

ABSTRACT

Title of Thesis: Designing for Water:
Case Studies in the Chesapeake Bay Watershed
Name of degree candidate: Allison M. Wilson
Degree and Year: Master of Architecture, 2011
Thesis directed by: Madlen Simon, Associate Professor and Architecture
Program Director, School of Architecture, Planning, and
Preservation

The built environment negatively affects the water cycle, introducing chemicals and nutrients into the system, impacting the ability of plant, fish, and animal species to survive. Stretching from New York to Virginia, the 64,000 square miles of the Chesapeake Bay watershed includes housing, commerce, and industry for 16.6 million people. While architecture is typically designed to shed precipitation away from buildings, it is not typically designed for the on-site retention and management of that rain, snow, and sleet. Exploring the possibilities of ecoregion-specific environments illustrates the best practices for rainwater harvesting and storm water management across the varied landscapes of the Chesapeake Bay watershed. By using technologies such as cisterns, green roofs, and constructed wetlands, the built environment can be designed to decrease our need for expensive water purifying infrastructure and preserve the health of fragile estuary ecosystems such as the Chesapeake Bay.

DESIGNING FOR WATER:
CASE STUDIES IN THE CHESAPEAKE BAY WATERSHED

Allison Marie Wilson

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Master of Architecture
2011

Associate Professor Madlen Simon, AIA
Associate Professor Amy Gardner, AIA, LEED AP
Associate Professor Brian P. Kelly, AIA

© 2011
Allison Wilson

Dedication

for Grampa who helped me build my first cities.

always and forever,
your beloved granddaughter

Acknowledgements

This thesis is significantly inspired by my work with the University of Maryland's entry into the U.S. Department of Energy's Solar Decathlon 2011, WaterShed. The Solar Decathlon, an international competition hosted every two years, challenges twenty student teams from colleges and universities around the world to design and build houses powered entirely by the sun. The houses are displayed to the public over ten competition days on the National Mall in Washington, D.C. where teams operate the houses to simulate normal residential use and are judged in ten contests. While the contests have changed with each iteration of the event, there are always both qualitative competitions (such as architecture and market viability) as well as quantitative competitions (such as hot water and energy balance).

My initial involvement in Maryland's Solar Decathlon project was through participation in a design studio that created the conceptual design for WaterShed. A studio of nine graduate architecture students in consultation with engineering and landscape students, faculty, and professional mentors developed a concept about a house that would be representative of what it means to build for water management in the Chesapeake Bay watershed. To accomplish this, the house was to illustrate a set of four core principles that the student-led team adopted.

The primary principle was to use the Chesapeake Bay ecosystem as a design mentor and precedent. At all reasonable points in the design process, the guiding question was to be, "How would the Chesapeake Bay do it?" This ecosystem-based design was to create a house that mimicked the local biological environment in such a way as to be beneficial to the fragile Chesapeake Bay watershed instead of damaging.

In keeping with the idea of ecosystem-based design, the house's active systems would be developed along the ideas of "cradle-to-cradle." Waste from one system would equal food for another, and through the synergies between systems the building would be more efficient than if each system were to operate completely independently of all other systems. These ideas led to a third principle which was that ecosystems are not efficient, they are abundant. WaterShed was to illustrate that sustainable design does not mean a decreasing quality of life or doing more with less, but that sustainability can result in abundance. While modern technology allows us to create highly controlled environments, WaterShed also believed in the idea that sustainable design utilizes both time-tested best practices and state-of-the-art technology.

Design of WaterShed continued beyond that initial conceptual studio and the house will compete in the Solar Decathlon in the fall of 2011. While the house has transformed since those initial conversations about design principles, there has remained something compelling about those original core ideas. While WaterShed does embody those ideas, it is also a competition prototype and to that end one of its goals is also to win the competition. It is a prototype home fit for a particular purpose, but it has inspired me to think at a larger scale about how buildings could more seamlessly integrate with the water cycle.

It would be impossible to imagine this thesis without WaterShed's inspiration and the constant enthusiasm of a very dedicated group of students, faculty, mentors, and friends who are committed to seeing a sustainable future. Many thanks to all of my teammates, friends, and mentors who have inspired this thesis; I could not have done any of this without your support and guidance. Thanks especially go to my parents for

their unending support and faith in me to do my best work, to my thesis committee for their belief that I could actually chew a piece as large as the one I bit off when I proposed this thesis, and to Amy Gardner especially for being WaterShed's resident Wonder Woman capable of feats of time management and life juggling that defy all reasonable expectations.

TABLE OF CONTENTS

List of Figures.....	vii
Chapter 1: Introduction.....	1
Sustainability and Green Architecture.....	1
The Water Cycle and the Built Environment.....	7
Chapter 2: Site.....	11
The Chesapeake Bay and Its Watershed.....	11
Regional Planning.....	20
Four Cities: Comparative Analysis of Cities in the Chesapeake Bay Watershed..	24
History.....	25
Corning, NY.....	25
Nanticoke, PA.....	30
Columbia, PA.....	32
Havre de Grace, MD.....	35
Ecological Comparisons.....	39
Precipitation.....	40
Temperature.....	42
Latitude.....	44
Topography.....	45
Urban Design Analysis.....	50
Parti and Relationship to the Water's Edge.....	51
FigureGround.....	53
Street Hierarchy.....	58
Land Use.....	63
Site Observations.....	69
Corning, NY.....	71
Nanticoke, PA.....	78
Columbia, PA.....	86
Havre de Grace, MD.....	93
Chapter 3: Program.....	100
Design Principles.....	101
Program Analysis.....	102
An Agenda for Water.....	104
Chapter 4: Design Solutions.....	107
Corning, NY.....	107
Nanticoke, PA.....	111
Columbia, PA.....	116
Havre de Grace, MD.....	125
Comparative Sections.....	133
Chapter 5: A Design Language for Water.....	136
Green Roof.....	136
RainBarrels.....	138
PermeablePaving.....	139
ConstructedWetlands.....	140

Green Walls.....	140
Scuppers.....	142
Chapter 6: Conclusions.....	144
Appendix A: Water-Related Resources.....	150
Bibliography.....	153

LIST OF FIGURES

Figure 1. A section through Hayward's Octagon House.

Figure 2. The water cycle.

Figure 3. Impacts of the built environment on the water cycle.

Figure 4. West-East freshwater to saltwater gradient.

Figure 5. North-South freshwater to saltwater gradient.

Figure 6. Northwest-Southeast freshwater to saltwater gradient.

Figure 7. Top to bottom freshwater to saltwater gradient.

Figure 8. Map identifying the area of the Chesapeake Bay watershed.

Figure 9. Map identifying the major river watersheds that comprise the Chesapeake Bay watershed.

Figure 10. Map identifying the ecoregions of the Chesapeake Bay watershed.

Figure 11. Map identifying the cities of the Chesapeake Bay watershed.

Figure 12. Map identifying the interstate highways that cross the Chesapeake Bay watershed.

Figure 13. Map identifying the Amtrak rail lines and stations that cross the Chesapeake Bay watershed.

Figure 14. Map identifying the four cities selected as representative of their particular ecoregions.

Figure 15. This figure number not used.

Figure 16. Chart comparing the average precipitation of Corning, NY; Nanticoke, PA; Columbia, PA; and Havre de Grace, MD.

Figure 17. Chart comparing the average temperatures of Corning, NY; Nanticoke, PA; Columbia, PA; and Havre de Grace, MD.

Figure 18. Graphic comparing the latitudes of Corning, NY; Nanticoke, PA; Columbia, PA; and Havre de Grace, MD.

Figure 19. Topographic map of Corning, NY.

Figure 20. Topographic map of Nanticoke, PA.

Figure 21. Topographic map of Columbia, PA.

Figure 22. Topographic map of Havre de Grace, MD.

Figure 23. Four diagrams illustrating ways to organize urban areas relative to water in the Chesapeake Bay watershed.

Figure 24. Figure ground diagram of Corning, NY.

Figure 25. Figure ground diagram of Nanticoke, PA.

Figure 26. Figure ground diagram of Columbia, PA.

Figure 27. Figure ground diagram of Havre de Grace, MD.

Figure 28. Street hierarchy diagram of Corning, NY.

Figure 29. Street hierarchy diagram of Nanticoke, PA.

Figure 30. Street hierarchy diagram of Columbia, PA.

Figure 31. Street hierarchy diagram of Havre de Grace, MD.

Figure 32. Land use diagram of Corning, NY.

Figure 33. Land use diagram of Nanticoke, PA.

Figure 34. Land use diagram of Columbia, PA.

Figure 35. Land use diagram of Havre de Grace, MD.

Figure 36. Site summary diagram of Corning, NY.

Figure 37. Dresser Rand factory buildings.

Figure 38. Residences north of the Chemung River.

Figure 39. Downtown historic district.

Figure 40. Corning, Inc. corporate headquarters.

Figure 41. Riverside park.

Figure 42. Selected site for Corning, NY design intervention.

Figure 43. Site Summary Diagram of Nanticoke, PA.

Figure 44. North-south streets exhibit grade change.

Figure 45. Residences in Nanticoke.

Figure 46. Luzerne County Community College.

Figure 47. Nanticoke town square.

Figure 48. Selected site for Nanticoke, PA design intervention.

Figure 49. View from site's high ground.

Figure 50. View from site's low ground.

Figure 51. A view down Locust Street in Columbia, PA.

Figure 52. A view of attached residences in Columbia, PA.

Figure 53. Site summary diagram of Columbia, PA.

Figure 54. Waterfront warehouses in Columbia, PA.

Figure 55. The National Watch and Clock Museum.

Figure 56. Site selected for Columbia, PA design intervention.

Figure 57. Site summary diagram of Havre de Grace, MD.

Figure 58. Boardwalk promenade in Havre de Grace, MD.

Figure 59. Institutions along the Chesapeake Bay.

Figure 60. Development pressures in Havre de Grace, MD.

Figure 61. Havre de Grace, MD's downtown retail core.

Figure 62. Selected site for Havre de Grace, MD design intervention.

Figure 63. Corning, NY site plan.

Figure 64. Crossing through the forest edge.

Figure 65. Meandering through the meadow.

Figure 66. Nanticoke, PA first floor plan.

Figure 67. Nanticoke, PA below-grade plan.

Figure 68. Recharging the aquifer.

Figure 69. Dry well detail.

Figure 70. Plans of the intervention in Columbia, PA.

Figure 71. Walking along Locust Street in Columbia, PA.

Figure 72. Entering through the garden in Columbia, PA.

Figure 73. Section through the Columbia, PA intervention.

Figure 74. Green roof detail.

Figure 75. Green wall detail.

Figure 76. Permeable paving detail.

Figure 77. Wetland filtration process diagram.

Figure 78. Plan of the Havre de Grace, MD design intervention.

Figure 79. Elevation of the Havre de Grace, MD design intervention.

Figure 80. Strolling along the boardwalk in Havre de Grace, MD.

Figure 81. Observing the wetland from the porch.

Figure 82. Section through Corning, NY design proposition with underground context.

Figure 83. Section through Nanticoke, PA design proposition with underground context.

Figure 84. Section through Columbia, PA design proposition with underground context.

Figure 85. Section through Havre de Grace, MD design proposition with underground context.

Figure 86. Watershed transect diagram.

Figure 87. Appropriate solar access for a green roof.

Figure 88. Inappropriate solar access for a green roof.

Figure 89. Appropriate slope for a green roof.

Figure 90. Maximum slope for a green roof.

Figure 91. Inappropriate slope for a green roof.

Figure 92. Rain barrels adjacent to location for water usage.

Figure 93. Rain barrels placed distant from location for water usage.

Figure 94. Permeable paving for pedestrian pathways.

Figure 95. Landscape swales to mediate parking runoff.

Figure 96. Circulation along edges of constructed wetland is advisable.

Figure 97. Circulation through the center of the constructed wetland is not advisable.

Figure 98. Constructed wetlands should be created to alternate areas of water movement and retention.

Figure 99. Appropriate solar access for a green wall.

Figure 100. Inappropriate solar access for a green wall.

Figure 101. Scuppers without rain chains create splashes.

Figure 102. Scuppers with rain chains minimize splashes.

Figure 103. Water cycle diagram.

Figure 104. Tracing a drop of water along the watershed transect.

Chapter 1: Introduction

Sustainability and Green Architecture

While sustainability as a cultural movement is a relatively new concept, the idea of building in tune with nature is not. Before the domestication of electric power in 1882¹ and the advent of air conditioning in the first half of the twentieth century², the only way to create a building that provided inhabitants with sufficient access to light and air was to design a building that was in tune with natural cycles. Modern technological systems that have granted architects the opportunity to control the indoor environment have provided more flexible design alternatives, but they have also created pitfalls. Our ability to control the environment has allowed us to fundamentally change the way we relate to the natural world, for example, our relationship to local temperature.

Before air conditioning allowed architects to dictate the exact indoor temperature and humidity of a structure, buildings were constructed in forms and materials that specifically related to the regional climate characteristics of the place. Compact structures with central hearths were typical of colder climates while expansive covered porches were standard practice in more temperate areas. New technology has changed this sort of regional approach to design as “with our current technology the temperature of a place need not be associated with the form of the building or the materials used or the region where it is located. But how unsatisfying is this dissociation of warmth or coolness from all of our other senses!”³ We have created buildings that provide thermal

1 Reyner Banham. *The Architecture of the Well-Tempered Environment*. (Chicago: University of Chicago Press, 1969), 25.

2 Ibid, 83.

3 Lisa Heschong. *Thermal Delight in Architecture*. (Cambridge, Massachusetts: The MIT Press, 1979), 25.

comfort, but is the architectural experience as rich when there is no variety in the temperate experience and no relationship to place?

Society champions the advances man has made in controlling the natural environment, but our words and actions do not always match. In our fast-paced, mechanized world, “there is a good deal of irony in the fact that to stave off physical and mental deterioration the urban dweller periodically escapes his splendidly appointed lair to seek bliss in what he thinks are primitive surroundings: a cabin, a tent, or, if he is less hidebound, a fishing village or hill town abroad. Despite his mania for mechanical comfort, his chances for finding relaxation hinge on its very absence.”⁴ While we simultaneously demand the ability to control the climatic conditions of our built environment, we also seem to have an innate need to be a part of the natural world without technological innovations.

Sustainability is at present a notoriously difficult term to define and is often interchangeably used with ecological design, green design, and green architecture. To differentiate these ideas in terms of the built environment, sustainability refers to creating structures that contribute to the overall economic, social, and environmental health of a society in a way that can be continued in perpetuity. Ecological and green design as well as green architecture have a more focused definition and consider only the ability of the built environment to respond to natural surroundings in a way that is mutually beneficial. Ecological and green design and green architecture do not intentionally respond to social or economic considerations, although as the costs of energy and infrastructure increase,

4 Bernard Rudofsky. *Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture*. (Garden City, New York: Doubleday & Company, Inc., 1964), no page number.

designing ecologically can have significant financial benefits. While sustainability is an idealized goal, the work proposed in this thesis deals with green architecture and ecological design far more so than it does true sustainability.

Perhaps the first move toward ecological design was related to air quality. In the era before electric lighting when the gaslight was king and buildings were created as tight envelopes in order to minimize drafts, poor air quality in buildings was a natural result of burning gas in small, enclosed spaces without providing sufficient access to fresh air.

Doctors, more than architects, were the first to notice the affects of indoor environmental problems as their patients would come in with ailments that could only be caused by poor access to fresh air. Doctors thus became some of the first ecological designers, creating houses that addressed issues of ventilation to solve human health problems.⁵

Dr. John Hayward designed and constructed a particularly notable house in 1867, the Octagon, which addressed issues of



Figure 1: A section through Hayward's Octagon House. From *The Architecture of the Well-Tempered Environment*, 36.

health and ventilation in the indoor environment in an integrated, holistic way. Illustrated in figure 1, the basement level was used as a plenum in which fresh air was collected and warmed by passing it over hot water pipes. A central corridor served as a vertical convection space in which hot air would rise and be distributed to the adjoining rooms

⁵ Reyner Banham. *The Architecture of the Well-Tempered Environment*. (Chicago: University of Chicago Press, 1969), 29-44.

through vents at ceiling level. While this provided a steady supply of fresh air to each room in the house, a fireplace in each room served to keep the air in each space warm. A central vent above the gaslight allowed for warm exhaust air to be drawn up and out of the room and exhausted into a foul air flue in the attic. The whole convection system was pressurized by the continuously burning kitchen fire.⁶ Given this precedent, it is clear that issues of ventilation and air quality have been a significant part of ecological design for over one hundred years. Solving these design challenges has grown from Hayward's common sense design to include advanced mechanical equipment, and responding to human needs for fresh air is a challenge in the built environment for which practitioners are well-equipped to design.

The same mechanical equipment that allows us to have control over indoor environmental conditions also utilizes a significant amount of energy. "From the beginning of the twentieth century to the early 1970s, electric power use grew by 400 times in the United States,"⁷ due mostly to greater quantities of electric lighting and the increasing use of mechanical equipment in ventilation. This put increasing demands on fossil fuel resources and has led to increasing conflict between the oil-rich and oil-poor countries of the world, including the Arab Oil Embargo of 1973-1974.⁸ This event led to a significant shift in American attitudes toward indoor environmental control and ventilation systems changed over from predominantly constant air volume (C.A.V.) systems to variable air volume (V.A.V.) systems which utilized less energy.⁹ Mechanical

6 Ibid, 35-38.

7 D. Michelle Addington, "Good-bye, Willis Carrier." In *The Green Braid*, ed. Kim Tanzer and Rafael Longoria, 160-172 (New York: Routledge, 2007).

8 Ibid.

9 Ibid.

systems have continuously been designed to meet higher energy efficiency standards and have begun to utilize new forms of energy in the built environment. The amount of energy required to operate buildings and the means used to supply this need are an on-going conversation in ecological design circles.

Providing for the construction and operation of buildings through traditional means, the burning of fossil fuels, uses a significant amount of energy. In 2004, the energy used in the operation of buildings totaled 39 quadrillion British Thermal Units (BTUs), which accounts for approximately 39% of the total amount of energy consumed in the United States during that year. Industry and transportation together represent the other 61% of energy used in the United States.¹⁰ Data also illustrates that there is approximately a one-to-one correlation between the amount of energy used and the amount of carbon dioxide emissions produced by buildings. Buildings thus accounted for 38% of the carbon emissions generated in the United States in 2004.¹¹ These statistics make it clear that changes in the way we construct and maintain our built environment can have significant impacts on the amount of energy used and the emissions produced.

The 39 quadrillion BTUs of energy used in buildings can be further subdivided into 18 quadrillion BTUs for commercial buildings and 21 quadrillion BTUs for residential buildings.¹² While these figures are relatively similar, the fact that residential buildings tend to use more energy than commercial buildings means a greater impact can be made on reducing our energy use and carbon emissions by revisiting how we power our homes. Statistics from the *Buildings Energy Data Book* indicate that renewable

10 Pat Murphy, "The Energy Impact of Our Buildings," *New Solutions*, Number 11, January 2007, 1.

11 Ibid.

12 Ibid.

energy use in buildings in the last five years has represented less than 1% of all energy used to operate our buildings. Natural gas and electricity represent the lion's share of energy use in buildings and all possible steps should be taken to increase our use of renewable energy sources while decreasing our dependence on fossil fuels.¹³

While the conversation about energy efficiency gets significant media attention, and it is certainly important in creating green architecture, there are critical resources that are ignored in that conversation, specifically water. Access to safe potable water is a basic necessity for life. While one might be able to live without consuming the amounts of energy that many Americans take for granted, no one in any country on earth can survive without access to water. More than two million people die worldwide of water-borne diseases each year with most being children below five years of age.¹⁴ Water is contaminated by more than 116,000 man-made chemicals including the pesticides used to fertilize crops, the chemicals our societies have created as weapons, and the pharmaceutical drugs we prescribe to preserve health. These chemicals all make their way into streams, waterways, and aquifers as runoff from the built environment or as human wastes flushed down toilets. We have no idea what happens when these chemicals interact, and yet that is exactly what happens when these chemicals meet in our rivers and streams. We take water from these same rivers and streams, put it into our water supply, and the process repeats. The water we use today has a fundamentally different chemical composition than the water people used one hundred years ago and we do not have a clear understanding of the impact that is creating in plant, fish, and animal species around

13 U.S. Department of Energy: *2008 Buildings Energy Data Book*, (Washington, D.C.: GPO, March 2009), 1-4 through 1-5.

14 *Flow: How Did a Handful of Corporations Steal Our Water?*, DVD, directed by Irena Salina (New York: Oscilloscope Pictures, 2008).

the world.¹⁵ Beyond the impacts to other species, we also have no idea what the changing chemical composition of water is doing to our own species.

If we are truly to develop green buildings, solving the issues of light and air and the energy crisis in the built environment will not be enough. We must design buildings that are in tune with the water cycle that conserve water and filter out the contaminants modern processes add to the preciously finite amount of water available to us. We must create a “blue architecture” of sorts that allows our built environment to become a steward of our water supply. This thesis seeks to explore ecological design by finding answers to the issues of storm water management in the Chesapeake Bay watershed through architectural design. The four design propositions that follow have allowed for exploration of the following research questions:

How can the built environment be a better mediator of the water cycle?

How do ecoregions affect the way buildings can best mediate the water cycle?

What is the ideal relationship between the built environment and the water cycle?

Providing answers to these questions will start to fill in the gap of knowledge we have in green architecture regarding the way the built environment interacts with our water system.

The Water Cycle and the Built Environment

To design a better relationship between the water cycle and the built environment it is critical to understand what is broken in today’s water cycle. Figure 2 illustrates the water cycle in ideal circumstances. Water on the surface of rivers, lakes, streams, and oceans is heated by the sun and evaporates into the air as vapor. In addition to this vapor,

15 Ibid.



Figure 2: The water cycle. Diagram from Dunnett, Nigel and Andy Clayden. *Rain Gardens: Managing water sustainably in the garden and designed landscape*. London: Timber Press, 2007.

plants and landmasses transpire, which also puts water into the atmosphere. All of this vapor condenses as it cools into clouds which are moved at the whimsy of the winds. Once the clouds become heavy and laden with water, precipitation brings this water back down to the earth as snow, rain, sleet, and hail. This water feeds the plants which lets them grow, assists in the transit of nutrients in rivers and streams, and can percolate underground to recharge aquifers.¹⁶ As is true of most idealized cycles, however, this ideal relationship almost never occurs simply because of the built environment humans have introduced into the landscape.

Figure 3 shows a graphic representation of the impacts of the built environment on the water cycle. The furthest left image depicts the situation in which the idealized water cycle most nearly occurs. In this situation, only 0 to 10% of the land area is

¹⁶ Howard Perlman, "Summary of the Water Cycle," *The Water Cycle*, <http://ga.water.usgs.gov/edu/watercyclesummary.html>.

