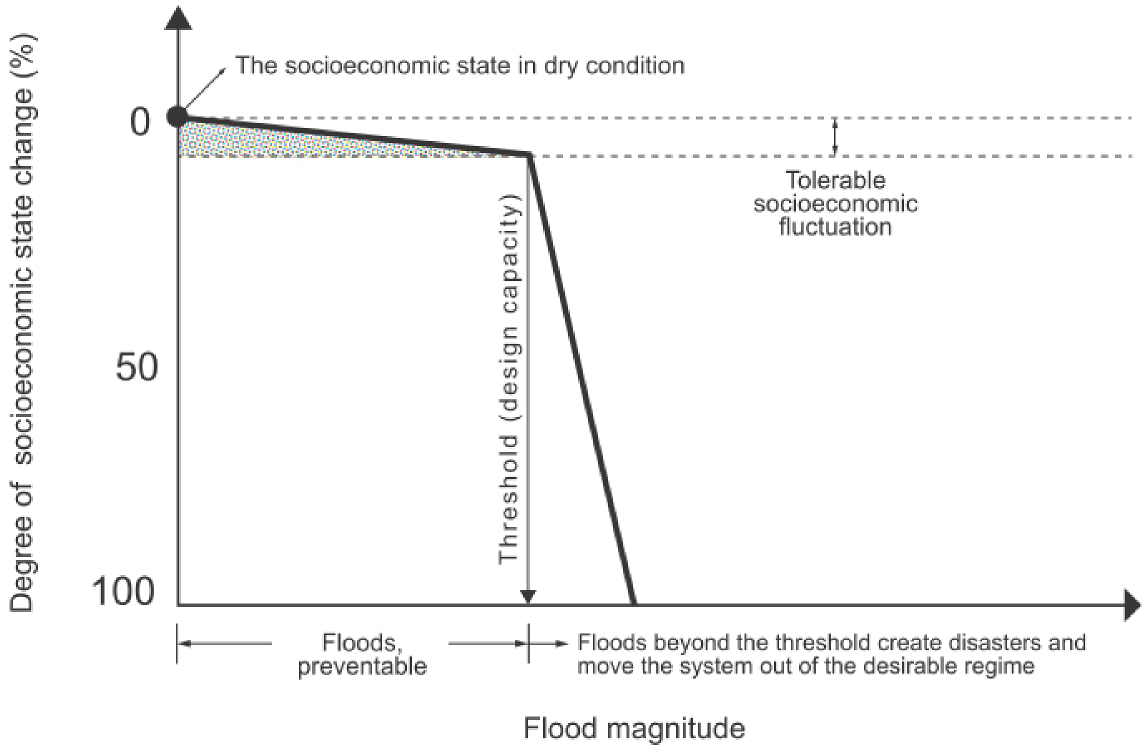

Figure 2.3: Flood Resistance and its Influence on Development as adapted from the paper A Theory on Urban Resilience to Floods (Liao 2012)

The main draw of continuing to design for a flood resistant city is that it allows developed areas to function normally during most flood events. This can be seen in the above diagram as the “Tolerable socioeconomic fluctuation”. However, once the threshold of flood prevention is breached, tolerability sharply decreases.

The risk of this drastic change of conditions is often overlooked due to less frequent events, resulting in a false sense of security in flood resistant infrastructure. This sense of security often leads to greater development in “protected” areas, increasing the potential for flood damage if the infrastructure fails (Montz and Gruntfest1986). Though residents in areas at risk of floods may have seen past flood events, time seems to fade the perception of the damage caused (Dunne and Leopold 1978, Jacobson 2012), often leading to unpreparedness when larger floods exceed the threshold of protection (Liao 2012).

Flood resistant infrastructure's efficiency not only affects the area of protection, but also downstream area flood events through increased discharge (Prominski 2012, Dunne and Leopold 1978). This effect has been seen occurring since the popularization of flood resistant infrastructure. In Gilbert White's 1945 paper Human Adjustment to Floods, White spoke of this pattern already as "well established by hydrologic measurements" (White 1945). He explained this phenomenon as it occurred due to levee construction on the Illinois River and the Yazoo River. When districts upstream of other districts along these rivers built levees, it increased the flood flows to downstream districts by "several feet above the height anticipated" causing the levees of districts to become inefficient. When those districts then heightened their levees as a response, they then increased flooding to districts below them, creating a domino effect (White 1945).

Some planners, designers, and scientists have suggested a focus on flood resilience instead of flood resistance (Liao 2012). Reducing reliance on resistant infrastructure enables riparian fluctuations, which over time provides a city with the opportunity to evolve through reorganization of land use to reduce flood damage. As stated by Liao, a flood resilient area is designed to tolerate and adjust to flooding, instead of resisting flooding. This increases the flexibility and variety of flood conditions decreasing the threshold of change. A decreased threshold could decrease the damage of major flood events and in some cases decrease the intensity of floods events (Liao 2012).

The diagram below by Liao illustrates this reduced threshold of flood resilience and its effect on the ability of a developed area to function (expressed as the "Degree of socioeconomic state change”). It is important to note that increasing resilience requires acceptance of more frequent inconveniences from flooding. This is illustrated on the below diagram which shows the degree of change (expressed along the y-axis) considered tolerable has a drastically increased range from the flood resistance diagram above (Liao 2012).

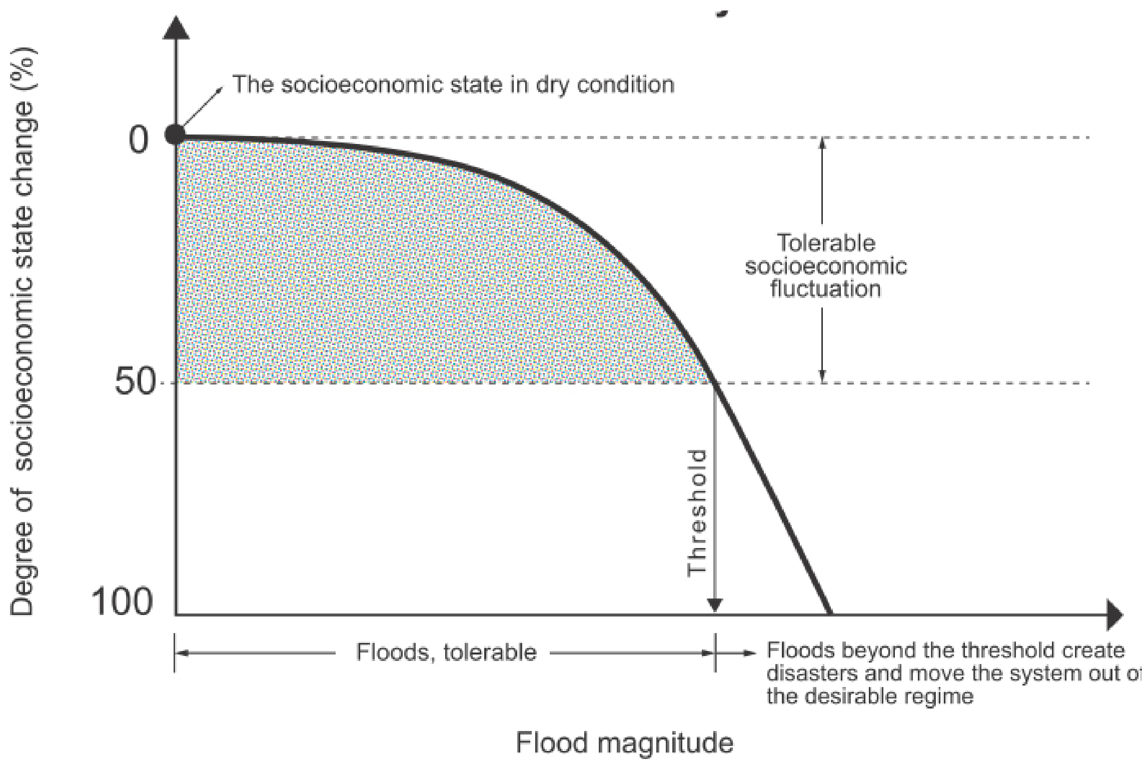

Figure 2.4: Flood Resilience and its Influence on Development as adapted from the paper A Theory on Urban Resilience to Floods (Liao 2012)

The main method of achieving flood resilience is through creating flood tolerant spaces, restoring the floodplain function of storing excess water during flood events (Liao 2012, Opperman et al. 2009). Allowing areas to flood in cities does require floodable areas to make adjustments in order to function without incurring additional flood damage.

Flood ‘damage’ is reliant on how flood-prone land is developed (Dunne and Leopold 1978). Development is still possible in floodable areas though it would need to be developed strategically. In order for development to withstand flooding, structures would need to be floodable, elevated, floatable, or flood-proofed (Liao 2012). Non-structural site features would also need to be carefully planned to allow for flood events.

Though a degree of compromise and adjustment may be necessary, flood resilient infrastructure can provide many benefits that outweigh the cost of compromise. Increasing floodable area has the potential to benefit a city by decreasing damage from and intensity of flood events (Liao 2012). It may also prevent larger problems downstream and improve environmental quality through allowing more opportunities for natural water movement (Liao 2012). Public awareness of river fluctuations would increase with more frequent flood events, reducing the false sense of security provided by resistant infrastructure. Allowing for more frequent flooding within a city may encourage learning opportunities and experimentation as well (Liao 2012). With smaller floods occurring more often, cities can experiment with new types of flood infrastructure at lower risk, increasing preparedness for larger flood events.

Using Flood Resilient Infrastructure

In order to determine how flood resilient infrastructure can be used in Binghamton, it is important to look at the use, or proposed use, of this infrastructure in other cities. This infrastructure will be simplified into two use groups: infrastructure associated with slowing water before stream channels and infrastructure associated with making room for water within stream channels.

Resilience through slowing and detaining

Slowing water focuses on restoring lag time during storm events and creating upland water storage opportunities. Conveyance, how water moves over the surface of the ground (Ferguson 1998), detention, and infiltration are methods used in the examples below. It is important to reiterate that slowing and detaining is not always beneficial for flood mitigation (See Figure 2.2) but can be useful if properly placed within the watershed.

A city wide approach that focuses on resilience through slowing water is Green City, Clean Waters, a new city-wide green infrastructure project in Philadelphia (Landers 2009). The goal of Green City, Clean Waters is to increase infiltration of runoff, treating precipitation where it lands (Philadelphia Water Department 2011). This is done by disconnecting inlets to sewer infrastructure, slowing on-site stormwater runoff (Landers 2009). This plan focuses strongly on water quality but also may aid in increasing flood resilience.

A “Sponge Park” is a scaled down version of the above network, addressing the detention, filtering, and infiltration of more localized runoff. The Gowanus Canal Sponge Park in Brooklyn, NY, developed by Susannah Drake and Yong Kim of dLandstudios, is currently under construction (Drake and Yong 2011). A Sponge Park is a green network system which temporarily detains storm water by absorbing it into the ground, allowing for evapotranspiration and infiltration to occur, with a focus on filtration for improved water quality (Drake and Yong 2011). Though this design is focused on water quality, it may have potential for floodwater management as well in situations where slowing and detaining runoff are beneficial to mitigation. Below are two diagrams illustrating precipitation movement through the Gowanus Canal Sponge Park.

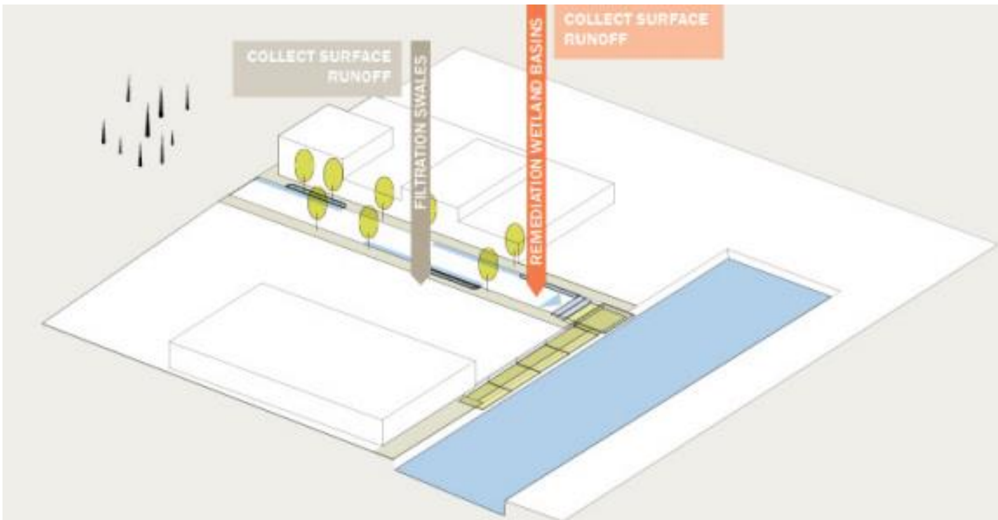

Figure 2.5: Precipitation movement through the Gowanus Canal Sponge Park during an average rain event adapted from <u>Gowanus Canal Sponge Park</u> pg. 7 <u>(dlandstudio 2008)</u>

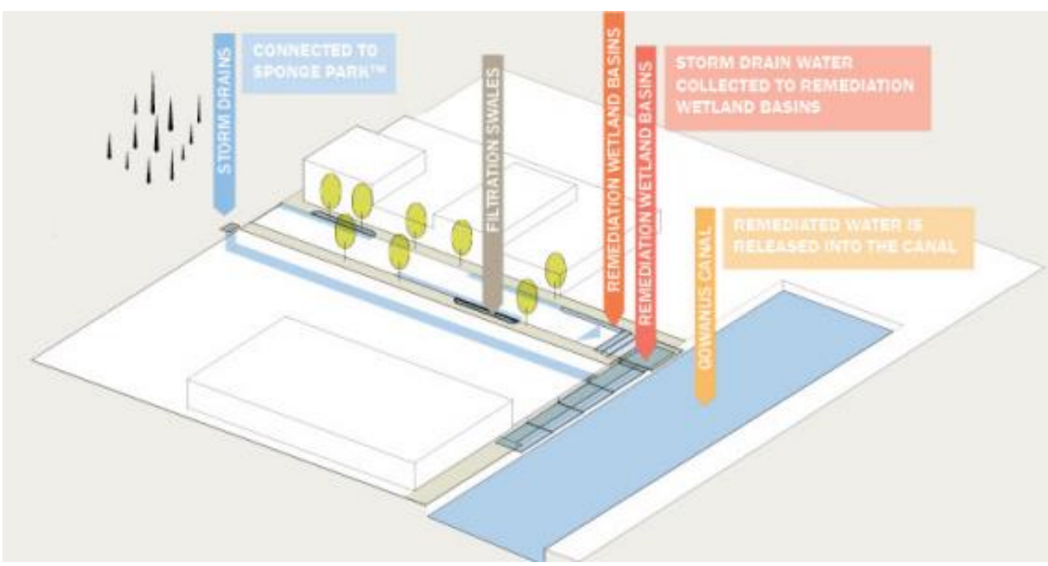

Figure 2.6: Precipitation movement through the Gowanus Canal Sponge Park during a heavy rain event adapted from <u>Gowanus Canal Sponge Park</u> pg. 7<u>(dlandstudio 2008)</u>

The Watersquare, developed by the landscape architecture firms De Urbanisten and Studio Marco Vermeulen for flood mitigation, slows water through detention (Boer 2010), holding and then releasing on-site runoff after a storm event has occurred. Some infiltration does occur within Watersquares due to plantings, but detention seems to be the primary means of slowing water. A Watersquare, if properly located and designed, serves as a functional and aesthetically pleasing public plaza or play area when not flooded. When flooded, it is designed to hold precipitation from building rooftops and other piped-in runoff. This runoff is filtered before entering the basin, flooding in specific patterns according to the volume of precipitation in a storm event (Boer 2010). The first watersquare was completed in 2013, though data on how effective this space is for flood mitigation was unavailable.

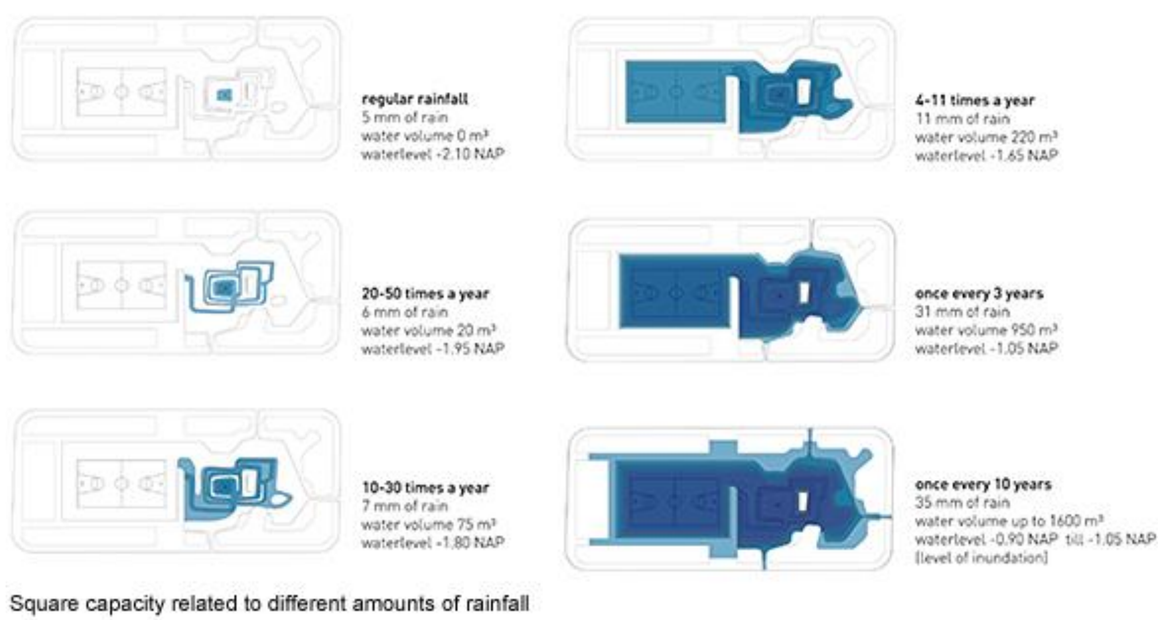

Figure 2.7: Illustration of flood patterns of a Watersquare adapted from Florian Boer's Watersquares: the elegant way of buffering rainwater in cities (Boer 2010)

Resilience through making space for river flooding

Designing floodable areas along rivers, space for river water to go when spilling over its banks, is another approach to increasing flood resilience. Unlike the above examples, these resilient infrastructures do not focus on slowing or detaining runoff, instead directing their flood mitigation to river discharge.

In the Netherlands, a country-wide flood prevention plan has been developed called Room for Rivers. As the name states, the goal of this program is to redevelop land in a way that allows more space for the river water to go (Ruimte voor de rivier 2012). This redevelopment is meant to provide areas for major water storage (Ruimte voor de rivier 2012) through restoring floodplains to areas where “flooding will be least harmful to people” (Hannan 2011).

A floodway park is a scaled down version of the above, providing room for localized river spread. Floodway parks strive to protect or restore the function of the floodplain directly adjacent to the river while also allowing community amenities. Mill Race Park, designed by Michael VanValkenberg Associates in 1989 (Michael Van Valkenburgh Associates N.D.) and Mill Creek Canyon Earthworks Park, designed by Herbert Bayer in 1982 (Baird 2003), are two examples of a floodway park. When not inundated, these parks function as public greenspaces providing communities with access to rivers. They are strategically designed and graded, allowing the parks to fill with water in ways which protect areas at higher risk of damage from floods and create patterns for the purpose of aesthetics. Below are images of Mill Race Park before and during a large flood event.

Figure 2.8: Mill Race Park photograph adapted from MVVA website (Michael Van Valkenburgh Associates. N.D.)

Figure 2.9: Mill Race Park during large flood event photograph adapted from MVVA website (Michael Van Valkenburgh Associates. N.D.)

Flood resilient infrastructure possibilities for Binghamton, NY

Because of the significant damage that has occurred in Binghamton, the city has received funding aimed at increasing flood resilience. Currently two grants have been awarded for this purpose (City of Binghamton Department of Planning, Housing, and Community Development (CPBP) N.D.). The first grant, the 50/50 Stormwater Management Fund, is funded by the National Fish and Wildlife Federation Chesapeake Bay Stewardship Fund. It is meant to provide landowners half of the expense incurred by the implementation of green infrastructure that reduces stormwater runoff (CPBP N.D.). The second grant, the Green Stormwater and Landscaping Matching Fund, is funded by a local community foundation. This fund is intended to support homeowners and businesses in implementing green infrastructure projects "that will contribute to the City's resilience to flooding and help improve water quality" (CPBP N.D.). As in the first grant, these projects are intended to be small-scale, private property projects.

Both of these grants seem to address flood resilience through detaining and infiltrating runoff, as in the first set of resilient infrastructure examples. However, it was determined previously in this chapter that, based on Binghamton's location within the Susquehanna River watershed, detaining and infiltrating runoff may not be the best methods for mitigating flooding.

Based on information cited within this chapter, the most beneficial method of increasing flood resilience in Binghamton may be to reduce flood resistance to areas along the Susquehanna and Chenango Rivers and to make space for river flooding. The next two chapters will focus on where these floodable areas should be located

CHAPTER 3

Examining Binghamton's Flood Infrastructure and Potential for Floodable Space

The following section explores Binghamton's potential for floodable areas. This was done through the use of ArcGIS mapping and supplemented with data from the Blueprint Binghamton Comprehensive Plan which was adopted by the city in 2014. Mapping data was obtained from the following sources: Broome County GIS, the National Hydrology Dataset, the Susquehanna River Basin Commission, ESRI maps, FEMA, Army Corps of Engineers, and USGS.

This section begins with context on Binghamton's location, landforms, and development patterns. Next is an examination of Binghamton's flood zones and current flood infrastructure. Lastly, existing green spaces and low use areas were mapped, showing potential spaces for floodable area.

Binghamton's position along the Susquehanna River

The Susquehanna River is 450 miles long, beginning at Otsego Lake, in Cooperstown, NY, and emptying into the Chesapeake Bay. The Basin of the Susquehanna River spans 27,501 square miles across New York, Pennsylvania, and Maryland. This basin can be broken into 6 subbasins: Upper Susquehanna, Chemung, Middle Susquehanna, West Branch, Juniata, and Lower Susquehanna. Binghamton is in the Upper Susquehanna subbasin, the first subbasin of the Susquehanna River. Though

Binghamton is within the first subbasin, it is still is far enough downstream to experience substantial flooding due to upstream discharge. As was previously mentioned, the effects of upstream discharge on Binghamton's flood events warrant a focus on creating floodable areas over localized water detention.

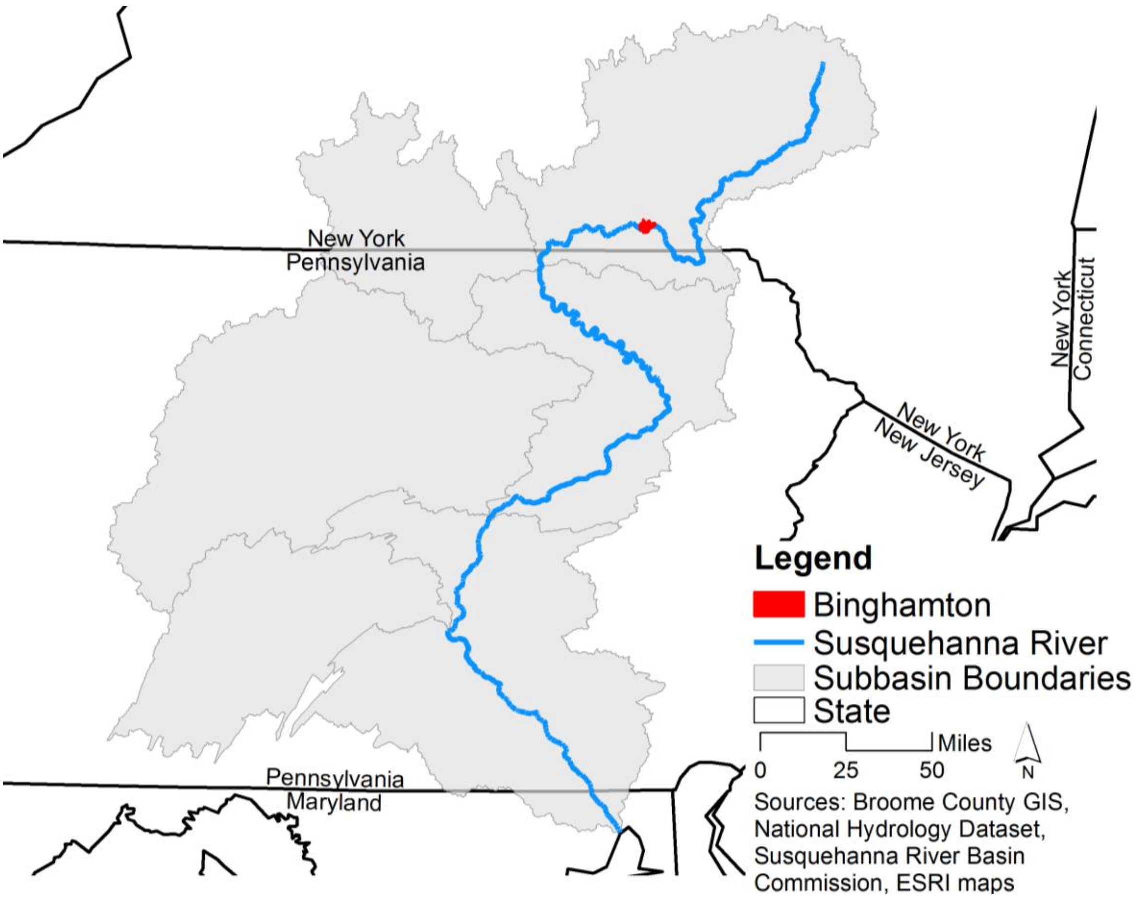

Figure 3.1: Map of the Susquehanna River Basin

Context of City Landforms

The City of Binghamton spans 11.06 square miles, mostly consisting of valley with bordering hills reaching up to 760 feet above the lowest recorded elevations. Two rivers, the Chenango River and the Susquehanna River, meet in Binghamton forming a confluence within the city. At this confluence, the Chenango River, flowing from North to South empties into the Susquehanna River which flows east to west through the city.

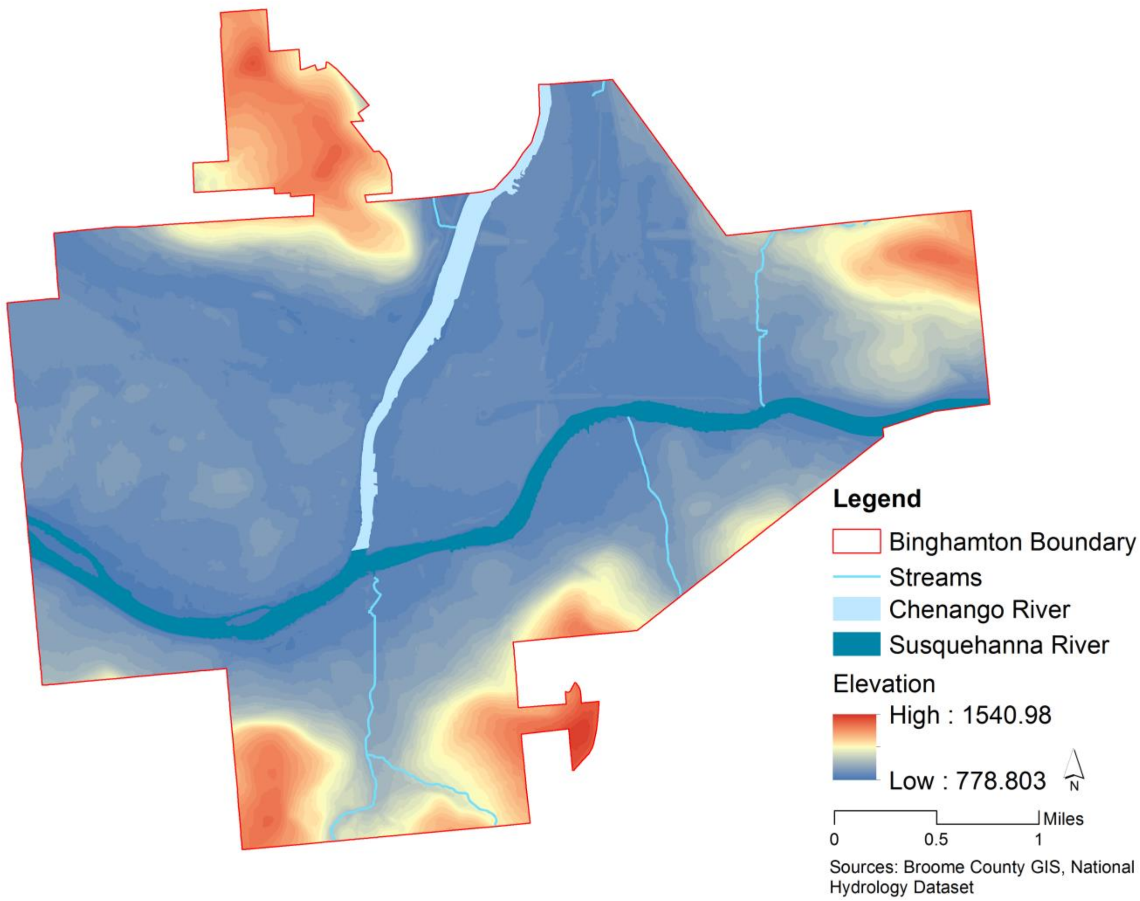

Figure 3.2: Map of Binghamton, NY Landforms

Context of City Development

The map below illustrates development in Binghamton focusing on buildings and census zoning data. The building data for Binghamton has not been updated since 1989, but is accurate enough to show development patterns within the City.

A downtown exists in Binghamton at the confluence of the Susquehanna and Chenango Rivers. Residential zoning areas appear to radiate from the downtown, with less dense development on the extremities of the city (at higher elevations) and more dense residential areas zoned closer to downtown (at lower elevations), with the exception of the Ely Park residential development at the northernmost point of the city. A large industrial corridor is zoned along a rail line and major highway just north of the Susquehanna River, cutting off the northeastern residential zone from the rest of the city. Three commercial strips branch off of downtown, the eastern strip again bisected by the industrial corridor.

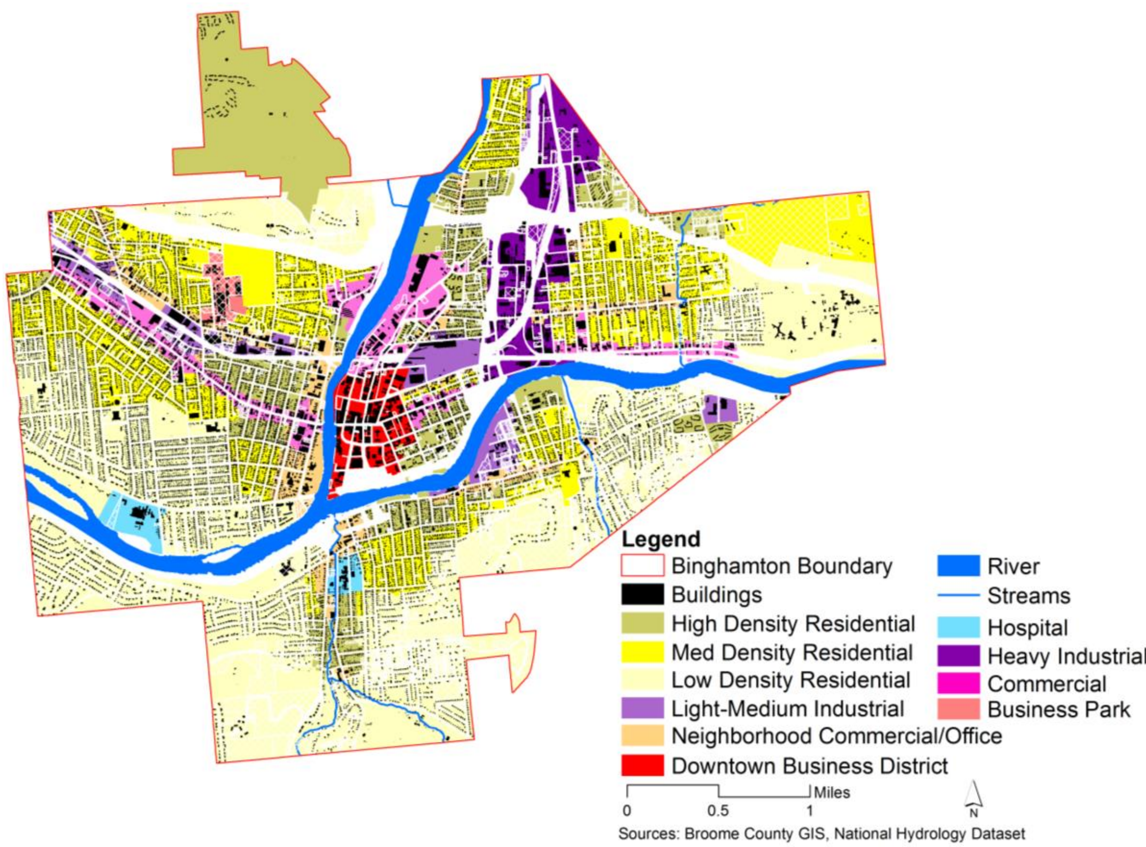

Figure 3.3: Binghamton, NY Zoning and Building Locations

Flood Zones and Preliminary FEMA Updates

The Federal Emergency Management Agency (FEMA) has been updating flood maps nationwide since 2003, the last update for Binghamton occurring 30 years before (Federal Emergency Management Agency 2010). FEMA reports these changes are due to “Changing topography, urban development and sprawl, loss of vegetation and an increase in impervious surface, as well as a longer record of flooding experience” (Federal Emergency Management Agency 2010). Preliminary flood map changes, Digital Flood Insurance Rate Maps (DFIRMs), were submitted to local officials in 2010 reflecting data from the flood of 2006. The 2010 DFIRMs show a significant increase in flood zone, because some of Binghamton’s levees “no longer meet federal requirements for minimum flood protection” (Federal Emergency Management Agency 2010). According to federal requirements, flood protection must be 3 feet higher than the 100 year flood event and this was not achieved during the 2006 flood (Federal Emergency Management Agency 2010). River water rose above Binghamton’s flood protection in multiple locations during both the 2006 and the 2011 floods (Blueprint Binghamton 2014).

Below are two maps indicating the current flood zone map and the preliminary DFIRM. The first map, below, illustrates the current designated flood zone, with the new preliminary DFIRM areas to be added to this current zone highlighted in cyan. Orange lines illustrate the 2011 flood event.

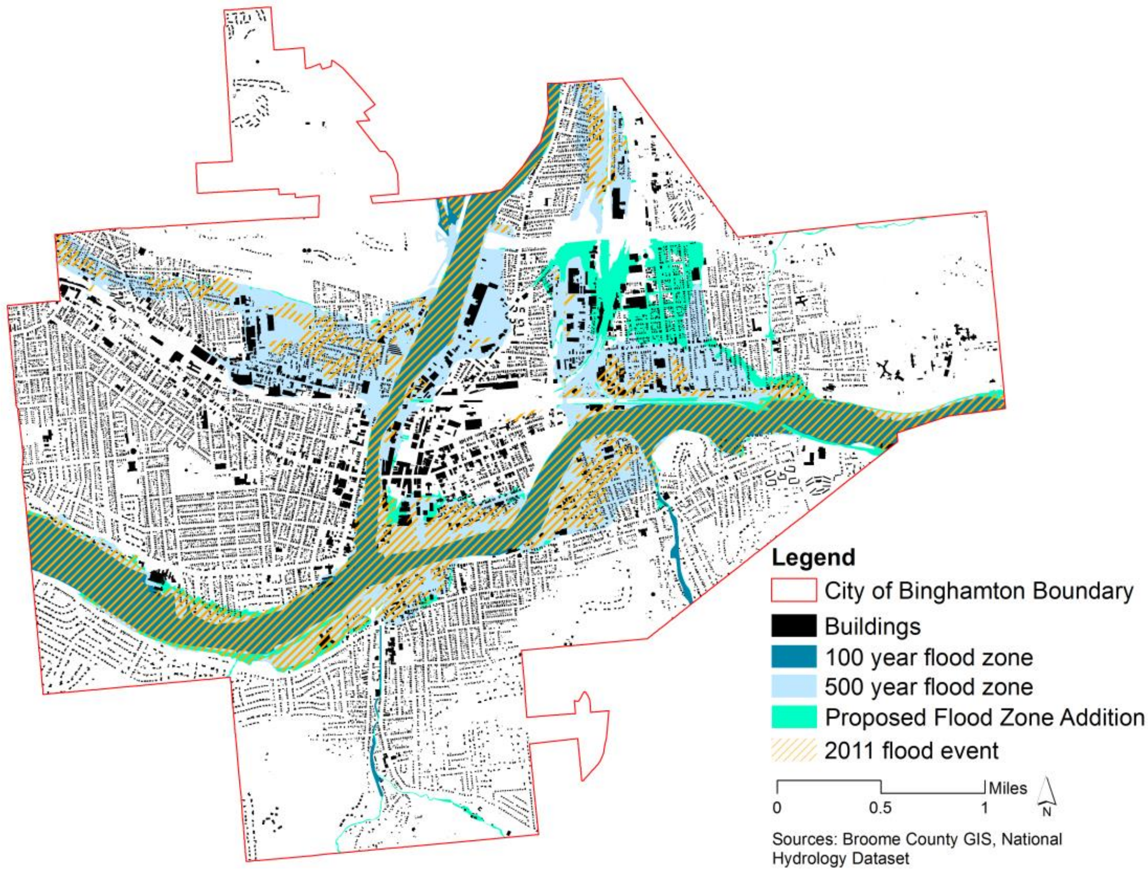

Figure 3.4: Existing Flood Zone with Proposed Additions and the 2011 Flood

The second map, below, illustrates the preliminary DFIRM with current flood zone areas to be eliminated highlighted in red. This 2011 flood event is represented in the same manner as the above map with orange hashes.

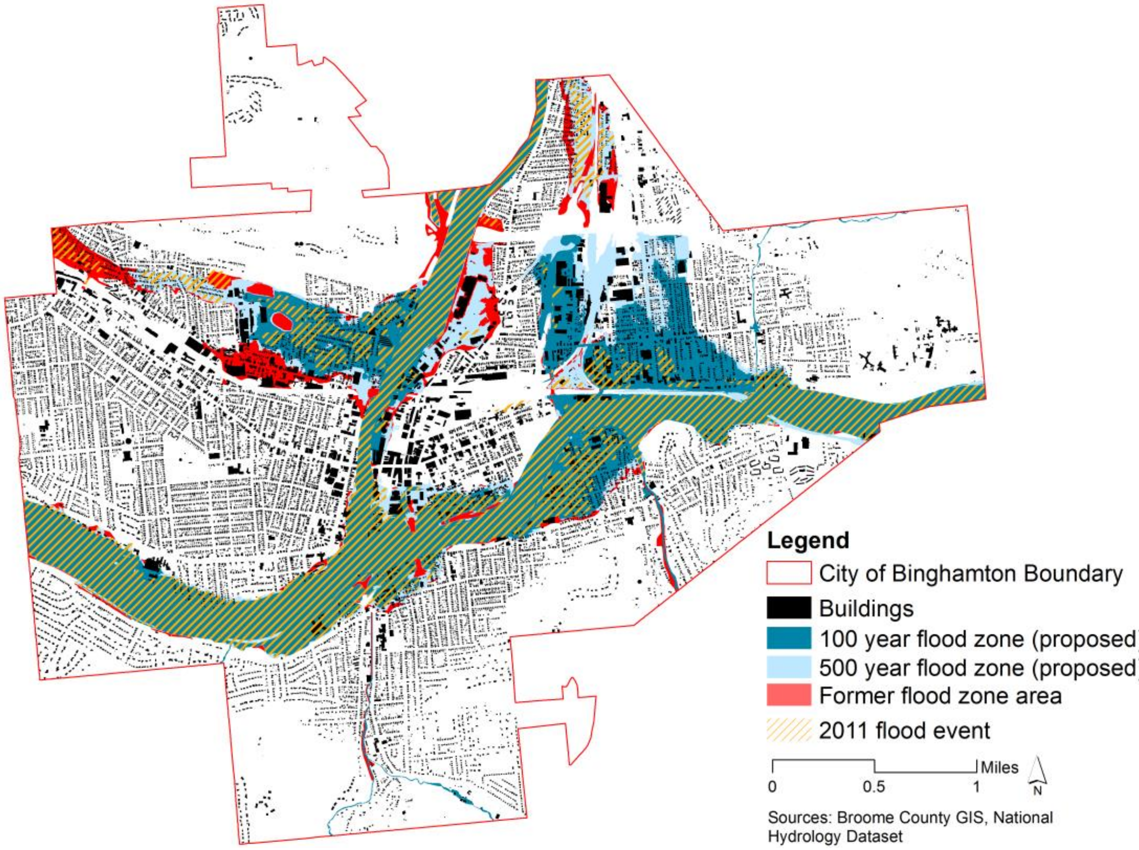

Figure 3.5: Proposed Flood Zone with Existing Reductions and the 2011 Flood

A large portion of the 500 year flood zone in the current flood zone map is considered 100 year flood zone for the DFIRM. Also, the current flood zone map stretches the flood zone further west and the preliminary DFIRM further north. When comparing these flood zone maps to the 2011 flood, the current flood event map aligns best. However, the 2011 flood covers almost the entire 500 year flood zone. The 2011 flood is the worst flood on record for Binghamton, but 5 years before, the 2006 flood was the worst on record (Jacobson 2012). The preliminary DFIRM map contains a larger area of flood zone and will therefore be used for the designs within this thesis.

Existing Flood Infrastructure

The map below illustrates the locations of floodwalls and levees in Binghamton. These were built in response to the 1935 and 1936 flood events in Binghamton. Channel improvements, dams, and reservoirs were also built in the vicinity during this time (Blueprint Binghamton 2014). As was mentioned above, sections of the floodwalls and levees were overtopped in both 2006 and 2008 (Blueprint Binghamton 2014). For the purpose of this study a floodwall will be defined as a concrete wall and a levee as an earthen berm designed to resist floods.

Slope data was also included in the below map, highlighting the steepest slopes in black. This was included to show raised roads and building footprints which impact flood patterns. The slope data also shows the steep hillslopes of some river sections and the bordering hills of the city.

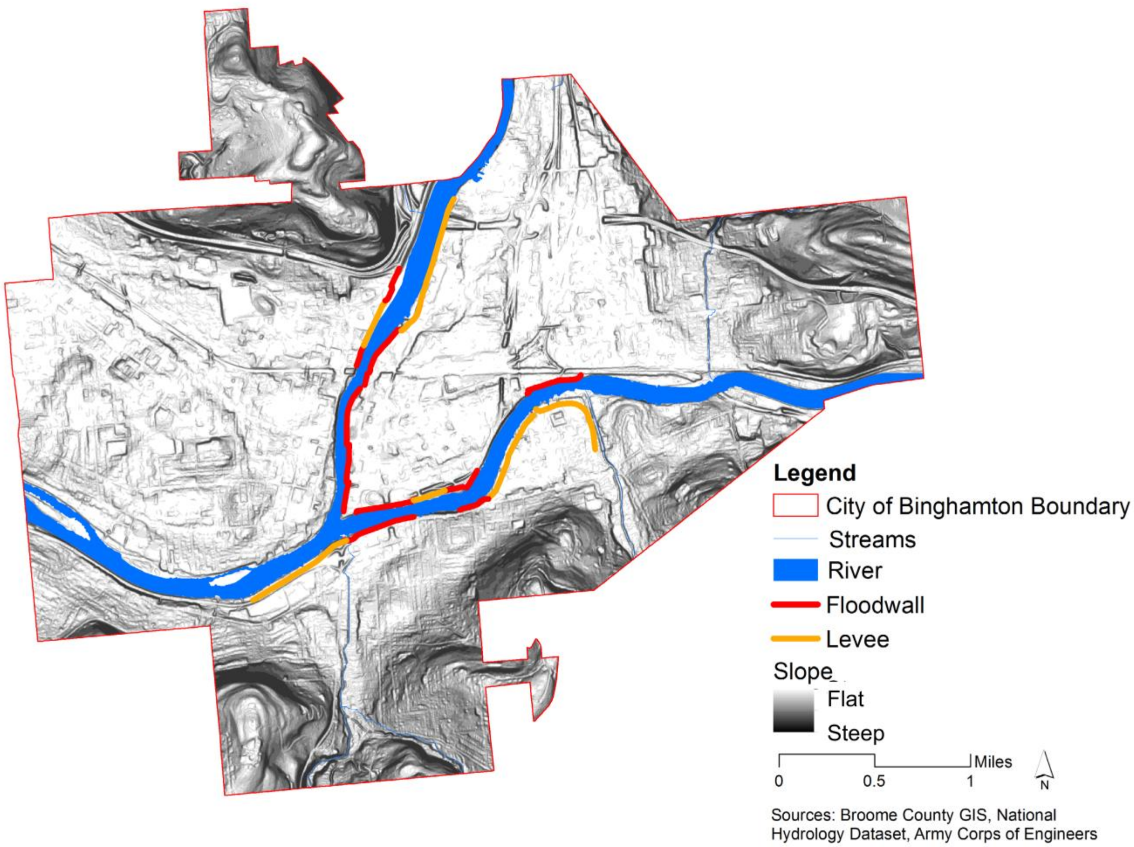

Figure 3.6: Existing Flood Infrastructure and Steep Slopes

Existing Greenspace

Existing green spaces could present the most convenient transition to floodable areas if located appropriately. The proximity of the park to the river would be key to their potential for increasing river flooding. These parks may also provide an opportunity to increase access to the river, reducing the perceived lack of access to the prominent water bodies flowing through the city.

The map below illustrates the locations of city-designated greenspaces and natural areas in order to determine whether or not retrofit opportunities exist. The largest city-designated greenspaces are Ross Park, a zoo, and the Ely Park Golf course which both occur on higher land far from the river. Many smaller parks occur close to the river, though not necessarily directly along the river, including: MacArthur Park, South Side Park, Confluence Park, Sandy Beach Park, Valley Street Park, and Cheri Lindsay Park. These parks may have potential to become floodable in the future.

Natural areas in Binghamton are mostly forested with a few small patches of herbaceous vegetation. Many of Binghamton's natural areas occur on the bordering hills of the city or directly along the riverbanks. The natural areas along hills are too far from the river to provide potential as floodable areas. The areas along the riverbanks are likely already functioning as floodable areas where not blocked by floodwalls and levees.

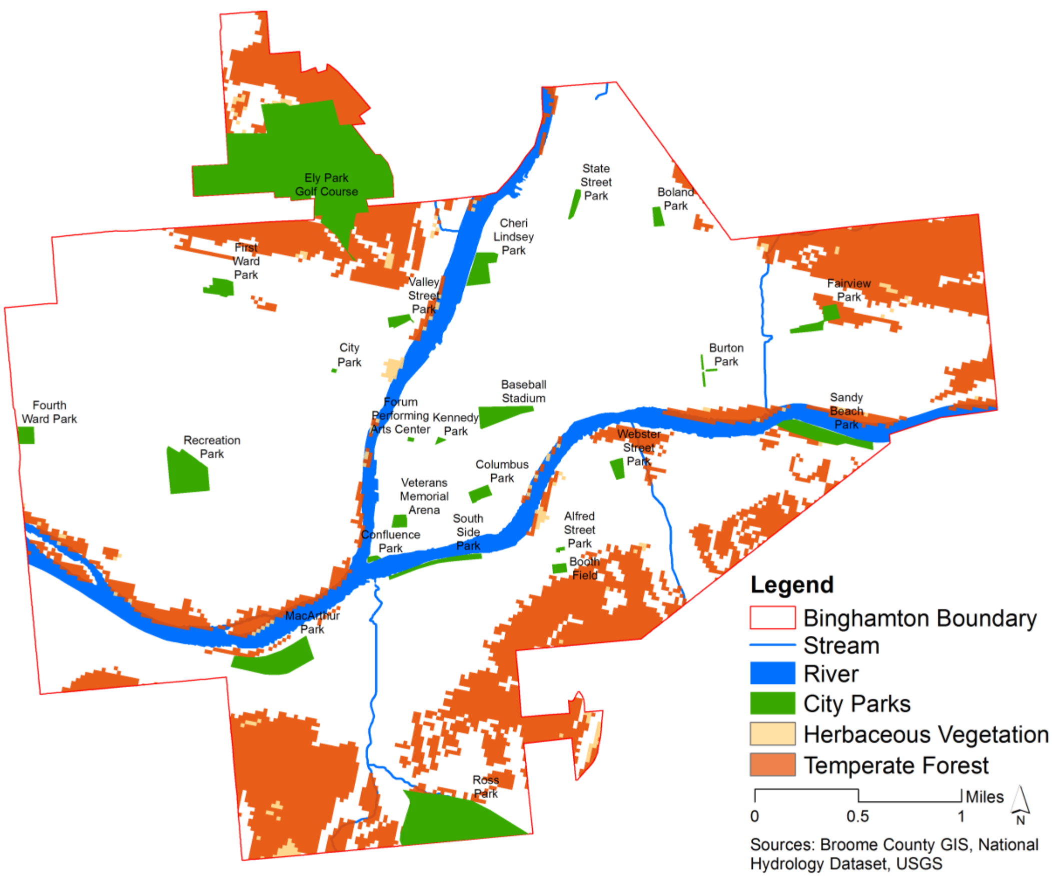

Figure 3.7: Existing Green Space in Binghamton

Low Use Areas

Areas of low use were determined based on Census parcel data of zoning and vacancy, my personal observations based on google maps and site visits, Binghamton's most recent comprehensive plan, and elevation data. Areas immediately excluded include: area zoned as downtown, areas at high elevation, commercial zones with low vacancy, and residential zones. Many areas of higher elevation are undeveloped in Binghamton, but were excluded from examination as low use areas because they are not possibilities for floodable areas. Large industrial zones were included as well as some large roadways.