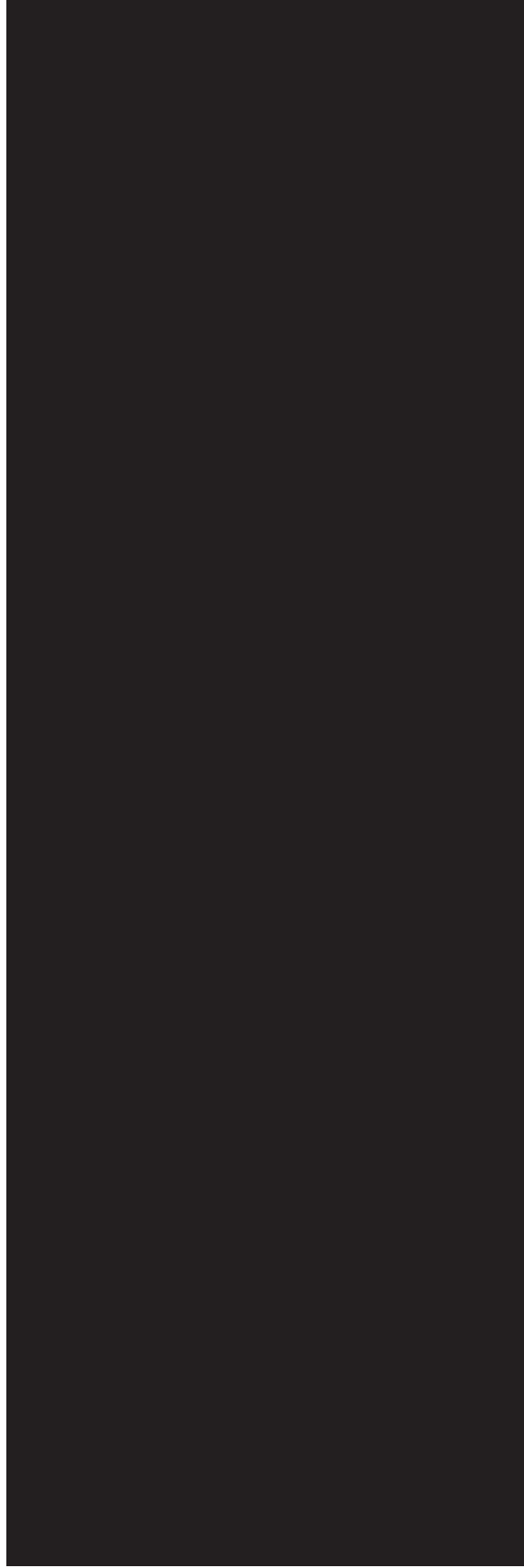


Figure 3: Impacts of the built environment on the water cycle. Diagram from Dunnett, Nigel and Andy Clayden. *Rain Gardens: Managing water sustainably in the garden and designed landscape*. London: Timber Press, 2007.

covered by hardscape and 40% of water that falls on the site immediately evapotranspires back to the atmosphere. Ten percent of precipitation in this situation runs along the surface, 25% feeds the plants, and an amazing 25% has the opportunity to reach deep infiltration and recharge groundwater resources. Moving further right, it is clear that increasing hardscape has a catastrophic impact on the relationships of the water cycle. When 75 to 100% of the land area is hardscape, common in our urban and even some suburban environments, almost no water is available for infiltration of any kind and most water, 55%, becomes runoff. Our built environment fundamentally changes the water cycle, a natural phenomenon that happens all over the globe. Because the water cycle is a global natural cycle, the issues that the built environment needs to solve with regards to water happen at every scale of design and development, from the global to the detail scale. The research questions posed by this thesis are most interested in the regional, site, building, and details scales as they relate to the Chesapeake Bay watershed and as such this work has focused itself on the Bay and its watershed while largely ignoring water-related issues that are simultaneously occurring at larger scales.

Chapter 2: Site

The Chesapeake Bay and its Watershed

“Two hundred years from now, in 2177, someone like me, with every one of my apprehensions, will be lunching in Patamoke and weighing the future of the Chesapeake. We have to ensure that the bay still exists for him to worry about.”¹

The Chesapeake Bay as we know it today took shape approximately 3000 years ago following the last Ice Age when melting glaciers carved the streams and rivers that would eventually become tributaries to the Chesapeake Bay and the Atlantic Ocean beyond. While the Bay itself is part of the Atlantic Coastal Plain, it is notable that the chemical identity of water coming from each of the four ecoregions comprising the Bay watershed is different.² The chemical makeup of water within the Chesapeake Bay varies depending on how much runoff from these different ecoregions is running into the Bay as well as how much salt water from the Atlantic Ocean is drawn into the Bay by tidal movements. This unique environment where freshwater and saltwater mix is called an estuary. Changes in the amount of water coming from each of the aforementioned sources affect the salinity, temperature, oxygen level, and sediment composition of the Bay.³ As the largest estuary in the United States, the Chesapeake Bay is home to more than 3600 plant, fish, and animal species and changes to the subtle nutrient balance in the

1 James A. Michener. *Chesapeake: A Novel*. (New York: Random House, 2003), 850.

2 Chesapeake Bay Program, “Bay Geology,” The Bay Watershed, <http://www.chesapeakebay.net/baygeology.aspx?menuitem=14604>.

3 Susannah Lawrence. *The Audubon Society Field Guide to the National Place of the Mid-Atlantic States*, (New York: Pantheon, 1984), 180-184.

water content of the Bay affect their ability to adapt and survive.⁴

Understanding the subtle ecological balance of the Bay can best be done by overlaying a three-dimensional grid over the area. As illustrated in Figures 4-5, there are nine divisions of the Bay west-east, nine divisions north-south. The farthest west in the Bay has the largest component of freshwater, while the farthest east has the greatest salinity. The northern waters contains less salt than the southern waters. These two gradients, when combined as in Figure 6, demonstrate there is a gradient from northwest to southeast that transitions the Bay from freshwater to saltwater. There is additionally a difference between the water on the top layer of the Bay and the bottom layer of the Bay because saltwater is denser than freshwater and therefore sinks to the bottom as illustrated in Figure 7.⁵

Given these three coordinates, the west-east grid quadrant, the north-south grid quadrant, and whether the water is on the top or the bottom of the Bay, a scientist can accurately describe the plant, fish, and animal life capable of surviving in that area of the Bay because of that quadrant's salt and nutrient content. As an estuary, the Chesapeake Bay acts as a filter for contaminated water, but the 64,000 square miles of the Chesapeake Bay watershed flushes too many pollutants into the Bay for the nutrient and salinity balance of the Bay to be maintained with the degree of subtlety described above.

The geologic processes that have produced such a dynamic yet fragile ecosystem have also “provided the raw materials for the farming, fishing, and manufacturing

4 Chesapeake Bay Program, “Facts & Figures,” About the Bay, <http://www.chesapeakebay.net/factsandfigures.aspx?menuitem=14582>.

5 Chesapeake Bay Program, “Physical Characteristics,” About the Bay, <http://www.chesapeakebay.net/physicalcharacteristics.aspx?menuitem=14657>.

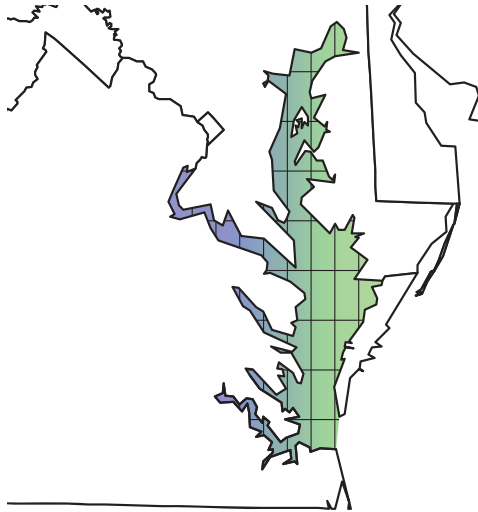


Figure 4: West-East freshwater to saltwater gradient. The Bay is mostly freshwater to the west, mostly saltwater to the east.

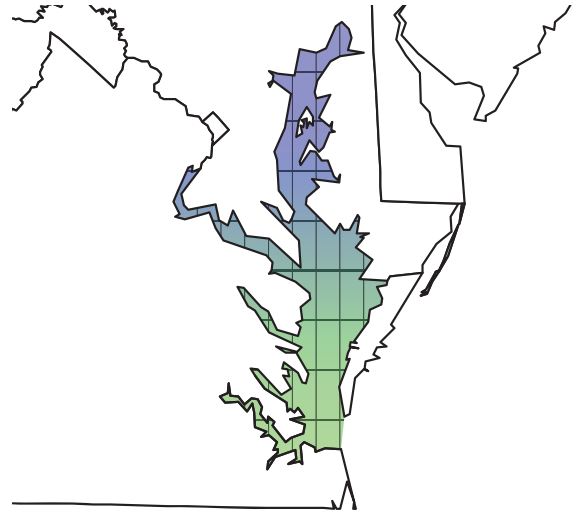


Figure 5: North-South freshwater to saltwater gradient. The Bay is mostly freshwater to the north, mostly saltwater to the south.

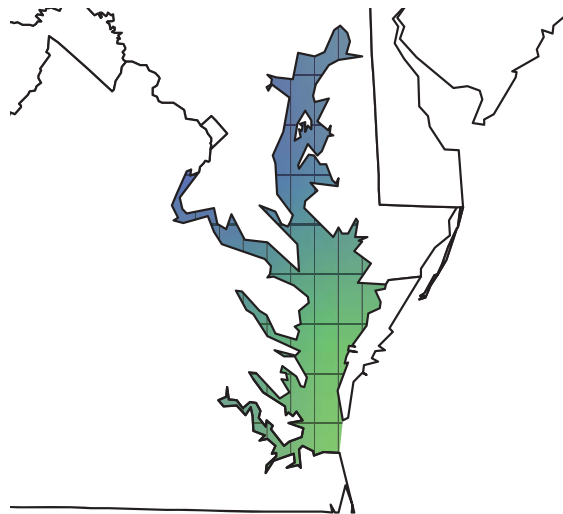


Figure 6: Northwest-Southeast freshwater to saltwater gradient. The Bay is mostly freshwater in the northwest, mostly saltwater in the southeast.



Figure 7: Top to bottom freshwater to saltwater gradient. The Bay is mostly freshwater on the top, mostly saltwater on the bottom.

industries”⁶ that have shaped life in the Chesapeake Bay watershed. The soil that composes the Chesapeake region is topped by a thick fertile layer which supports large-scale farming interests and the rich estuary ecosystem of the Bay sponsors biodiversity which allows fishing to be profitable. Iron, copper, and chromium reserves in the region’s ground, when coupled with large deposits of coal, create a land primed for industrial development.⁷ These resources have been used since the population of the Chesapeake region and continue to “influence the economy and the region long after the initial exploitation of those resources has died out.”⁸ Because the initial use of these resources was largely unregulated and uncontrolled, the legacy left by agricultural, fishing, and industrial interests is one that requires the present population of the watershed to reverse the ecological damage has been done in the past and which continues into contemporary water management practices.

The Chesapeake region is expansive. Covering 64,000 square miles, the Chesapeake Bay watershed covers parts of New York, Pennsylvania, Maryland, Delaware, West Virginia, Virginia, and the District of Columbia.⁹ It is also home to more than 16.6 million people.¹⁰ Figure 8 illustrates the geographic area that drains to the Chesapeake Bay in grey while also providing the adjacent states for context. The Chesapeake Bay is the area in white formed by the shores of Maryland and Virginia.

While the watershed does cross multiple state boundaries, it is notable that nearly the

6 George W. Fisher and Jerry R. Schubel, “The Chesapeake Ecosystem: Its Geologic Heritage,” in *Discovering the Chesapeake*, eds. Philip D. Curtin, Grace S. Brush, and George W. Fisher, (Baltimore, MD: The Johns Hopkins University Press, 2001), 1-14.

7 Ibid.

8 Ibid.

9 Chesapeake Bay Program, “Facts & Figures,” Facts and History, <http://www.chesapeakebay.net/factsandfigures.aspx?menuitem=14582>.

10 Ibid.

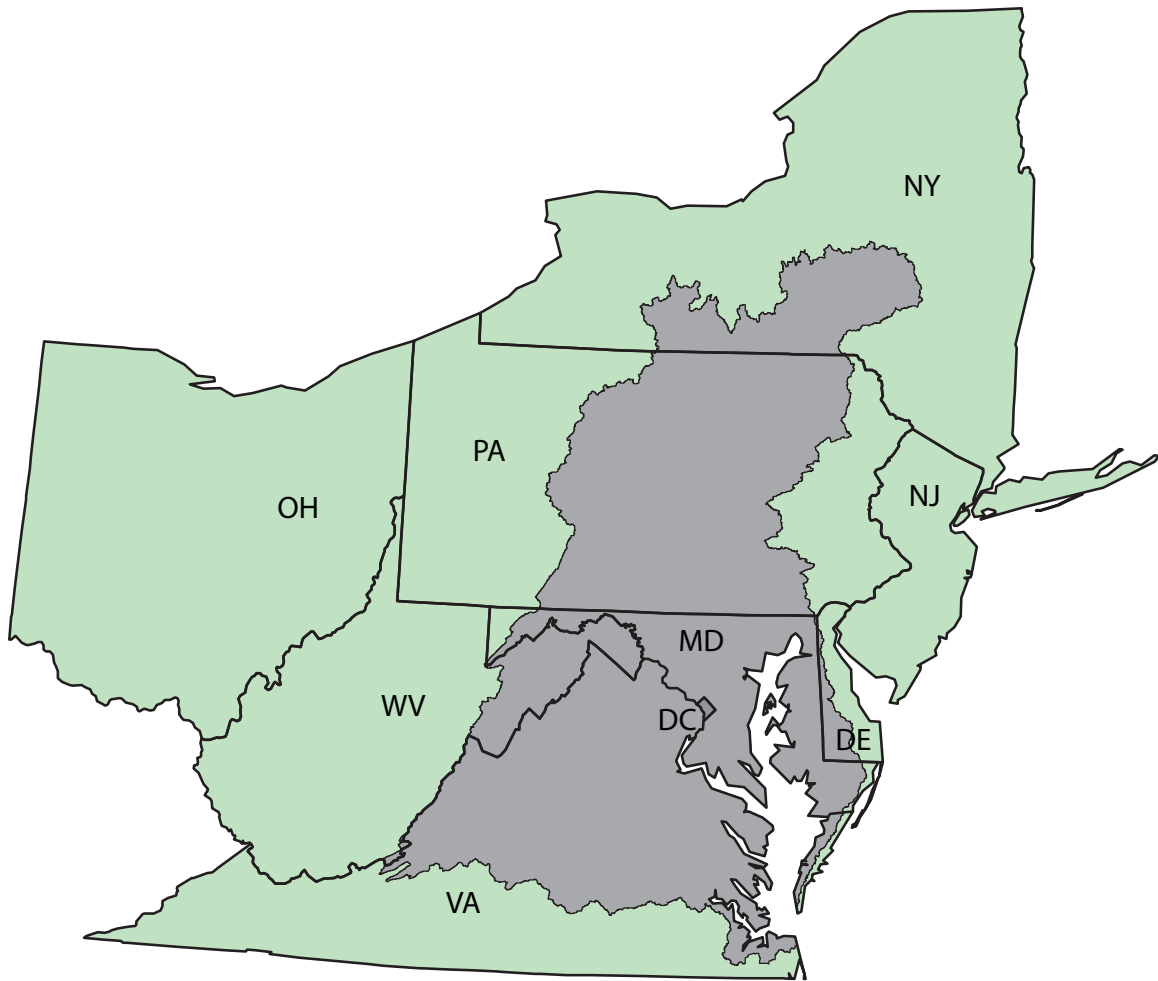


Figure 8: Map identifying the area of the Chesapeake Bay watershed.

entire state of Maryland falls within the watershed while only small portions of New York and West Virginia are included.

Unlike the other states that are part of the Chesapeake Bay watershed, Maryland is united by its interest in the Chesapeake Bay because almost all water used in Maryland eventually ends up in the Bay. Along with Maryland's proximity to the Bay itself, the idea that most water used in Maryland ends up in the Chesapeake Bay might suggest preservation of the Bay and its watershed are more actively felt in the state of Maryland than in other states where the Chesapeake Bay watershed is only part of the natural water drainage system of the state and the Bay itself is distant. Even though the Bay may be

distant from some parts of its watershed, “everyone in the watershed lives just a few minutes from one of the more than 100,000 streams and rivers that drain into the Bay. Each of these tributaries can be considered a pipeline from communities to the Bay.”¹¹ Communicating the importance of water management and the impact people across the watershed are having on the health of the Chesapeake Bay to those who live distant from this natural resource is an important step in preserving the Bay’s health.

The Chesapeake Bay watershed needs to be understood as a set of ecological relationships without consideration of the state boundaries crossed. The difficulty of studying a geological entity that crosses into multiple state jurisdictions and countless smaller municipalities is that no one entity is responsible for maintaining information on the watershed. States and other political and institutional entities fund research and as a result data are easily found on smaller subsets within the watershed as well as areas larger than the watershed. Finding Geographic Information System (GIS) data that limits itself to the extents of the Chesapeake Bay watershed require culling data from multiple sources including the U.S. Geological Survey, the National Atlas, and the Environmental Protection Agency.

If we are truly to achieve buildings that work within their geological context, it is important that research be conducted on the scale of geological features and that the arbitrary political boundaries we have created to define areas on the earth become less significant. If data on an ecologic basis are made more easily accessible, architects and others invested in the improvement of the relationship between the natural and the built environments would have a better opportunity to use geological data to inform

11 Ibid.

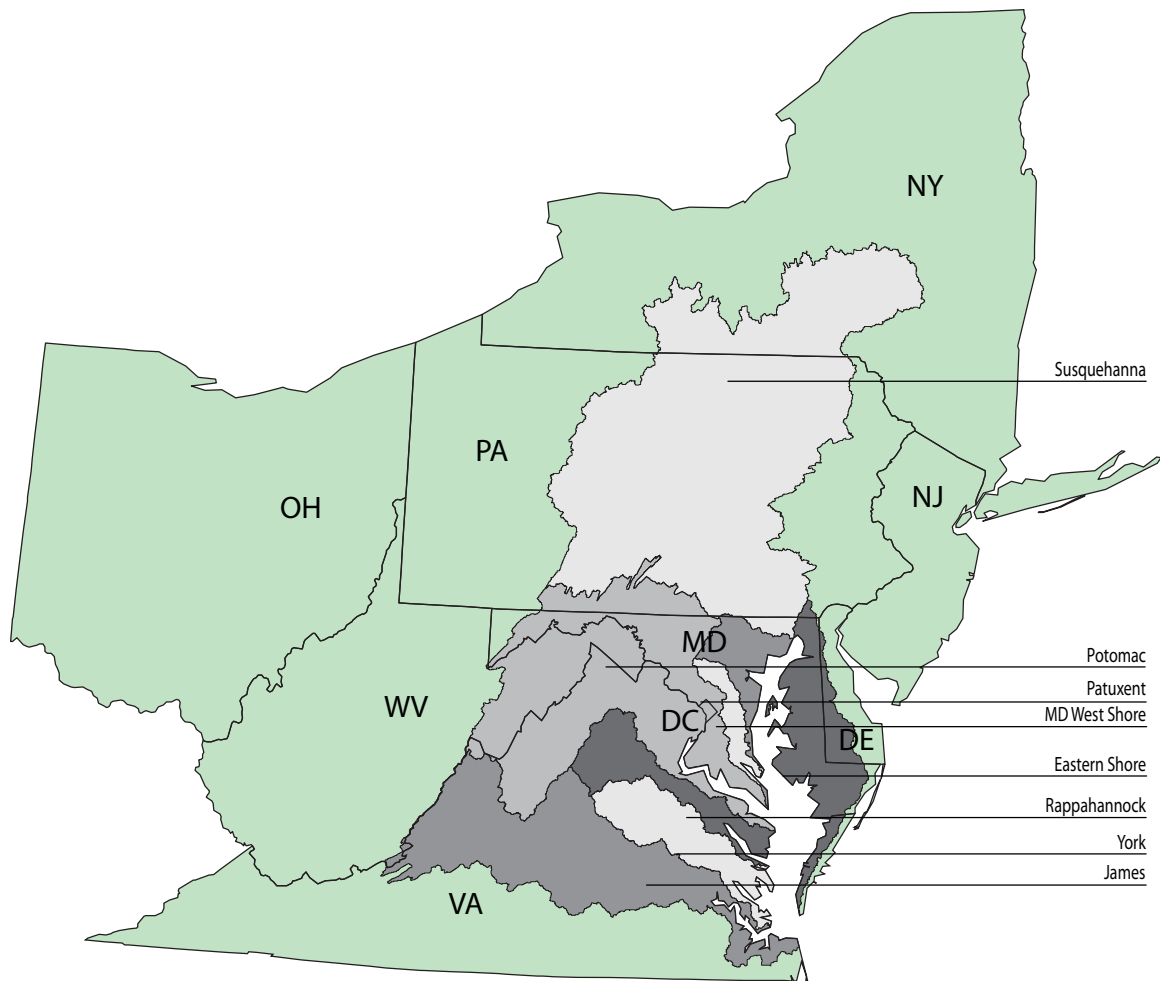


Figure 9: Map identifying the major river watersheds that comprise the Chesapeake Bay watershed.

their design processes. At a regional scale, stewards of the built environment need to encourage such work to be continued and made publicly available.

It is more constructive to understand the Bay watershed as a number of smaller watersheds than to divide it by state lines. Illustrated in Figure 9, eight major river watersheds comprise the larger region that drains to the Chesapeake Bay. From north to south these watersheds are: the Susquehanna watershed, the Potomac watershed, the Patuxent watershed, Maryland's western shore, the eastern shore, the Rappahannock watershed, the York watershed, and the James watershed. Of these watersheds, the Susquehanna, Potomac, and James watersheds cover the largest geographic areas. The

Susquehanna, Potomac, and eastern shore watersheds are the only three within the larger whole to cross state lines. Because the Patuxent and western shore watersheds fall exclusively in Maryland and the Rappahannock, York, and James watersheds fall exclusively in Virginia, it may be easier to manage the water runoff specifically in these watersheds because it requires less inter-state cooperation. While highlighting the various watersheds comprising the Chesapeake Bay watershed identifies smaller divisions within the larger whole, these areas are not readily different enough from one another to merit a reasonable way to test how storm water management design changes based on ecological factors.

Another way to segment the area of the Chesapeake Bay watershed is to look at the major ecoregions comprising it. Figure 10 illustrates the four ecoregions that are a part of the watershed. From north to south these ecoregions are: the Appalachian Plateau, the Appalachian Mountains, the Piedmont, and the Coastal Plain. These geographic areas have fundamentally different geological conditions and are part of the water cycle at different points. The Appalachian Plateau sits at the top of the watershed and has the springs which feed the headwaters of the Susquehanna River. This ecoregion also features many small networked streams and riverbeds etched into flat areas punctuated by deep gorges where major rivers have carved into the layered sedimentary rock.¹² The Appalachian Mountains ecoregion includes a series of steeper folded rock features with strong ridge lines. The Blue Ridge, on the southeast edge of this ecoregion, includes volcanic and granitic rocks as well as much of the coal that has powered industry in the Chesapeake region.¹³ Continuing south, the Piedmont can be characterized as

12 Ibid.

13 Ibid.

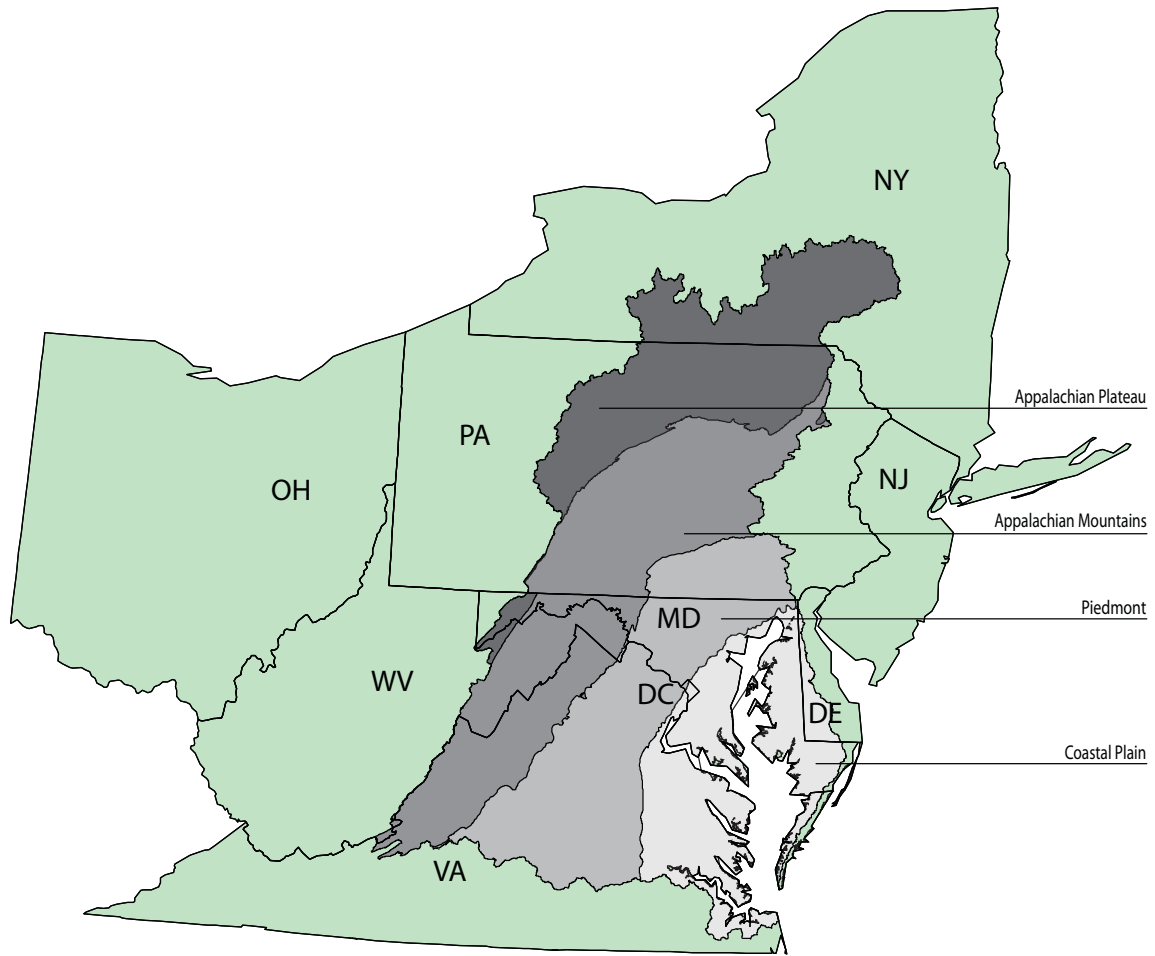


Figure 10: Map identifying the ecoregions of the Chesapeake Bay watershed.