Table 1: Criteria for Classification as "Low Existing Use"

Land Use or Parcel Contents	Criteria for classification as "low existing use"			
	Any Conditions	Close to River	High Vacancy Area	High Elevation
River Channel	Excluded	Excluded	Excluded	Excluded
Stream Channel	Excluded	Excluded	Excluded	Excluded
Downtown District	Excluded	Excluded	Excluded	Excluded
Heavy Industrial	Conditionally Included	Included	Included	Excluded
Light/Medium Industrial	Conditionally Included	Included	Included	Excluded
Hospital	Excluded	Excluded	Excluded	Excluded
Residential	Conditionally Included	Conditionally Included	Conditionally Included	Excluded
Commercial	Conditionally Included	Conditionally Included	Conditionally Included	Excluded
Undeveloped	Included	Included	Included	Excluded
City Parks	Conditionally Included	Included	Included	Excluded
Forested	Conditionally Included	Included	Included	Excluded
Major Roadways	Conditionally Included	Included	Included	Excluded
Railroad Corridors	Conditionally Included	Included	Included	Excluded

Downtown zoned area was excluded from examination as low use area because of its importance to the identity of Binghamton. This area includes many historic buildings, the highest concentration of commercial buildings, and cultural amenities including a theatre, arena, courthouse, and baseball stadium (Blueprint Binghamton 2014). Binghamton University has recently become a large presence in Downtown Binghamton as well, building and reclaiming buildings for off-campus housing in the area. The University has also been collaborating with the city to build the Southern Tier High-Tech Incubator downtown, creating another future amenity (NY Rising Community Reconstruction Program 2014).

Residential areas were also avoided as much as possible when determining low use areas. The City of Binghamton has suggested considering some flood prone residential areas for other uses such as open space and residential vacancy, which may increase in the future due to new flood zone designations which will require higher flood insurance rates in these areas (Blueprint Binghamton 2014). However, repurposing residential spaces for floodable areas should be considered with a critical eye and will be considered separately from the determined low use areas during the design portion of this study.

Industrial zoned areas were almost completely included as low use areas despite Binghamton's historic role as a center of industry. In the past, manufacturing provided the main source of jobs within Binghamton; however between 2002 and 2011 Binghamton lost 66% of its manufacturing jobs within the City (Blueprint Binghamton 2014). Today Health Care and Social Assistance, Professional and Business Services, Education Service, and Accommodation and Food Services are projected to provide the source of employment in the future (Blueprint Binghamton 2014). These services do not require a large industrial corridor, leading to this corridors designation as low use.

It is important to consider the railroad lines existing within the industrial corridors marked as low use areas. Binghamton has 3 freight rail lines within its boundaries: Norfolk Southern, Canadian Pacific, and a local carrier called New York, Susquehanna, and Western Railroad Corporation (Blueprint Binghamton 2014). The majority of these rail lines run along the river turning in to the industrial corridor on bridges elevated over the roadways at the southern end of the industrial corridor. These lines are active and own some of the land within the industrial corridor which could create complications when considering these areas for floodable scenarios.

Some major roadways have also been considered within the low use area. Blueprint Binghamton, conducted an analysis of Binghamton's roadways, concluding that some roadways are unnecessary for the population density of Binghamton (Blueprint Binghamton 2014). Their proposed road and ramp removals are all within the low use area and if followed through on could increase opportunities for potential floodable areas.

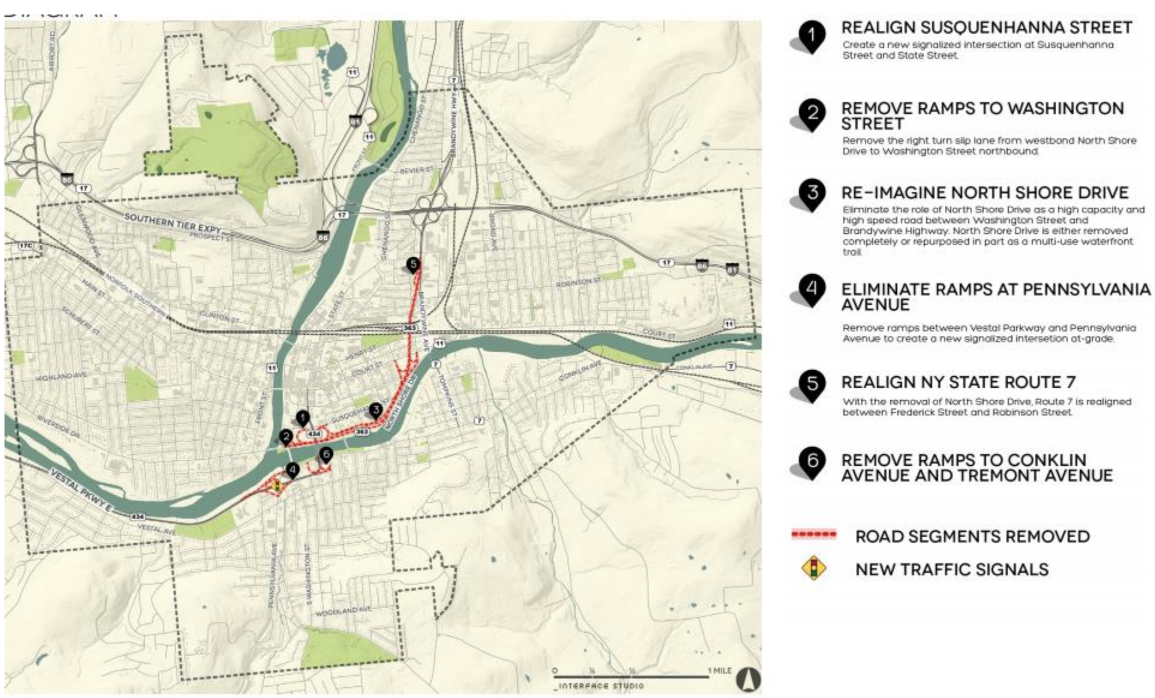

Figure 3.8: Map of Proposed Circulation Interventions adapted from Blueprint Binghamton Mini-plan on Transportation pg. 169 (Blueprint Binghamton 2014):

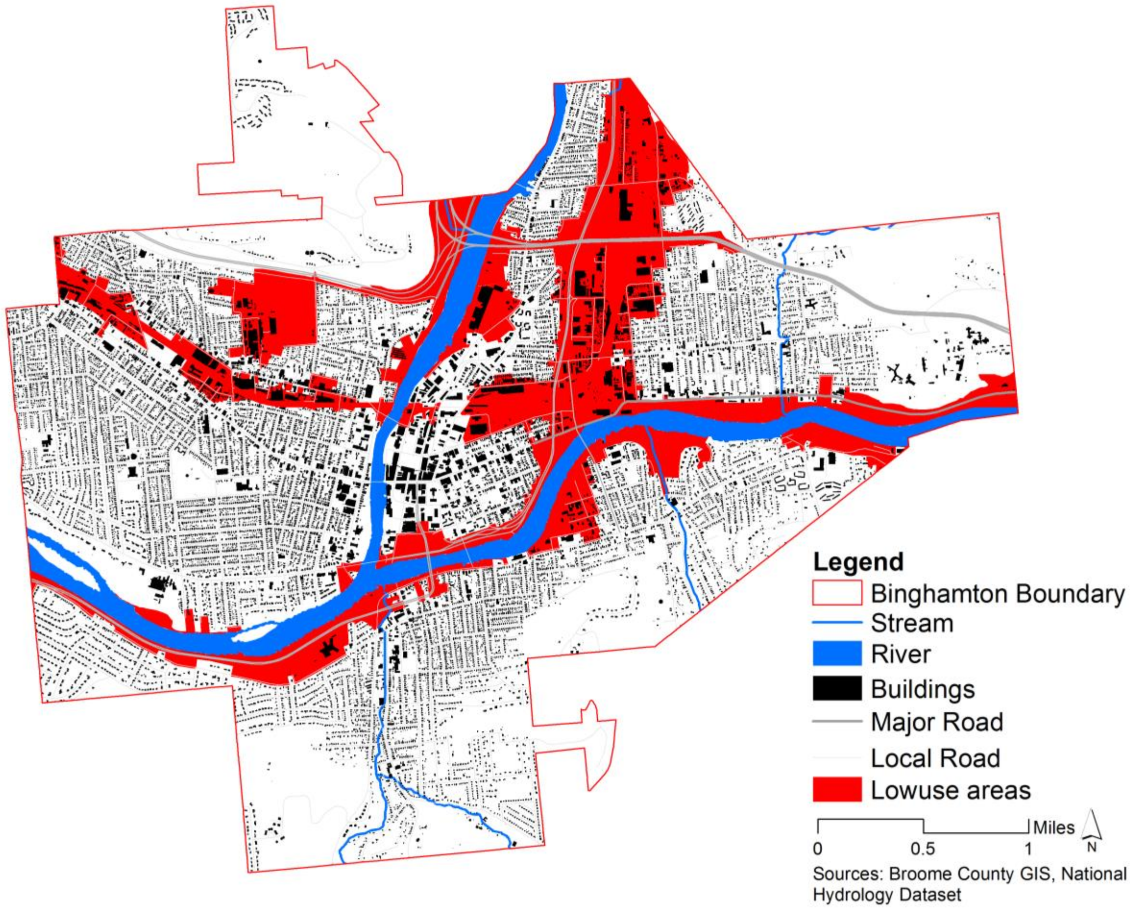

Figure 3.9: Map of Area Determined to be Low Use

Using information on existing conditions, future plans, and predicted trends this chapter has developed an overall conclusion as to areas of low use in Binghamton. However, these low use areas are not necessarily appropriate for floodable areas. The next chapter will examine these low use areas in greater detail to assess potential spaces for encouraging flooding.

CHAPTER 4

Identifying Floodable Areas

This chapter examines the low use areas defined in Chapter 3 for potential areas to be redesigned as floodable space intended to increase flood resilience. This will be done by identifying low use areas for potential study, examining the flood protection existing in these areas according to the base flood elevation, and lastly by acknowledging river flow velocity patterns within the rivers.

Low Use Areas for Potential Study

Ten areas from the low use area determined in Chapter 3 (See Figure 19) are examined below for their potential as floodable areas. These areas have been defined based on primary land uses and have each been assigned a name and number below for clarity. Each potential study area was chosen based on proximity to a river, continuous form, and personal observations on the areas. In order to determine their potential as floodable spaces, the following are examined for each site: what is in the site, what is bordering the site, elevation and slope, obstacles between the site and the river, opportunities, and site constraints.

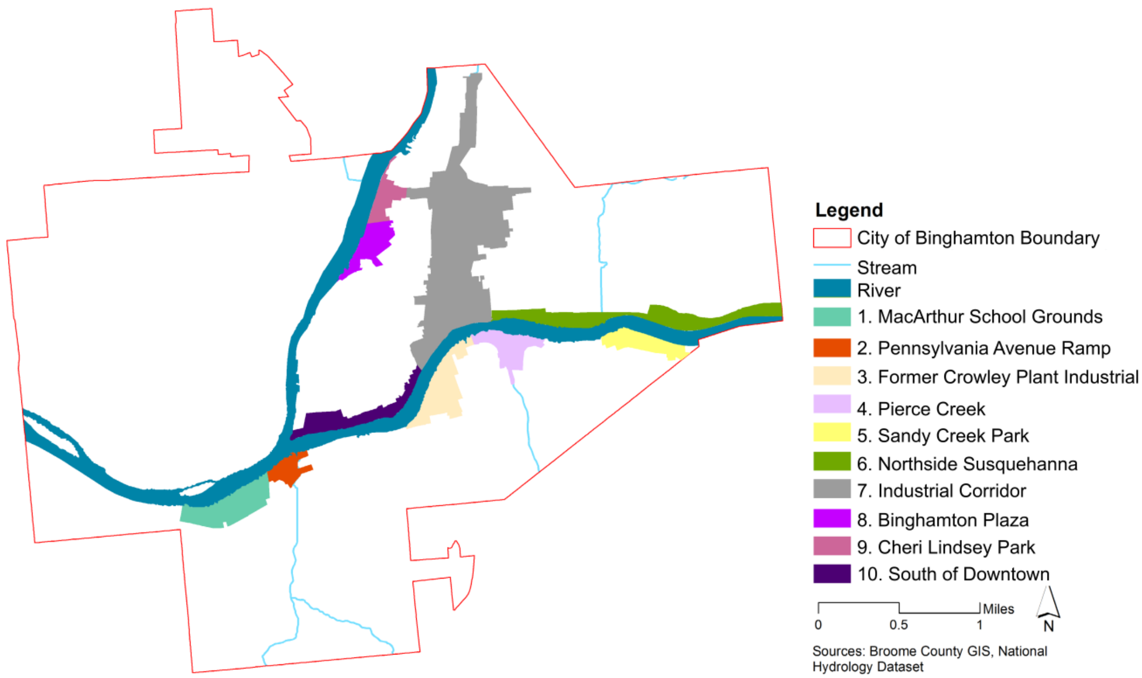

Figure 4.1: Low Use Areas of Potential Study

Below are a series of 10 aerial maps of the above potential areas of study. Aerial maps were obtained by ESRI online and aerial map data was sourced as the following: Esri, DigitalGlobe, GeoEye, Easthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

1. MacArthur School Grounds

MacArthur School Grounds was originally home to MacArthur Elementary School, which has been closed since the flood of 2011 (Binghamton City School District N.D.). The 2011 flood inundated the entire parcel, causing unrepairable damage to the school (See Figure 1.3). Though the building does appear within this aerial image, it has since been torn down and plans to rebuild the school have already begun (Binghamton City School District N.D.). The west end of the site is wooded and contains a nature trail.

The rest of the site is developed and includes the following amenities: ¼ mile track, 2 soccer fields, 2 playgrounds, basketball court, tennis court, city pool, and 3 baseball fields. The site is relatively level with the river, without accounting for the levee, except at the western end. The grounds are separated from the river by a major road and levee and the rest of the area is bordered by low-density residential development.

Figure 4.2: MacArthur School Grounds

2. Pennsylvania Avenue Traffic Ramp

The Pennsylvania Avenue traffic ramp has been included because it is one of the roadways deemed unnecessary by Blueprint Binghamton based on population density (See Figure 3.8). Removing this traffic ramp would provide a fairly large area of unused space that could be used for floodable area. Alternatively, this traffic ramp could be reused as a pedestrian bridge to provide access to other floodable areas of the river itself. This area, protected by the same levee as the school and a floodwall east of the levee, is southwest of the Bayless Creek outlet, just west of Binghamton's iconic South Washington Street Pedestrian Bridge, and directly adjacent to the South Bridge Business District. Elevation is slightly higher than the elevation of Area 1, MacArthur School Grounds.

Figure 4.3: Pennsylvania Avenue Traffic Ramp

A major road, Vestal Parkway E, separates most of these two sites from the river. Safety issues for both pedestrians during non-flood use, and the safety of the road itself during or directly after flood events will need to be taken into consideration with this design. The school site provides more constraints as it contains many site amenities regularly used by surrounding residents within the park. Particularly well used amenities are the large western baseball field and the central track.

These areas have potential for increased pedestrian connectivity between a park, the South Bridge Business District, and the South Washington Bridge which would lead directly into a trail along the east side of the Chenango River. A lot of available area exists for flooding and since a majority of the area is already a park, it has high potential for retrofit as a floodable park.

3. Former Crowley Plant Industrial

Crowley Foods Plant, primarily a milk manufacturer, began business in Binghamton in 1915, ceasing production in 2012 due to no longer being equipped to handle modern production capacity. It continued working as a distribution area until bought in 2013 by Mountain Fresh Dairy, which is currently working to reopen the plant (Harris 2014). The western end of this plot contains the parking lots of the plant, separated from the plant by a small strip of commercial properties that are partly vacant. The rest of this light industrial zoned area consist of vacant lots, used car lots, mechanic shops, construction businesses, a fire department training center, a Humane Society animal shelter, and a Community Hunger Outreach Warehouse (CHOW). This area was initially considered low use because of a high concentration of unused parking and vacancies, but on closer inspection it has been found that some essential businesses, such as CHOW exist within this site. This area is separated from the river by a levee which did not prevent flooding in 2011 (See Figure 1.3). The Crowley Plant industrial area is bordered by high and medium density residential development. The area is relatively flat except for manmade retaining walls through the site and it is at low elevation.

A major constraint of this space as floodable area would be the removing, or at least relocating, of area businesses. However, inundation during the 2011 flood event was high (See Figure 1.3) and the preliminary FIRM map (See Figure 3.5) now locates this area within a higher flood insurance bracket, which may deter businesses from remaining in the area. Due to the nature of many of the businesses in this area, flood-proofing of buildings could be an option for some businesses and could provide for interesting design compromises.

Figure 4.4: Former Crowley Industrial Area

4. Pierce Creek

The Pierce Creek Confluence is currently undeveloped but zoned for high density residential. It is mostly forested and bordered by high, medium, and low density residential development. It is also adjacent to Binghamton's water treatment plant. This area is directly next to the river with a levee starting at the border of the west side, separating the space from the residential development. In its current state it is already functioning as a floodable greenspace for Binghamton.

Figure 4.5: Pierce Creek Confluence

Between the Former Crowley Plant Industrial and Pierce Creek is a bridge across the Susquehanna River which could provide new neighborhood connections. The bridge already has sidewalks and bike lanes, further encouraging travel to and from this area.

5. Sandy Creek Park

Sandy Creek Park is largely undeveloped except for a grass field and small parking lot. It is bordered by low density residential properties with a high rate of vacancy and two businesses zoned as light industrial: a screen printing business and a small electronics lab. A railroad runs through the site, crossing the river, and a highway borders a large part of the site. The site is at a low elevation and there are no obstructions between the site and the river. In its existing condition it is already functioning as a floodable park space for Binghamton.

Figure 4.6: Sandy Creek Park

6. Northeast side of Susquehanna

The Northeast side of the Susquehanna River is undeveloped except for a railroad corridor. It contains the Chamberlain creek outlet and is bordered by highway and commercial corridor. The site is at low elevation and contains no floodwalls or levees.

In its current state it already functions as a floodplain area for Binghamton, flooding naturally due to river expansion.

Figure 4.7: Northeast Side of the Susquehanna

The railroad crossing both of these underdeveloped sites is the largest constraint for redesigning either of these areas for more community use. However, both sites provide major opportunities as floodable areas because they are largely undeveloped. There are no levees or floodwalls on either site, so the railroads are currently unprotected from large flood events. The best focus for these areas may be to allow them to continue as undeveloped floodable areas.

7. Industrial Corridor

As was mentioned in the section on low use areas (See Chapter 3), this corridor contains some vacancies and a lot of underused space. A major rail corridor exists within this corridor, along with North Shore Drive, a major road suggested for removal by Blueprint Binghamton (See Figure 3.8). This area is partially protected by a flood wall, is bordered by high and medium density residential development, and is very flat and at low elevation.

Figure 4.8: Industrial Corridor

The two largest constraints on this area are the large functioning railroad corridor and that the site contains most of Binghamton's industrial zoned land. In order to design this area as a floodable space, compromises will be necessary to protect railroad land when possible and areas designed with flood-proofed or relocated buildings for industry or commercial use.

The topography and current flooding patterns make this an area of high potential for floodable design. Location is also important. The central location of this area could provide a major point of connection between neighborhoods on the east side both north of and south of the Susquehanna. Designing both this area and area 3, Former Crowley Plant Industrial, would further strengthen the pedestrian network across the river. North Shore Drive, the highway proposed for removal by Blueprint Binghamton (See Figure 3.8), runs through this space on a raised platform. It could provide for interesting new design opportunities if converted from vehicular use. Many of the railroad tracks on the southern end of the corridor are raised as well, increasing potential to flood this space while avoiding track damage.

8. Binghamton Plaza

Binghamton Plaza is largely underused for the amount of space it covers. The main plaza still contains a few long standing businesses, including a Kmart, but the plaza and parking lot are largely unused. This area is bordered by a commercial corridor and high density residential development. The elevation is low, separated by the river by a levee.

Because of the location of nearby high density residential development and commercial properties, this site could provide an opportunity for flood resilient multiuse development. This area is also connected to downtown Binghamton through a riverside trail. The existence of this trail could encourage pedestrian support for the redesign of this space.

Constraints to redeveloping this area would include flood proofing or moving of commercial businesses and, most importantly, the existing brownfield under the plaza. Binghamton Plaza sits atop a former landfill closed in the 1940s and is scheduled for contamination cleanup in the near future (Khuu 2014). Because this site does not currently flood and contains a 1940s landfill, it does not seem to be an appropriate location to increase flooding.

Figure 4.9: Binghamton Plaza

9. Cheri Lindsey Park

Cheri Lindsey Park contains a variety of community amenities including a public pool, playground equipment, a dog park, a skate park, and a baseball field.

The amenities of the existing park could create both opportunities and constraints. For example, the existing skate park could create an interesting floodable space. However, the intensive programming of the site could create conflict of use if the site has too many alterations. This site is also directly next to Area 8, Binghamton Plaza, a former landfill. This would likely create environmental complications if encouraging more frequent flood events.

Figure 4.10: Cheri Lindsey Park

10. South of Downtown

This linear riverside area contains roadways, trees, and grass but no built area. Roadways include two traffic circles and the southern end of North Shore Drive, proposed to be removed by Blueprint Binghamton (See Figure 3.8). Just north of the west end of the site is Downtown Binghamton and northeast is high density residential. Prominent nearby structures include an arena used for sports and ceremonies, the South Washington Street Pedestrian Bridge, and Binghamton University Dormitories. This corridor is separated from the river by a flood wall and steep slope.

Because of its prominent location near the confluence of the Susquehanna and Chenango Rivers, this site has potential as a well-used floodable public greenspace. Pedestrian traffic of Arena visitors, Binghamton University students, area residents, and pedestrians crossing the South Washington Street Bridge would create frequent site visitors. A local park, Confluence Park, and a river walk also connect to the site.

A major constraint for allowing more frequent flooding of this area would be the often used roadways on site. Because of these roadways, regular flooding of this area would impede vehicular circulation. This area has been found to flood during major flood events including the 2011 flood (See Figure 1.3) and redesigning this area for flood resilience may be most appropriately reserved for large storm events without increasing flood frequency.

Figure 4.11: South of Downtown

Potential Floodability Treatments

Based on analysis and site observations the above areas have been categorized for their potential as floodable space using the following categories: floodable greenspace, floodable built, maintain as floodable, no flooding.

Areas determined as “floodable greenspace” will be designed as park/natural areas for community use. These areas may already be largely park areas in need of retrofits to allow more frequent flooding or they may be areas with low levels of development. Areas determined as “floodable built space” will be designed for flooding but may need to make necessary accommodations for necessary built structures or compromise losses of built structures to accommodate flooding. Potential built structure compromises could involve buildings, land uses, and roadways. “Maintain as floodable” areas will be areas already flooding with existing land uses already conducive to flooding. Areas determined as “no flooding” are areas that, based on the above, are not appropriate for flooding.