“a gently rolling upland”¹⁴ similar to the Appalachian Plateau, but with a different soil composition. Where the Appalachian Plateau features layered sedimentary rock, the Piedmont consists of a mix between igneous, metamorphic, and sedimentary rocks. The streams are similarly networked in this ecoregion and it is this land that provides the most prime real estate for agriculture in the watershed.¹⁵ The lowlands to the east that surround the Bay, the Coastal Plain, also have rich soils from the sediment deposits carried by the east-flowing streams on their way to the Chesapeake Bay.

Also notable in the ecoregion understanding of the Chesapeake Bay watershed

14 Ibid.

15 Ibid.

is the significant fall line which roughly aligns with the seam between the Piedmont and Coastal Plain ecoregions. This fall line separates navigable waters from inland areas with a series of waterfalls which initially served as power sources for the cities that sprang up along the fall line. Richmond, Virginia; Washington, D.C.; and Baltimore, Maryland all lie along the fall line and were initially port locations where goods would be transferred from oceangoing vessels to land-based transportation systems and vice versa.¹⁶ Figure 11 illustrates the cities of the Chesapeake Bay watershed, including the clearly visible northeast corridor stretching from New York City in the northeast, outside the area of the Chesapeake region, to Washington, D.C. in the heart of the watershed. South of Washington, D.C., the city of Richmond is clearly visible and Norfolk slightly stands out on the eastern edge of Virginia. Developing along the fall line, urbanization of the watershed initially started out with a clear understanding of our relationship to water, but somewhere between the initial settlement of the watershed and today that logic of developing in tune with water's natural cycles was lost.

Regional Planning

Because ecological design is not just a building issue but also one of regional planning, it is important to select building sites that are sustainable at a regional scale. Analysis was undertaken to determine the major interstate highway and passenger rail infrastructure within the Chesapeake region to understand how these two regional transit systems relate to where development has happened and what connections may be underutilized or under provided for in terms of regional connectivity.

Figure 12 identifies the major interstate highways marking the watershed as well

16 Ibid.

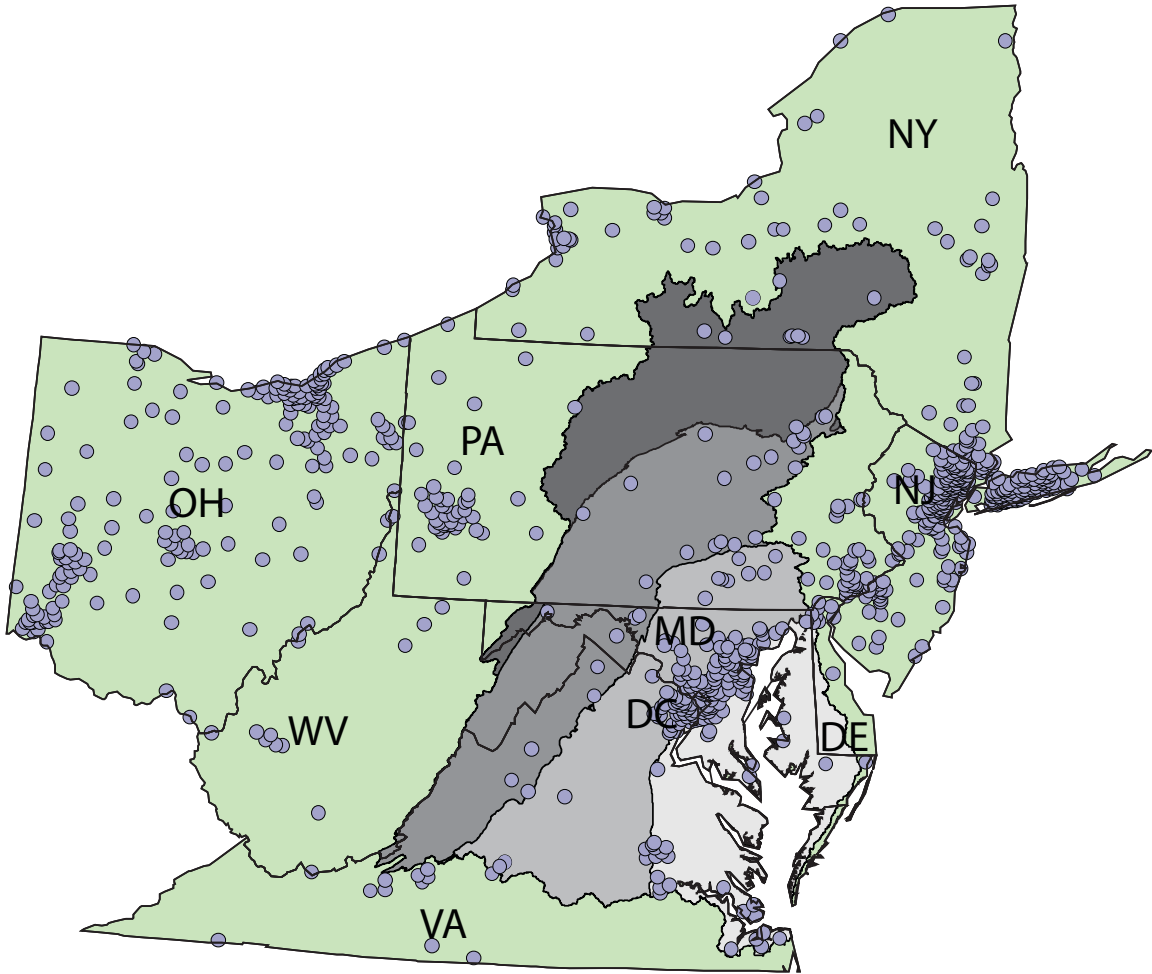


Figure 11: Map identifying the cities of the Chesapeake Bay watershed.

as their connections to cities outside the watershed. West of the major metropolitan areas along the fall line, the interstate highway system is far less prevalent. While many east-west connections exist across the watershed, there are far fewer north-south access routes inland than there are along the coastline and it is much more difficult to identify dense areas of development inland within the watershed.

Mapping the cities across the same area (Figure 11) illustrated a similar pattern of a defined northeast corridor along the coast with development petering out north and west through the watershed. Where Pittsburgh in western Pennsylvania and its suburbs are clearly visible in Figure 11, they are notably not as well defined by the interstate

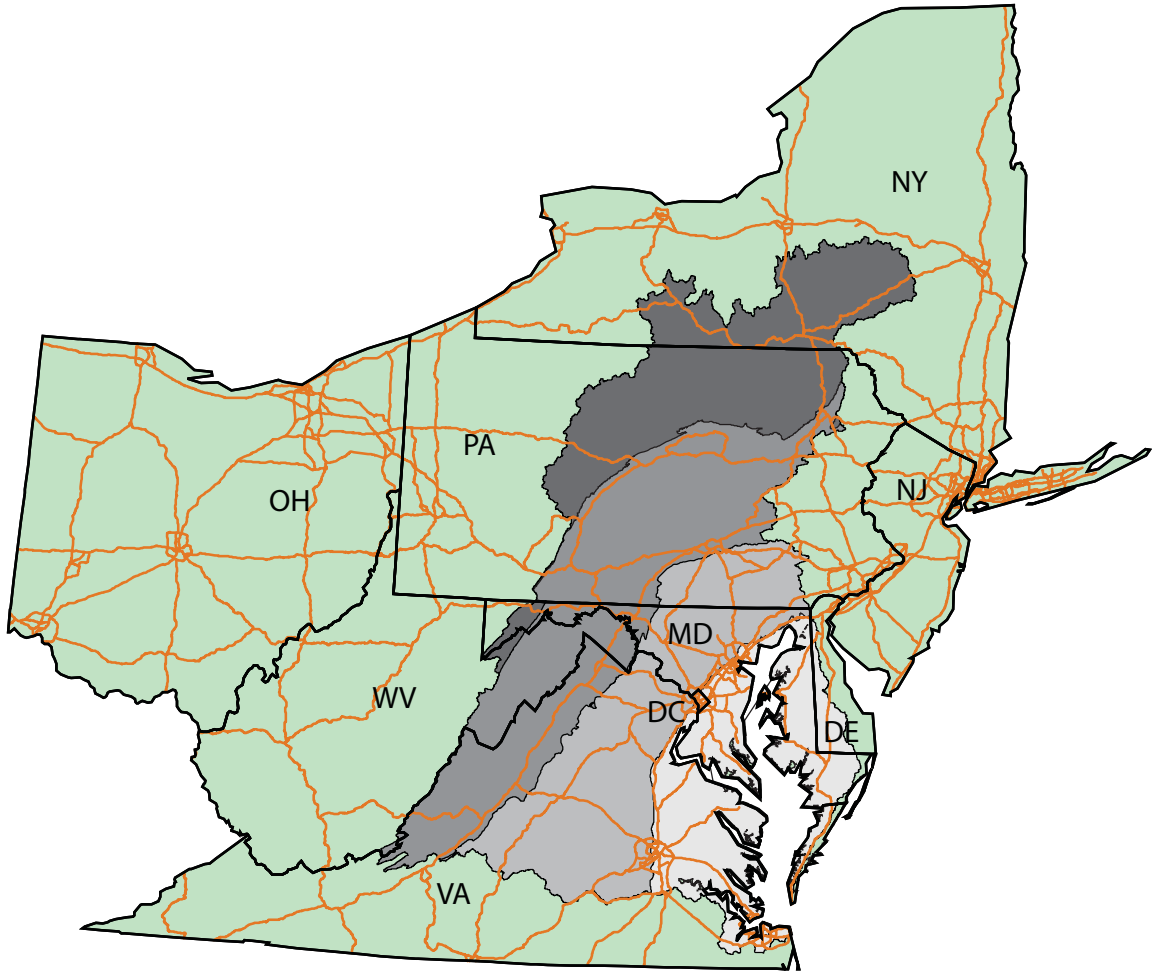


Figure 12: Map identifying the interstate highways that cross the Chesapeake Bay watershed.

highway system as, for example, Baltimore or Philadelphia are. Buffalo, New York is also much more easily identifiable in Figure 12 than in Figure 11. This suggests not all urban areas that are a part of the watershed and its context are equally well-connected. While the obviously important connections are within the northeast corridor, it is much more difficult to understand what the important connections are between the coastal cities and the inland development when looking at the interstate highways and the urban developments. Also evident in comparing the placement of the cities with the placement of the interstates is that aside from the northeast corridor, there is no clear ecological

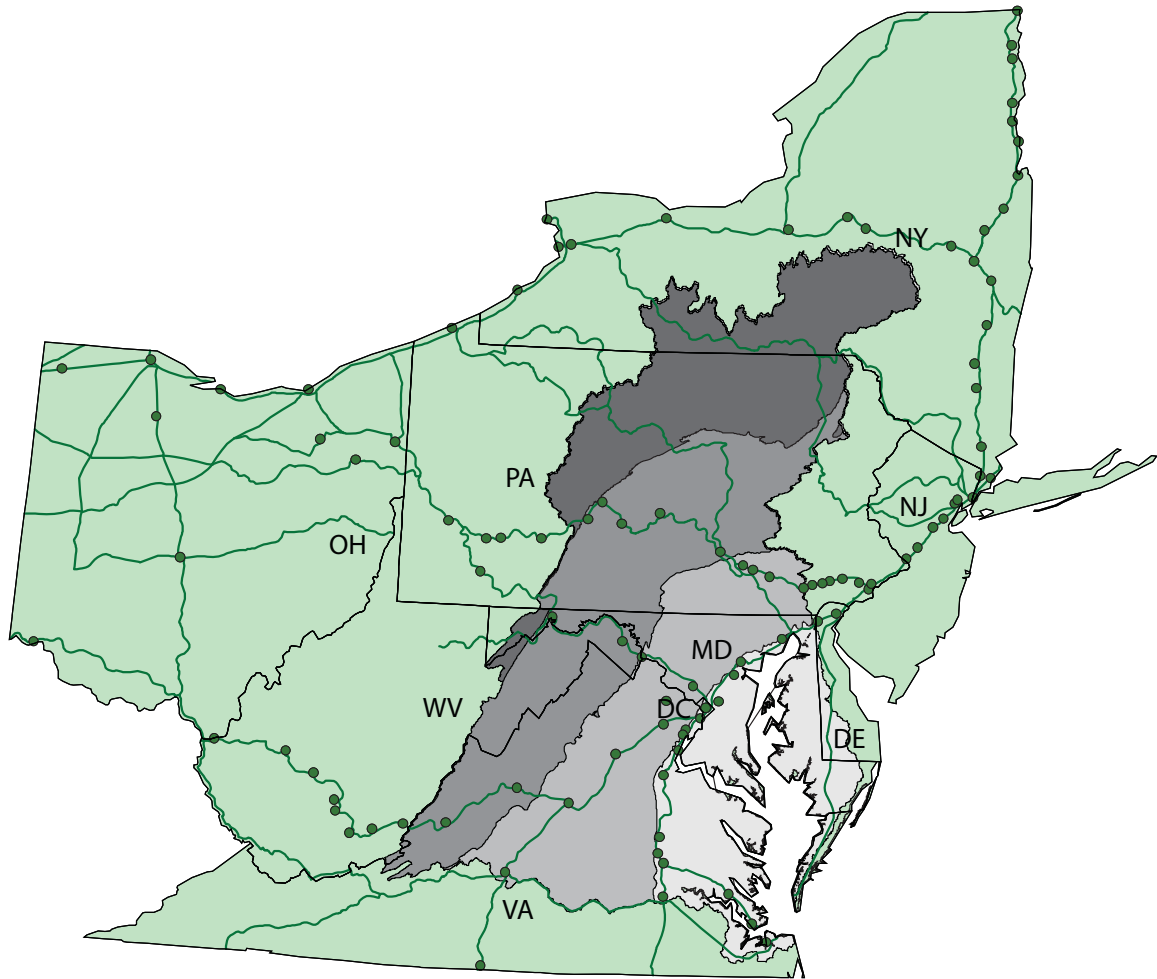


Figure 13: Map identifying the Amtrak rail lines and stations that cross the Chesapeake Bay watershed.

explanation for why the interstate highways crisscross the watershed where they do. A set of highways do seem to run along the breaks between the Appalachian Plateau and Appalachian Mountains ecoregions and a second set between the Appalachian Mountains and Piedmont ecoregions, but there are numerous other interstates in the watershed that seemingly have no connection to the ecosystem of the Chesapeake Bay watershed.

Looking at passenger rail connections across the Chesapeake Bay watershed and its context in Figure 13 illustrates an even clearer breakdown between regional development and the natural processes of the Chesapeake Bay watershed. Passenger

rail connections are similar to the interstate highway system in the watershed in that they are dominated by east-west connections and only provide major north-south connections along the coastline. The connection between Washington, D.C. and Pittsburgh is much more clearly legible in terms of passenger rail than it is in terms of interstate highways, but this relationship seems arbitrary and has no clear relationship to the ecoregion breakdowns of the watershed. The frequency of train stations along the line stretching southwest from Washington, D.C. through Virginia and across southern West Virginia suggests that this line is well-utilized; the stations would not be profitable unless there were passengers making use of the station stops.

Ultimately, however, the takeaway from looking at such regionally significant infrastructure is that these systems are created without a clear regard for the water cycle and other natural systems. The initial urban development of the watershed follows the fall line and clearly can be traced to interests in water, but subsequent development has ignored natural water systems and placed regional transit infrastructure without a clear relationship to the water which is the region's most precious asset.

Four Cities: Comparative Analysis of Cities in the Chesapeake Bay Watershed

Four cities, one representing each ecoregion, were selected for further study to understand what issues are salient for storm water management design at a finer grain. These cities served as the test sites for understanding how storm water management systems vary across the Chesapeake Bay watershed. The 240 boroughs, Census designated places, cities, towns, and villages identified in Figure 11 were sorted to understand which locations fell into which ecoregion. cursory analysis culled this initial set to 56 cities by eliminating sites without a clear urban form as well as those locations

within the watershed that did not have a direct adjacency to a Chesapeake Bay tributary or the Bay itself. These criteria were developed because clear urban areas with a direct relationship to one of the Chesapeake Bay's tributaries or the Bay itself provide greater opportunities to illustrate the interaction between the built environment and the issues of storm water management than locations that do not provide these characteristics. Given the scope of this thesis, preference was also given to small towns instead of major metropolitan areas such as Washington, D.C. and Baltimore. The four towns selected for further study were: Corning, New York representing the Appalachian Plateau ecoregion; Nanticoke, Pennsylvania illustrating the Appalachian Mountains ecoregion; Columbia, Pennsylvania to represent the Piedmont ecoregion; and Havre de Grace, Maryland to illustrate the Coastal Plain ecoregion. Figure 14 illustrates these cities in the context of their ecoregion and their location in the watershed relative to one another.

History

Corning, NY. Before jumping into the comparative analysis of the selected cities, it is important to have some historical background on why these towns exist and what their relationship to water has been over time. Corning, New York lies approximately 200 miles northwest of New York City and is home to 11,000 people and one very important corporate giant: Corning, Inc.¹⁷ Before the glass company gave the town a reason for being, the Corning area was a rural outpost for shipping and agricultural trade. Vast lumber resources were taken to market by floating the sections down the Chemung River via a process called rafting. The river also provided power for sawmills.¹⁸ When

17 Edmonson, Brad, "Corning's Choice," *Preservation* 53, no. 4 (2001): 42.

18 Tom Dimitroff. "Settlement." *History of Corning, NY*, http://www.corningny.com/visitors_history.shtml.

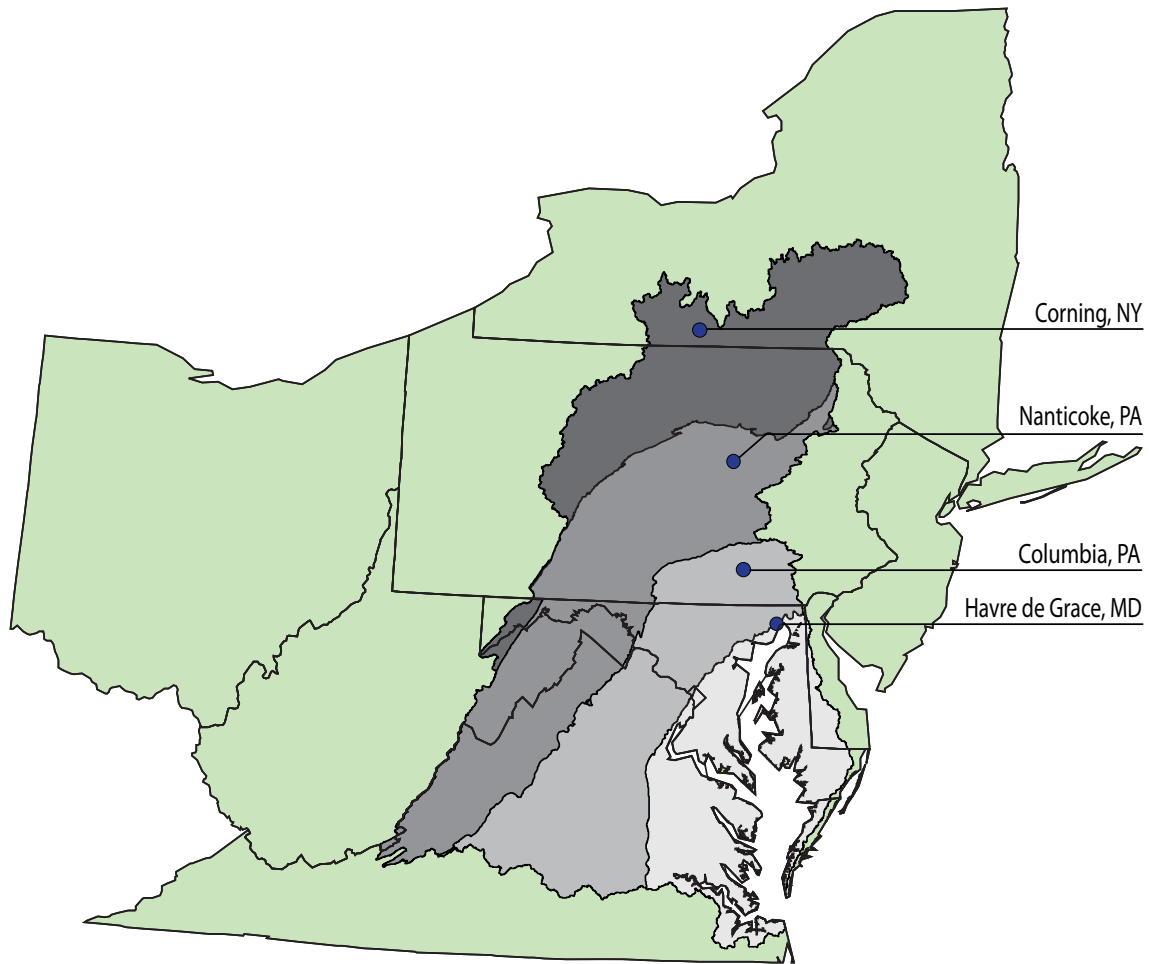


Figure 14: Map identifying the four cities selected as representative of their particular ecoregions.

this resource had been mostly consumed and the lumber business moved north and west, canal fever heralded the next phase of the area's development. As the Erie Canal brought prosperity to cities along its length, towns across New York state demanded connection to the canal network to encourage industry. Elmira, Corning's neighbor on the river, gained a feeder canal to the Erie system and boat traffic increased industrial developments throughout the area although passenger travel via water routes remained low.¹⁹

Corning was created as a speculative development by investors from Albany who purchased land along the Chemung River to create a new village, believing that

¹⁹ Tom Dimitroff. "Canals." *History of Corning, NY*, http://www.corningny.com/visitors_history.shtml.

a town where the planned railroad and existing canal business met would make a good investment. The development, named after one of its initial investors, quickly grew and surpassed its predecessors in the area in terms of population, businesses, and services. Corning became a bustling trade hub transferring coal, lumber, tobacco, grain, and whisky between river and land travel and vice versa. Although the canals were abandoned in 1878, the railroads continued to provide year-round service to area industries including railroad and rock drilling manufacturing and glass making.²⁰

As these businesses brought employees and commercial activity to the area Corning developed the “stability, maturity, and wealth of an urban center.”²¹ In 1866, Corning resident Elias B. Hungerford invented an indoor blind which he unsuccessfully tried to get several glass companies to manufacture. As he learned more about the glass industry, he began to believe his hometown would be an ideal site for a glass-manufacturing firm. Amory Houghton Sr., owner of what was then known as the Brooklyn Flint Glass Works, was also interested in moving his sluggish family business out of New York City. Successful negotiations between the Corning, New York and the Brooklyn Flint Glass Works brought the company to Corning in 1868 as the Corning Flint Glass Company.²² The one-hundred-fifty-year history of Corning, Inc. in Corning, New York tells a beautiful tale of big business being a good corporate citizen to a small town along a river.