Table 2: Potential Floodability Treatment Table

Low Use Area	Floodability Treatment Criteria					Proposed Floodability Treatment
	Elevation	River Obstacles	Undeveloped	Some Development	Mostly Developed	
1. MacArthur Park Grounds	Low	Levee and highway	No	Yes	No	Floodable Greenspace
2. Pennsylvania Traffic Ramp	Low	Levee and highway	No	Yes	No	Floodable Greenspace
3. Former Crowley Industrial	Rises	Levee	No	No	Yes	Floodable Built
4. Pierce Creek Confluence	Low	None	Yes	No	No	Maintain as Floodable
5. Sandy Creek Park	Low	None	No	Yes, very little	No	Maintain as Floodable
6. Northeast S. River Edge	Rises	None	Yes	No	No	Maintain as Floodable
7. Industrial Corridor	Low/Rises	Some Flood wall	No	No	Yes	Floodable Greenspace/ Built
8. Binghamton Plaza	Rises	Levee	No	No	Yes	No Flooding due to Landfill
9. Cheri Lindsey Park	Rises	Levee	No	Yes	No	No Flooding due to Landfill
10. South of Downtown	Low	Flood wall	No	Yes	No	Floodable Greenspace

The following map illustrates the proposed floodability treatments determined by the Potential Floodability Treatment Table.

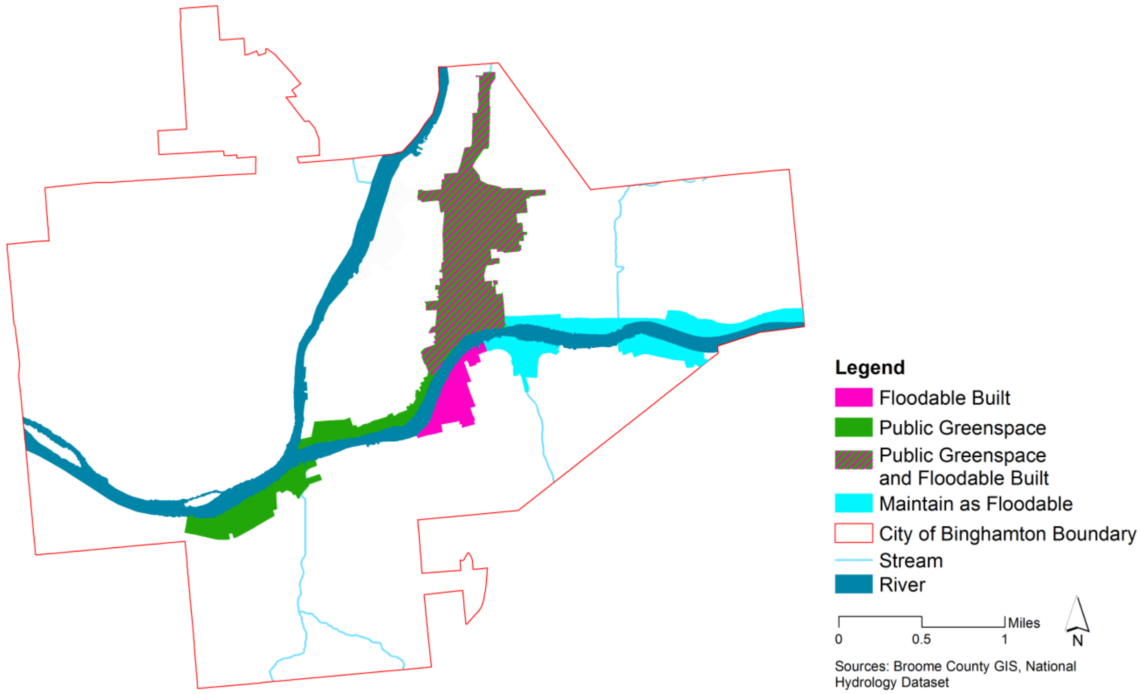

Figure 4.12: Proposed Floodability Treatment Map

In the above map, similar floodability treatments appear to be in close proximity, and sometimes directly adjacent, to one another along the Susquehanna River. "Floodable Greenspace" appears grouped around the confluence. "Floodable Built" appears just east of the greenspaces. "Maintain as Floodable" areas encompass both the north and south sides of the Susquehanna River on the eastern end of Binghamton.

MacArthur School Grounds (Area 1), Pennsylvania Avenue Traffic Ramp (Area 2), and South of Downtown (Area 10) have been designated as "Floodable Greenspace". Because MacArthur School Grounds and the Pennsylvania Avenue Traffic Ramp are directly connected, they may function well as a continuous floodable park, connecting the South side of Binghamton to the South Washington Street Pedestrian Bridge. If South of

Downtown was also developed as a floodable space, it would then connect to this park via the pedestrian bridge.

The Former Crowley Plant Industrial (Area 3) and the Industrial Corridor (Area 7) have been designated as “Floodable Built” areas and the Industrial Corridor is also designated as “Floodable Greenspace”. Both areas will need to be carefully examined and balanced to increase floodability while still allowing for some built structures on site. The large size of the Industrial Corridor could allow for different zones of use, creating a floodable community greenspace on the southern end of the corridor and floodable built spaces further north in the corridor.

. Pierce Creek Confluence (Area 4), Sandy Creek Park (Area 5) and the Northeast side of Susquehanna (Area 6) will remain as is, functioning as natural floodable areas. For this reason, they will not be addressed further in this thesis.

Current Flood Protection

In order to redesign these new floodable areas, it is important to examine how existing levees and flood walls influence flooding patterns on site. This was initially to be done through an examination of base flood elevation (BFE), the elevation reached during a 100 year flood event. Using this elevation, hypotheses of flood pattern changes with removal of levee or flood wall sections could be illustrated. However, many of Binghamton’s flood walls and levees no longer meet federal protection requirements, already flooding to the BFE despite existing structures(Federal Emergency Management Agency 2010). Because these sites are already flooding to the BFE with flood protection it will be assumed that removal of these structures would not affect the elevation reached during a 100 or 500 year flood event. The FEMA FIRM map excerpts below illustrate the new BFE delineations of the 2010 Flood Zone maps (See Figure 3.5). In these maps cyan dots indicate areas below the BFE and black dots indicate 500 year flood zone.

Areas Designated as "Floodable Greenspace"

1-2. MacArthur School Grounds and Pennsylvania Avenue Traffic Ramp

According to the map below, the majority of both the MacArthur School Grounds and Pennsylvania Avenue Traffic Ramp sites are at or below BFE despite an existing levee and floodwall.

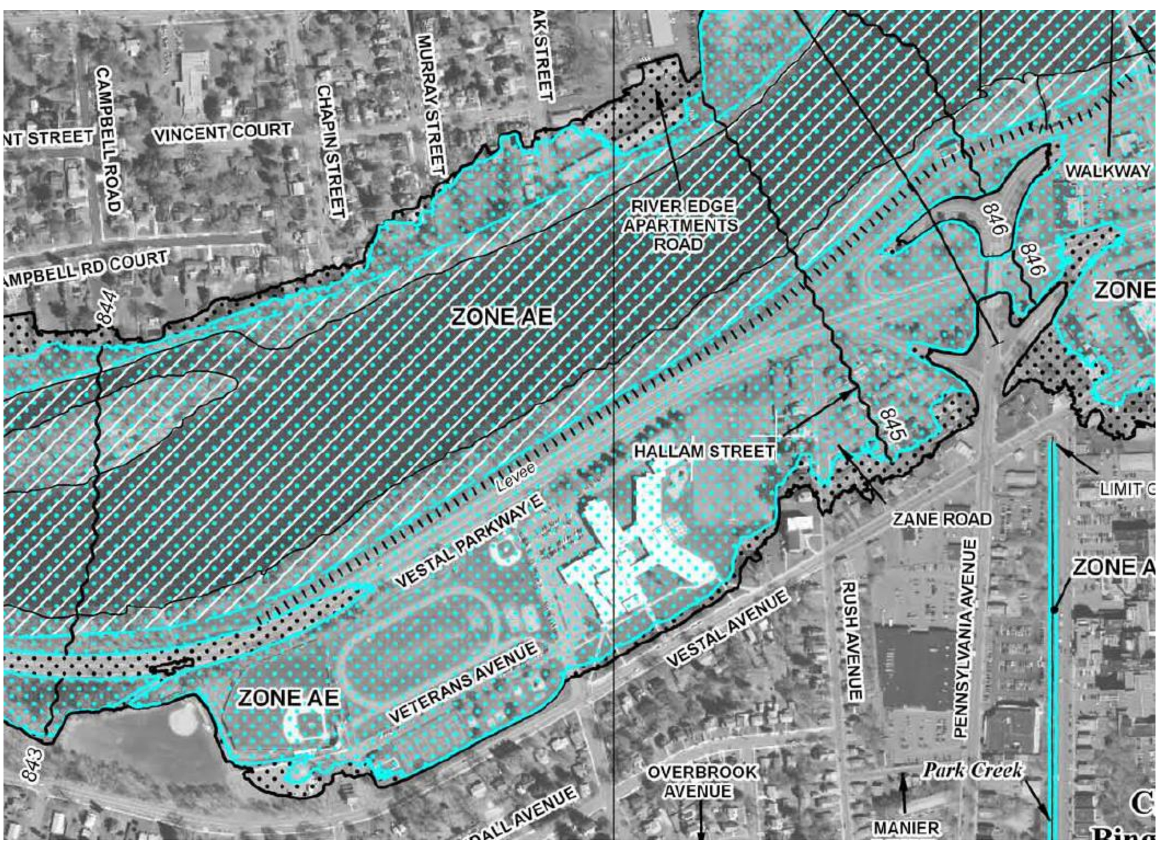

Figure 4.13: MacArthur School Grounds and Pennsylvania Avenue Traffic Ramp FEMA FIRM map excerpt (Risk Assessment, Mapping, and Planning Partners 2010)

10. South of Downtown

Aside from a few raised roadway sections, South of Downtown (Area 10) is completely below the BFE. This area is meant to be protected by a floodwall along the Chenango River and both a floodwall and levee along the Susquehanna River.

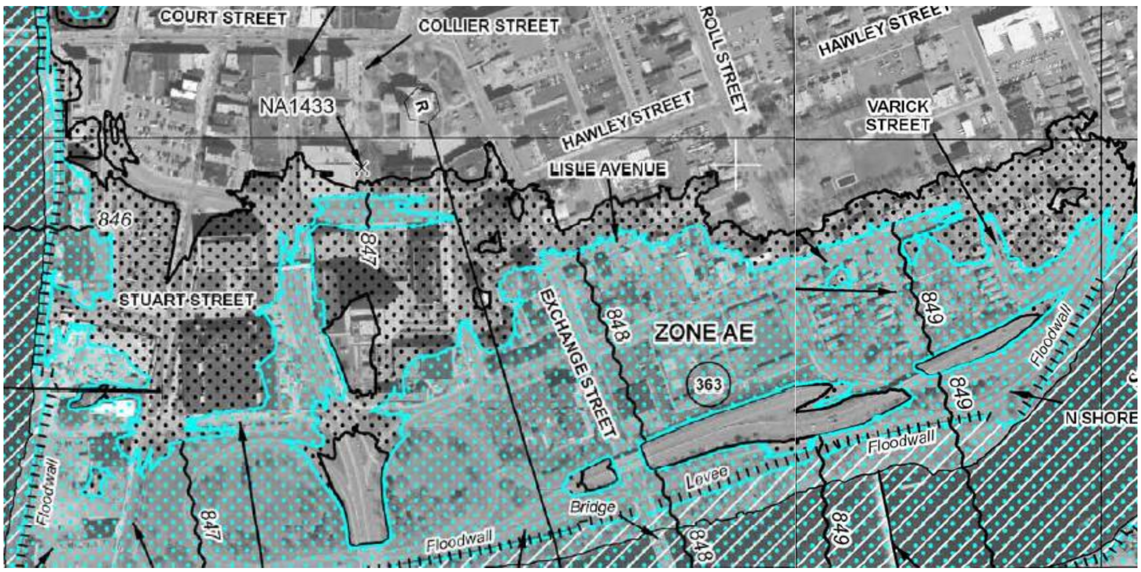

Figure 4.14: South of Downtown FEMA FIRM map excerpt (Risk Assessment, Mapping, and Planning Partners 2010)

Areas Designated as "Floodable Greenspace" and "Floodable Built"

7. Industrial Corridor

The FIRM maps created by FEMA contain pieces of the industrial corridor, Area 7, on two separate maps; therefore two excerpts are shown below. The first map encompasses the northern portion of the area and the second map the southern end. These maps indicate a large portion of the corridor is below BFE despite an existing floodwall. It can also be observed that the majority of the railroad corridor appears to be above BFE, though still within the 500 year flood event.

Figure 4.15: North Industrial Corridor FEMA FIRM map excerpt (Risk Assessment, Mapping, and Planning Partners 2010)

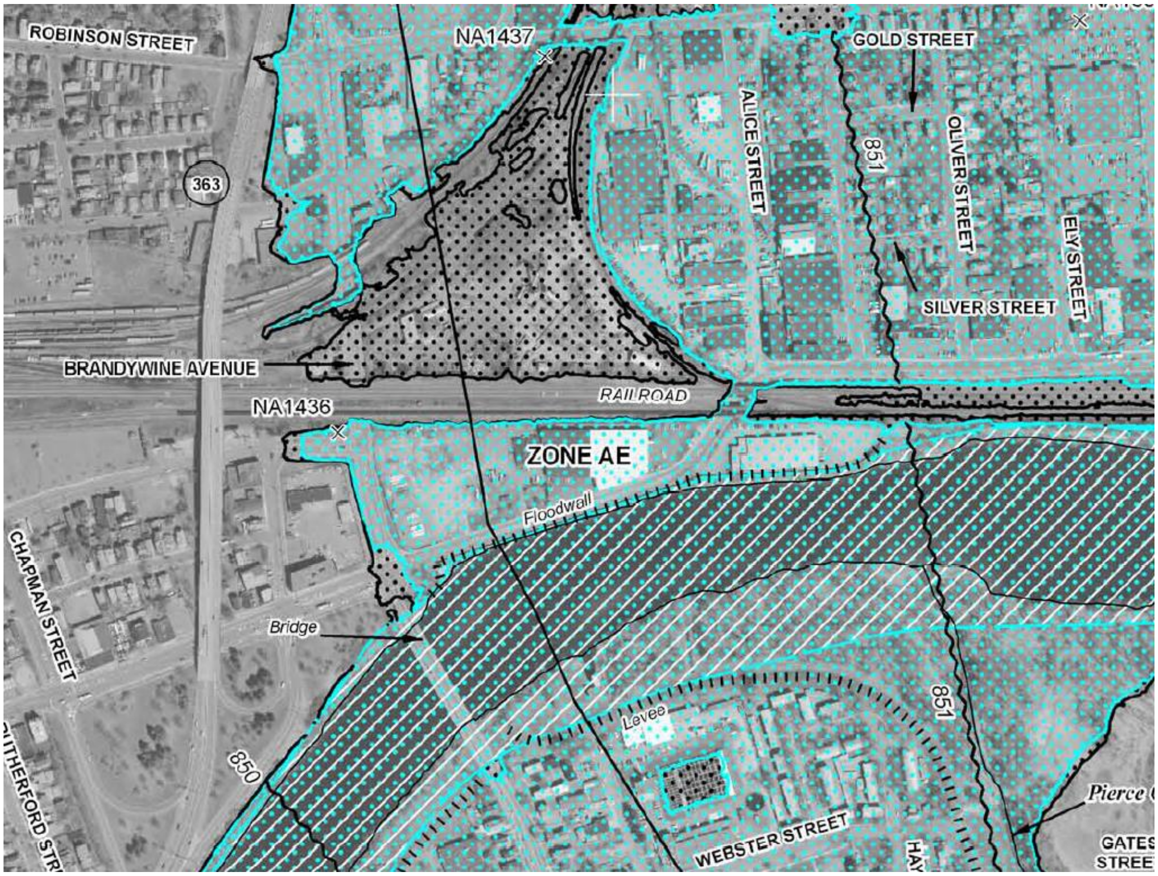

Figure 4.16: South Industrial Corridor FEMA FIRM map excerpt (Risk Assessment, Mapping, and Planning Partners 2010)

Areas Designated as "Floodable Built"

3. Former Crowley Plant Industrial

According to the map below, the majority of Former Crowley Plant Industrial, Area 3, is below BFE and no longer protected by the existing levee.

Figure 4.17: Former Crowley Plant Industrial FEMA FIRM map excerpt (Risk Assessment, Mapping, and Planning Partners 2010)

River Flow Direction

One limitation of this study is that because a modelling program, such as HEC-RAS, was unavailable the effect of velocity on the low use areas of focus was not able to be properly accounted for. Some assumptions and hypotheses can be made as to flood velocity, but accurate measurements cannot be made. For instance, velocity tends to be higher closer to the stream and slower as distance increases (Federal Emergency Management Agency 2009). To further hypothesize stream velocity, a thalweg was drawn on each river. A thalweg is the path of maximum water velocity, which responds to bends in a river (Petts and Amoros 1996).

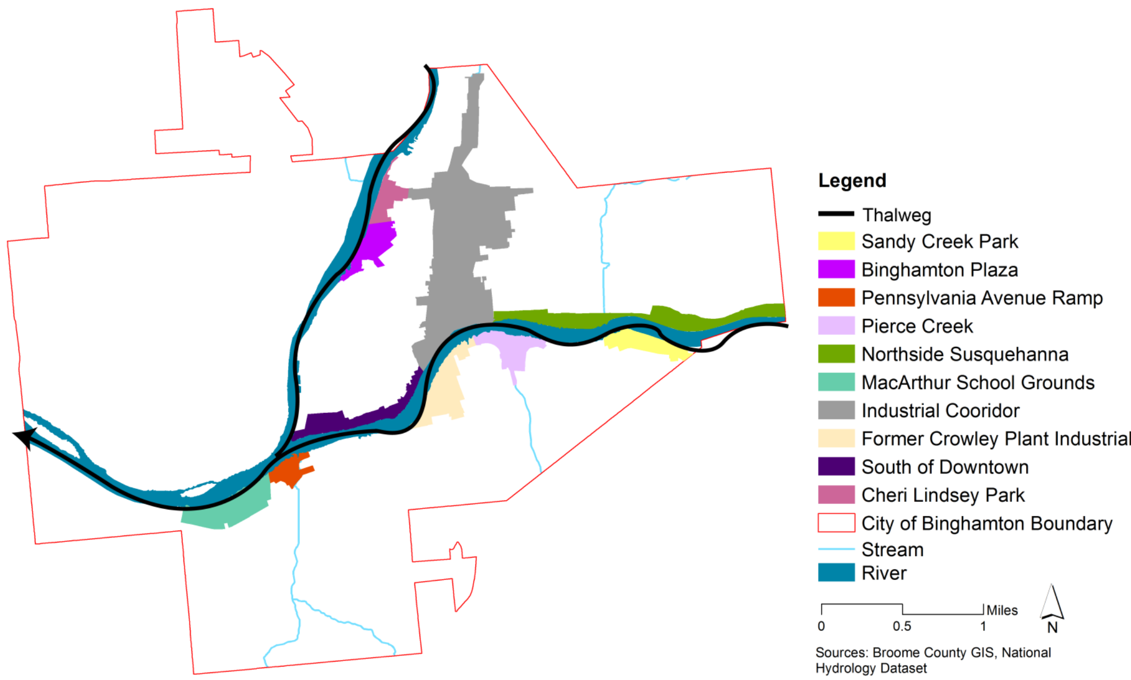

Figure 4.18: Hypothesis of Thalweg Patten in the Susquehanna and Chenango Rivers

Conclusion of Floodable Area Identification

This chapter has identified three areas as existing floodable natural areas, three areas appropriate as "Floodable Greenspace", one area appropriate as "Floodable Built", and one area determined as both "Floodable Greenspace" and "Floodable Built". The next chapter will choose two design areas with different designations in order to explore and test the feasibility of implementing these new floodable spaces.

CHAPTER 5

Flood Resilient Design (Projective Design)

In order to further examine the potential of floodable space in Binghamton, two sites have been selected for hypothetical implementations of floodable technology. These sites have been chosen due to a high level of contrast in the extents of development on site. The designs will explore the extent to which flooding can increase, how it might occur, what conflicts with land use may arise, and how these floodable spaces can function as a public amenity. Based on these designs I hope to discover the feasibility of reducing use conflict in floodable areas, how they might possibly function, and what major challenges may arise in their designs.

The first site was selected to represent potentially low conflict between existing land use and floodable technology. This site, Floodable Design 1, consists of the MacArthur School Grounds, Area 1, and Pennsylvania Avenue Ramp, Area 2. This site was chosen because it largely lacked built structures and forested area. Because it is already largely park space, this design would be a park retrofit project with a low level of land use conflict. Program requirements of this retrofit would allow flood events below the height of the levee on to the property, locating a new school building, and preventing the site's increased flooding from negatively impacting adjacent properties.

The second site, Floodable Design 2, was selected to represent potentially high conflict between existing use and floodable technology. This site consists of the

Industrial Corridor, Area 7. This site was chosen because of its abundance of built structures and hypothesized high potential for land use conflict. The Industrial Corridor is much larger than the MacArthur School Grounds and Pennsylvania Avenue Ramp site, which may lead to more diverse use of spaces. Railroads and roadways crossing occur on multiple planes within the site, which may provide unique opportunities and constraints for the layout of the design.

The flood resilient infrastructure examples presented in Chapter 2 did not appear to distinguish the type of sites redesigned. Some appeared to be largely open space retrofits, like Floodable Design 1, but others appeared to be located in built areas in cities, like Floodable Design 2. These two contrasting sites were chosen to examine how redesigning for flood resilience of a site with higher potential for conflict may or may not contrast with a lower conflict area to see whether the idea is equally attractive in both scenarios.

Floodable Design 1: MacArthur School Grounds and Pennsylvania Avenue Ramp

To begin this design, I assessed the site's existing program elements, when these are regularly used, whether they could be relocated, and how they would likely interact with flooding. The Pennsylvania Avenue Ramp has little conflict if removed according to the Blueprint Binghamton comprehensive plan (See Figure 3.8), but the MacArthur School Grounds, containing more program elements, has a higher potential for conflict.

Table 3: Potential for Programming Conflict with Uses of MacArthur School Grounds

Existing Program Element	Time of Regular Use	Ease of Relocation	Conflict with Flooding
School Building	Year-round including summer programs	School has been demolished, Relocation possible	High potential for damage and high disruption of use
Nature Trail and Natural Area	Year-round during nice weather	Relocating natural area would take an unreasonable amount of time and effort	Low potential for damage and temporary disruption of use
¼ Mile Track	Year-round during nice weather	Relocation possible	Low potential for damage and temporary disruption of use
Soccer Fields	Year-round during nice weather	Relocation possible	Low potential for damage and temporary disruption of use
Playgrounds	Year-round during nice weather	Relocation possible	Low potential for damage and temporary disruption of use
Basketball Court	Year-round during nice weather	Relocation possible	Low potential for damage and temporary disruption of use
Tennis Court	Year-round during nice weather	Relocation possible	Low potential for damage and temporary disruption of use
City Pool	Mid-June to September	Relocation possible but would require new excavation	Low potential for damage and temporary disruption of use
Baseball Fields	Year-round during nice weather	Relocation possible	Low potential for damage and temporary disruption of use

According to the above table, most site program elements are used year-round during agreeable weather, are flexible to relocation, and have a low potential for damage with only temporary disruption of use due to flood events. The city pool and natural area are the two elements which would be challenging to relocate and should remain in their current locations. The school building is the only element with high potential for damage and high disruption of use during flooding. A building would usually be considered difficult to relocate, but this school was demolished after the 2011 flood, with plans to rebuild on site. Building location must be chosen carefully to reduce damage and disruption potential and will be the first design element considered in the below design.

Locating a School on a Flood-prone Site

My first question when addressing the relocation of the school building was: Does the recently demolished MacArthur School building in fact need to be rebuilt on the site? According to a study conducted by the City of Binghamton and FEMA, which studied 6 alternative locations for the new school, the answer is yes (Federal Emergency Management Agency 2012). Of the other potential school sites within range for the school zone, all were considered unsuitable based on steep slopes on or leading to the potential areas. Since the school closed in 2011, students have been attending local Catholic Schools, but this temporary solution has been determined an inadequate solution by the city (Binghamton City School District 2013).