Beyond the relationship between the city and Corning, Inc., other notable historic events include the flood of the Chemung River in 1972. Six to eight inches of rain fell

20 Ibid.

21 Tom Dimitroff. “Industry.” *History of Corning, NY*, http://www.corningny.com/visitors_history.shtml.

22 Edmonson, Brad, “Corning’s Choice,” *Preservation* 53, no. 4 (2001): 44.

into the Chemung River basin when Hurricane Agnes combined with a low-pressure system from the Midwest. The dikes that controlled the river broke in multiple locations and by approximately 9 am on June 23, 1972, the river reached its highest point in Corning.²³ Many became trapped in their attics and second floors as the flood waters rose, although surprisingly few died given how unprepared the city was. The waters only stayed high for a few hours, but the work of cleaning up took significant assistance from the National Guard, the Salvation Army, the Department of Housing and Urban Development, and the Small Business Administration. In the immediate aftermath of the flood, fresh drinking water was trucked in from as far as New York City to provide for Corning's residents.²⁴

Corning Glass Works, as the company was known at this time, also suffered from the flood. The factory found itself under twenty-five feet of water, and while measures were taken to clean up the mess, Corning Glass Works also stepped up and assigned many employees to community projects where their skills could be utilized while the factory was being cleaned up.²⁵ The company also quelled fears that Corning, Inc. might abandon the area by announcing "interest-free loans for employees and retired employees"²⁶ to help fund the clean up effort. The clean up, since 1972, has had visionary leadership which has used the flood's destruction as an impetus for urban renewal and restoration of the historic character of the town.²⁷

23 Tom Dimitroff. "The Flood." *History of Corning, NY*, http://www.corningny.com/visitors_history.shtml.

24 Ibid.

25 Ibid.

26 Ibid.

27 Tom Dimitroff. "Post Flood." *History of Corning, NY*, http://www.corningny.com/visitors_history.shtml.

Changes in Corning, New York also reflect changes in Corning, Inc. Where the company used to be mostly manufacturing, Corning, Inc. has seen its business shift to more research and engineering work. Corning engineers were part of the development of optical communications and the company now creates 40% of the world's fiber optic cable.²⁸ This has brought in a workforce of a slightly different character for Corning and the city itself has responded, developing museums, commerce, and tourist attractions. Corning, Inc. recognizes they must invest in the town in order to attract and retain the most talented employees for their industry. In 2000 alone the company donated \$1.6 million to the YMCA, \$2.2 million to the city library, \$5 million for sewer improvements, \$12.5 million for a new bridge, and \$14 million for a new hotel. Corning, Inc. is also responsible for the \$2.5 million dollar historic renovation of the city's town hall which is now going to be used as a mixed-use project. "Local pride and deep pockets have turned the city's five-block historic district into a small-town American dream,"²⁹ according to one writer.

Corning's relationship to the Chemung River has allowed the city to flourish with industry and commerce. Although the technology has changed and the city no longer features an industrially active waterfront, the city's renewal owes itself to the 1972 flood. The fate of Corning, New York is intimately tied to Corning, Inc., but the diversification of the company's business since the flood has allowed the city to grow and expand beyond its industrial reason for being. Development since 1972 has seen Corning become a center for tourism with the continued support of Corning, Inc.

28 Edmonson, Brad, "Corning's Choice," *Preservation* 53, no. 4 (2001): 44.

29 Ibid.

Nanticoke, PA. Although its origins were in small-scale manufacturing, Nanticoke, Pennsylvania is the quintessential Pennsylvania coal mining town. The area bounded by the Susquehanna River on the north and the Blue Ridge Mountain foothills to the south was settled in the 18th century by people who saw the opportunity apparent in the Susquehanna Rapids. They established a gristmill, iron forge, and sawmill all powered by the river.³⁰ The same asset in the rapids that provided power, their turbulence, also made it difficult for Nanticoke to establish itself as a port along the Susquehanna. The rapids made navigation difficult and while skilled pilots could take boats up and down the river, transit along this stretch of the Susquehanna River never particularly caught on as a business.³¹ The city remained small and was incorporated as a village in 1830.³² While the river was eventually used as part of an extensive canal system around this time, “the canal was hardly completed before its insufficiency for the age became apparent,”³³ and railroads quickly took over transportation of goods and passengers in the area in 1861.³⁴

A group of landowners with coal deposits formed the Nanticoke Railway company and created a rail line along the route of their lands to transit the coal they mined from the earth. Within the decade this line was purchased by the Lehigh & Susquehanna company and was subsequently connected to more far-reaching railroads throughout Pennsylvania.³⁵ The first anthracite coal mine in the area opened in 1825, and

30 *History of Nanticoke*, <http://www.nanticokecity.com/history.htm#HISTORY>.

31 Henry C. Bradsby, ed., *History of Luzerne County, Pennsylvania*, (Chicago: S.B. Nelson & Co., Publishers, 1893), 259.

32 *History of Nanticoke*, <http://www.nanticokecity.com/history.htm#HISTORY>.

33 Henry C. Bradsby, ed., *History of Luzerne County, Pennsylvania*, (Chicago: S.B. Nelson & Co., Publishers, 1893), 259.

34 Ibid.

35 Ibid, 261.

it took approximately fifty years for coal to catch on with the public and for Nanticoke to become a major coal-mining center in the region.³⁶ The city was formally chartered as a Borough by the state of Pennsylvania in 1874 and the combination of rich coal deposits and rail transit to move the product to market allowed Nanticoke to reach its heyday between 1917 and 1925.³⁷

As coal moved from local entrepreneurs to big business, the Delaware, Lackawanna, and Western Railroad Company (DL&W) became prominent in the area. DL&W transited anthracite on extensive rail networks and slowly began to acquire coal-rich land.³⁸ By the 1870s the company's holdings included 25,000 acres of the richest, most accessible coal fields in the region.³⁹ The business brought an influx in population and housing was in short supply. In 1911 DL&W constructed Concrete City, a worker housing complex made of poured concrete, on the outskirts of Nanticoke to house its mine workers.⁴⁰ The concrete city, now derelict and in ruins, was a unique solution to the issue of worker housing at the time. Contemporary developments were stick-built and of low quality. Concrete City utilized the modern construction of the day and while it did not have a wide impact on other corporate housing developments, it did create a pocket of forward-thinking development in an isolated community.⁴¹

Because DL&W controlled both the means of production for anthracite and the ability to transit that good to market, it was eventually ruled a monopoly by federal law

36 *History of Nanticoke*, <http://www.nanticokecity.com/history.htm#HISTORY>.

37 Luzerne County, "City of Nanticoke," *Luzerne County Living*, http://www.luzernecounty.org/living/municipalities/city_of_nanticoke.

38 Robert A. Janosov, "Concrete City: Garden Village of the Anthracite Region," *Pennsylvania Heritage*, Summer 1997, 34.

39 Ibid.

40 Ibid, 32.

41 Ibid, 35.

and the company was forced to divest itself of its coal land in 1908.⁴² After a series of court rulings and changes in operation and ownership, the mines became the property of the Glen Alden Coal Company in 1921.⁴³ The new mining company also took ownership of Concrete City who abandoned the development in 1924 when sewer repairs proved to be cost prohibitive. The demand for coal slowly declined as fuel oil, natural gas, and electricity use increased and by 1973 all of the coal mines were closed.⁴⁴

Today Nanticoke is dominated by residential development with a small amount of light manufacturing and retail and Luzerne County Community College's main campus.⁴⁵ Development has not moved toward the river, potentially because of extensive flooding in the first half of the 19th century. While Corning, New York's access to the river proved to make transit and industry possible, the turbulent characteristics of water in the Appalachian ecoregion led Nanticoke to develop the other resources available to them in the watershed.

Columbia, PA. Columbia, Pennsylvania is advantageously located in the Piedmont ecoregion of the Chesapeake Bay watershed on a wide, calm area of the Susquehanna River halfway between the county seats of York and Lancaster counties. The area was first settled by Europeans in 1726 when John Wright, his family, and a small group of other settlers established permanent homesteads.⁴⁶ Wright started a ferry service for goods and people to cross the Susquehanna in 1730 and the business quickly

42 Ibid, 34.

43 Ibid.

44 *History of Nanticoke*, <http://www.nanticokecity.com/history.htm#HISTORY>.

45 Luzerne County, "City of Nanticoke," *Luzerne County Living*, http://www.luzerne-county.org/living/municipalities/city_of_nanticoke.

46 Columbia Borough, "History," *Borough of Columbia, Pennsylvania*, <http://psab-content.com/columbiapa/content/history.php>.

became profitable. Columbia, then known as Wright's Ferry, was connected by road to Lancaster to the east in 1734 and by the end of the decade thirty-four miles of public road were laid south and west of the city to connect Wright's Ferry to Monocacy Road which led to the Potomac River in Maryland.⁴⁷ The crossing at Wright's Ferry thus became a critical travel link during colonial development and the frequency of the travelers inspired development.

Wright's Ferry was the best connected river crossing point in the area and it was not uncommon that travelers would have to wait multiple days to cross the Susquehanna River.⁴⁸ Businesses such as taverns, inns, and various dry goods stores sprang up to accommodate travelers and business remained strong until the first bridge across the Susquehanna was built in 1814.⁴⁹ By this time John Wright's grandson Samuel had already laid out 160 lots and named the development Columbia after Christopher Columbus.⁵⁰

The turn of the 19th century brought canal fever to Columbia. Canals were completed north of the city, but the falls south of the city remained rough and unnavigable.⁵¹ Columbia thus became the southernmost point of the canal route and developed as a hub where goods from northern and central Pennsylvania were transited from water vessels to land travel. The roads that had made the ferry crossing profitable made Columbia ideally suited as a gateway between river and land travel. Rail lines

47 The Gombach Group, "Columbia Borough," *Living Places*, http://www.living-places.com/PA/Lancaster_County/Columbia_Borough.html.

48 Ibid.

49 Ibid.

50 Columbia Borough, "History," *Borough of Columbia, Pennsylvania*, <http://psab-content.com/columbiapa/content/history.php>.

51 The Gombach Group, "Columbia Borough," *Living Places*, http://www.living-places.com/PA/Lancaster_County/Columbia_Borough.html.

opened in 1834 and Columbia maintained its status as a commercial center.⁵²

Columbia's status as a gateway city became significant during the Civil War when General Robert E. Lee ordered the Confederate troops to march on Lancaster. While the Confederacy was still on the west side of the Susquehanna, the Union Army set fire to the Columbia River Bridge to impede the Confederacy's progress and to keep the war out of Lancaster county. The Confederate soldiers were rerouted through Gettysburg, where the Union Army met them and fought one of the most important battles of the entire war.⁵³ As Gettysburg was one of the most significant Union victories, the Civil War might have taken a very different course had the bridge at Columbia not been destroyed. After the war, the bridge was rebuilt and Columbia continued to be a transit hub.

Moving forward to the late 19th century, the discovery of iron ore led to new industry in Columbia. At its height, the iron industry would reach thirteen blast furnaces within a three-mile radius of the town.⁵⁴ Other industries, including silk and textile production, were also established in Columbia but would begin to slow down toward the turn of the 20th century. Iron ore deposits were exhausted and the lumber industry decimated the woodlands, bringing economic decline to the once prosperous community. Railroad use continued to grow and Columbia's initial reason for being, the ferry and the canal operations, were shut down entirely in 1901.⁵⁵

The community continued to struggle economically through the Great Depression but saw a short resurgence during the interwar period before declining again. Strong

52 Columbia Borough, "History," *Borough of Columbia, Pennsylvania*, <http://psab-content.com/columbiapa/content/history.php>.

53 Ibid.

54 Ibid.

55 Ibid.

public leadership is currently inspiring private investment in Columbia. The area is undervalued relative to surrounding communities and the area is beginning to experience some economic renewal.⁵⁶ The city's rapid decline after so many years of wealth and prominence means that Columbia has retained many of its 18th to early 20th century buildings and historic preservation efforts in the community are strong.⁵⁷

Havre de Grace, MD. Havre de Grace, Maryland, on the northwest edge of the Chesapeake Bay at the mouth of the Susquehanna River can trace its history back to its first recorded exploration by John Smith, of Pocahontas fame, in 1608.⁵⁸ The city's initial settlement was mostly through family homesteading although business did find a foothold in Havre de Grace when the city became established as a ferry point in the 1690s.⁵⁹ The Lower Susquehanna Ferry to connect the western and eastern shores of Maryland quickly became a profitable way to transport goods and people. Early industry in the area focused on the riches of the Bay with fishing, farming, and hunting in addition to the processing and transiting of the resultant goods keeping Havre de Grace's waterfront booming.⁶⁰ The Conowingo Dam, opened in 1927, markedly changed Havre de Grace's relationship to the water and today the city is in transition from a bustling industrial harbor town to a more picturesque vacation and retirement community with a boardwalk promenade.⁶¹

56 Ibid.

57 The Gombach Group, "Columbia Historic District," *Living Places*, http://www.livingplaces.com/PA/Lancaster_County/Columbia_Borough/Columbia_Historic_District.html.

58 Bill Bates. *Images of America: Havre de Grace*. (Chicago: Arcadia Publishing, 2006), 7.

59 Virginia Colburn, Elizabeth H. Amoss, and Kathryn W. Mike. *A Bicentennial Sketch*. (Havre de Grace, MD: Susquehanna Publishing Co., Inc., 1976), 6.

60 Bill Bates. *Images of America: Havre de Grace*. (Chicago: Arcadia Publishing, 2006), 31.

61 Ibid, 7.

Havre de Grace's unusual name came about as a result of the city's prime location on the north-south transit route during the Revolutionary War. As a result of its location and the ferry crossing across the Bay, the city became a frequent stop along the journey for important figures in the war effort, including General George Washington and the Marquis de Lafayette.⁶² During one of Lafayette's 1782 visits, he noted similarities between the city he was in and Le Havre, France. The citizens, impressed with his stature in the war effort, formally named the town Havre de Grace, French for Harbor of Grace, in 1785.⁶³ Around this time, it was also put forth that Havre de Grace might be an ideal site for the new capital of the United States. At one time the city was also considered as a possible location for the county seat of Harford County. Either of these events would have significantly changed the course of Havre de Grace's history and would have impacted Havre de Grace's most notable characteristic - "its success in staying much the same as the decades passed."⁶⁴

This harbor town, which owed its initial success to river and bay transit switched to trains and trucks once tracks and roads were in place. As part of Amtrak's Northeast Railroad Corridor, Havre de Grace has always been located on the major north-south train route for the east coast. Access to Route 40 in 1940 and Interstate 95 in 1963 also allowed Havre de Grace to remain connected to the growing vehicle transit network.⁶⁵

Thus while Havre de Grace maintains its quaintness, its easy access to the larger

62 Virginia Colburn, Elizabeth H. Amoss, and Kathryn W. Mike. *A Bicentennial Sketch*. (Havre de Grace, MD: Susquehanna Publishing Co., Inc., 1976), 7.

63 "City Profile - History." *Havre de Grace: Unique on the Chesapeake*. http://www.havredegracemd.com/city_profile_history.php

64 Peter A. Jay, ed. *Havre de Grace: An Informal History*. (Havre de Grace, MD: The Susquehanna Publishing Company, 1986), 165.

65 Bill Bates. *Images of America: Havre de Grace*. (Chicago: Arcadia Publishing, 2006), 31.

infrastructure of the region keeps it from becoming a forgotten heirloom city.

The year 1912 is significant in Havre de Grace's history because the opening of a new hospital as well as a new racetrack breathed life into the city. Harford Memorial Hospital has been continuously operated in Havre de Grace since 1912 and makes the city an important link in Harford County's health care delivery system.⁶⁶ The racetrack, created with stockholder money from Maryland, New York, and Pennsylvania, brought new faces to the town and introduced new economic activity.⁶⁷ Off-track betting was illegal in New York, Pennsylvania, and Delaware, and as a result those hoping to strike it rich made their way to Havre de Grace to try their luck.⁶⁸ Races ended and the 117-acre site was sold in 1951 to the National Guard but has since been resold to the City of Havre de Grace.⁶⁹

The changes in transit and the general diversification of business in Havre de Grace proved to be exceptionally beneficial as the relationship to the Susquehanna and the Bay have changed. Managing water always affects those downstream, and the opening of the Conowingo Dam in 1927 significantly impacted the future development and character of Havre de Grace. Before the dam, "the Susquehanna cursed Havre de Grace with fierce floods and ice gorges that covered much of the streets close to the water. At the same time, the river blessed the residents with spawning grounds for fish and nutrients for plants that attracted and sheltered waterfowl."⁷⁰ The duck decoys that

66 Virginia Colburn, Elizabeth H. Amoss, and Kathryn W. Mike. *A Bicentennial Sketch*. (Havre de Grace, MD: Susquehanna Publishing Co., Inc., 1976), 11.

67 Ibid, 19.

68 Bill Bates. *Images of America: Havre de Grace*. (Chicago: Arcadia Publishing, 2006), 113.

69 Virginia Colburn, Elizabeth H. Amoss, and Kathryn W. Mike. *A Bicentennial Sketch*. (Havre de Grace, MD: Susquehanna Publishing Co., Inc., 1976), 19.

70 Bill Bates. *Images of America: Havre de Grace*. (Chicago: Arcadia Publishing,

Havre de Grace had once produced to fulfill a functional need of the community became collector's items and fishing, farming, and hunting recoiled in the aftermath of the dam.

The dam made it impossible for fish to travel between the Bay and their native spawning grounds north of the dam. The Philadelphia Electric Company, which initially built and still operates the dam, has repeatedly turned down requests to build a fish ladder which would allow species to migrate and bypass the dam.⁷¹ Some relief from the dam's impact came in 1971 when the Philadelphia Electric Company's 50-year license to operate the dam came up for renewal. Summer droughts "raised water temperatures and depleted oxygen below the dam, and on many occasions produced huge fish kills."⁷² Events like this, which brought the impacts of the dam to the attention of the non-fishing public, forced Philadelphia Electric to maintain a minimum flow through the dam in order to renew its contract.⁷³ The minimum flow required is still far below what would naturally flow from the Susquehanna, but it does help to mitigate the dam's impact. While commercial fishing interests in the area have subsided in the area of the dam, sport fishing remains popular as rockfish and other native species come to the waters just south of the dam to feed on the broken fish that come through the turbines.⁷⁴ Waterfowl are in turn attracted by the fish which allows the ecosystem to continue, but the commercial possibilities the joint between the Susquehanna River and the Chesapeake Bay once provided are no longer a reality.

Where Corning, New York illustrates a good relationship between big business
2006), 21.

71 Peter A. Jay, ed. *Havre de Grace: An Informal History*. (Havre de Grace, MD: The Susquehanna Publishing Company, 1986), 58.

72 Ibid, 59.

73 Ibid.

74 Ibid.

and its surrounding community, Havre de Grace illustrates a cautionary tale. Philadelphia Electric has not been a good corporate citizen to Havre de Grace and it is only thanks to the fact that the city's businesses had already begun to diversify before the dam was built that the city continues. While the city has not developed in the same way that its neighbors Bel Air and Towson have, the city is capitalizing on its uniqueness of place to establish Havre de Grace as a tourist attraction and retirement community.

Ecological Comparisons

With a historical understanding of the cities under analysis, comparisons were made across four ecological indicators to understand how site conditions quantitatively vary among the ecoregions using the representative cities. Average precipitation was compared over the course of the year to understand how much water is incident on these sites. This is significant because it establishes how much water naturally arrives and must be managed on-site during storm events before it is released to the natural drainage system. Comparing the temperature variable across the four cities helps illustrate how warm and cold the cities are relative to one another over the course of the year and helps describe whether precipitation comes to the cities in rain or snow. It also helps to determine the length of the growing season. Latitudes were also recorded at all sites to understand each city's unique relationship to solar movements. Designing for passive solar exposure as well as active systems such as solar thermal and photovoltaic systems will benefit from this information. Topographic maps in each city were analyzed to understand how water might behave once it hits the earth; whether it will run quickly down the site because of steep slopes or whether it will roll more gently down flat terrain. This information forms the foundation for an ecological understanding of the watershed

and how the four ecoregions relate to one another.

Precipitation. The amount of precipitation incident on the site helps determine what plant and animal species will be successful in an area and it helps to describe the breadth of the storm water management issue. The more precipitation there is, the more measures must be taken to manage that storm water effectively. Figure 16 is a chart comparing the average monthly rainfall in each of the four cities selected for further analysis and study.

Corning, New York, the representative Appalachian Plateau site, consistently has the least amount of precipitation among the four sites, which is surprising given New York's reputation for heavy winter snowfall. Nanticoke, Pennsylvania and by extension the Appalachian Mountains ecoregion has the highest average precipitation of the watershed in the winter months, January and February. Columbia, Pennsylvania has the highest average monthly precipitation for any single data point represented on the chart with more than 4.5 inches of precipitation in the month of July. Havre de Grace, Maryland consistently has at least 2.5 inches of precipitation each month.

All the data points represented in the chart illustrate that rainfall throughout the Chesapeake Bay watershed averages between 1.5 and 5 inches monthly, regardless of ecoregion. While the difference between 1.5 and 5 inches is not insignificant, it is also not so drastically different as to require a completely different approach to storm water management throughout the watershed because of volume. If the sites under comparison were more drastically different, for example comparing a desert to a rain forest, this precipitation data might suggest that more fundamentally different design approaches with regards to storm water management might be appropriate. As it stands, variations in

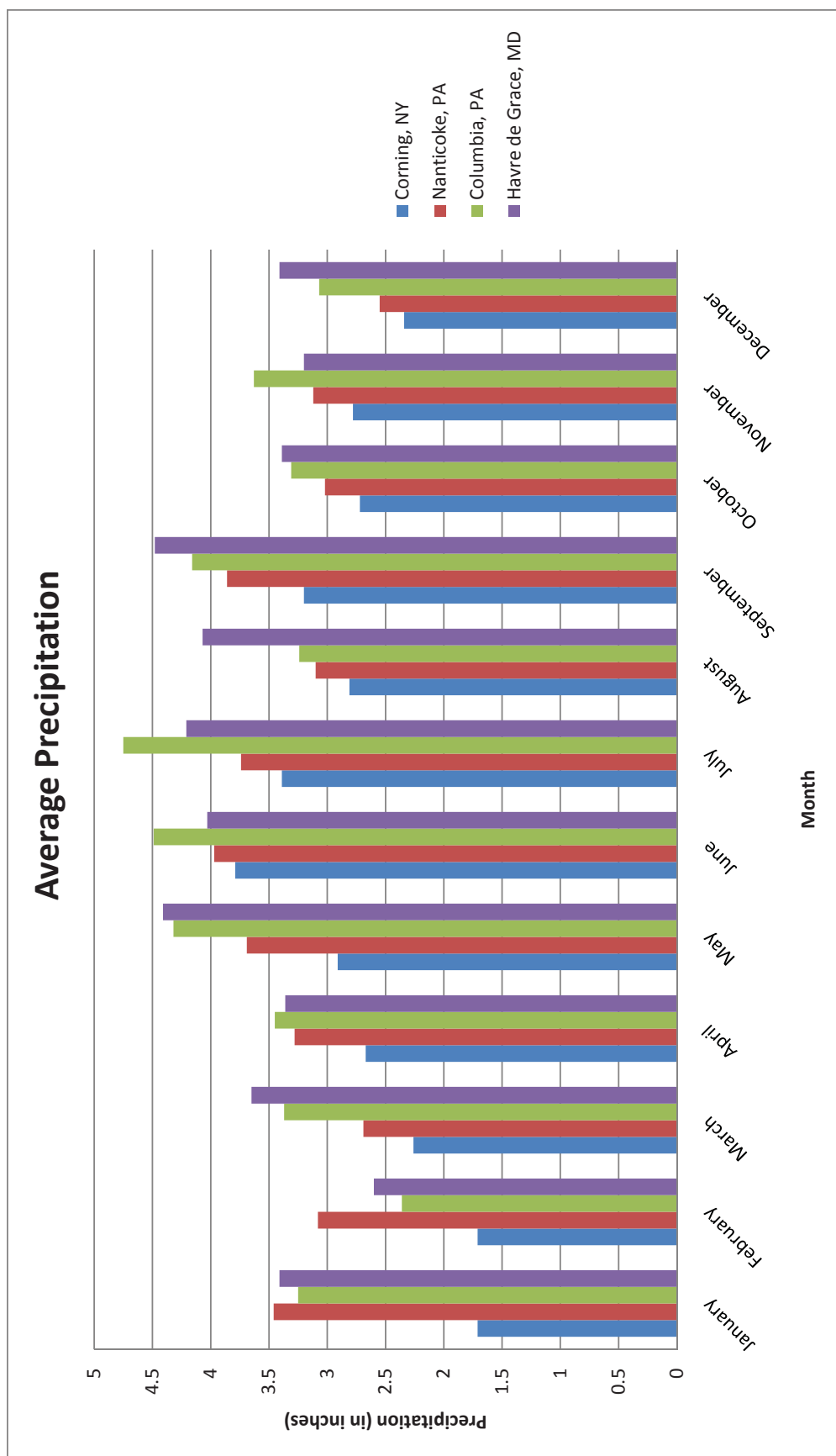


Figure 16: Chart comparing the average precipitation of Corning, NY; Nanticoke, PA; Columbia, PA; and Havre de Grace, MD.

precipitation volume are not significant enough across the Chesapeake Bay watershed to appreciably differentiate design strategies for storm water management.