Rebuilding MacArthur Elementary on this property requires particular criteria for its building location. The school building must be protected from flood damage in some way, whether from flood-proofing the structure or raising the structure on natural or artificial topography. The building would require parking for cars and buses, ADA entry compliance, a loading dock, and a fire truck accessible route. A series of hypothetical locations to build are located below. These maps use the 100 and 500 year flood zones and topography of the site to assess the buildings relation to flood damage potential, parking potential for cars and buses, ease of creating ADA compliant entry to the building, potential for a truck access to a loading dock, and the ease of emergency vehicle access.

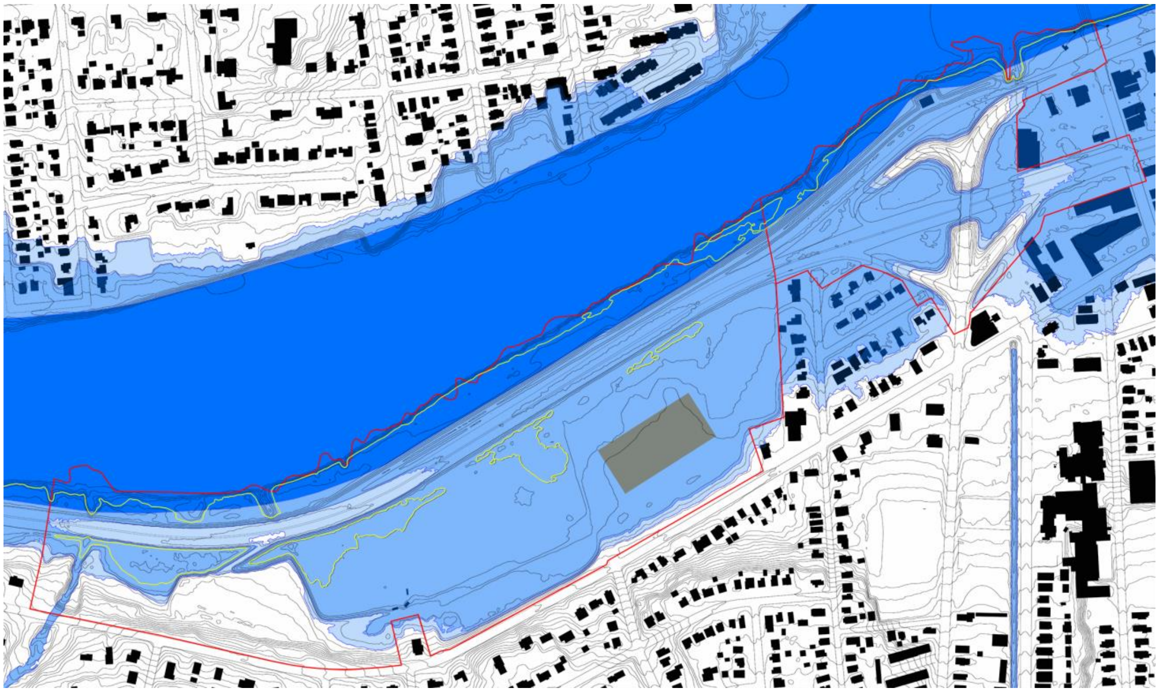

Figure 5.1: School Location Alternative 1: Rebuild at previous location

The original building location, indicated in the above map by an orange rectangular area, has a reasonable slope for vehicular circulation and plenty of space for parking, ADA compliance, a loading dock, and emergency vehicle access. However, this site falls far below the 100 year flood zone. To build here would require one of the following three options: intensive re-grading to elevate the building which would decrease floodable area on- site; allowed building flooding during large flood events which would be costly and impede use of the building; or a flood-proofing which would protect against damage but still render the building inaccessible during flood events. The accessibility of this building when not flooding would make this building site optimal if not for the extreme level of conflict during flood events.

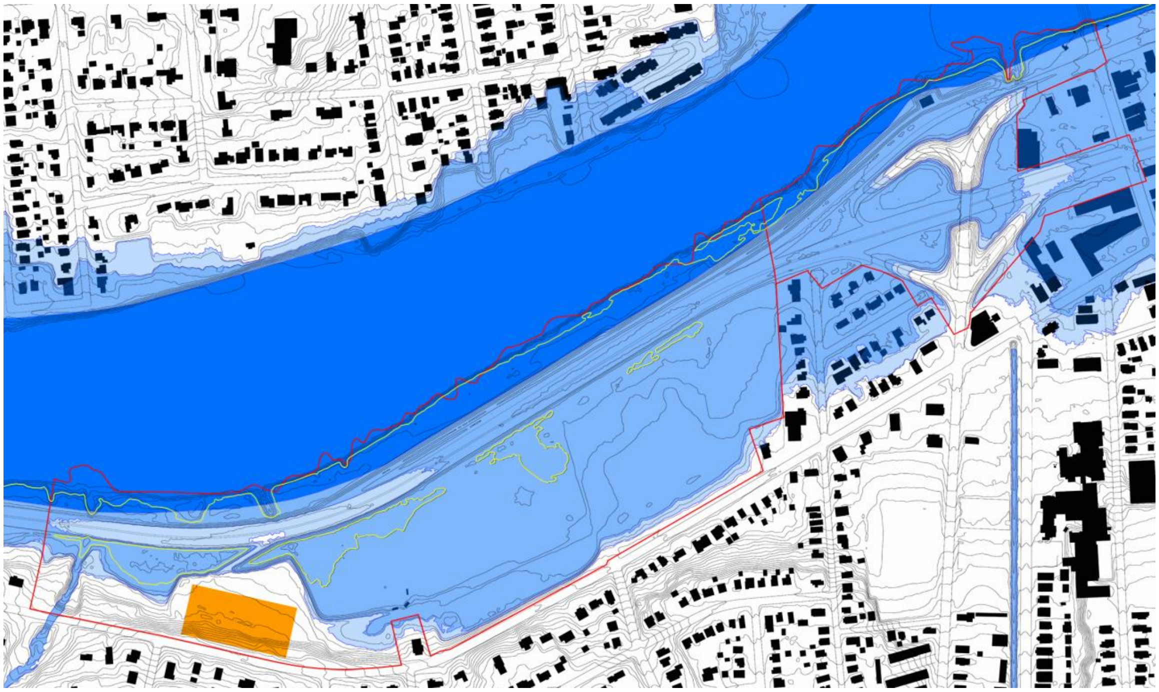

Figure 5.2: School Location Alternative 2: Build on land above the base flood elevation

This location is the only area within the school parcel that is not within the 100 or 500 year flood zone. Because of this it seems to be a logical site for the new school building. The topography of the site, however, could create problems of access. The elevated area is small and is bordered by steep slopes on all sides. A smaller building footprint could be designed, but the steep slopes render this site largely inaccessible to vehicles, including delivery trucks and emergency vehicles. ADA compliance could prove to be difficult as well. This would be a good location for the new school building considered alone, but when accounting for additional circulation needs around the building, the location is not as promising.

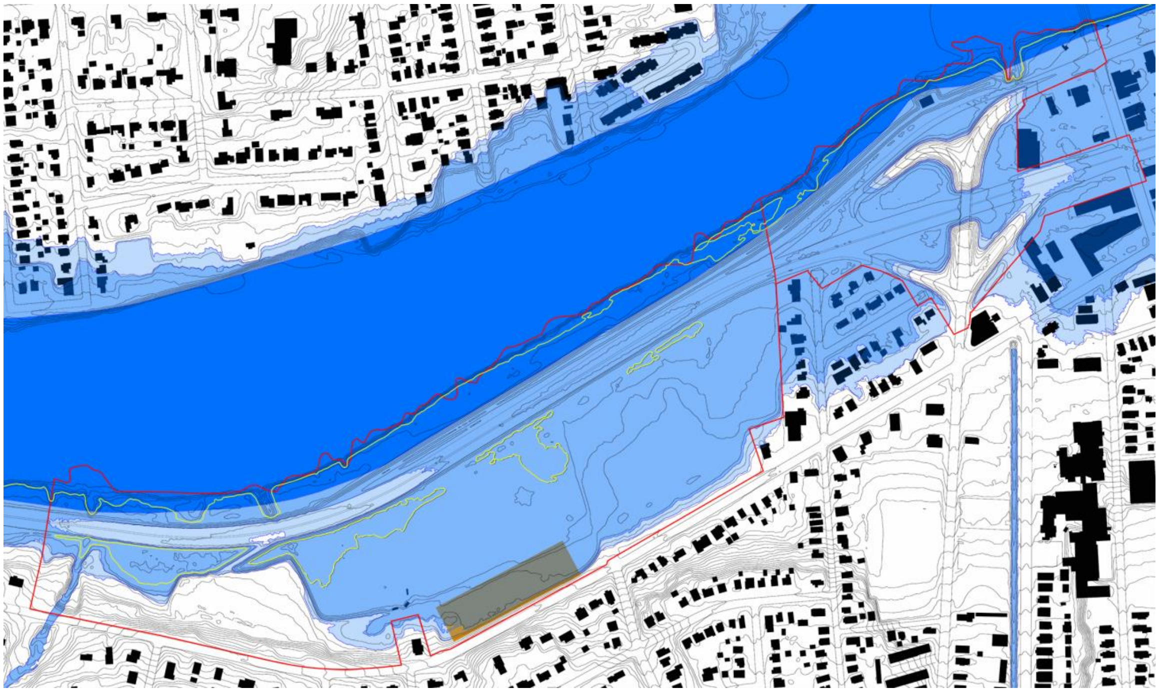

Figure 5.3: School Location Alternative 3: Rebuild toward the road in center of the site

School Location Alternative 3 is located along the road in the center of the site. Slopes are reasonable for vehicular circulation and emergency vehicles and there is space for parking and deliveries. This building location is within the base flood elevation, but is slightly higher than the original elevation, reducing the fill necessary to elevate the building. This building location does seem promising, but would involve the removal and relocation of a city pool, tennis courts, and playground. The city pool is one of the site program elements that were previously determined to remain in its current location. This building site could possibly work for the new school location considered alone; however it would require the relocation of many of the site's program elements.

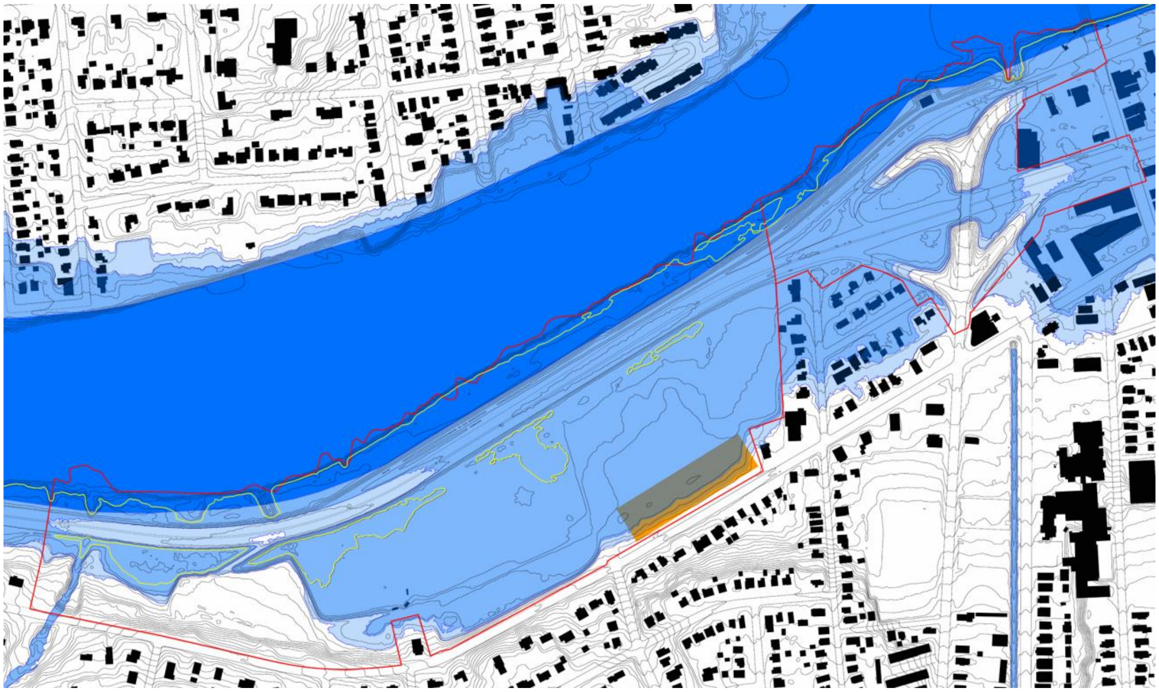

Figure 5.4: School Location Alternative 4: Rebuild toward the road on the east edge

This site is close to the original building location, but closer to the road. Like the original location, this site has reasonable slopes for vehicular circulation and emergency vehicles and plenty of space for parking and deliveries. This location is still within the 100 year flood zone; however, like alternative 3, it is at a higher elevation than the original location reducing the fill necessary to elevate the building. Locating the building here would require less fill than alternative 3, due to higher elevations extending further down the site, and this location would not require relocation of program elements.

Proposed School Location

School Location Alternative 4 would be the best location for the new school building. This conclusion has also been reached by the firms hired to redesign the site. Construction began on the MacArthur School property in January 2015 with a building design by Ashley Mcgraw Architects and landscape by Appel Osbourne (Appel Osborne Landscape Architecture). This design has also chosen to locate the building closer to the road near the original location, the location of Design hypothesis 4. Below is a site schematic plan by Appel Osbourne. This plan incorporates the school parcel site only and does not address the adjacent park parcel.

Figure 5.5: MacArthur School Site Schematic Plan by Appel Osbourne (Appel Osborne Landscape Architecture)

Increasing Flood Events

In order to increase flood events at this site, a method of getting water past the levee must be devised. Based on the new FEMA FIRM map (See Figure 3.5), the 100 year flood overtops the levee, but data is not available for more frequent flood events. Overtopping the levee in Binghamton occurs only during large flood events. Because of this, the water would need a way through the levee to allow the site to flood more often. Below are a series of options to allow water on to the site more often. These diagrams represent the usual river stage of the Susquehanna River along the levee, according to a comparison of 2 foot contours with aerial photographs. A 4’ rise in water level is necessary for water to begin flooding the design area. The selection and final solution for increasing flood frequency would need to be determined by specialists in hydrology and engineering along with the Army Corp of Engineers.

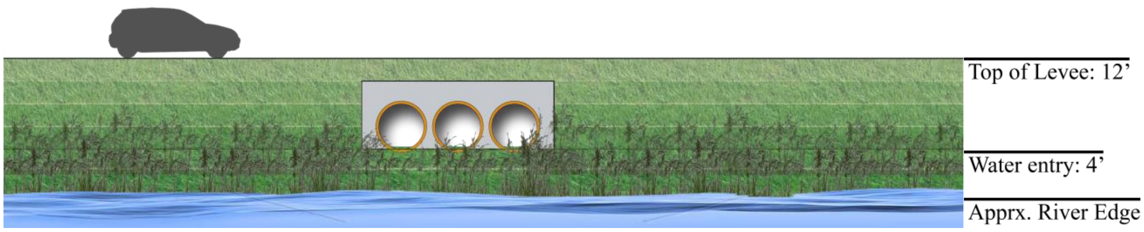

Figure 5.6: Pipe culvert design

Allowing water entry via pipe culvert would likely be the most cost-efficient method. This method would have the lowest maintenance and installation costs.

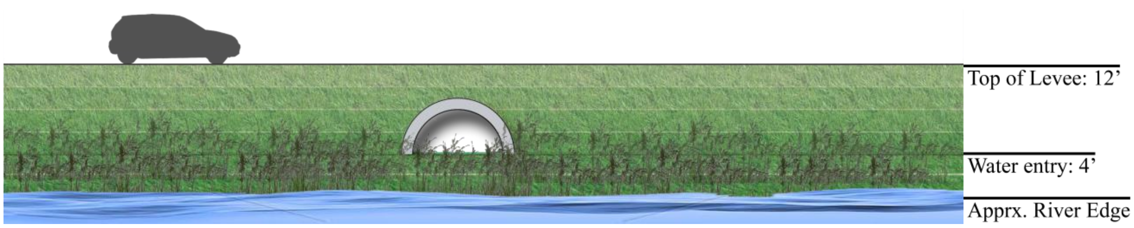

Figure 5.7: Open bottom culvert design

An open bottom culvert would also be fairly cost-efficient depending on size. The open bottom design could have ecological benefits and encourage wildlife use.

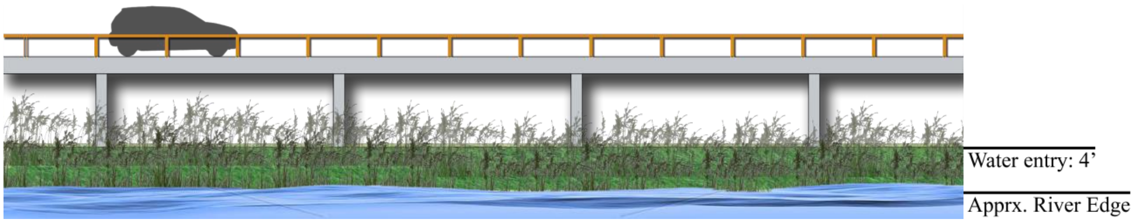

Figure 5.8: Bridge design

Partly or completely removing the levee and supporting the highway as a bridge is likely to be the most expensive option. This design would encourage wildlife use and allow for the easiest transition between the river and floodplain. A bridge could also be designed to fit the character of existing nearby bridges.

Figure 5.9: Low Points for Potential Levee Openings

If an option is chosen which is applied at only one or two points, and not continuously along the levee, it would be best to choose site low points for frequent water entry. Above, the site has been analyzed based on elevation to determine the lowest points on site. Two potential entry areas are indicated by arrows as the lowest points on site. Locating culverts in these locations would allow the most frequent flooding with the lowest level of river-side grading.

Controlling Flooding

One requirement of this site is to protect adjacent properties from increased flooding, while introducing frequent flooding on the site. The eastern end of this site, below the 100 year level, is adjacent to a residential area which extends into the site boundary. This residential area floods during the 100 year flood event, but still receives protection from the levee to the same level as the eastern end of the site. If the levee is breached, this residential area would also flood more often. Removing these residences is not an option under my floodable area conditions (See Table 1) and homes of the residents may not be adequately prepared for more frequent flooding, so the area must be protected in some way. A small levee around these residences would prevent more frequent flooding of the area, while also connecting the park property to the traffic ramp property. The levee would be designed to maintain the current level of protection to residents, which does not protect against the 100 year flood event. The possibility of raising the protection level above existing levels here or anywhere else in the city is outside the scope of this thesis.

To incorporate the levee into the floodable site design, I have designed the levee to function as a raised walkway from the park to the pedestrian bridge created from the removed traffic ramp. This design is meant to be multifunctional, not only preventing low-level flooding and connecting spaces, but also functioning as a small amphitheater for the school property.

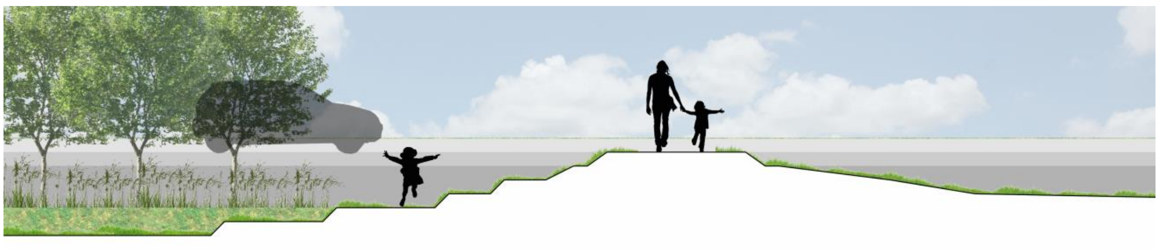

Figure 5.10: Cross-section of Levee during times without flooding

Figure 5.11: Cross-section of Levee during 12 feet above river stage flood

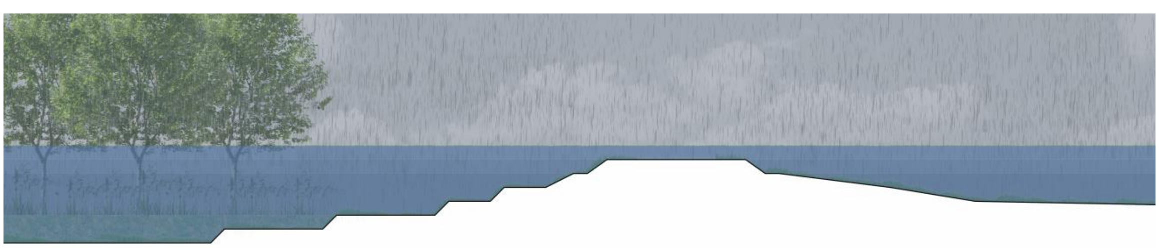

Figure 5.12: Cross-section of Levee during 100 year flood event (water level approximately 13 feet above river stage)

Conceptual Masterplan

The plan below incorporates the new school building location and levee designs mentioned above. This plan has been designed to accommodate more frequent flooding at site low points and the site programming hierarchy follows the previously determined flood conflict potential outlined in Table 3 above. The ¼ mile athletic track has been converted to a walking track, still providing the same benefits to community members who frequently use the track but allowing for flexibility of form. The soccer fields have been replaced with a recreational lawn with more topographic change for children's play. The pool, tennis courts, and playground remain in their original locations with the basketball court added to the area.

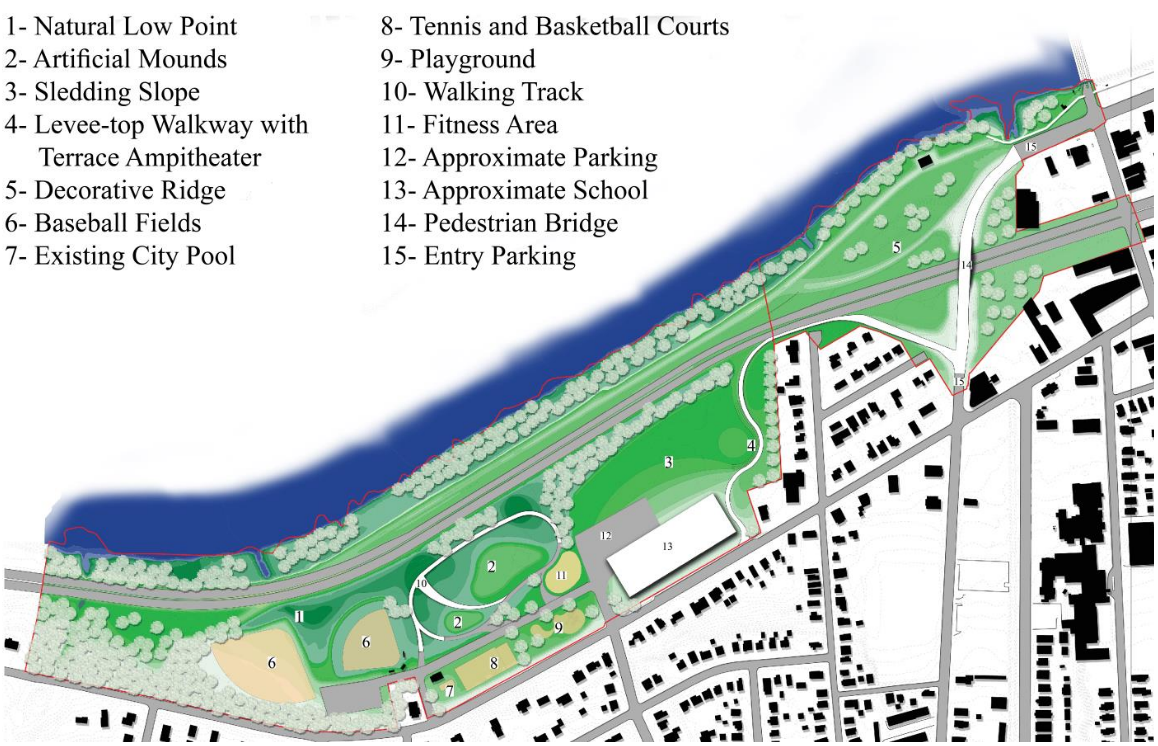

Figure 5.13: Floodable Design 1 Conceptual Masterplan

Flood Scenarios

Below is a series of 5 flood scenario hypotheses for the above design based on elevation change. This initial increment of 4 feet was chosen because a 4 foot rise of the river is necessary for river water to enter the site. Since data on flood heights for events occurring more frequently than the 100 year flood event were unavailable, the scenarios below are divided arbitrarily into increments of 4 feet for the purpose of illustrating more frequent flood events. These scenarios also provide the percentage of the site flooded during each event.

Figure 5.14: Floodable Design 1, 4ft above River Stage

The 4 foot flood event would flood the lowest areas of the site. Use would not be disturbed and water fluctuation could be easily observed from the walking track raised above the flooding. This scenario would flood 8% of the study site.

Figure 5.15: Floodable Design 1, 8 feet above River Stage

An 8 foot rise of the river would inundate the smaller baseball field, walking track, and wetland forest trees behind the school. Most site programming would not be affected by the flood event. Decorative mounds would remain above the flood surface, creating an interesting visualization of the flood event as waters rise or fall. This scenario would flood 28% of the site.

Figure 5.16: Floodable Design 1, 12 feet above River Stage

A 12 foot rise above the river stage would result in a high proportion of the site flooding. The residential area and school are still protected. This scenario would flood 44% of the study site.

Figure 5.17: Floodable Design 1, 13 feet above River Stage (Approximate 100 Year Flood event)

The 100 year flood event falls at approximately 13 feet above river stage. This event would flood most of the site. The levee protecting the residential area would no longer prevent flooding. This flood event would flood 70% of the study site.

Figure 5.18: Floodable Design 1, 15 feet above river stage (Approximate 500 year event)

The 500 year flood event is approximately 15 feet above the river stage. The school and large baseball field are the only program elements not flooded. This flood event would cover 84% of the site.

Safety is a concern for all schools, but a school in a floodable area may face more safety concerns. Of the 41 major flood events recorded in Binghamton's history (See Figure 1.1), 36 (88%) occurred during the school year. Assuming that these major flood events follow the pattern of flooding generally experienced in Binghamton, smaller flood events would flow onto the site as well if not for the levees. Flooded areas in close proximity to children could be a safety hazard and this would need to be addressed if allowing this site to flood regularly. This could be addressed by constructing fencing around the school and/or adjusting school programming during flood events to keep students indoors.

Floodable Design 2: Industrial Corridor

The industrial corridor differs from the first design as the area is currently protected by a flood wall instead of a levee. I propose removing this wall to create increased water circulation between the site and the river for this design. The floodwall is no longer functioning to prevent the 100 year flood event according to FEMA and a large portion of this site is considered 100 year flood event (See Figure 3.5). It is possible that a culvert draining a buried stream, Brandywine Creek, under or around the wall into the river has caused or decreased the function of this floodwall. The exact location of this culvert was not discovered in this research, but rising river water could naturally back up creek water through the culvert during flood events.

As with the first design, I will begin this design by assessing the site's existing program elements and hypothesize when these are regularly used, if they could be relocated, and how they would likely interact with flooding.

Table 4: Potential for Land Use Conflict with Flood Events of the Industrial Corridor

Existing Land Uses	Time of Regular Use	Ease of Relocation	Conflict with Flooding
Railroad Corridor	Year-round	Relocation of an active railroad would be difficult and expensive	Moderate potential for damage and high disruption of use
Major Roadways	Year-round	Relocation of active roadways would be difficult and expensive, though one large but deemed unnecessary roadways is proposed for removal	Low potential for damage and temporary disruption of use
Industrial Properties	Year-round	Relocation possible if railroad and highway access are still maintained	High potential for damage and high disruption of use
Residential Properties	Year-round	Possible	High potential for damage and high disruption of use
Commercial Properties	Year-round	Possible	High potential for damage and high disruption of use

The area is primarily industrial; however there are small patches of residential and commercial properties as well. Based upon the table above, this corridor has potential for flooding conflicts with all existing program elements. Since this area is currently flooding with no new plans to reduce flooding, the existing programming elements may not be the most beneficial uses for the area.

Reducing or removing existing program elements

To restate the analysis of Binghamton's job industry as reported in the 2014 comprehensive plan (Blueprint Binghamton 2014), industry is not believed to have a major role in Binghamton's economic future. Binghamton was built upon industry, however today's most promising economic ventures lie in health care, social assistance, professional and business services, education, accommodation, and food services. Because industry does not appear to be the future of Binghamton's economy, I have made a qualitative decision to hypothetically reprogram much of this corridor for non-industrial community uses which may be better suited to regular flooding.

Relocation to existing higher ground is an option for active businesses and residents of the corridor. Industrial programming could be retained along the railroad where elevation is higher, relocated north of the site boundary along the railroad, or on the west side of town where large areas of vacant non-flooding industrial buildings exist. Residential properties could be relocated along the border of the area where land is higher, adjacent to existing neighborhoods. Commercial properties could also be relocated along the border in non-flooding areas, connecting to existing commercial areas or relocated off the site in other commercial districts.

Reprogramming the site

This industrial corridor is located over a large expanse east of downtown. The corridor currently serves as a barrier between multiple neighborhoods and downtown Binghamton. Reprogramming this site could create new community connections, making this corridor a central meeting place instead of a large industrial barrier.

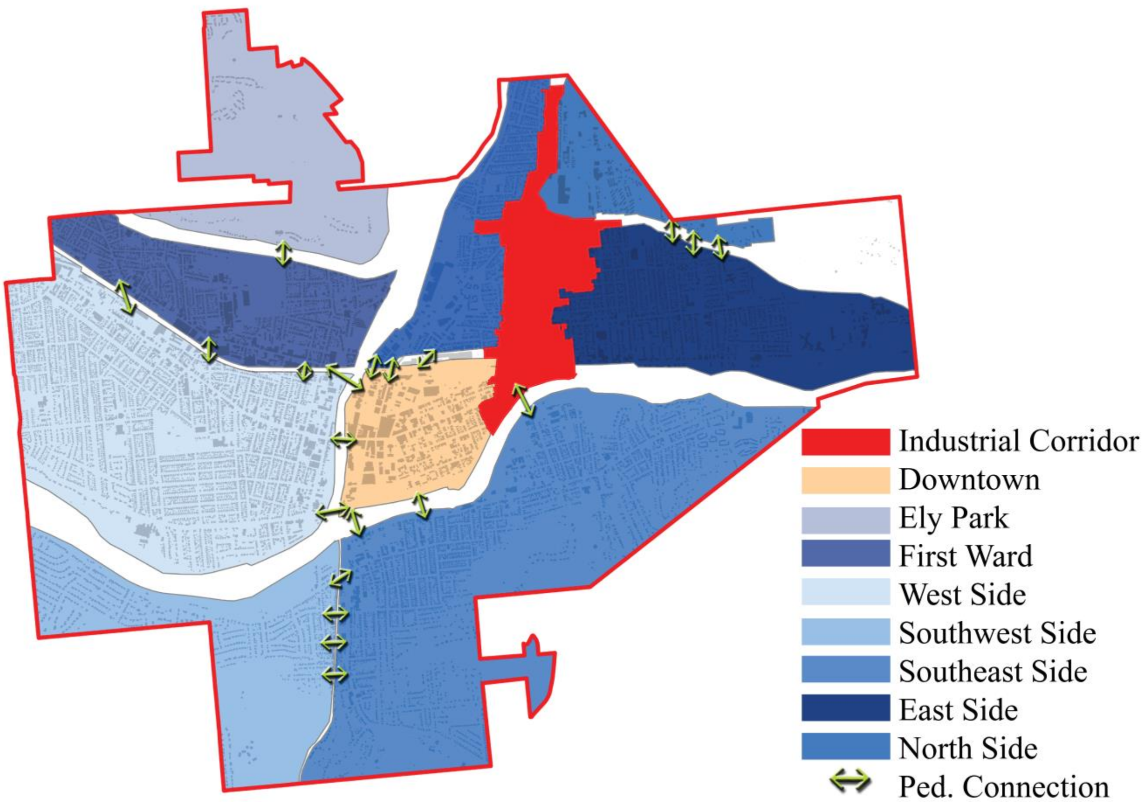

Figure 5.19: Existing Connectivity between neighborhoods

Currently, both pedestrian and vehicular circulation exists within the corridor; however the pedestrian travel is not pleasant. The corridor is focused on vehicular circulation and, aside from the bridge connecting the south side to the corridor, little else has been done to improve biking access. For this hypothetical design, increasing public connectivity to the degree possible would be considered a benefit.

Figure 5.20: Existing connectivity within the corridor

Reprogramming the corridor

Reprogramming this corridor for greater connectivity and with resilience to flooding requires a new table of program elements. To create these new program elements, I drew upon my personal knowledge of the city and popular Binghamton events, potential natural features, and program elements used in Mill Race Park and Mill Creek Canyon Park, the floodable parks mentioned in Chapter 2.

Mill Creek Canyon Park and Mill Race Park both contain large grass areas and outdoor staging areas (Baird 2003, Michael Van Valkenburgh Associates N.D.). These program elements could be overlapping, allowing a grass lawn to function as space for those attending events. Outdoor events could include those of Binghamton University or Binghamton City School students, community charity events, festivals, and concerts of the Binghamton Philharmonic. The lawn space could also be used as open community space outside of events for informal recreation and as a central space to view fireworks. Firework events happen often during Binghamton Mets baseball games.

Popular events in Binghamton that could be enhanced by this corridor include 5K charity events, First Friday Art Walks, and the Farmers Market. A 5K route within this corridor would allow a central space for charity races to occur, or start and end for longer races, within the city. The event space mentioned above would further support the events. When races are not occurring, this route could be utilized as walking or biking trails. Large outdoor art could also be displayed along these trails, supporting local artists and incorporating the First Friday Art Walks into the corridor. Many farms exist around Binghamton, but currently little space is available for a large Farmers Market within the city limits. Nearby markets do exist, but are either small and infrequent or not easily accessible without a vehicle. Including a pavilion and parking area in this corridor would allow for a large central market space as well as a covered alternative event space. A pavilion could also be designed as a floodable site feature.

Two program elements have been considered to activate the space on a daily basis. A playground is proposed to encourage parents and children to utilize the corridor and a beer garden is proposed to encourage college students and adults to use the area. A playground can be designed to be flood resilient, as in the above MacArthur design, and makes logical sense to include due to the surrounding residential spaces. This playground will need to be carefully designed to avoid direct contact with roadways, railroads, and open water. The beer garden could bring regular evening crowds to the corridor and would encourage connection between this corridor and nearby Downtown Binghamton.

In order to encourage river and floodplain health, two program elements have been proposed: a new wetland area and daylighting Brandywine Creek. The new wetland area would be located in the southern end of the corridor and could accommodate walking trails as well as holding excess floodwater, filter Brandywine Creek stormwater, and encouraging biodiversity. This wetland would also logically connect with the newly daylit Brandywine Creek outlet to the Susquehanna River. Brandywine Creek historically ran through the entire length of the Industrial Corridor but it is completely buried underground today. Daylighting the creek would create a public amenity and encouraging biodiversity. The image below shows an excerpt of a 1902 American Street Railway Investment Map (American Street Railway Investments Maps. 1901) which illustrates the former Brandywine Creek flow.

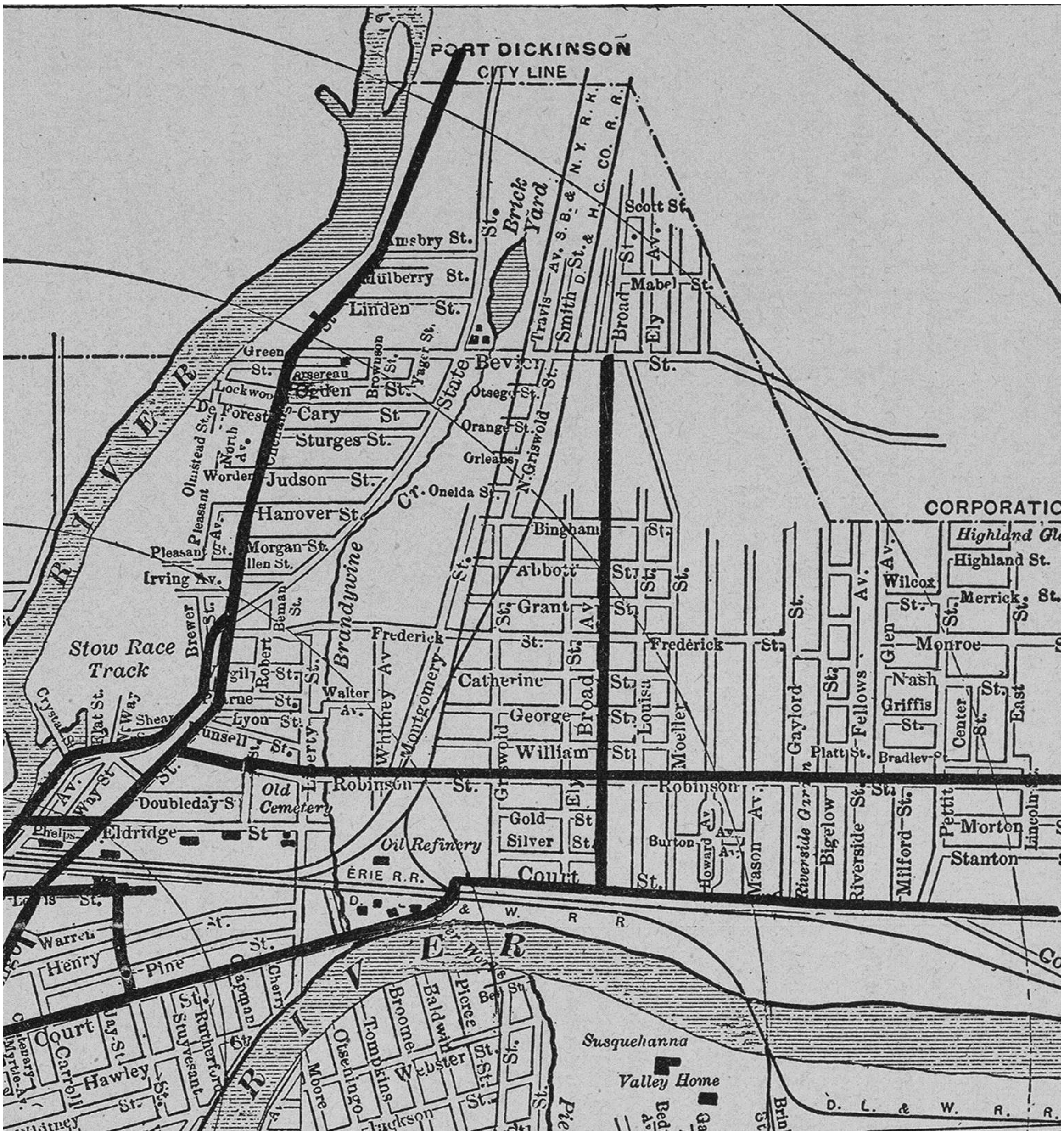

Figure 5.21: Excerpt of a 1902 Railway map showing Brandywine Creek (American Street Railway Investments Maps. 1901):

Potential Program Elements

The table below summarizes the new potential program elements described above while also analyzing their time of regular use and possible conflict with flood events.

Table 5: Potential Programming Elements and Flooding Conflict

Potential Program Element	Time of Regular Use	Conflict with Flooding
Railroad Corridor	Year-round	Moderate potential for damage and high disruption of use
Major Roadways	Year-round	Low potential for damage and temporary disruption of use
Relocated Industrial	Year-round	High potential for damage and high disruption of use
Relocated Residential	Year-round	High potential for damage and high disruption of use
Relocated Commercial	Year-round	High potential for damage and high disruption of use
Pedestrian Bridge	Year-round during nice weather	Low potential for damage and temporary disruption of use
Outdoor Concert Venue	Year-round during nice weather	Moderate potential for damage and temporary disruption of use
Lawn	Year-round during nice weather	Low potential for damage and temporary disruption of use
5k Loop	Year-round during nice weather	Low potential for damage and temporary disruption of use
Pavilion	Weekly	Moderate potential for damage and temporary disruption of use
Playground	Year-round during nice weather	Low potential for damage and temporary disruption of use
Beer Garden	Year-round	High potential for damage and high disruption of use
Wetland	Year-round	Low potential for damage and no disruption of use
Stream Restoration	Year-round	Low potential for damage and no disruption of use

According to this table, the highest programming conflicts would occur within the railroad corridor, relocated elements, and the beer garden. Because of this, these elements should be located on higher land or properly flood-proofed. The outdoor concert venue and pavilion may conflict with flood events as well. Materials, location, and careful design of built structures would reduce this conflict.

Sizing of a new park

Many of these new program elements are conducive to the creation of a park as resilient to flood events, but should this whole area be devoted to a park? At approximately 312 acres, this site would be a very large park. According to the National Parks and Recreation Association, the desired size of a community park provides 5 acres for each 1,000 people (National Recreation and Park Association). This would mean the optimal park size range may be approximately 230 acres, leaving 82 acres for other uses that could be reserved for uses less appropriate to flooding such as the railroads, relocated industrial, commercial, and residential, and major roadways.

Vehicular Circulation Change

Many of the existing roadways of the Industrial Corridor are included within the 100 and 500 year flood events. Decreasing flooding of these roadways during 100 and 500 year flood events is outside the scope of this study and will not be addressed in the upcoming design. However, a decision to allow continued flooding, or more frequent flooding if it would accompany flood wall removal, must be informed by examining roadway circulation. Flooding these roadways more often than the 100 year flood event could cause more disruption than the city is willing to tolerate. Court Street, Tompkins Street, and connections to Route 81 are the major concerns when investigating more frequent flooding to this area. Below are a series of roadway circulation alternatives for the corridor.

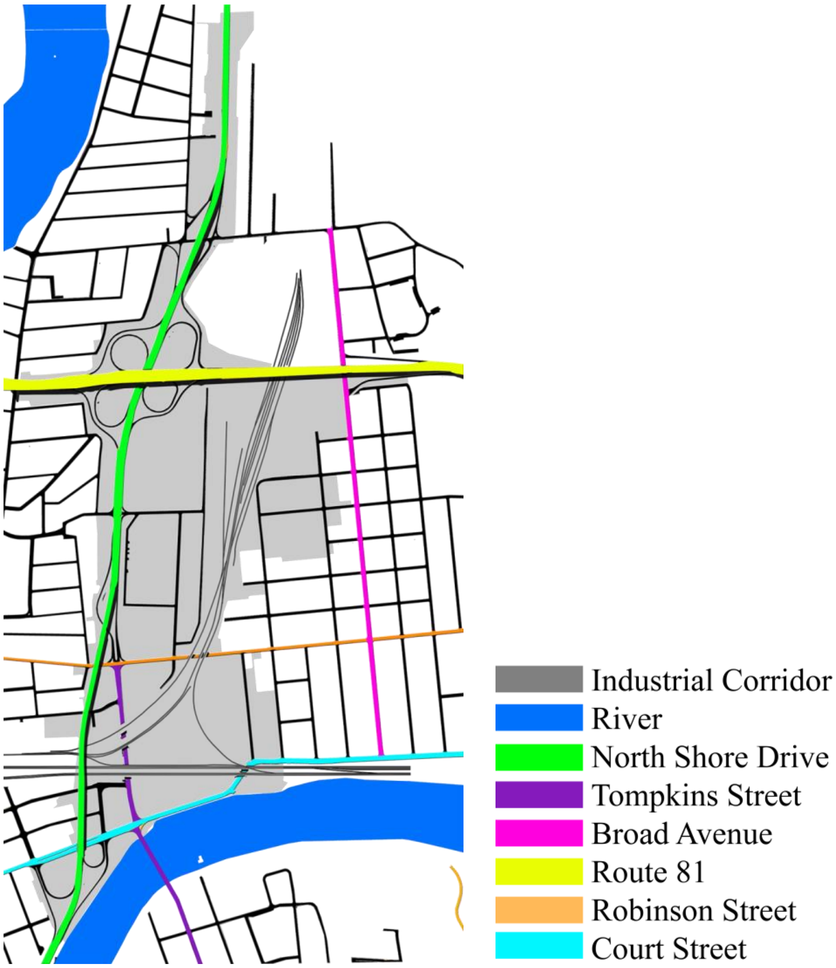

Figure 5.22: Circulation Alternative 1: Keep Roadways as is

If circulation is maintained as is, it would be very challenging to allow continued or more frequent flooding to the corridor without flooding certain roadways.

Court Street runs along the river, like the roadway in the previous MacArthur School design, but the road is not raised on a levee. Raising this roadway, allowing water to flow under the roadway, as in the MacArthur Design, is not possible because the height of Court Street is limited due to the underpass created by the existing railroad that Court Street travels under. If the river water was allowed to laterally expand into this corridor more often, Court Street, a well-used street, would be flooded more often as well. This would not only create circulation inconveniences but, if not properly monitored and closed for flooding, could create dangerous conditions for roadway users unaware of flood events.

Tompkins Street creates a challenge to the corridor redesign when considering daylighting Brandywine Creek. Brandywine Creek historically passed under the railroad where Tompkins Street currently passes (See Figure 5.21). To resolve this conflict, this road must be redirected or eliminated or else the creek must remain piped under this section of roadway.

Interstate Route 81 is a major roadway passing through Binghamton. It is important to maintain as many connections to this roadway as possible. Tompkins Street and North Shore Drive are the major roadway connections to 81 under existing conditions. Broad Ave exists as a secondary connector and Robinson Street could aid in alternative connections as long as flooding is not increased. The proposed pedestrian bridge in the new program elements for this site would repurpose North Shore Drive. This was proposed based on Blueprint Binghamton's roadway analysis which deemed the roadway unnecessary for Binghamton's population (Blueprint Binghamton 2014). However, if removing or flooding other connections to Route 81, North Shore Drive may again be necessary for vehicular circulation.

Local roads running within this corridor may be unnecessary with the new site programming. These roadways are currently used for circulation between buildings within the corridor. If these buildings are removed, they may be unnecessary and may impede new program elements.

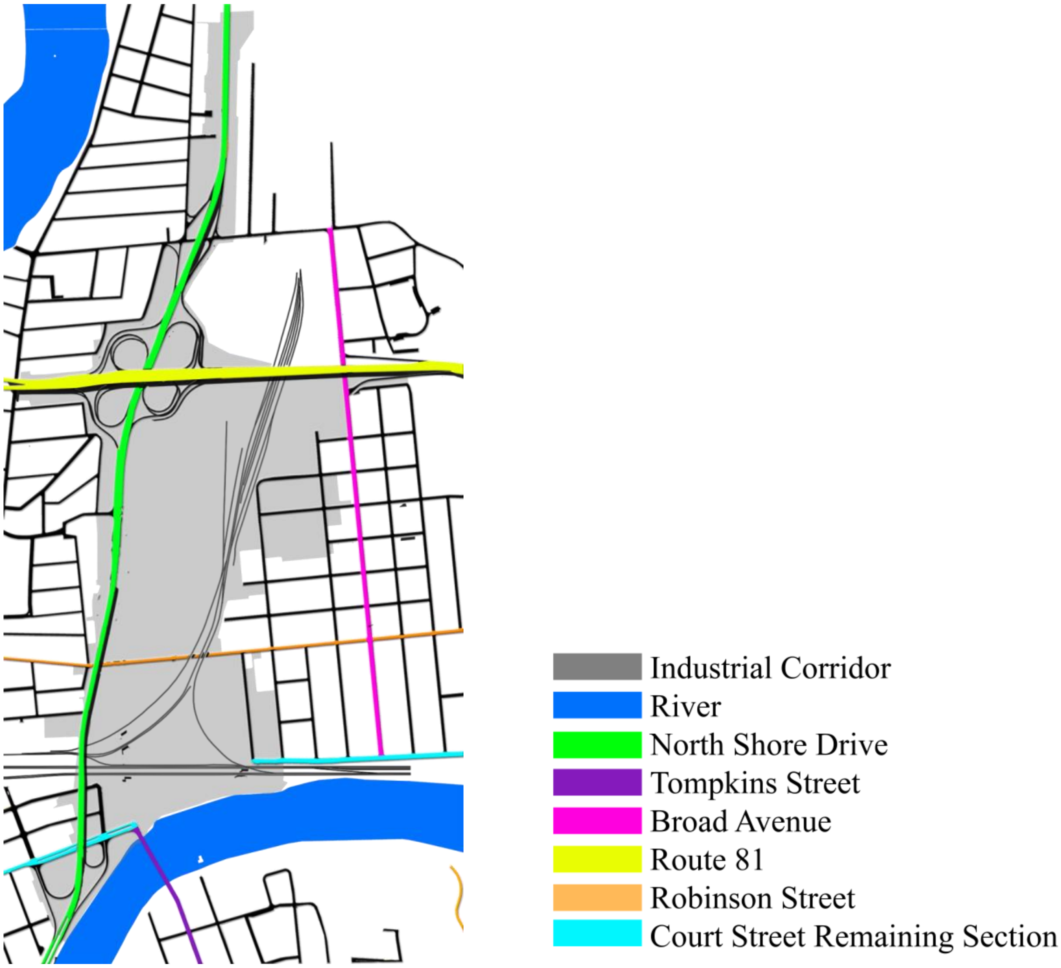

Figure 5.23: Circulation Alternative 2: Removing Court Street and Tompkins Street

This design eliminates the section of Court Street that would flood more often. In its place, users from the east could access Route 81 via Broad Ave and access travel west via Robinson Street. Tompkins Street has been removed north of the bridge, allowing bridge users to access Route 81 and downtown using North Shore Drive. With this design, travel directly east from the bridge is not an option. This design does not allow for North Shore Drive to be converted to a pedestrian bridge.