Temperature. Figure 17 represents a chart comparing the average monthly temperatures in the four cities under consideration to understand what fundamental differences exist between the ecoregions of the Chesapeake Bay watershed. Corning, New York, the northernmost site, always has the lowest averages temperatures and Havre de Grace, Maryland, the southernmost site, always has the highest averages temperatures. The two Pennsylvania sites fall in between with the northern Pennsylvania site, Nanticoke, being on average cooler than its neighbor Columbia to the south. Average winter temperatures in the watershed fall between 20°F and 40°F while summer temperatures reach between 60°F and 80°F.

This data set also suggests that the growing season for all four ecoregions of the watershed is of similar length. Havre de Grace, Maryland averages temperatures above 50°F between April and October, a seven-month growing season. Columbia, Pennsylvania and Nanticoke, Pennsylvania are just breaking 50°F in April and in reality are more likely to have a growing season lasting approximately six months between May and October. Corning, New York has the shortest growing season, breaking 50°F between May and September.

The length of the growing season is significant because it demonstrates thriving in the coastal areas of the watershed will be different than those that are most successful in the northernmost reaches of the watershed. Because minimizing hardscape allows the water cycle to happen most ideally, landscape interventions can serve an important role in mediating between the built environment and the water cycle. It is important

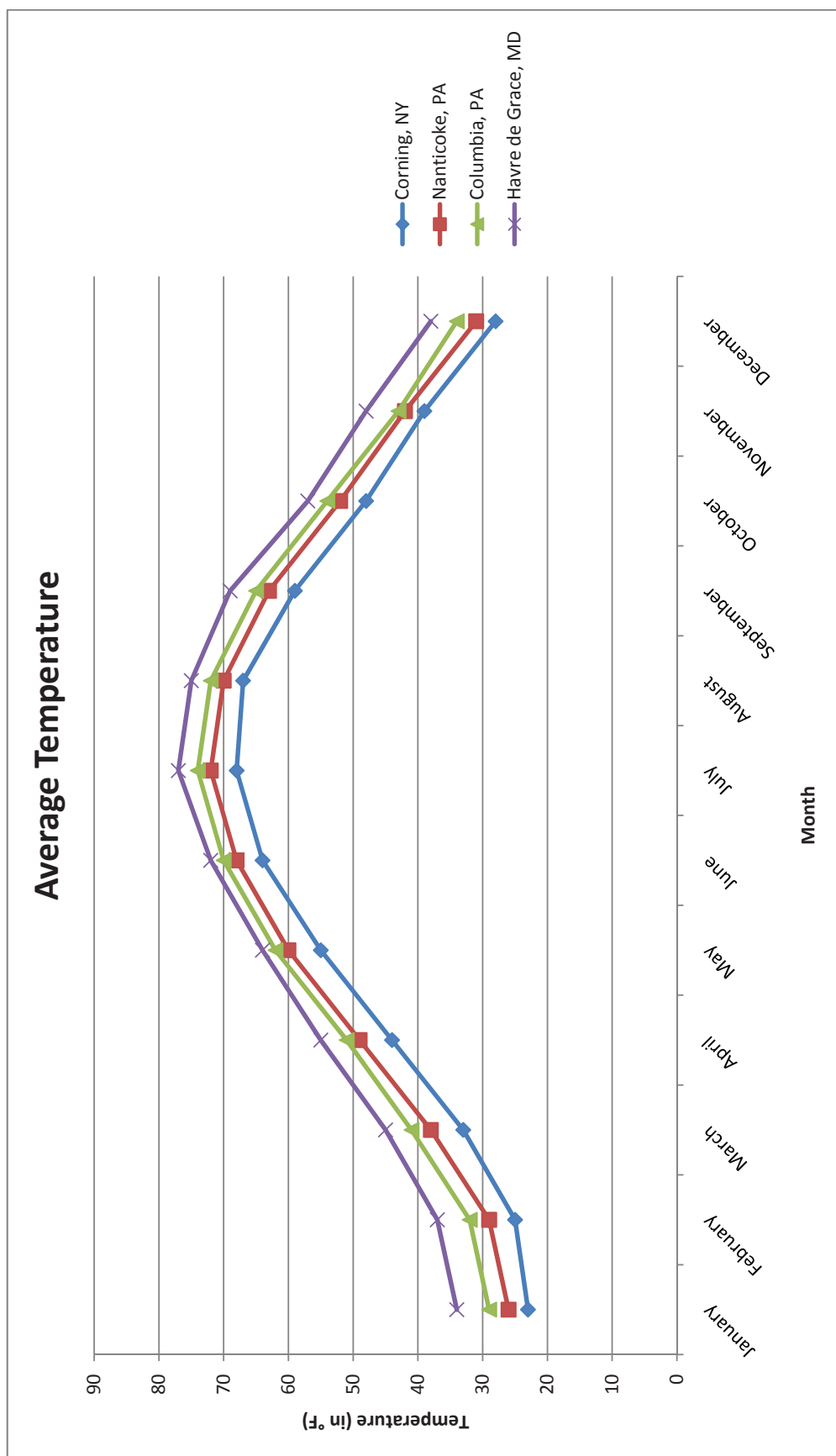


Figure 17: Chart comparing the average temperatures of Corning, NY; Nanticoke, PA; Columbia, PA; and Havre de Grace, MD.

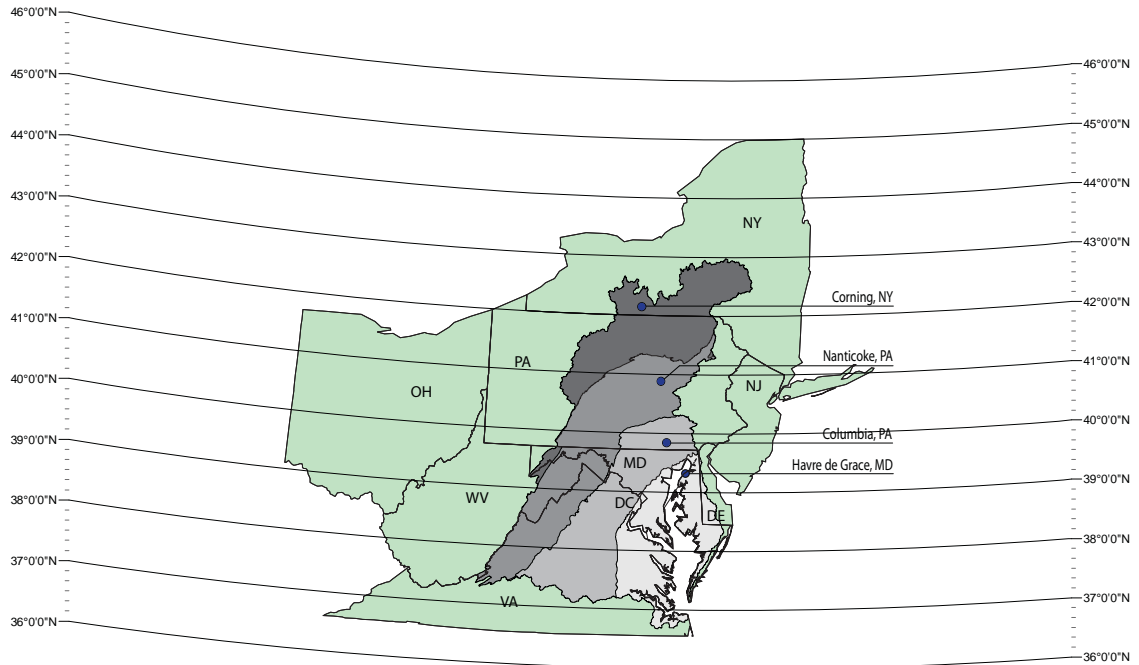


Figure 18: Graphic comparing the latitudes of Corning, NY; Nanticoke, PA; Columbia, PA; and Havre.de Grace, MD. The selected cities fall between 39.0 ° N and 43.0 ° N latitude.

to understand variations across the watershed that impact landscape because similar landscape design elements might be possible and appropriate tools for storm water management in different ecoregions but may require different plant species to effectively manage storm water on-site in different locations.

Latitude. Figure 18 shows the watershed map in its context with the divisions of the ecoregions, the placement of the four cities under study, and the latitude of the earth. Latitude is an important consideration when designing for natural cycles because it describes the relationship between the site and the sun. Knowing the relationship between the site and the sun, a designer can appropriately design for passive solar gain and active solar power generation. The watershed stretches from approximately the 37th parallel in the south to the 43rd parallel in the north. Havre de Grace, Maryland and

Columbia, Pennsylvania are located between 39° and 40° north latitude. Nanticoke, Pennsylvania is just south of 41° north latitude and Corning, New York is just north of 42° north latitude.

Similar to the data about precipitation, variations with regards to latitude and solar orientation exist across the watershed but are not significantly different enough to require fundamentally different design strategies. If the comparison were more than a few degrees difference between north and south and more like the difference between a tropical climate with a very low latitude and an arctic climate with a much higher latitude this data might become a significant design driver, but as the data show, the variations in latitude across the Chesapeake Bay watershed are not a compelling inspiration for design variation in storm water management.

Topography. Figures 19 - 22 compare the topographical change in each of the four cities under analysis. Blue in these diagrams represents water. The darker brown tones represent lower elevations relative to their most immediate body of water and light grey and white tones represent higher elevations relative to their most immediate bodies of water. Topographical lines are drawn at every 20' of change in elevation.

Represented at the same scale, these images provide clear topographical similarities and differences between the selected cities and by extension the ecoregions of which they are a part. Corning, New York is sited in the valley between a set of mountains. The southern portion of the city begins to climb the foothills of these mountains, but in general, the city is flat and the majority of it falls within 40' of the elevation of the Chemung River. Nanticoke, Pennsylvania in the Appalachian Mountains, is hilly and has significant changes in grade. While the highest points in elevation happen



Figure 19: Topographic map of Corning, NY. Scale: 1" = 2500'



Figure 20: Topographic map of Nanticoke, PA. Scale: 1" = 2500'



Figure 21: Topographic map of Columbia, PA. Scale: 1" = 2500'



Figure 22: Topographic map of Havre de Grace, MD. Scale: 1" = 2500'

to the northwest of the city, the elevation changes through the city grid are significant and it is clear this town is quite literally built onto the face of a significant slope. Columbia, Pennsylvania in the Piedmont is similarly in the foothills of a few small peaks. North and southwest of the city there are small spikes in local elevation, but the city itself is a relatively even, rolling hillside. Havre de Grace, Maryland adjacent to the Chesapeake Bay itself falls almost entirely within 40' of the elevation of the Bay.

In summary, of the four ecological points of comparison described above, two do not illustrate a significant enough difference to promote design variations while two do. Precipitation and latitude across the watershed vary, but not enough for it to fundamentally change design strategies across the watershed. Temperature, and by extension length of the growing season, as well as variations in topography across the watershed differ enough amongst the ecoregions to inform differentiations in design strategies for storm water management across the watershed.

Looking at these four sets of data in comparison with one another demonstrates the general trend that Corning, New York is generally coldest and reasonably flat, while Nanticoke, Pennsylvania is generally cold but significantly sloped. Columbia, Pennsylvania is generally warm and on a slightly rolling hillside while Havre de Grace, Maryland is the warmest and has a generally flat landscape. These simplifications help to clarify the results of analyzing the ecological comparisons among the ecoregions and served to drive four unique design propositions for designing for water.

Urban Design Analysis

While the ecological criteria are significant in terms of comparing these four cities and their relationships to water, it is also important to have an understanding of

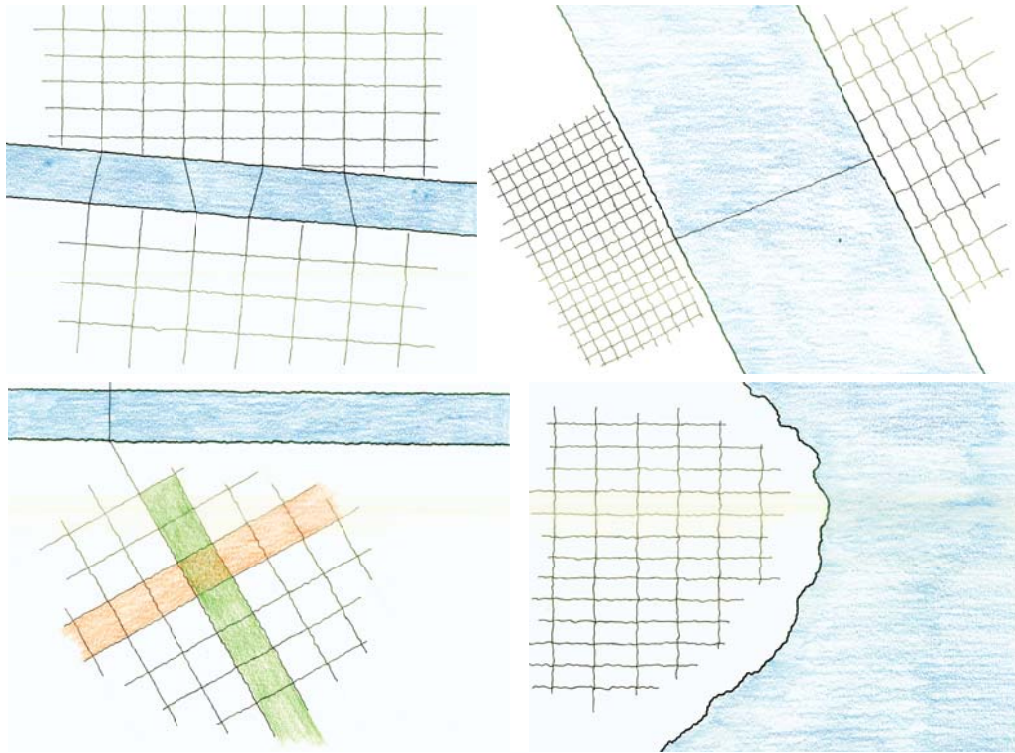


Figure 23: Four diagrams illustrating ways to organize urban areas relative to water the in Chesapeake Bay watershed. The top left diagram illustrates Corning, New York. Moving counterclockwise, the bottom left image shows Nanticoke, Pennsylvania. The top right image shows Columbia, Pennsylvania and the bottom right image illustrates Havre de Grace, Maryland.

the underlying urban design principles at work in the cities. A combination of these two branches of analysis will allow sites to be chosen for case study designs with regard for both the ecological implications as well as the urban design impacts. Urban design issues that were documented and analyzed include: the overall urban parti and relationship to the water's edge, the figure ground relationship, street hierarchy, and land use.

Parti and Relationship to the Water's Edge. Comparing the parti diagram underlying each city as shown in Figure 23 demonstrates four different ways in which man builds cities relative to the water. Corning, New York illustrates a city that bridges the water. North of the Chemung River the city's grid is oriented to the cardinal directions while south of the river the grid is turned perpendicular to the water. Despite

this change in grid orientation, multiple crossings over a narrow portion of the Chemung River allow the city to be a single entity. Nanticoke, Pennsylvania orients its grid without a clear relationship to the water, choosing instead to lay the grid 45° east of North. The city developed significantly farther away from the waterfront than any of the other cities studied because topography is the most drastic in Nanticoke and the grid instead aligns itself with the topographic lines. Historically water has also had less of an impact on Nanticoke's reason for being than in the other cities so access to the water was not as critical for Nanticoke's success. The urban parti of Nanticoke relies on a set of axes that cuts perpendicularly through the primary city square instead of a clear relationship to the water. Columbia, Pennsylvania demonstrates some similarities to Corning, but in this instance the urban areas on either side of the Susquehanna are separate entities. The Susquehanna River is wide at this point on its way to the Chesapeake Bay and the crossings are few. As a result two distinct cities developed: Columbia on the east side of the river and Wrightsville to the west. Havre de Grace, Maryland shows that some cities are cradled by the water's edge. The city is sited on a slight peninsula and as such the irregularly-shaped shoreline hugs the city grid with its streets oriented in the cardinal directions.

This parti comparison illustrates three major considerations in designing urban areas relative to water. The first consideration is the breadth of the water. If the river is narrow and easily bridged, it is possible to get a single city that spans the river as Corning does, but if the river is wide there are likely fewer links and twin cities develop on opposite sides of the river as in the Columbia example. The second consideration is topography. In Nanticoke, the issues of topography were far more important to urban

development than access to water and as a result the grid in Nanticoke aligns to the topography instead of the water. Nanticoke's grid is separated from the water and other design principles such as axis and hierarchy are evident in the urban plan. Third, access to the water also has an impact on how the cities are platted. The four cities studied demonstrate that grids have three orientations: they run to the cardinal directions, they run perpendicular to the water, or they have no clear relationship to the water. The design option chosen is linked to the history of the area and how the water has influenced economic development as well as the regularity of the shoreline. Even though access to water has influenced the development of each of these cities, each illustrates a different parti and relationship to the water because of the varying values each city has placed on its local waterway.

Figure Ground. From the figure grounds under study in Figures 24 through 27, the clear takeaway is the object buildings and urban figures that dominate the graphics. Corning, New York, illustrated in Figure 24, has a clear residential fabric punctuated by a large factory building in the northwest of the city. The Chemung River is also clearly visible in the center of the diagram as well as a set of developments perpendicular to the north side of the river and a downtown core parallel to the south shore of the river.

In Nanticoke, Pennsylvania, illustrated in Figure 25, figural elements in the city include the community college campus isolated in the southeast corner as well as a set of industrial buildings in the northeast. Also notable in Nanticoke's figure ground is the clearly visible public square in the center of town. This public space has the most defined edges on the north, east, and south faces while the west edge is less clearly articulated.

Columbia, Pennsylvania's figure ground in Figure 26 shows the clearest urban



Figure 24: Figure ground diagram of Corning, NY. Scale: 1" = 2500'



Figure 25: Figure ground diagram of Nanticoke, PA. Scale: 1" = 2500'



Figure 26: Figure ground diagram of Columbia, PA. Scale: 1" = 2500'



Figure 27: Figure ground diagram of Havre de Grace, MD. Scale: 1" = 2500'

environment. Street edges are clearly defined by buildings in almost the entire downtown core and there are few figural elements in the city grid that disrupt the overall urban order. Notable exceptions to that rule are the National Watch and Clock Museum along the north edge of the city and larger big box retail in the southeast.

In Figure 27, Havre de Grace, Maryland's figure ground illustrates a strong downtown core on the east edge of the city with several larger public and industrial buildings being sited inland along the western edge of the city. These larger buildings include the buildings of the public school system as well as the Coca-Cola bottling plant. The far west edge of the city breaks the scale of the city and shows big box retail along Route 40. The southwest of the city shows a degradation of the grid as the city has begun to develop large cul-de-sac residential neighborhoods that are at odds with Havre de Grace's historical grid.

Street Hierarchy. Examining the street hierarchy diagrams in Figures 28 - 31 illustrates three points of comparisons among the cities: the alley systems, the way the highway comes into the city grids, and the comparative block dimensions. First, all four cities notably include an alley system which makes it clear what the fronts and backs of the blocks are. Although all the initial blocks may have included alleys, as the cities under consideration have developed parts of these alley systems have eroded to accommodate building types that did not fit into the initial grid. Notable examples of this include hospital blocks on the south side of the river in Corning, and in the heart of Havre de Grace, and public parks in Nanticoke and Corning.

The interaction between the regional highways and the city grid offers an interesting comparison among the cities. Corning, New York has the most dominating

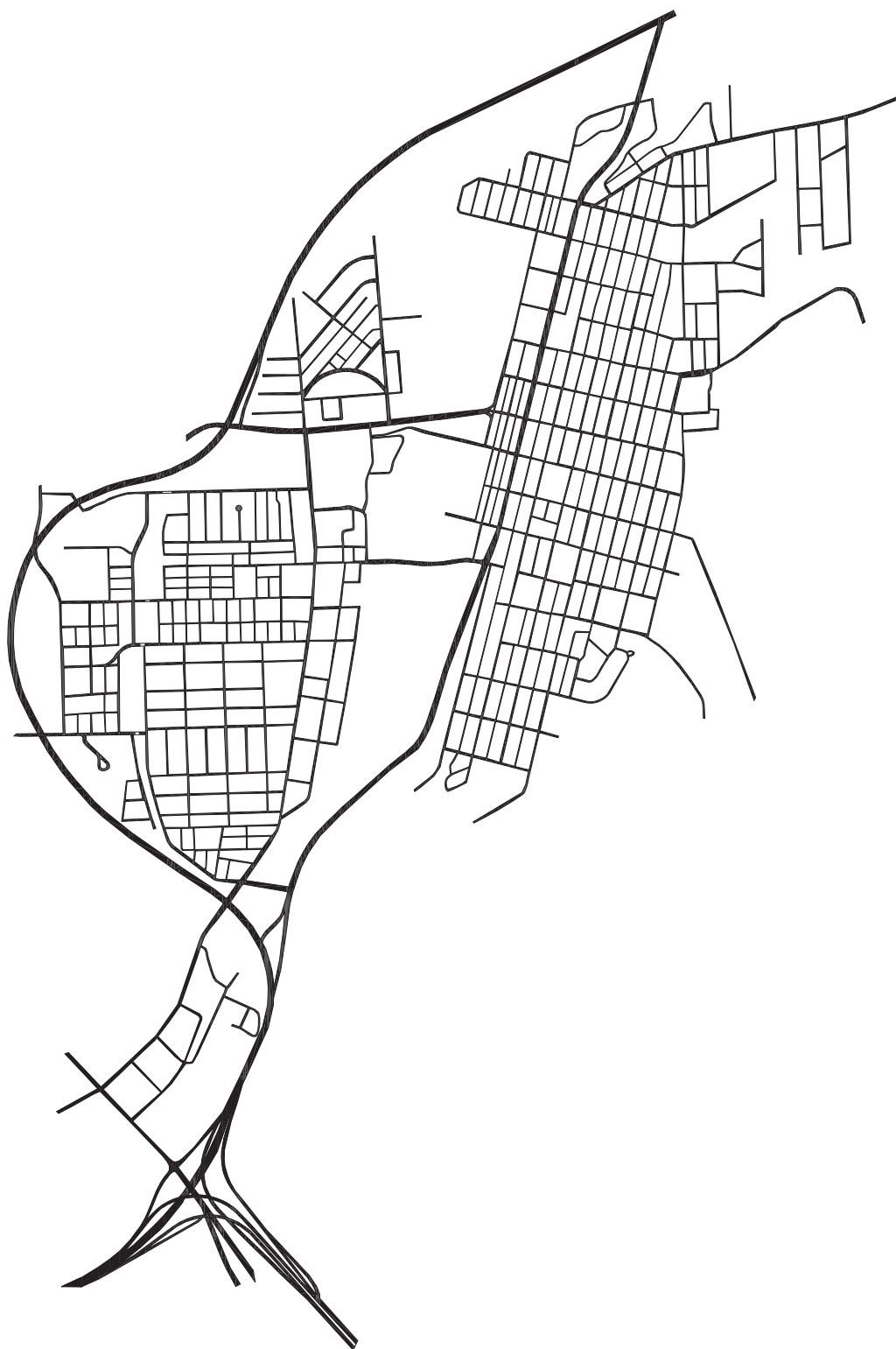


Figure 28: Street hierarchy diagram of Corning, NY. Scale: 1" = 2500'



Figure 29: Street hierarchy diagram of Nanticoke, PA. Scale: 1" = 2500'



Figure 30: Street hierarchy diagram of Columbia, PA. Scale: 1" = 2500'

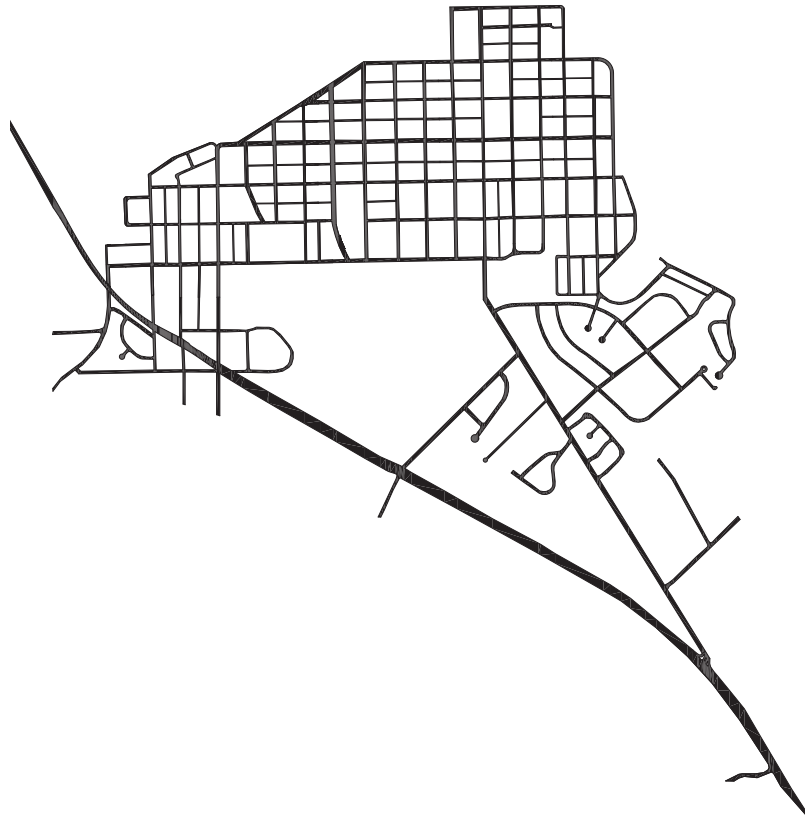


Figure 31: Street hierarchy diagram of Havre de Grace, MD. Scale: 1" = 2500'

highway interchange, west of the city and just southwest of the Dresser-Rand industrial facilities. This interchange connects the Southern Tier Expressway with Route 15 and bounds the entire northern edge of the city. The highway connects to the city grid via a set of primary streets which do not clearly direct traffic into the downtown core. Nanticoke, Pennsylvania has access to Route 29, and while the interchange is a dominating figure in the street hierarchy, it happens outside the city and as a result has little connection to the city grid. Sans Souci Parkway, which runs east-west and connects Route 29 to Nanticoke is a relatively insignificant street in the city grid and largely serves as a bypass to the city and misses the downtown core. Columbia, Pennsylvania is bounded on the north and east by Route 30 which becomes the Wright's Ferry Bridge as it crosses the Susquehanna River. A small interchange in the northeast corner of the city connects the urban grid to the interstate, but the intersection is unassuming and does not command much real estate. The interchange connects to North 3rd Street, one of the primary retail streets in the city. This connection between the interstate and the heart of downtown separates Columbia from the other three cities studied. Havre de Grace, Maryland is connected to the highway system by Route 40 which bounds the city on the northwest edge. The connection between the city grid and the interstate occurs along a spur which has fostered sprawling development that does not extend the grid of the city. As the interstate enters the grid it becomes Revolution Street which most notably includes the access to the Harford Memorial Hospital, one of the most significant institutions in Havre de Grace.

Land Use. Diagramming the land use in the cities under study showed the balance of residential, commercial and retail, institutional, and industrial development

in the four cities under study. The same scale and color scheme is used across all diagrams to allow for easy comparison. Yellow represents residential buildings of any kind, although in almost every case the housing is either single family homes or duplex development. Red represents commercial and retail development. Institutional buildings are represented in blue and industrial developments in purple.

Looking at Corning, New York in Figure 32 shows a clear retail street south of and parallel to the Chemung River. An institutional core of schools and museums is clearly identifiable north of the river. Industrial facilities in the northwest also stand out in the city's land use. The vast majority of the rest of the city is residential development with schools, churches, and public facilities spread out amongst the neighborhoods.

Figure 33 describes the land use of Nanticoke, Pennsylvania. A large retail core exists in the northwest corner of the city, closest to the river and the highway development. Retail and institutional uses continue around the public square at the heart of the city but then dissolve into mostly residential functions. Scattered institutions throughout the rest of the city provide small scale amenities throughout the community. The community college stands out as a figural institution in the southeast of the city. A large public school complex on the east edge of the city stands out against the residential fabric of the community.

Columbia, Pennsylvania's land use, illustrated in Figure 34, shows a clear downtown main street with a large number of shops and institutions focused along one street running perpendicular to the Susquehanna River. A large industrial facility east of the city's urban core provides many jobs for the residents of the community. The National Watch and Clock Museum along the northern edge of the community is the

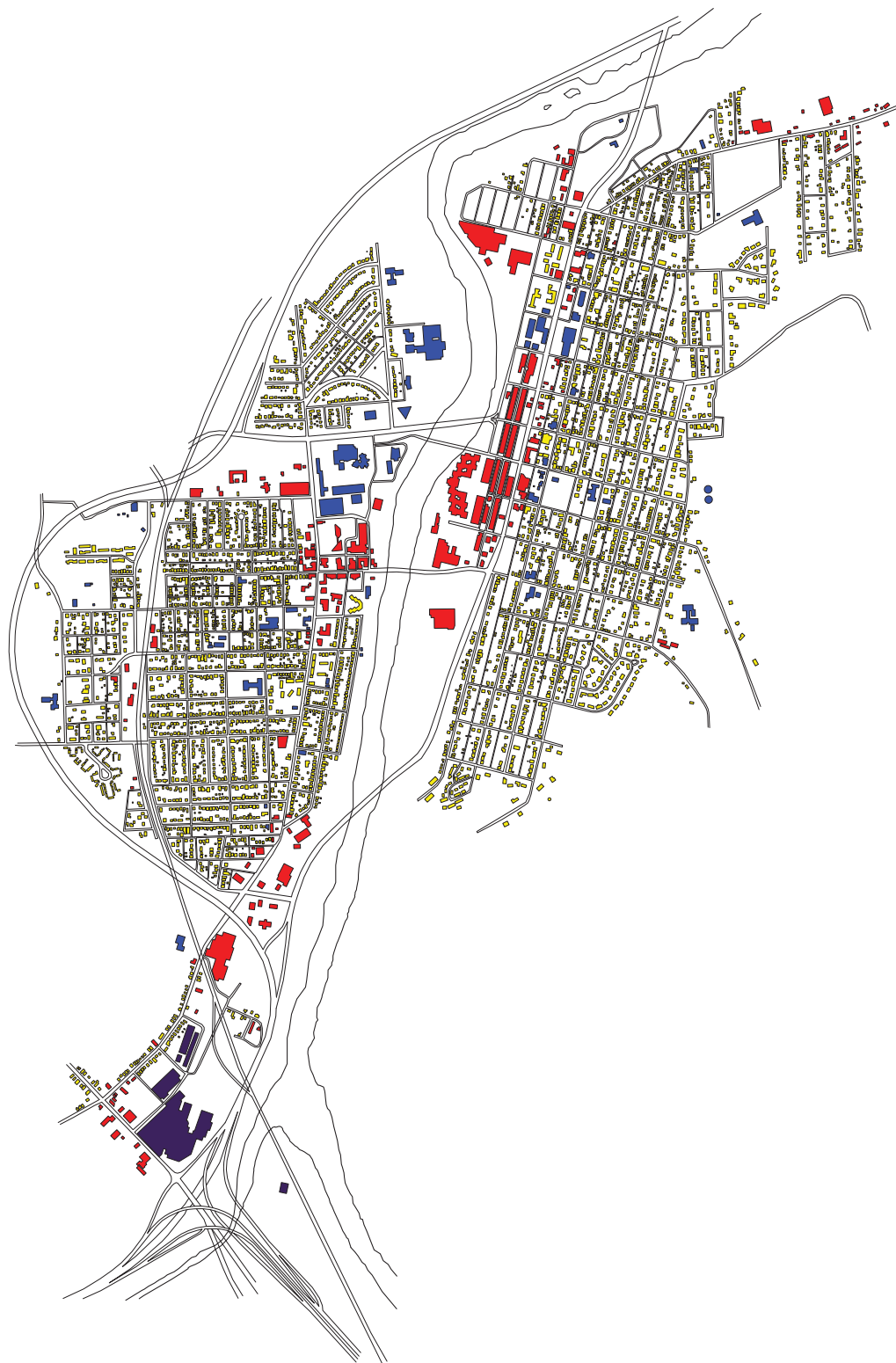


Figure 32: Land use diagram of Corning, NY. Scale: 1" = 2500'



Figure 33: Land use diagram of Nanticoke, PA. Scale: 1" = 2500'



Figure 34: Land use diagram of Columbia, PA. Scale: 1" = 2500'



Figure 35: Land use diagram of Havre de Grace, MD. Scale: 1" = 2500'

only prominent institution in the community with the exception of the many churches that become part of the city's urban fabric. A few industrial buildings remain along the waterfront, but many of these have been or are in the process of being repurposed into commercial or retail facilities.

Havre de Grace, Maryland illustrates the greatest number of clear land use districts in Figure 35. A clear retail core exists along the water in the northeast while the public school institutions are all focused inland in a three-block radius of one another. The hospital complex stands out amongst its residential context in the heart of town with flanking retail and commercial activity in support of the hospital's mission. The only notable industrial structure is the Coca-Cola bottling plant on the west edge of the urban grid.

Creating the figure ground diagrams in conjunction with the street hierarchy and land use diagrams before visiting the sites allowed for efficient and effective visits to the cities. Armed with this knowledge of the figural areas of the city and the programmatic functions of particular neighborhoods and districts allowed for effective site selection to happen within the cities while on-site. The section that follows includes photographs taken on-site as well as summary diagrams that collapse the information that is pulled apart into its component pieces in this section.

Site Observations

Visits to the four analyzed cities occurred in January 2011. The intention for these visits was first to get an understanding of the genius loci of each of these places by spending some time exploring that which had only previously been researched and drawn. Going into these visits, there was a significant understanding of where the important

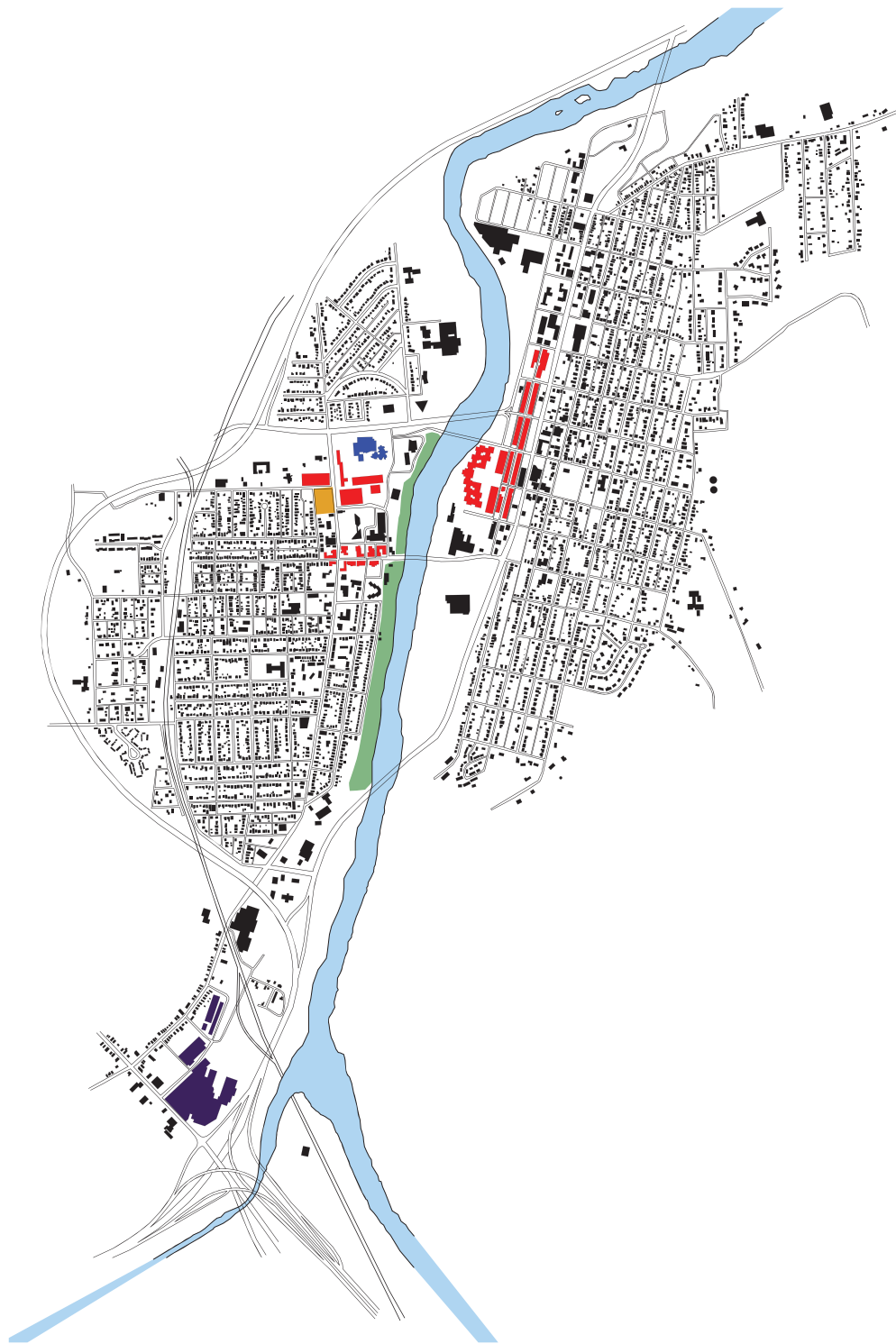


Figure 36: Site summary diagram of Corning, NY. Scale: 1" = 2500'



Figure 37: Dresser-Rand factory buildings. The factory facilities present a closed edge to the community.

places in the cities were, but not a clear understanding of what these places looked and felt like. The following images and diagrams show a graphic catalog describing what the character of these various places is as well as the parcel of land that was selected in each site to serve as the test location for a design intervention for water.

Corning, New York

The northernmost cast study city for this thesis was visited just following a snowstorm that hit most of the east coast in January 2011. The weather was overcast and snow covered the ground, but Corning's unique character as a post-industrial city kept the visit inspired. Figure 36 collapses the information identified through pre-site visit analysis into one graphic as well as identifies the site and highlights other major urban features that mark the city. Beginning in the northwest corner of the city, the tour of



Figure 38: Residences north of the Chemung River. These houses are representative of the housing available in Corning, New York.

Corning, New York starts with the Dresser-Rand factory building because the site was previously home of the Corning, Inc. factories when the corporation was more of a heavy industry company. Today the factory still presents itself as a figure in the community's land use and figure ground diagrams, but has a much more contained presence in the urban experience of the city. Figure 37 shows the public entrance to the Dresser-Rand factory which is both small and unassuming for so large a figure in the community. The edges of the factory's precinct are all fenced creating a clear delineation between the industrial landscape and the urban one. The brown corrugated metal facade that faces the community is blank except for a few truck-size door openings which does not create a good pedestrian environment in this part of town.

Most development north of the Chemung River in Corning is single-family residential housing punctuated by a smattering of churches and public school buildings. Figure 38, a pair of single family residential homes, are representative of the residential



Figure 39: Downtown historic district. This area, south of the Chemung River features many small boutiques and restaurant options.

character of the town. The homes in Corning, New York are almost all two stories tall with gable roofs appropriate for dealing with Corning's heavy winter snowfalls. The two homes featured in this figure are also adjacent to the site selected to be the Corning, New York site representative of the Appalachian Plateau.

Other notable features of Corning, New York include the historic downtown district on the south side of the Chemung River and illustrated in Figure 39. With significant financial support from Corning, Inc., the town has been able to preserve a 5-block historic district which features many boutique shops and a variety of restaurant options. This hot spot for travelers and locals also features the modern headquarters of Corning, Inc., placing the corporate giant in a prominent location within the city fabric.

Located between the historic district and the Chemung River, Corning Inc.'s corporate headquarters, photographed in Figure 40, is a series of modern glass pavilions that at once dominate the landscape and sit quietly within it. From the south side, the



Figure 40: Corning, Inc. Headquarters. This glass pavilion is the present headquarters for the corporate giant that calls Corning, NY home.



Figure 41: Riverside park. What has developed into a linear park initially began as the right-of-way cleared for electric power lines.

headquarters is screened from the rest of the city by the historic district, making its presence in the community almost invisible. Looking to the headquarters from the riverside, however, the building dominates the landscape and its materials and massing make it stand out prominently from the surrounding context buildings. This duality at once expresses the powerhouse that Corning, Inc. has been in the community while quietly accepting that the community as a whole is more important than the corporate entity.

The linear park running along the north edge of the Chemung River is the only large scale public open space in the community. In some locations along the waterfront the park has been developed with playground facilities and picnic grounds, but as evidenced by Figure 41, the park was originally developed as the right-of-way for the

power lines that frame the running trail on the ridge line. This park is nonetheless significant as it keeps development from encroaching on the river's north edge. This tendency to stay away from the river's edge is perhaps a response to flooding in the 1970s although it is unclear if development prior to the flooding had been allowed immediately adjacent to the river. This limited amount of public open space became a significant design driver as a design strategy began to form around the Corning, New York site.

Beyond the corporate offices of Corning, Inc., the most modern building in town is the Corning Museum of Glass which recounts the history of both the corporation as well as the glass industry. This museum is a regional draw for people traveling through the Finger Lakes of New York state and draws significant crowds during the summer months. The campus of the museum features both indoor and outdoor exhibits and is integrated with additional office buildings that are part of Corning's corporate facilities.

The site is identified on Figure 36 as the yellow rectangle on the north side of the river. The site is also represented photographically as a panorama in Figure 42. This site is an existing empty plot of land north of part of Corning, Inc.'s corporate offices. The site is bordered on the east by a parking garage for Corning, Inc.'s employees and to the west by an existing Pizza Hut. The northern border of the site is created by residential development, including those homes featured in Figure 38.

This site was selected because of its location near the existing Corning Museum of Glass, its prominence on the main east-west thoroughfare through town, and its vacancy. The proximity to the existing Corning Museum of Glass made this site particularly attractive because the program for this thesis's set of buildings was concurrently developing as a set of visitors' centers for the Chesapeake Bay Foundation.



Figure 42: Selected site for Corning, NY design intervention. View from northeast corner looking southwest.

Knowing the program was going to be institutional in character drove to selection of sites that would build on existing cultural landscapes - places people were already coming to for education and enrichment opportunities. Being prominently located on a busy street insures high visibility for the project and would increase visitor traffic to the site. Selecting land with existing use that would require either adaptive reuse or demolition is beyond the scope of this thesis and preference in all case studies was given to underdeveloped parcels of land.

From an ecological standpoint, the site has minimal topographic change although what change there is puts the high ground of the site on the north side and the low ground toward the south, closer to the river. The site has relatively unimpeded solar access although some shadows are cast by the four-story parking garage to the east. Shadows cast by the multi-story Corning, Inc. corporate offices to the south are minimal because the Corning, Inc. building is set back from the street.

Nanticoke, Pennsylvania

Site information about Nanticoke, Pennsylvania is collapsed into a single graphic in Figure 43. While the topography diagram created before visiting Nanticoke graphically represented a city built onto the face of a mountain, the experience of visiting such a place was far more powerful than the analysis suggested. Driving in from the northeast corner of the city, the topography is almost unnoticeable because the east-west streets run on the topographic lines, but as soon as one turns north or south the change in grade is immediately apparent. As illustrated in Figure 44, the streets that run north-south have frequent drop offs such as the one shown in the image where the street literally seems to drop off into nothingness. This characteristic is perhaps the most memorable



Figure 43: Site summary diagram of Nanticoke, PA. Scale: 1" = 2500'



Figure 44: North-south streets exhibit grade change. These significant changes in grade are perhaps the most memorable part of a visit to Nanticoke, Pennsylvania.

element of Nanticoke and significantly impacts both the way the city is experienced as well as how the urbanism takes shape on the landscape.

Walking around the urban environment, one is constantly aware of their movement along topographic lines or perpendicular to them. As design work in Nanticoke began, this became a design driver in terms of developing both the building



Figure 45: Residences in Nanticoke. These dwellings show that in adjacent lots as much as a story's worth of grade change can exist, creating unusual relationships between the buildings.

form as well as the circulation system. The impact of this changing topography is generally speaking not acknowledged by individual buildings but is evident in the relationship between one building and the next. Figure 45 shows two residences in Nanticoke on a north-south street. Notable in this image is the way the first floor of the house on the right aligns with the second floor of the house on the left. Assuming the first floor of most homes has the public spaces and the second has more private spaces, adjacencies such as the one illustrated create conflict between buildings and their context.

Major figures in Nanticoke's urban landscape include the Luzerne County Community College which at present is a significant portion of the town's reason for being. The college campus, illustrated in Figure 46, is largely divided from the community although there are several buildings leased by the college in the downtown area. The community college is broken into a series of smaller buildings each with a



Figure 46: Luzerne County Community College. This institution gives Nanticoke, Pennsylvania much of its present reason for being.

dedicated academic focus. There is no real “campus” to speak of as the buildings are simply linked by paths with no formal open space and the surrounding landscape given over to vast seas of surface parking.

One of the most prominent spaces in town is the central town square in Figure 47 that serves as the design generator for the urban parti. This square is at once both a market square and a residential square. The north and east faces of the square are dominated by low-rise retail buildings notably including the town diner and butcher shop. The south edge of the square includes a multi-story public housing complex that seems both out of scale with the square as well as at odds with the design language of the other buildings on the square. The side flank of a church faces the square on the west edge as well as a few small professional offices. The square itself features a centralized memorial and a community bandstand. The square is accessed mostly by personal vehicle as the square is ringed by parking but also by public transit as bus stops occur at each corner. The square has significant open spaces but also features many mature trees that provide significant shading in the summer months.

The site selected to be representative of the Appalachian Mountains ecoregion is identified in yellow on Figure 44. This site is advantageous because of its location one block north of the public square, its significant slope, and its currently vacancy. The location near the town square is beneficial because it places the proposed intervention in close proximity to the core of downtown development. The significant slope on the site creates interesting design opportunities that will allow the proposed intervention to clearly communicate the relationship of storm water to underground water resources. Pictured in Figure 48, the site is currently an empty lot with evidence of backfill from



Figure 47: Nanticoke town square. This square is the generator of Nanticoke's urban parti.