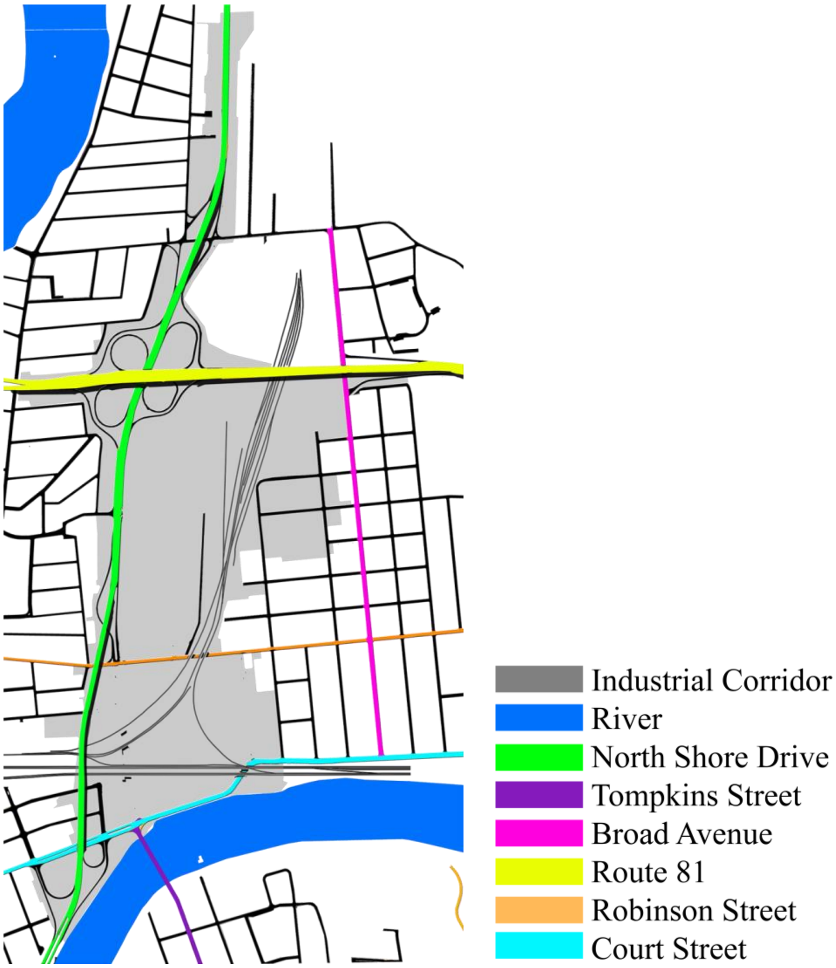

Figure 5.24: Circulation Alternative 3: Conserving Court Street and North Shore Drive Ramps

This design maintains all of Court Street, but would require excavation of land under the roadway to allow for more frequent flooding. This would allow water to flow onto the site under the roadway and would allow water to flow onto the site more often than it is able with the height of the current riverbank. Excavation could be very expensive and would require intensive erosion control. Tompkins Street has been removed north of the bridge but the ramp connecting Robinson Street and North Shore

Drive would be maintained, allowing access between them. North Shore Drive is still maintained for vehicular use in this design, connecting traffic to Route 81 directly.

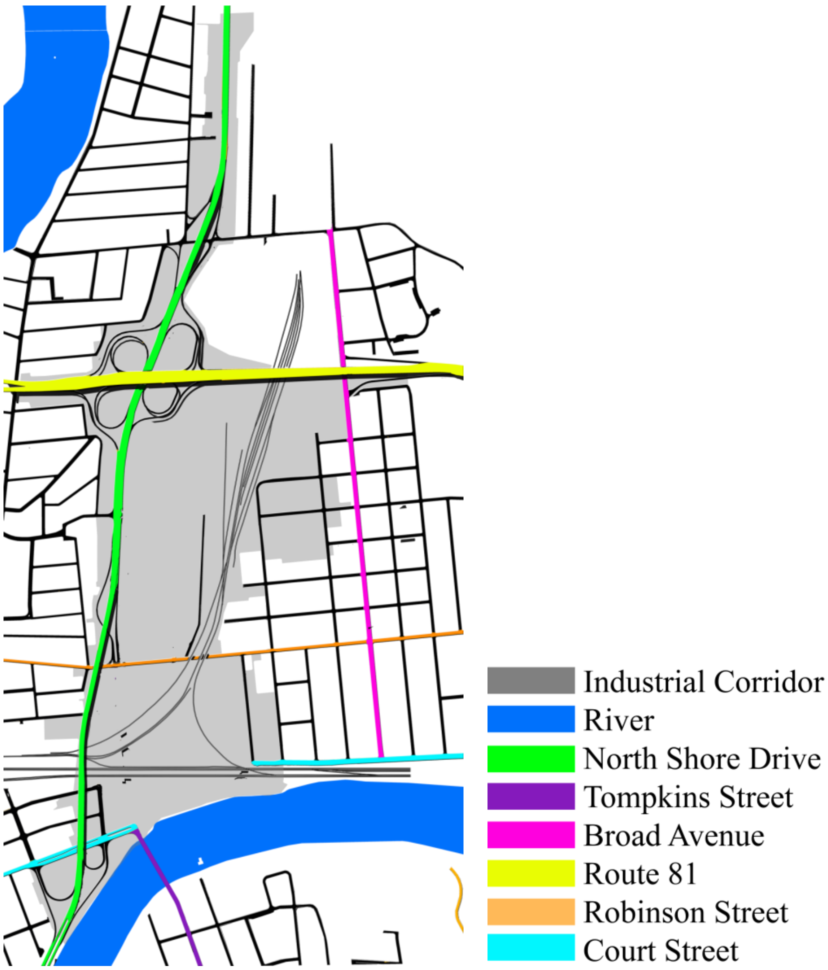

Figure 5.25: Circulation Alternative 4: Removing Court Street and Conserving North Shore Drive Ramp

This design is a combination of Circulation Alternative 2 and Circulation Alternative 3. The section of Court Street along the river, as in Circulation Alternative 2, has been removed, requiring vehicular circulation to use Broad Ave and Robinson Street for east-west circulation and access to Route 81. The ramp connecting Robinson Street to North Shore Drive is retained, as in Circulation Alternative 3, allowing a secondary access point between the east side, west side, and Route 81. North Shore Drive would remain open to vehicular circulation.

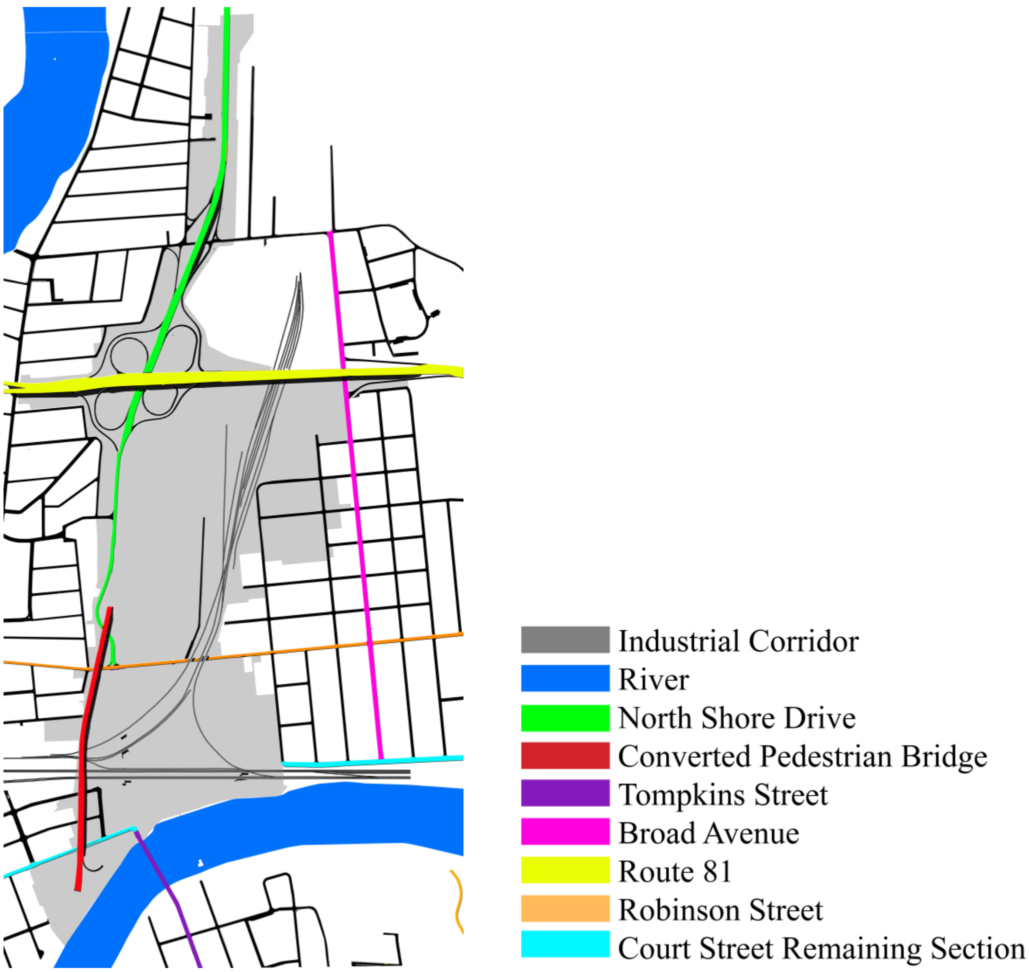

Figure 5.26: Circulation Alternative 5: Implementing Pedestrian Bridge

This design would eliminate a large section of Court Street within the corridor, requiring east west access via Robinson Street. Access to Route 81 on the east side could utilize Broad Ave and Robinson Street and would provide access from the west side. The bridge would connect to downtown Binghamton, but connection to the east side and

Route 81 would not be directly available. Converting North Shore Drive to a pedestrian bridge could allow easy travel over the railroad corridor for pedestrians, along with a unique viewpoint of the new corridor and the river. Another benefit of this pedestrian bridge conversion would be the available open space that would be created by disconnecting the southern ramp from the existing roadway.

Proposed Circulation Change

I have chosen Circulation Alternative 4 for the redesign of this corridor. I believe this alternative to be the simplest solution to prevent safety issues, maintain circulation, and allow for new site program elements. There will still be reduced ability for vehicular access through the site and redesign of connectors such as Broad Ave may be necessary to maintain appropriate traffic flow. Though vehicular circulation would be partially impeded, this design solution would provide many new benefits including daylighting of Brandywine Creek and allowing room for new proposed program elements. Though I hoped to utilize North Shore Drive as a pedestrian bridge, as in Circulation Alternative 4, removing the section of Tompkins Street north of the bridge creates circulation challenges best solved by North Shore Drive remaining open to vehicular traffic.

Conceptual Masterplan

The conceptual masterplan of this corridor contains the above roadway circulation and programming elements discussed. Because it is a large, complex site, it has been designed at a programmatic level, in contrast with the relative detail applied on the smaller MacArthur School site, allowing plenty of space for adaptation or addition of amenities requested by the community. Portions of the site have been designated for particular uses, such as the athletic fields, relocation areas, and picnic/garden space. I was unable to accommodate a full 5k track within the site and instead created a 1-mile north loop and 1-mile south loop which are able to be connected. This masterplan will be explained through a series of maps to better explain the design at this scale. The first map will be the full masterplan, followed by two program maps, and then two circulation maps.

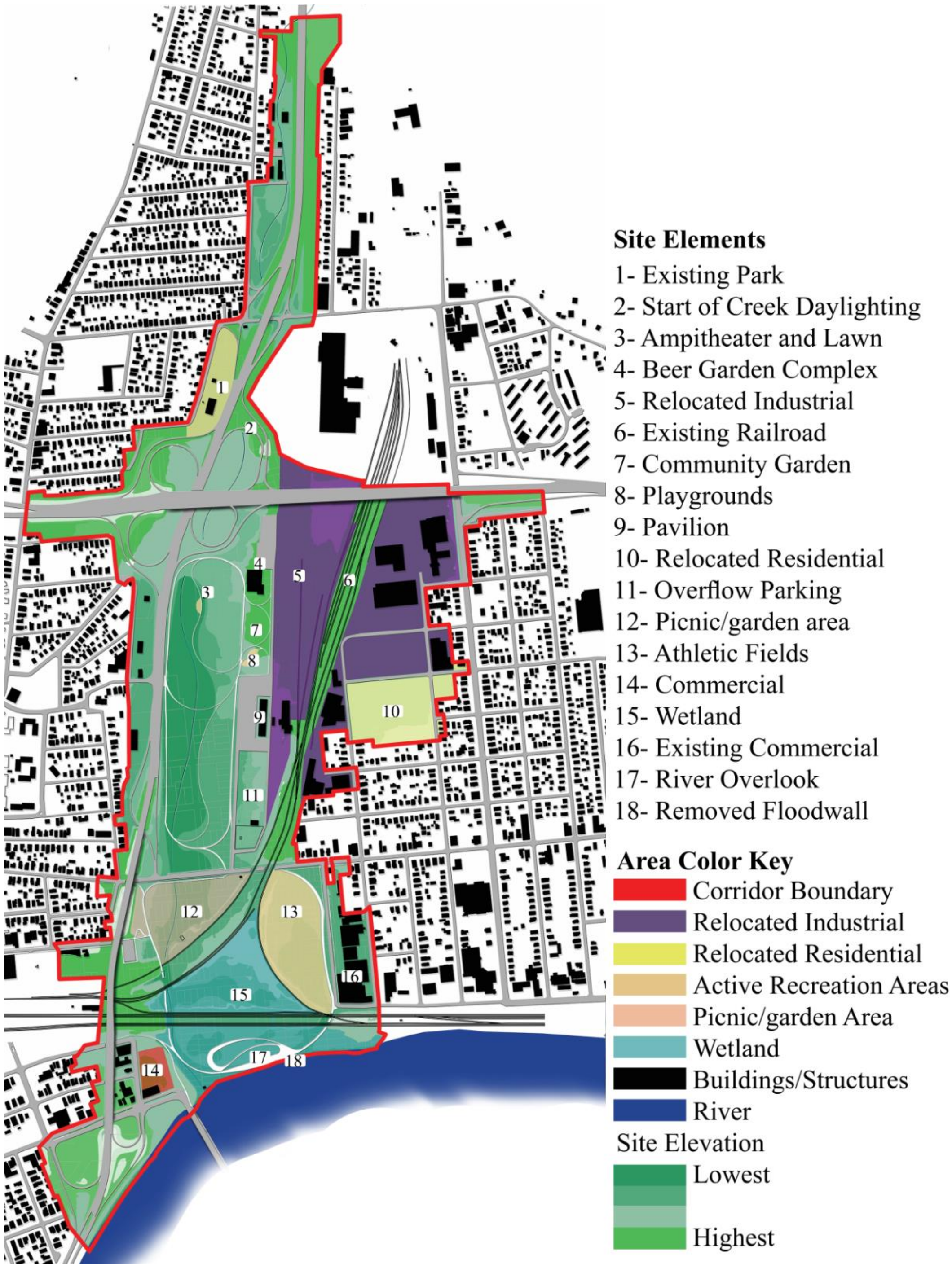

Figure 5.27: Floodable Design 2, Conceptual Masterplan

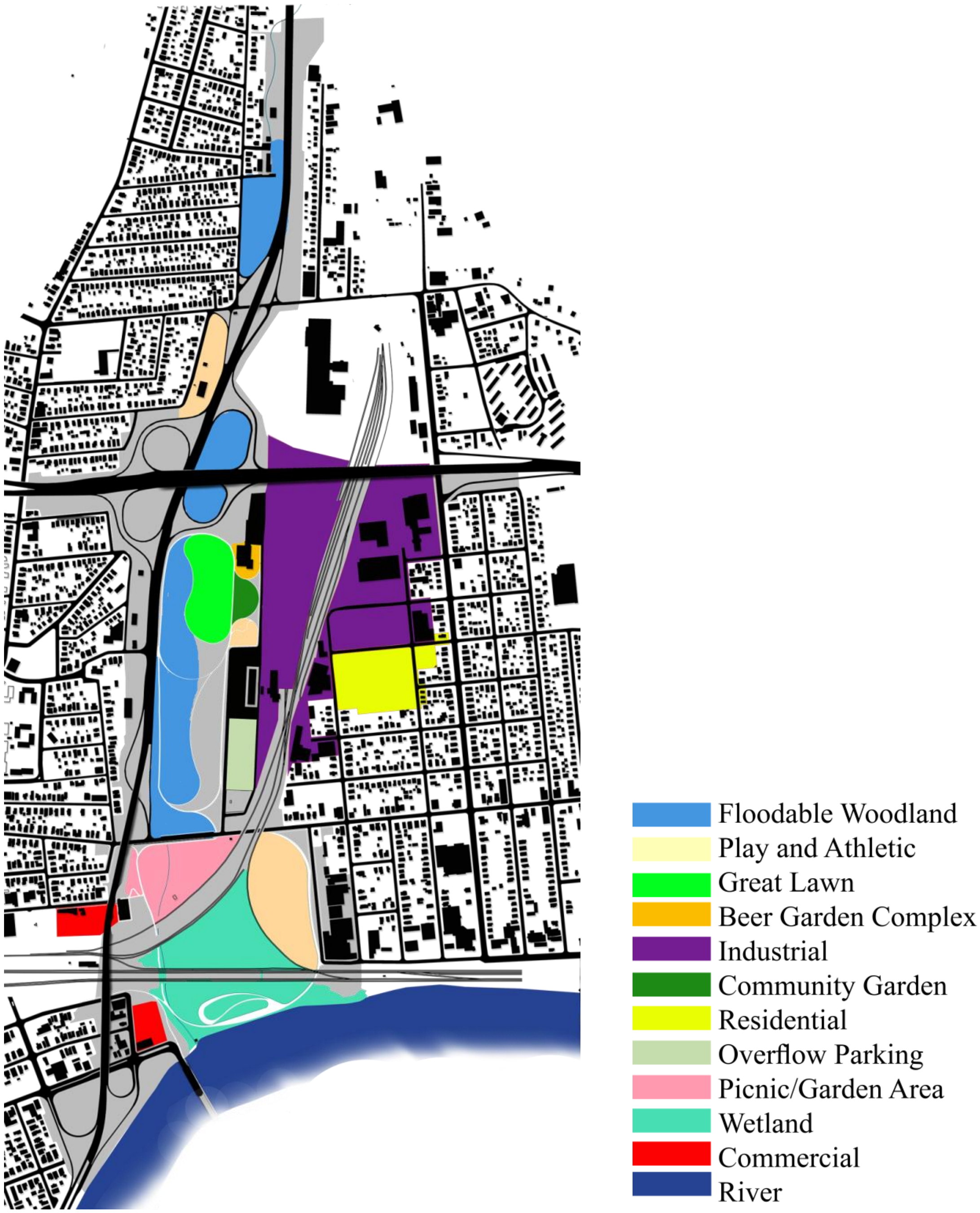

Figure 5.28: Floodable Design 2, Site Programming

The above map illustrates the proposed programming within the conceptual masterplan. High activity program elements have been grouped together on the eastern side of the site where elevation is higher.

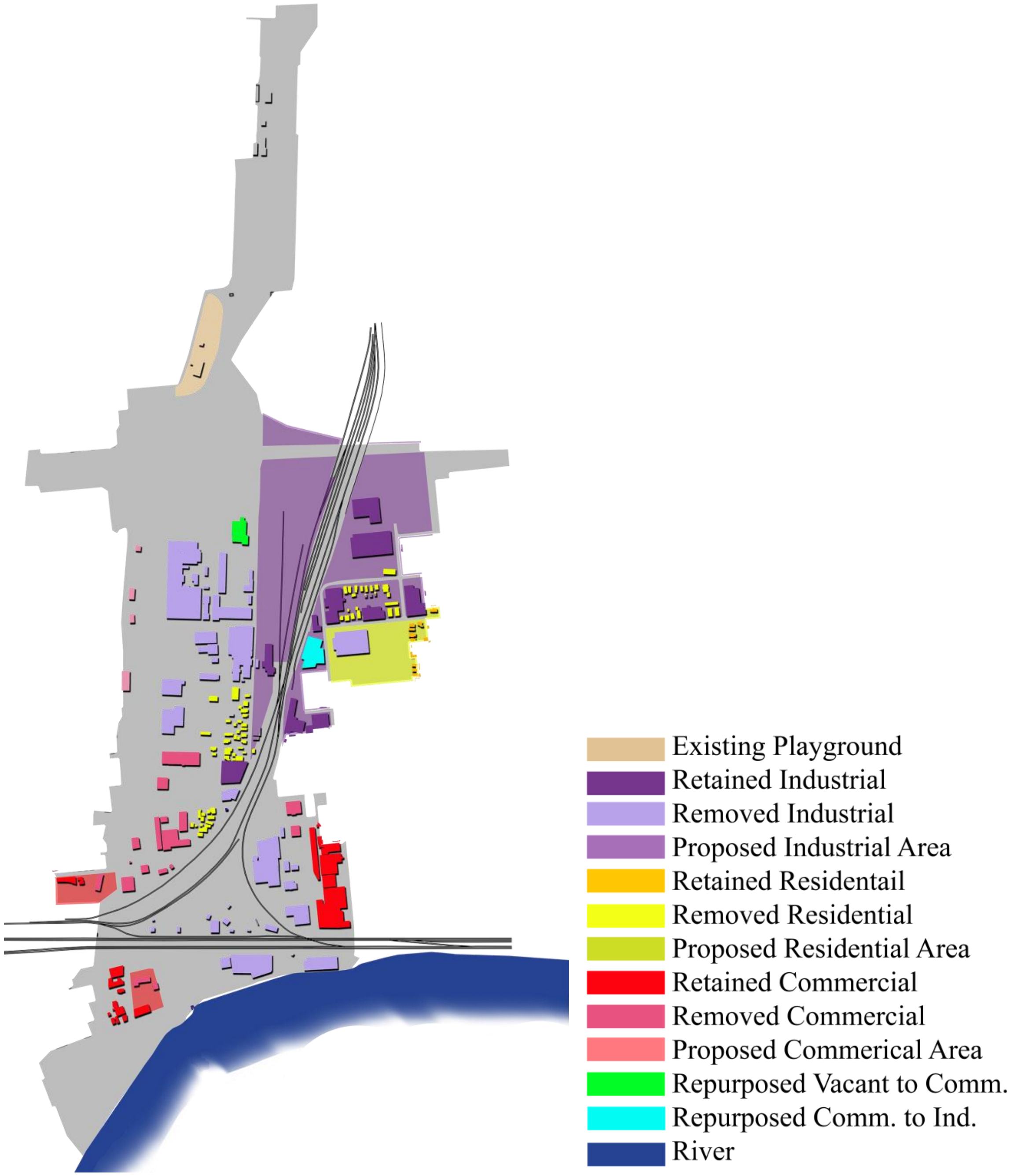

Figure 5.29: Floodable Design 2, Programming Change

The map above illustrates how use was changed within the corridor through existing structures. Though a large amount of the site was originally open due to previous parking requirements, extensive change was required to accommodate the new design and some uses will be required to be located completely off-site.

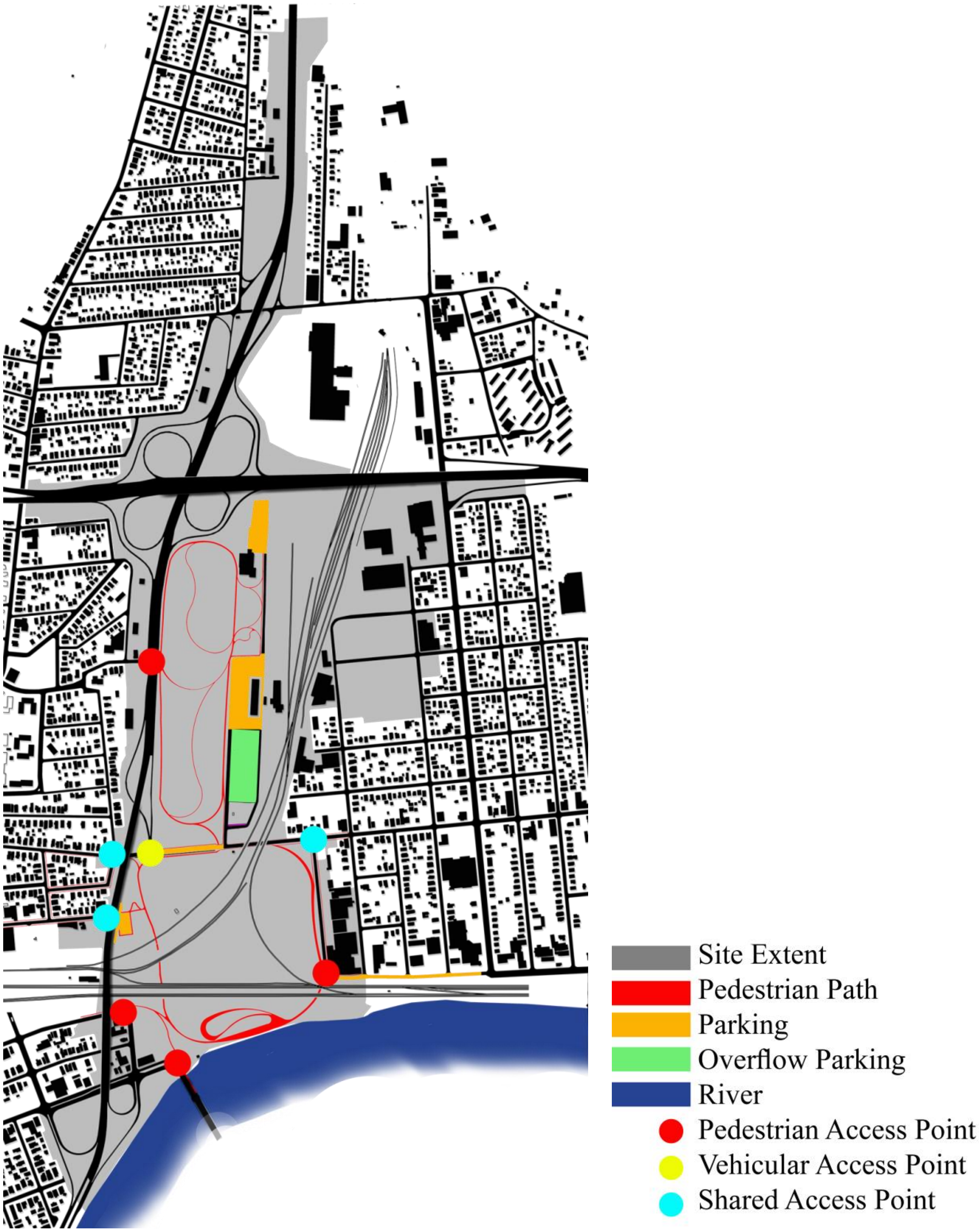

Figure 5.30: Floodable Design 2, Circulation Plan for Vehicles and Pedestrians

The above map shows the new vehicular circulation as well as new pedestrian circulation through the site. Vehicular entry to the site has been limited to the center of the site with alternative parking options along the Court Street pedestrian access point and within a secondary parking lot two blocks south of the primary west vehicular entry point. The beer garden complex and pavilion have been provided with parking lots and are located along the existing roadways shared by the industrial area which already are able to accommodate truck circulation. An overflow parking area has been designated just south of the pavilion parking for larger community events.

Figure 5.31: Floodable Design 2, Circulation Plan for Stream Daylighting and Wetland

A large portion of Brandywine Creek has been daylit within this corridor as close to the historic flow line as possible (See Figure 5.21). The creek is still piped underground in three locations on site to avoid conflict with road circulation. As the creek flows under the railroad tracks it will remain daylit, but may need to be channelized. A majority of the creek will be bordered by floodable woodland and the southern portion will intersect with wetland areas.

Flood Scenarios

Below are a series of flooding hypotheses for the corridor redesign based on site elevation. As in Flood Design 1, increments were arbitrarily chosen to illustrate flood patterns of different event levels. Daylighting Brandywine creek will also impact flooding, however the scale of this flooding would likely be minimal in comparison to the flooding created by the Susquehanna River and has not been included in the below hypotheses. Velocity would likely also impact flooding within this area and hydraulic modelling would be necessary to analyze these effects.

Figure 5.32: Floodable Design 2, 4 Feet above River Bank

Water rising 4 feet above the river banks would flood the lowest areas of the site. Use of the athletic area and picnic/garden area would be disturbed and water fluctuation could be easily observed from higher elevations of the site. A slight raise in elevation would be necessary to keep flooding from the southeastern commercial buildings. Depressions created within the wetland area would collect higher volumes of water. Circulation would not be impeded. This scenario would flood approximately 11% of the study site.

Figure 5.33: Floodable Design 2, 6 Feet above River Bank

A 6 foot above the river bank would inundate the athletic fields, parts of the walking trails, wetland, amphitheater, and portions of the pavilion parking and overflow parking. High conflict programming would not be affected by the flood event. This scenario would flood approximately 21% of the site.

Figure 5.34: Floodable Design 2, 100 year flood event (approximately 12 feet above river bank)

The 100 year flood event falls at approximately 12 feet above the river bank. This event would flood most of the site, excluding beer garden complex, pavilion, and relocated high conflict areas. This flood event would flood approximately 33% of the study site.

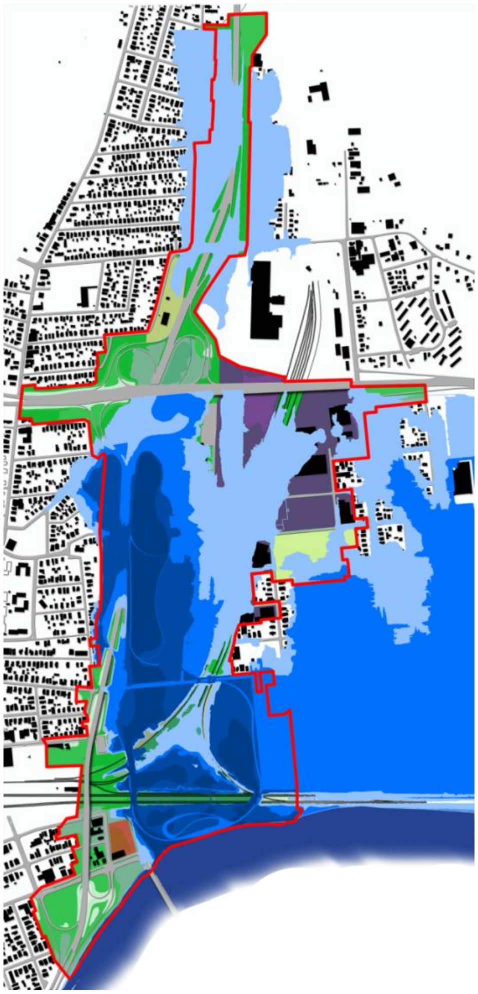

Figure 5.35: Floodable Design 2, 500 year flood event (14 feet above river bank)

The 500 year flood event is approximately 14 feet above the river stage. Almost all of the corridor would be flooded, including the majority of the high conflict sites. A level of accepted risk of flooding from a 500 year event would be necessary for users of all program elements within the corridor. It is an option that new buildings within the corridor, including new residential homes, be built on a raised footprint above the 500 year flood elevation. This flood event would cover approximately 62% of the site.

CHAPTER 6

Conclusion

This thesis explored the possibility of increasing flood resilience: how it could be done, how it could benefit and create amenities for residents, and whether this could be done without conflicting with existing uses in a river city. The concept of flood resilience has been presented by theoreticians, such as Liao, with simple assumptions about its effects. This thesis has been a test of the concept and its effects by looking tangibly at how it could be done, how it could benefit the community, and what conflicts may arise. Flooding is a natural function of rivers, and according to Liao and others, it may be time to transition many cities from resisting floods to an approach of resilience. According to their concepts, increasing resilience in flood prone areas would reduce the potential for damage incurred by flood events. As was said by White back in 1959, "Floods are "acts of God", but flood losses are largely acts of man."

Within this thesis I attempted to answer the following questions: What type/s of flood resilient infrastructure would work best in Binghamton? Is there room for floodable space in Binghamton? Where could these floodable spaces be located? What services could these spaces provide and how could they be designed to increase public amenities with minimal urban land use conflict?

Through background research on why riparian flooding occurs, existing riparian flood infrastructure, and landscape architecture literature on flood resilient design (Chapter 2), I determined that encouraging floodable area within the floodplain would be the most effective solution for Binghamton. An investigation of the existing conditions and Binghamton's comprehensive plan, Chapter 3, allowed me to determine low use areas within the city. It was hypothesized that these low use areas would have a lower level of conflict if converted to floodable areas. In Chapter 4 I examined these low use areas in greater detail in order to hypothesize whether or not these spaces were well-suited for floodable spaces and what kind of change would be necessary: conservation, retrofit, or intensive redesign. The projective designs, Chapter 5, allowed me to examine two contrasting sites (one a retrofit, the other an intensive redesign) and explore the challenges of redesigning them as floodable areas. Through this design process I determined that a level of urban land use change would be necessary for both sites in order to transition them to be flood resilient while providing as many public amenities as possible.

The table below compares approximate inundation levels before and after conceptual designs based on elevation. It is important to note that the numbers below do not account for inundation area lost to building footprints.

Table 6: Percent Inundation before and after Designs

	MacArthur School Site		**Industrial Corridor Site**	
	Before Design	After Design	Before Design	After Design
4 foot rise	~0%	8%	10%	11%
6-8 foot rise	~0%	28%	23%	21%
100 year flood	70%	68%	30%	33%
500 year flood	84%	83%	62%	62%

According to the table above, Floodable Design 1 increased the percent inundation of lower level flood events significantly. This makes sense, as the area does not currently flood during these events due to an existing levee. Design 1 also experienced a slight decrease in inundation during the 100 year flood event and 500 year flood event levels due to fill required to elevate the school footprint.

Floodable Design 2 maintained relatively equivalent inundation levels. A slight decrease in inundation occurred during the 6 foot event due to re-grading around a roadway and substation. A slight increase in inundation during the 100 year event is likely due to daylighting the stream and increasing wetland water circulation.

The aim of this thesis has been to explore the possibility of increasing flood resilience through implementing new floodable space, adding public amenities while limiting conflict with existing urban land uses. The two designs developed in the previous chapter attempted to implement these spaces and this chapter will now evaluate whether these goals were able to be reached within these designs. Evaluation will be conducted using a table which will analyze both pre- and post-design program elements for the degree land use changed, public amenity increase, and improved flood resilience.

Flood resilience change was broken down into the following three categories: increased floodplain, flood awareness, and damage reduction. For the purpose of this analysis, increased floodplain is not necessarily natural area, but any area that allows for lateral river fluctuations. Program elements were included within this category if they allowed flooding within their space, or if they were removed to make way for increased flooding. Flood awareness, as discussed in Chapter 2, is an important aspect of resilience. If people are more aware of the realities of flooding, they may be more likely to be prepared when a flood occurs, and develop land in accordingly. This could reduce the damage incurred during a flood event. Flood awareness points were assigned to program elements that flood during events below the 100 year flood event, publically visualizing lower level floods. Flood damage reduction points were awarded to program elements which either are able to withstand flooding or were removed from flood danger if at risk of flood damage.

Land use change was categorized as the following: removed use, reorganized use, maintained use, and new use. Removed uses have been eliminated from the design, such as many of the industrial properties in the industrial corridor. These removed uses receive a change score of 1 on the below table. Reorganized uses have been relocated, such as the school building in design 1. The scoring for these reorganized uses receive half a point for change, as the use is still on site but moved. Maintained uses remain functioning in their original, or nearly original, location such as the railroad tracks in design 2. These sites are marked with an "X" and carry no numerical value on the below table, as they are not site changes. New uses have been added through the design, such as the walkable levee in design 1. New uses, like removed uses, receive a score of 1 on the below table.

Public amenity change was evaluated by listing major possible amenities created through these redesigns. The following are the amenities chosen for analysis: connectivity, aesthetic value, recreation, river access, water quality, and biodiversity. Connectivity points were awarded to program elements which either literally connect spaces, such as pathways, or draw people into the sites, such as playgrounds. Connectivity points were awarded for all forms of transportation within a site, including train and roadway travel. Aesthetic value was awarded if a program element visually improved the site, such as the levee walkway of design 1, or if the removal of program elements visually improved the site, such as the removal of many low-use industrial facilities in design 2. Recreation points were awarded to program elements that provided for both active and passive recreation activities, such as sports fields and walking trails. River access points were awarded to program elements that allowed users closer proximity and visual access to the river. Water quality addresses program elements which either function to directly improve water quality, such as stream daylighting or wetlands, as well as elements whose removal may increase water quality by encouraging infiltration, such as industrial properties which contained largely impervious area. According to the Department of Environmental Conservation, the most prominent water quality concerns in Binghamton's section of the Susquehanna River are caused by upstream agricultural runoff and combined sewer overflows in urban areas (New York State Department of Environmental Conservation, 2015). Biodiversity has been included as a public amenity as well, for existence value, viewing opportunities, and as an indicator of ecosystem health. Biodiversity points were primarily awarded to program elements that function as natural areas.

Table 7: Floodable Design 1, Change Evaluation Table

	Flood Resilience				Land Use Change					Public Amenity Change						
Floodable Design 1: Original uses and Program Elements	Floodplain	Flood Awareness	Damage Reduction	Resilience Change	Removed Use	Reorganized Use	Maintained Use	New Use	Use Change	Connectivity	Aesthetic Value	Recreation	River Access	Water Quality	Biodiversity	Amenity Change
MacArthur School	0	1	1	2	0	½	0	0	½	1	0	1	0	0	0	2
Natural Woodland	1	1	1	3	0	0	X	0	0	1	1	1	0	1	1	5
¼ Mile Track	1	1	1	3	0	½	0	0	½	1	1	1	0	0	0	3
Soccer Fields	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Playground	1	1	1	3	0	0	X	0	0	1	0	1	0	0	0	2
Basketball Court	1	1	1	3	0	½	0	0	½	1	0	1	0	0	0	2
Tennis Court	1	1	1	3	0	0	X	0	0	1	0	1	0	0	0	2
City Pool	0	0	0	0	0	0	X	0	0	1	0	1	0	0	0	2
Baseball Fields	1	1	1	3	1	½	0	0	1 ½	1	0	1	0	0	0	2
Fitness Gym	1	1	1	3	0	½	0	0	½	1	0	1	0	0	0	2
Pedestrian Bridge Retrofit	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	4
Traffic Ramp	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Levee Walkway	0	1	1	2	0	0	0	1	1	1	1	1	0	0	0	3
Terrace Amphitheater	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	3
Recreation Lawn	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	3
Wetland Pools	1	1	1	3	0	0	0	1	1	0	1	0	0	1	1	3
Totals	10	12	12	34	3	2.5	4	4	9.5	13	7	13	1	2	2	38
Percentage of Total Possible Value				71%					40%							4%

Table 8: Floodable Design 2, Change Evaluation Table

	Flood Resilience				Land Use Change					Public Amenity Change						
Floodable Design 2: Original Uses and Program Elements	Floodplain	Flood Awareness	Damage Reduction	Resilience Change	Removed Use	Reorganized Use	Maintained Use	New Use	Use Change	Connectivity	Aesthetic Value	Recreation	River Access	Water Quality	Biodiversity	Amenity Change
Railroad Corridor	0	0	0	0	0	0	X	0	0	1	1	0	0	0	0	2
Major Roadways	1	1	0	2	1	½	X	0	1 ½	1	0	0	0	1	1	1
Industrial Properties	1	0	1	2	1	½	X	0	1 ½	0	1	0	0	1	1	1
Residential Properties	1	0	1	2	1	½	X	0	1 ½	0	0	0	0	0	1	1
Commercial Properties	1	0	1	2	1	½	X	0	1 ½	1	0	0	0	1	1	2
Existing Park	1	0	1	2	0	0	X	0	0	1	1	1	0	0	0	5
Outdoor Concert Space	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	5
Lawn	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	5
Athletic Fields	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	5
Running Loop	1	1	1	3	0	0	0	1	1	1	1	1	1	0	0	6
Pavilion	1	1	0	2	0	0	0	1	1	1	1	1	0	0	0	2
Playground	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	5
Beer Garden	0	1	0	1	0	0	0	1	1	1	1	0	0	0	0	3

Community Garden	1	1	1	3	0	0	0	1	1	1	1	0	0	0	1	4
Picnic Area	1	1	1	3	0	0	0	1	1	1	1	1	0	0	0	5
Wetland	1	1	1	3	0	0	0	1	1	0	1	0	1	1	1	6
Stream Restoration	1	1	1	3	0	0	0	1	1	1	1	0	0	1	1	4
Floodable Woodland	1	1	1	3	0	0	0	1	1	0	1	0	0	1	1	4
River Overlook	1	1	0	2	0	0	0	1	1	1	1	1	1	0	0	5
Totals	17	14	6	44	4	2	6	13	19	15	16	9	3	7	8	71
Percentage of Total Possible Value				77%					67%							62 %

Using the information provided in these tables overall, it can be seen that Design 2, Industrial Corridor, was changed to a much higher degree than Design 1, MacArthur School Grounds and the Pennsylvania Ave Ramp. Many changes recorded in both designs are due to increasing the number of program elements in the designs.

Design 2, which had more land use change, created more public amenities. This is likely due to the large size of the site and the removal of low-use industrial facilities and their conversion to community amenities, allows for many new public amenities. Design 2 scored higher as a public amenity than Design 1, even after difference in program elements was taken into account, largely because of its additional environmental functions of daylighting Brandywine Creek and providing more natural spaces because removing industry released space for these additional environmental changes. These additional program elements scored high in water quality and biodiversity, amenities lacking in the smaller Design 1 site.

Both designs scored high for flood resilience. This makes sense, as the intention of both designs was to decrease elements prone to damage, highlight flood fluctuations, and allow for increased flooding through removing or reducing existing flood barriers.

Based on the above analysis, it may be possible to increase flood resilience within Binghamton and provide new public amenities through the design of floodable spaces such as the two designs created for this thesis. However, even when choosing spaces of lower use within the city, there will be a degree of land use change required to implement these designs. Depending on the site this change could be minimal, as in Design 1, or extreme, as in Design 2. Decisions as to the degree and type of change allowed would ultimately need to be determined by the city.

In designing these two floodable areas, I was better able to understand some of the opportunities and constraints of the physical conditions of the landscapes. Elevation strongly influenced inundation potential, either enabling or obstructing floodability depending on height. Proximity of the river also enabled floodability and was a requirement of the design areas. Existing flood protection proved to be an obstruction as well, especially in Floodable Design 1 where a major roadway ran along the top of the levee. Roadways and railroads proved to be major obstacles within both designs, especially in Floodable Design 2. Existing structures were also often considered an obstruction within the design areas and were, in most cases, eliminated from inundation areas.

Table 9: Physical Conditions Influencing Floodable design adaptation to flooding

	Physical Conditions Influencing Floodable Design Adaptation to Flooding					
	Elevation	River Proximity	Existing Flood Protection	Roadways	Railroads	Existing Built Structures
Floodable Design 1	Enabled	Enabled	Obstructed	Obstructed	N/A	Obstructed
Floodable Design 2	Both	Enabled	Enabled	Obstructed	Obstructed	Obstructed

The designs in this thesis are hypothetical, with no plans of implementation. They were meant to explore new possibilities, and additional action would be necessary before more accurate design or thought of implementation could occur. Direct communication, through meetings and charrettes, with city officials and residents would be essential to truly understand the social and economic factors influencing the city, which would then re-determine low use areas within the city. Involving area experts and the Army Corps of Engineers within the design process would be necessary to gather more data and reduce the need for assumptions. This thesis used a simplistic method of hypothesizing flood patterns based on elevation data. Data was unable to be obtained, within the timeframe of this thesis, on flood patterns below the 100 year flood event and velocity was unable to be addressed within designs. Involving the above professionals and running appropriate flood modelling software, such as HEC-RAS, would be necessary to truly understand the flood patterns within these new floodable areas and how these areas would impact the city during flood events.

In Liao's 2012 paper A Theory on Urban Resilience to Floods—A Basis for Alternative Planning Practices, an assumption was made as to the possibility of eventually phasing out flood resilient infrastructure completely within urban floodplain areas without retreat, but through adaptation (Liao 2012). Adaptation methods described within the paper involve redundancy and flexibility, including: elevating structures, wet-proofing, making floatable, and utilizing temporary structures within floodplain areas (Liao 2012).

Existing uses within the flood zones of Binghamton are diverse, including: residential, industrial, commercial, and transportation uses. In attempting to design both Floodable Design 1 and Floodable Design 2, a degree of retreat seemed to be inevitable within the designs. Though I attempted to elevate or wet-proof existing structures, I kept finding that access seemed to be a limiting factor.

In Floodable Design 1, if the school had not retreated to higher ground, it could be elevated or wet-proofed but it would be unusable during flood events without adapted access. Walkways and elevated roadways could be used to access the building, but the size of the roadway necessary to accommodate an ambulance or firetruck access may outweigh the benefits of the access.

I originally planned to keep more industrial use within Floodable Design 2, adapting buildings according to Liao's suggestions above. Upon beginning my designs I realized that though damage could be prevented during flooding using these adaptations, elevating the roadway network necessary to support industrial use would be costly and may surpass the benefit of retaining the industrial properties. Instead, these uses retreated to higher land where roadways still provided access without elevation and lower areas of the site were reserved for non-vehicular uses.

Based on the research conducted within this paper, I conclude that urban adaptation to flooding for increased resilience is feasible. However, if completely removing all flood protection, as suggested by Liao, a degree of retreat of existing land use may be inevitable. The degree of retreat feasible for an individual city would vary depending on multiple political and economic variables, influencing the degree of protection removal that could be tolerated. Because of the timeframe of this study, political and economic values were unable to be measured adequately.

A major limitation of this thesis was the lack of data available on installed flood resilient infrastructure projects. It was difficult to find data on how these projects performed during flood events or impacted the pattern of flooding. This lack of information was partially due to projects not being implemented or being implemented too recently, however parks such as Mill Race Park located in Indiana and Mill Creek Canyon located in Washington were implemented decades ago. Data on the effectiveness, obstacles, and maintenance of these parks is not openly available. In order to truly understand the impacts of flood resilient infrastructure and encourage its implementation, more information is needed. Monitoring and measuring actual flood impacts to existing flood resilient infrastructure projects could be an interesting, and immensely beneficial, avenue of follow-up research.

The exploration of possibilities for flood resilient infrastructure conducted in this paper can be built upon in the future and applied to other river cities. Through this process, I have determined that, pending city official and community response to change of use, increasing flood resilience and increasing public amenities through encouraging floodable space could be possible for Binghamton. All river cities naturally have some flood hazard, and many river cities are facing increasing frequency and intensity of flood events. Whether by change in precipitation patterns, land development, river alterations, or other causes, flooding is an obstacle in river cities. Subject to the contingencies and challenges discovered in this thesis, flood resilient infrastructure could provide an alternative for river cities, allowing an opportunity to work with this natural phenomenon instead of fighting against it.

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