Figure 48: Selected site for Nanticoke, PA design intervention.

other construction projects. The site is bounded on the south side by a pair of townhouse buildings with central parking. The north and west boundaries of the site are defined by the street edges and the east boundary is a single family residence and the street beyond.

The site features several unique opportunities that might inspire design solutions. First, the change in grade provides a distinct change in vantage points from the top and the bottom of the site. Figure 49 shows a view from the top of the site where visitors could quite literally look out over the city and see the mountains in the distance. The unfortunate foreground building is a low-income housing structure that is out of scale with the rest of the town's development, but the rest of the view is quite picturesque in all directions. Figure 50 shows the view from the bottom of the site, specifically focused in on a small gap between buildings that provides a view corridor down to the town square. These changes in view may provide direction for how the building is massed and where circulation may want to direct visitors.

Columbia, PA

While the drawings made of Columbia before visiting made it clear this was the most urban site under consideration, the town had a much more frozen-in-time *genus loci* than was expected. The character of the town has a distinctly turn-of-the-century feel because of the relatively uniform design of buildings in the town. There are some mid-nineteenth century buildings, but as evidenced in Figures 51 and 52, much of the town has a somewhat older neo-gothic and neo-classical attitude toward it. Figure 51, looking down Locust Street, shows reasonable sidewalks and a comfortable pedestrian environment with street lamps but few street trees. Parking on both sides of most streets serves as a buffer between the pedestrians and the driving lanes. The buildings



Figure 49: View from site's high ground.



Figure 50: View from site's low ground.



Figure 51: A view down Locust Street in Columbia, PA.



Figure 52: A view of attached residences in Columbia, PA.

are mostly between one and three stories although the churches scattered through town show moments of hierarchy in the street elevations. While Columbia does have a large selection of single family homes on small urban lots, many of the homes are three-story attached townhouses. Many of them feature articulated bays which give the streets a certain rhythm as seen in Figure 52. Some of these residences have been divided into several apartments within one unit.

Figure 53 collapses the site analysis information in a single image. Similar to the previously described towns, most of Columbia is residential development with a clear retail district downtown. The town really does not have any public outdoor green space to speak of and the waterfront is largely dominated by the existing industrial train lines and aging industrial warehouses. The lot sizes in Columbia are significantly smaller than in the other sites under consideration which helps create the urban character of Columbia.

Much of the waterfront is populated with warehouse buildings from a time when the waterfront was actively engaged in trade and industry. Today many of the warehouse buildings are vacant, as shown in Figure 54, but some have been repurposed into retail and commercial spaces. The local farmer's market leases space in one of these buildings bringing local produce to the residents several days each week. A crafts market has also turned one of these buildings into a permanent home.

Beyond the churches in Columbia, the only really significant institution is the National Watch and Clock Museum seen in Figure 55. This museum is a regional draw, but sets itself apart from the urban context. On the outskirts of the downtown grid, the National Watch and Clock Museum is a freestanding building that does not try to be a part of the urban character. It has a surface parking lot which adds to the already



Figure 53: Site summary diagram of Columbia, PA. Scale: 1" = 2500'



Figure 54: Waterfront warehouses in Columbia, PA.

considerable amount of hardscape in town and while the architectural style aligns with that of the rest of town, it does not help to reinforce the urban design because it is a freestanding building.

Figure 53 shows the site selected to be representative of Columbia, Pennsylvania and the Piedmont ecoregion in yellow. This infill site, photographed in Figure 56, offers unique differences from the other sites under consideration and will serve as an interesting point of comparison because of its significant differences from the other sites. This site is a good choice because its size constraints will require a more compact solution for water management than any of the other sites selected. The site is also currently underutilized as a parking lot and building on this lot will improve the street wall. As part of the downtown core the site will be heavily trafficked, drawing attention to the new institution proposed for the site.

The site is bounded on the south side by Locust Street giving it significant solar access as the closest building to the south is a two-story building across a four-lane street. The western boundary is formed by a party wall with the red brick building in Figure 56 which is currently vacant. The eastern boundary is formed by a party wall with the grey



Figure 55: The National Watch and Clock Museum.



Figure 56: Site selected for Columbia, PA design intervention.

brick building in Figure 56 which houses a bank. The north edge of the site abuts an access alley which provides a service corridor for the buildings on Locust Street. Given the urban character of much of the Piedmont ecoregion, selecting an infill site with the constraints typical of many sites in the Piedmont will allow the design work created in Columbia, Pennsylvania to have a greater resonance with developments occurring elsewhere in the Piedmont.

Havre de Grace, MD

This city was visited on a clear, crisp winter day with the intention of walking the historical loop the town is trying to build on and encourage. This walking loop is illustrated in Figure 57 which summarizes site analysis information on Havre de Grace, Maryland. The blue loop is the historical walk and it was decided that a prominent site for the new institution would be somewhere along this route to encourage developments



Figure 57: Site summary diagram of Havre de Grace, MD. Scale: 1" = 2500'

already underway in the town. The southeast corner of the city features a large city park which gives residents the opportunity to be in immediate contact with the Chesapeake Bay. Institutional buildings such as the Duck Decoy Museum and the Maritime Museum are along this walk as well as a number of historic buildings. The downtown retail core is north of this protected open space along the historic walk.

The public open space preserved along the Chesapeake Bay can be seen in Figure 58 which shows a family walking along the pathways even in the middle of winter. This path is frequented by joggers as well and provides a great amenity to the residents of Havre de Grace. The space is exceedingly pedestrian friendly as can be seen by the frequent street lamps, benches, and wide pathways. It was assumed that somewhere along this walk there would be an access point to the small island south of the peninsula Havre de Grace sits on, but it turns out the island is divided from the town and there is no pedestrian, vehicular, or boat traffic possible to the island which is ringed in protective fencing. Many of Havre de Grace's significant institutions, among them a historic hotel (now office space), the Decoy Museum and the Maritime Museum do happen along the boardwalk and tangential paths strike out from the main public way to provide access to these amenities. These institutions can be seen in Figure 59 and while the buildings themselves are not architecturally spectacular, they do connect rather elegantly to one another and to the park at an urban scale. Given this clear desire to create an institutional core of museums along the waterfront promenade, efforts were made to find a site that would help build into the existing attitude toward waterfront development.

Walking through Havre de Grace, it is also clear that there have been some recent pressures to develop which have pushed against the charming historical character of



Figure 58: Boardwalk promenade in Havre de Grace, MD.



Figure 59: Institutions along the Chesapeake Bay. From left to right these institutions are: the Maritime Museum, the Duck Decoy Museum, and a historic hotel.

the town. Figure 60 illustrates this conflict in which a modest home composed of an additive set of volumes is dwarfed by its newly constructed neighbor that is both oversize and massive without being properly scaled to the neighborhood of which it is a part.

The same development pressures that have allowed this type of development have also allowed for privatization of much of the waterfront. Private residences immediately adjacent to the waterfront have closed view corridors to the water in parts of town and architectural forms that do not match the character of the town. New developments have



Figure 60: Development pressures in Havre de Grace, MD.

been allowed to create garages on street frontages which ignore the alley system of the town and create for unattractive streetscapes and unpleasant pedestrian experiences.

While some new developments have been unfortunate in Havre de Grace, others such as the revitalization of downtown have been resounding successes. The heart of downtown as illustrated in Figure 61 is a beautiful assortment of boutique retail shops, family-run restaurants, and small dry goods and hardware stores all housed in well-maintained historic buildings. The downtown core also features a bevy of antique shops, many of which feature collectible decoys similar to what historically was used to bait ducks, geese, and other waterfowl when the Chesapeake Bay in this area was widely hunted.

The site selected to be representative of the Coastal Plain ecoregion in Havre de Grace, Maryland is photographed in Figure 62 and marked in yellow on Figure 57. This site is adjacent to both the Duck Decoy Museum and the Maritime Museum as well as along the boardwalk promenade that features many of Havre de Grace's most prominent sites. This site has the potential to build into an existing institutional infrastructure that



Figure 61: Havre de Grace, MD's downtown retail core.

the city is eager to improve on as they grow Havre de Grace's reputation as a vacation destination and retirement community. The site is bounded by residential streets on the north and west sides and the two museums on the east and south. The site is reasonably flat although the slight slope does roll down slightly southeast towards the Chesapeake Bay.

The site visits taught unique characteristics of the towns that could not be understood from research in College Park. All four towns have a somewhat quaint character that makes them all similar, but in all cases the topography and relationship to local waterways help to distinguish each site from one another. The sites are of varying sizes with the Corning, New York site being the largest. The Nanticoke, Pennsylvania and Havre de Grace, Maryland sites are comparable in size and the Columbia,



Figure 62: Selected site for Havre de Grace, MD design intervention.

Pennsylvania site is noticeably the smallest. In all cases the sites chosen are in well-trafficked areas which will help provide visibility for the design interventions to be created. The sites are also all currently empty, eliminating the need to consider what to do with existing structures.

Chapter 3: Program

Preserving the health of the Chesapeake Bay and its watershed requires greater awareness of best water management practices across the region regardless of the program of the building being designed. As such, the denotative program of the buildings designed by this thesis is potentially the least important element. The principles and design elements being explored are in many regards independent of the program and as a result minimal time was spent developing the denotative program of the buildings under consideration.

To give depth to the story about water, however, research was conducted about advocacy organizations in the watershed and what work is being done to spread the story about the interaction between the built environment and the water cycle. The Chesapeake Bay Foundation, which actively engages in education and advocacy across the watershed without regard for state lines, currently utilizes the Philip Merrill Environmental Center in Annapolis, Maryland as their headquarters. This places the organization amidst a human population in the watershed that is perhaps among the most informed about our relationship with the Bay and what our actions are doing to the health of the ecosystem.

In order to illustrate how buildings can be better stewards of the water cycle and allow the Chesapeake Bay Foundation to improve its education and outreach mission, this thesis proposes that a visitors' center be developed in each of the previously identified cities and sites. These visitors' centers would serve as outreach posts for the Chesapeake Bay Foundation and serve as living laboratories where the public could learn what impact the built environment has on the Chesapeake Bay and what they might do to improve the relationship between the built environment and the Bay. Each of these visitors' centers

will uniquely relate to its ecoregion and site but also be intelligible as part of a set of buildings that are designed for water.

Design Principles

The connotative program of the buildings, the didactic mission, and the principles behind this type of ecological design is perhaps more telling of the programmatic intent of this thesis. These principles serve as guides to the design process and allowed for efficient decision making through the design process. When design options were at odds with the design principles, choices were eliminated in favor of alternatives that aligned more closely with the guiding principles listed.

1. The visitors' centers didactically illustrate the cyclical nature of the Chesapeake Bay watershed. The primary message of the visitors' centers is to teach the story of how water used throughout the watershed ends up in the Chesapeake Bay, how the built environment is a part of that cycle, and what people can do to be better stewards of the water cycle. Through design, the proposed design interventions will highlight storm water's path through the built interventions. The propositions will also aim to be instructive in other ways, teaching generally about ecological technologies and green architecture. The visitors' centers will use the natural cycles of the watershed for inspiration.

2. The visitors' centers will blur the line between indoors and out. The visitors' centers will value the special relationship created between indoor and outdoor spaces and work to make this relationship as seamless and integral to the experience of the sites as possible. Strong connections between indoor and outdoor spaces increase users' awareness of the landscape while using interior space and will help to illustrate

connections between the built and landscape environments.

3. The visitors' centers will illustrate the best of water-related design while also responding to their immediate context. A building is most sustainable when it is not torn down before its useful life is over. The mission of water is critically important in these buildings, but the buildings must also show respect and deference for their immediate context and be good neighbors to the buildings and environment immediately around them. The community will not embrace this new institution into the community unless it integrates with the contextual landscape in some way and provides amenity.

Program Analysis

The following table was established to quantify the basic program areas to be created in each visitors' center as well as their approximate square footages. Each building can be broadly understood as including four zones of space: visitor spaces accessible to the public, controlled access spaces accessible to staff as well as select visitors such as donors or the press, circulation and mechanical spaces to support the mission of the building, and outdoor landscape areas which will become part of the public realm and serve to mediate between the building and the watershed.

While this chart served as the initial understanding of how much space would be ideal in a visitors' center, it should be noted that the actual makeup of each visitors' center immediately began to vary because of site constraints and transforming design intentions on each site. Each building contains a different permutation of these spaces with varying levels of importance. Changes from these initial thoughts on the building program reflect a changing understanding of the water cycle narrative being told through the buildings both independent of one another as well as when taken together as a collective set.

VISITORS' CENTER PROGRAM		
VISITOR SPACES:		
Lobby	Including information desk	1000 square feet
Lecture hall/auditorium	100 seats	1200 square feet
Permanent exhibit space	To have the same exhibit in all four visitor's center	2500 square feet
Changing exhibit space	To have site specific changing exhibits	2000 square feet
Bathrooms	2 @ 200 square feet	400 square feet
Gift shop		200 square feet
	Subtotal:	7300 square feet
CONTROLLED ACCESS SPACES:		
Administrative suite:	Director's office	150 square feet
	Open office space	500 square feet
	Conference room	400 square feet
	Staff kitchen	200 square feet
	2 staff ADA-accessible bathrooms @ 75 square feet each including shower facilities	150 square feet
	Volunteer work room	200 square feet
	Staff laundry	100 square feet
	Copy room	100 square feet
	Storage space	200 square feet
	Subtotal:	2000 square feet
Classroom	To be used for group tours, orientation, special programming	400 square feet
Classroom	To be used for group tours, orientation, special programming	400 square feet
	Subtotal:	800 square feet
Exhibit storage/preparation		1450 square feet
CIRCULATION/ MECHANICAL:	20% of building square footage	2310 square feet

	BUILDING TOTAL SQUARE FOOTAGE:	13860 square feet
LANDSCAPE/ OUTDOOR SPACES:		
Wetlands and/or other remediating landscape		3000 square feet
Patio/hardscape		1000 square feet
	SITE TOTAL SQUARE FOOTAGE:	4000 square feet
	TOTAL PROJECT SQUARE FOOTAGE:	17860 square feet

An Agenda for Water

Developing the program for this thesis also meant establishing what role the built environment plays in the water cycle in each ecoregion of the Chesapeake Bay watershed. Through studies in section, a clear narrative emerged about what role the built environment needs to take in each ecoregion in order to benefit the Bay. In the Appalachian Plateau, the northernmost ecoregion of the watershed where the headwaters of the Susquehanna River are, the most important agenda for the built environment is to retain nutrients. Once water leaves the Appalachian Plateau it begins to pick up nutrients and carry them downstream, but the only way for the Appalachian Plateau to maintain its biodiversity is to self-generate that new growth. Rain and snowfall must be captured in order to retain the nutrients on the site. These nutrients must be capitalized on in order to create biodiversity and thus sustain the ecosystem at the top of the watershed.

Moving slightly further south into the Appalachian Mountains ecoregion, buildings must be created that foster recharging underground aquifers. The water that

flows through the thirsty cities of the Piedmont is largely provided from underground aquifers below the Appalachian Mountain chain. More often than not, this precious groundwater is pumped out faster than natural systems can replenish it because the amount of hardscape in the built environment (as seen in Figure 3) keeps most precipitation from reaching deep infiltration. In order to ensure this groundwater resource is not depleted, the built environment in the Appalachian Mountains ecoregion must be created in such a way as to give the greatest volume of water the opportunity to reach deep infiltration, thereby recharging the aquifer.

The Piedmont ecoregion features the greatest density of urban development and hardscape. In these urban environments it is most critical to design solutions that minimize runoff. Also shown in Figure 3, in urban environments where 75% to 100% of the land are covered by hardscape, 55% of the precipitation immediately becomes runoff. This runoff can create flash flooding and in areas with combined sewers can introduce an excess of harmful pollutants to waterways. The cities of the Piedmont must find a way to decrease their runoff on-site so it does not become an issue for those downstream.

It is almost inevitable that precipitation incident on the Coastal Plain ecoregion will eventually become part of the Chesapeake Bay because of its geographic immediacy. Because of this fact, water in this ecoregion must be purified so as to maintain the subtle ecological balance of the Bay as previously described in Figures 4 through 7. Excess nutrients inhibit the ability of the plant, fish, and animal species of the Bay to survive and built interventions that allow for water to be purified before being reintroduced in a controlled way to this ecosystem will improve the relationship between the built and natural environments.

While these program drivers are called out with one agenda for each ecoregion, it is important to understand all four of these agendas happen simultaneously in all ecoregions with varying levels of significance. It is important to purify water in the Appalachian Plateau as well as the Coastal Plain, but other factors prevail which make the mission of retaining nutrients more significant in the Appalachian Plateau than in the Coastal Plain. Similar relationships can be made with any of the processes and locations outlined previously. The following chart summarizes the four cities chosen to represent the ecoregions and the agenda for water that was deemed most pertinent in the developing the built solution for that environment.

Site-Specific Design Theses		
Case Study City	Ecoregion	Water Agenda
Corning, NY	Appalachian Plateau	Retain nutrients.
Nanticoke, PA	Appalachian Mountains	Recharge the aquifer.
Columbia, PA	Piedmont	Reduce runoff.
Havre de Grace, MD	Coastal Plain	Remove pollutants.

Chapter 4: Design Solutions

The four design solutions created for this thesis were carried through concurrently with the intent to make comparisons between schemes. As such, every effort was made to bring the level of design work up evenly on all schemes so ideas with a similar level of development could be discussed. In some instances there is more clarity than in others as a result of the time constraints placed on this thesis.

Corning, NY

The design solution most appropriate for Corning, New York and the agenda of retaining nutrients in the Appalachian Plateau was to create a park on the site that featured the built program in a series of pavilion structures spread throughout the landscape. In an urban environment largely devoid of public open space, this natural oasis would become a figure in the community drawing those looking for recreation and information. The site plan in Figure 63 illustrates the intention to create a forested buffer around the perimeter of the site with spaces carved out of the foliage for built form. The center of the site was developed into a meadow landscape with a large water feature. The runoff from all the buildings would be directed to this feature and through retention would begin to inspire biodiversity by creating a landscape that could be self-sustaining. This site illustrates what building 10% of a site with hardscape looks like. According to the data in Figure 3, the immediate site context could naturally filter the runoff displaced by the built forms proposed and as a result no technical innovations (such as green roofs or green walls) were necessary to mitigate the impact of the built environment on the water cycle. Parking for the park was provided along the east edge of the site, outside the forested edge and immediately adjacent to the parking garage providing parking to



Figure 63: Corning, NY site plan. The overall intention with this site was to create a park landscape.



Figure 64: Crossing through the forest edge.

the Corning, Inc. offices across East Pulteney Street. The site strategy itself helps to both create amenity in the town as well as fulfill the water agenda of retaining nutrients determined for the Appalachian Plateau.

This idea of creating a forested edge is also evident in Figure 64 which shows a tree buffer along the left edge with small pockets created for the buildings. The meadow, featuring shorter landscape elements, fills the center of the site. This image also features a dock which would give visitors to the park the opportunity to closely come in contact with the natural environment around them. The path encircling the meadow would in this design not be composed of permeable paving because of the climate of Corning. Permeable paving requires careful snow removal, and in a location such as Corning, New York (which experiences heavy snowfall) permeable paving would require intense



Figure 65: Meandering through the meadow.

maintenance through cold, sometimes brutal winters.

Figure 65 illustrates what the experience of walking through the meadow landscape would be like. The building to the right of the image shows the hierarchal gallery pavilion building which would serve as the main display area for this outreach center of the Chesapeake Bay Foundation. The building to the left in the image would house classroom spaces. Because the landscape in this intervention is perhaps the most significant part of the strategy to mitigate the relationship between the built and natural environments, the landscape takes the foreground and would be open to the public even when the institution itself was closed, allowing for constant educational opportunities. Notable too is that the clients and users of this space are not only people, but also the animals that would begin to use such a place for habitat.

Nanticoke, PA

The design intervention for Nanticoke, Pennsylvania had two major moves to achieve its goal of recharging the aquifer. The building form is firstly terraced into the landscape slowing runoff from flowing freely down the steeply slope site and secondly runoff from the site is directed to a dry well. These two moves help to introduce precipitation incident on the site to soil below grade in such a way that the precipitation has an opportunity to reach deep infiltration and actually recharge the aquifer.

The site plan illustrated in Figure 66 shows the building pushed towards the intersection giving the building prominence and helping to reinforce the urban grid. An alley was reintroduced on the site's block in order to provide a driveway access for the parking area on the high ground of the site. This alley also builds on the existing alley structure of Nanticoke's urban design. The structure itself is divided into three sections. The enclosed space in Figure 66 shows the primary entry sequence through the lobby with an adjacent double-height space that highlights a visitor's movement down into the earth. Circulation in the building is always conscious of its relationship to changes in grade as vertical movement always happens along the topographic lines while circulation in plan happens perpendicular to changes in elevation.

Also visible in figure 66 is the significant landscape terrace that begins as a green roof on top of the building's below grade level. This terrace starts as a gathering space on the green roof and as visitors' move east they transition to being on true terra firma, but the line where that change occurs is purposely blurred so as to create one continuous garden blurring the line between the green roof and the garden. The garden features the dry well access prominently, celebrating the place where water re-enters the



Figure 66: Nanticoke, PA first floor plan.



Figure 67: Nanticoke, PA below-grade plan.

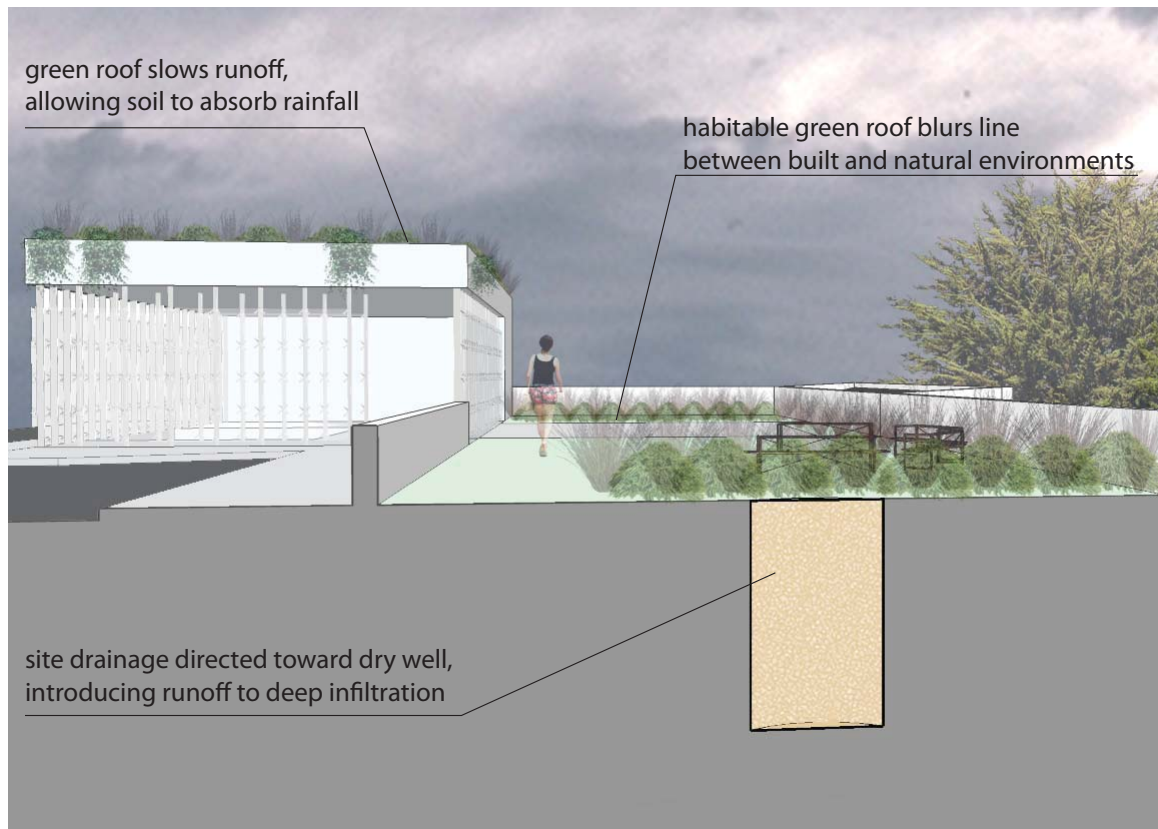


Figure 68: Recharging the aquifer.

ground to recharge the aquifer. The lowest terrace level features a native species garden with specimen plantings to encourage visitors to plant local vegetation in their own landscapes.

The below-grade floor plan shown in Figure 67 shows a significant auditorium space. This space was developed as part of the educational promenade because it gives visitors a clear path down into the earth and then a climb back out of it. This crevasse stairwell is naturally lit from above, allowing visitors to understand their underground experience because of the position of the light source. The secondary lobby on the south side of the building would provide entrance to pedestrians walking along the street.

Figure 68 is a section perspective through the dry well in the landscape that helps to explain in part how the building and the landscape would work together in

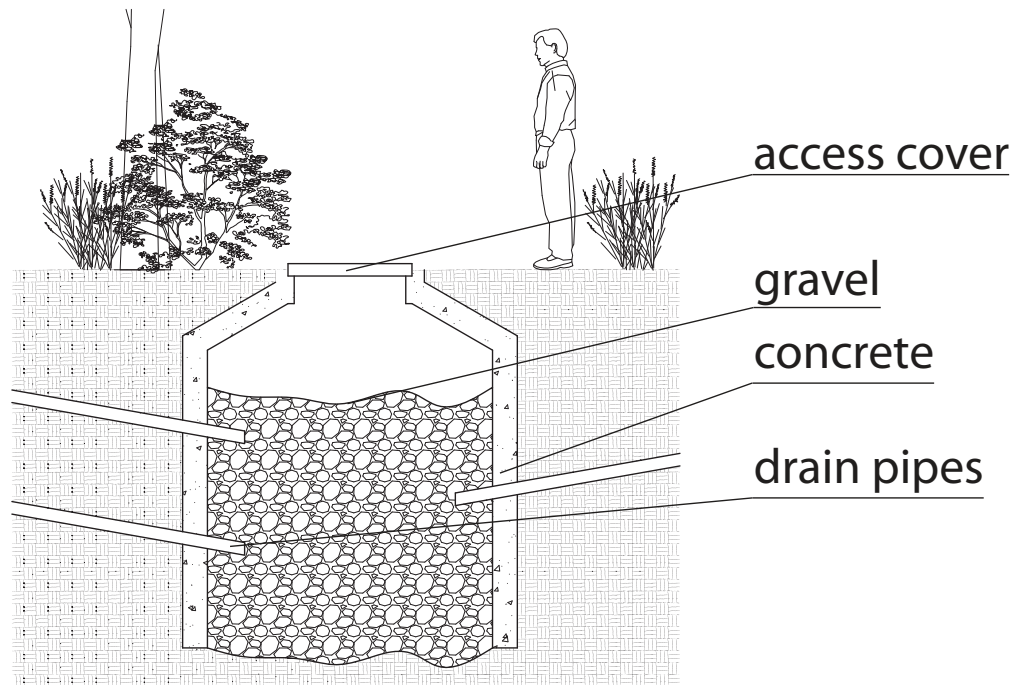


Figure 69: Dry well detail.

this intervention to recharge the aquifer. The green roof atop the highest form would help to slow runoff, giving soil the opportunity to absorb the first initial rainfall. The habitable green roof on top of the middle level of the building would continue out into the landscape, eventually transitioning from green roof to landscape on grade which would then include the dry well feature. The site would direct drainage to the dry well through a series of underground pipes.

The dry well detail shown in Figure 69 is a more technical understanding of how storm water would actually be reintroduced into the aquifer. An articulated access cover would be the visible mark of the dry well in the landscape and would essentially be a glorified manhole cover created in such a way as to be a design object and not the utilitarian object most people take for granted. The dry well itself is a concrete cylinder

partially filled with large aggregate such as gravel. The cylinder would be punctured in a variety of locations to allow drain pipes from various parts of the site to be introduced to the dry well. Water would naturally percolate down the aggregate and be reintroduced to the soil some 10' below the surface of the land. Through this deeper introduction to the soil, the water would not have the opportunity to either evaporate or runoff but would instead be able to reach deep infiltration and recharge groundwater resources. This would increase the health of the Bay by limiting the amount of nutrient-rich water that would make its way to the Chesapeake Bay and additionally sustain the relationship between groundwater resources beneath the Appalachian Mountains and the cities of the Piedmont.

Columbia, PA

The case study designed in Columbia, Pennsylvania presents the only infill site under consideration. This is relevant to Columbia's context within the watershed as the Piedmont features the greatest amount of urban development making an infill site the most relevant design context in terms of choosing a case study that is representative of this ecoregion. Because the site is the most densely built, featuring constructed form on 75% to 100% of the site's area, significant technical innovations were incorporated into the building's design. Landscape still plays a major role in repairing the water cycle in the urban environment, but in order to also design a building with an urban instead of a more suburban character, technology must be employed effectively to manage storm water. What separates this building as being particularly designed for water is that it celebrates those elements specifically and highlights the path of storm water instead of concealing that movement.

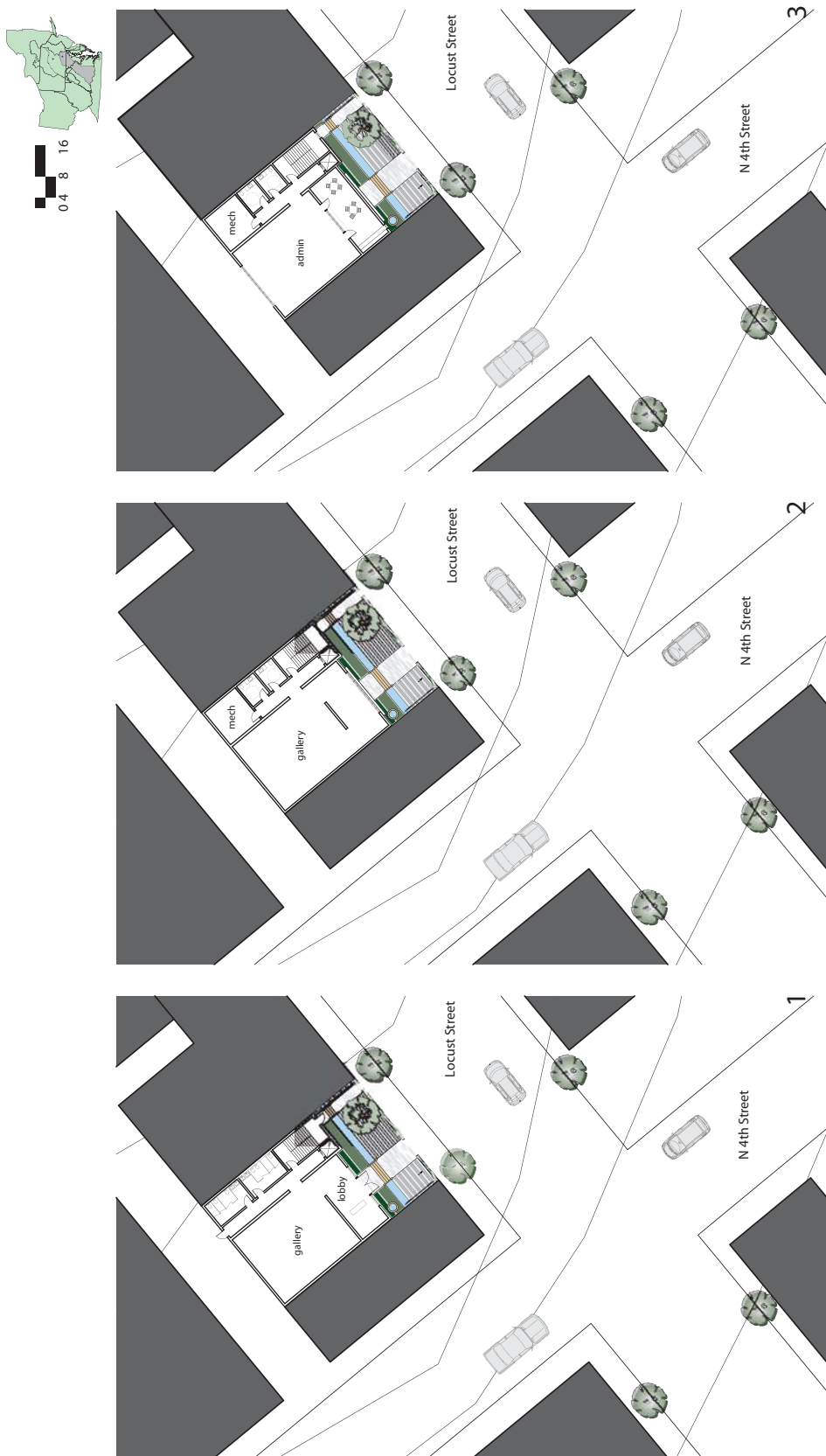


Figure 70: Plans of the intervention in Columbia, PA.



Figure 71: Walking along Locust Street in Columbia, PA.

Figure 70 shows the plans of the building and landscape proposed for Columbia, Pennsylvania. The building is three stories tall in order to be appropriate for its context and fit the program desired within the site's footprint. The general part of the building creates a clear linear division between served and service spaces in the building. Service functions are consolidated into a poche bar running along the east party wall of the building in order to clarify the relationship between served and service spaces and leave the greatest amount of uninterrupted floor space for exhibition areas. Major program features include an entry Zen garden as well as a rooftop terrace on the third floor adjacent to the administrative offices. The public areas of the building are located on the first two floors of the building, giving privacy to the office functions of the building.

Technologies such as green roof, green wall, and permeable paving were used in



Figure 72: Entering through the garden in Columbia, PA.

order to achieve this site's goal of reducing runoff. Choices were also made that limited the building footprint, pulling it back from the street wall and creating a landscaped oasis in the middle of the city. The Zen garden developed into a lush growing billboard to broadcast the building's mission on the south elevation of the structure as seen in Figures 71 and 72. Because pulling the mass of the building off the street weakens the street wall, a planted wall was erected along the line of the street wall to create a translucent plane that would at once continue to the line of the street and allow sporadic views into the garden.

Limiting the building footprint and creating the entry garden minimizes hardscape on the site and additionally requires visitors to experience nature on their promenade into the building. If this landscape were on the back of the building the structure itself would

have been able to continue the street wall, but the garden would not be as prominent and could potentially be overlooked by visitors. Placed as a focal point in the city, this institution can teach its methods of water management to populations that may never visit the building simply by boldly putting those efforts on display in the public realm.

Entering the building would look as it does in Figure 72. Visitors would walk on permeable paving as they pass manicured lines of gravel on the ground. A specimen tree would appear uniquely beautiful separated from other landscaping and a birdbath would encourage birds to visit the space. Crossing a bridge over a linear water feature would put people in close proximity to the building's driving design feature while two lines of planting at different heights would be nourished by storm water captured from the building. The green wall, trellis systems, and planter box would continue the garden into the vertical plane, literally surrounding the visitor with vegetation, constructing an experience that quickly transitions visitors from the urban environment of the city to the natural missions the building and its program aim to teach.

Figure 73 demonstrates how water would actually transition from the sky to the earth. Water incident on the building would first be slowed by the green roof. As previously described, green roof slows precipitation down which helps to minimize flash flooding. It also insulates the roof, minimizing the heat island effect, which is particularly important in cities where average temperatures are significantly higher than less developed areas. Water would then flow across the elevation in a celebrated box gutter. Instead of minimizing this detail, it would be celebrated and the movement of water could be visually traced along the elevation. Water then transitions to a channel cut in the floor of the roof terrace. This water would cascade over a scupper adjacent

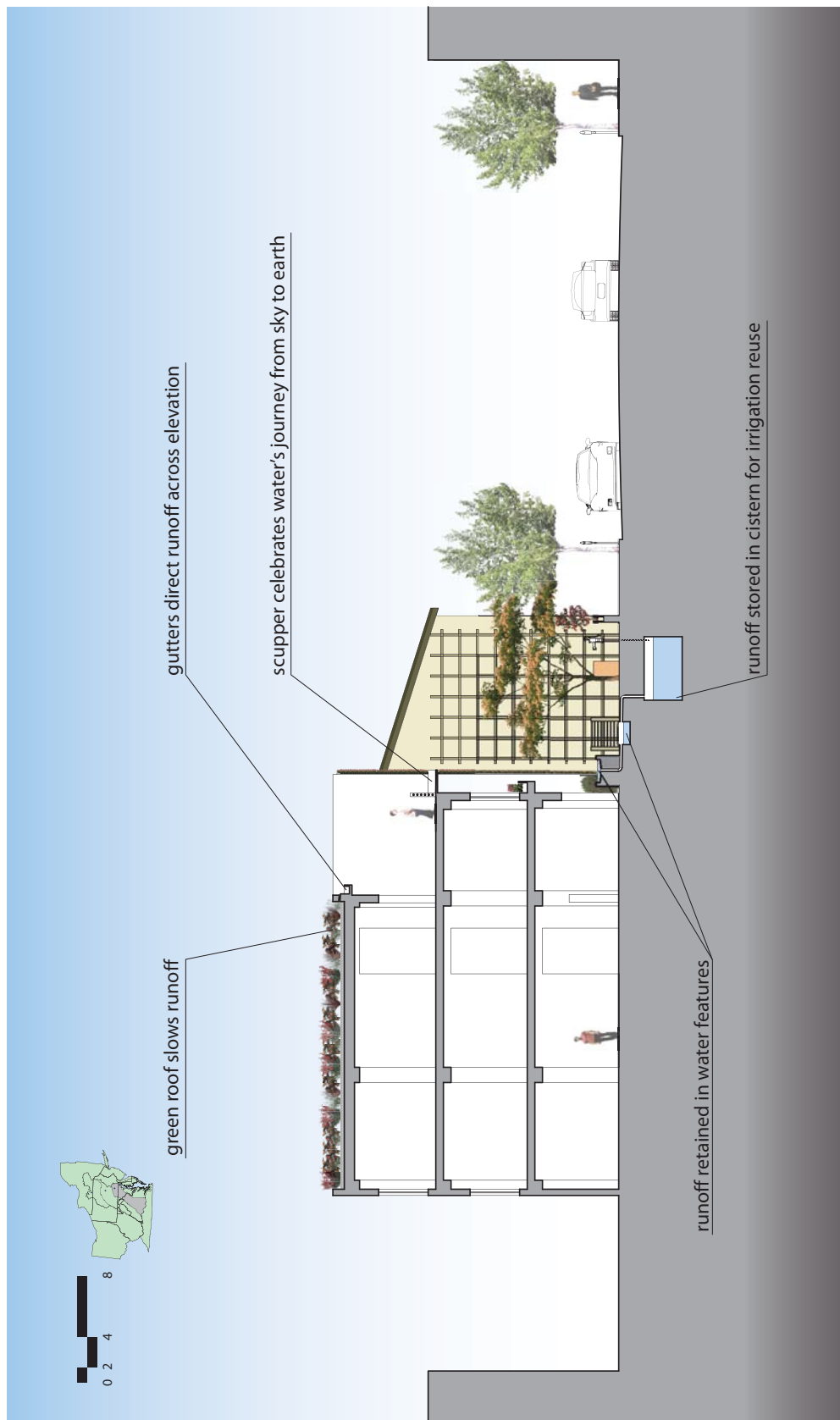


Figure 73: Section through the Columbia, PA intervention.

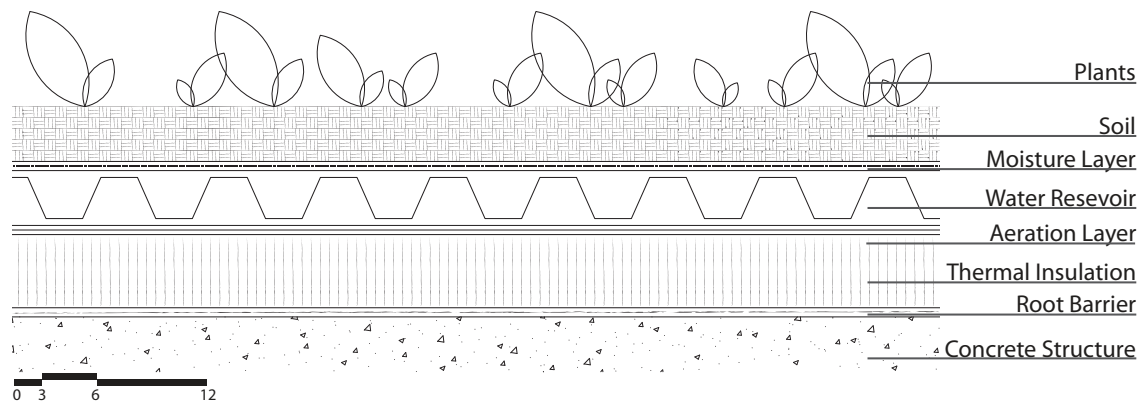


Figure 74: Green roof detail.

to the entrance making a celebrated moment out of water's journey from the sky to the earth. This water would be captured in a bird bath feature which would then overflow into the linear water feature of the Zen garden. This feature would in turn overflow into a below-grade cistern where water could be stored indefinitely until manually pumped out for irrigation of the landscape. This narrative about water notably does not include rainwater's introduction into the municipal drainage system because the building is designed to minimize this use of infrastructure. Alleviating pressures on such systems through designing for water management would allow infrastructure to be less taxed, and if implemented widely, perhaps rendered obsolete.

This work in the urban context particularly featured a number of specific systems for storm water management. Detailed sections in figures 74 - 76 show the composite layers of green roof, green wall, and permeable paving systems to illustrate a higher level of understanding of these systems. It should be noted that green roof can come in one of two forms: an extensive system and an intensive system. An extensive system refers to one of the popular tray systems that are commercially available and is installed entirely separate from the roofing system and can be retrofitted onto existing buildings if the structural system will support it. An intensive system, such as the one detailed in Figure

74, is built with the building and becomes part of the building's permanent structure.

Such a system is rarely if ever retrofitted onto an existing building because of the weight associated with such a system and its relationship to other building elements.

Running through the layers of an extensive green roof from top to bottom, the first is obviously the plants themselves. Plants may be of any variety although the larger the plants, the more soil depth is required. The more soil that is a part of the system, the greater the weight, which then places additional stress on the structural system. Large scale green roof systems with large plants can be done, but additional design and maintenance considerations must be taken into account. The plants can be rooted in either a natural or an engineered soil. An engineered soil might incorporate materials that have better water retention which would allow plants to be more drought-resistant. Beneath the soil a moisture layer and water reservoir could additionally retain water in the roof sandwich to nourish the plants during drought and store water from larger storm events. An aeration layer provides an air gap in the sandwich, giving condensation a drainage plane. Insulation would be beneath this drainage plane and would provide additional thermal protection beyond that already provided by the soil. A root barrier beneath the insulation would protect the structural elements from the potential growth of the plants. The structure beneath supports the load of the green roof and helps to create architectural form in the interior space below.

A green wall introduces vegetated elements into a vertical plane. In the proposed building for Columbia, Pennsylvania, a green wall was created to face the service bar on the street elevation and is detailed in Figure 75. Describing these elements from exterior to interior, the furthest outboard layer is again the plants themselves. These plants are

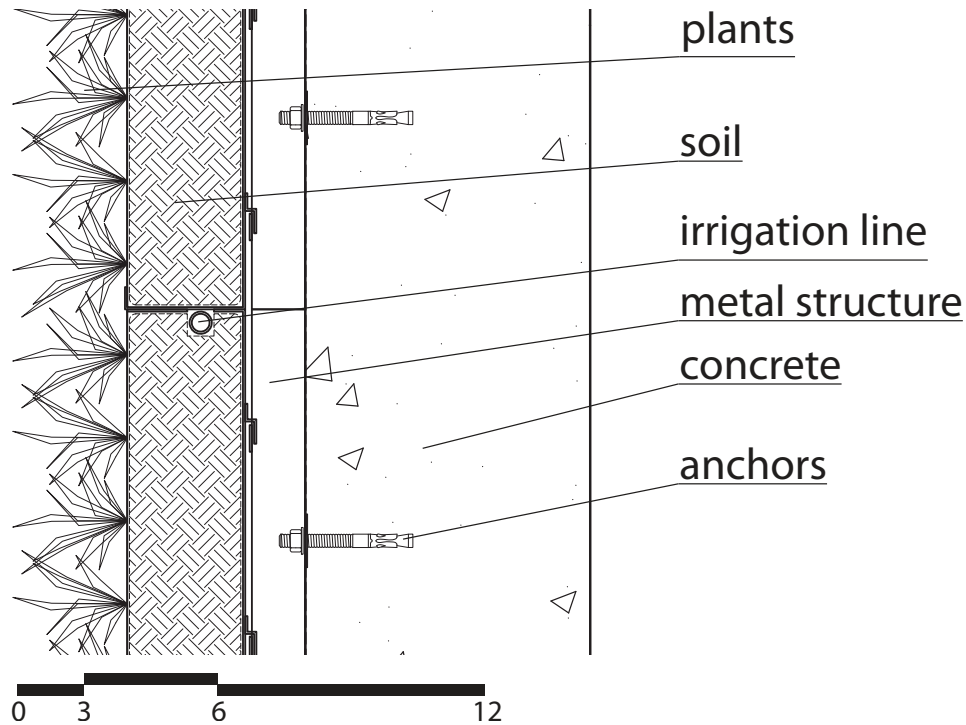


Figure 75: Green wall detail.

rooted into a vertical soil or engineered soil medium which is contained in a panelized tray system. This makes the system decidedly different from a trellis system in which the plants are actually rooted in the ground and grow vertically up an armature. In a green wall, the plants are truly rooted into the vertical plane. This soil plane also contains drip irrigation lines which water the plants and need to be hooked into the building's plumbing system. The green wall is mounted in panels onto a metal structure that is tied back into the concrete structure of the building via a series of screw-in anchors. Similar to the green roof, the green wall provides insulation to the wall which may be supplemented by additional insulation in the wall system.

Permeable paving, detailed in Figure 76, creates walking surfaces that allow water to percolate down into the soil without displacing as much precipitation as a concrete sidewalk or asphalt path would. Instead of layering a continuous surface over the earth,

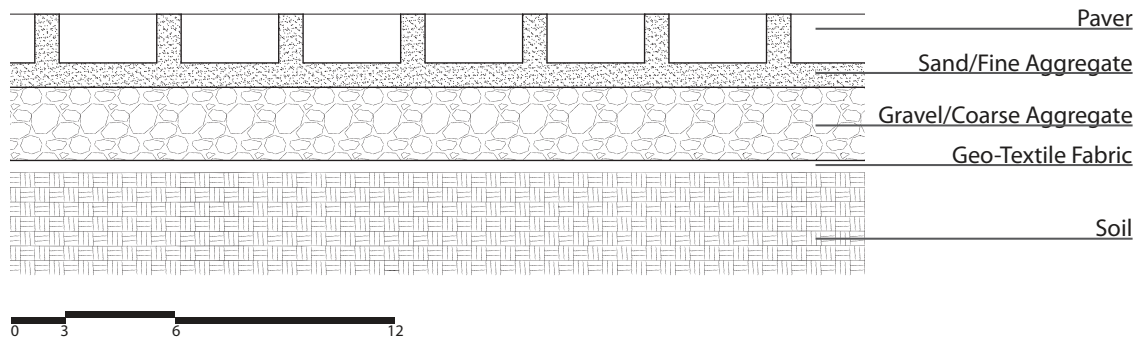


Figure 76: Permeable paving detail.

permeable paving uses a series of spaced pavers to create the walking surface. The space in-between pavers is filled with a fine aggregate that keeps the pavers from shifting but allows water to percolate into the soil instead of running off into the surrounding landscape. Beneath the fine aggregate that serves as the setting for the pavers, coarser aggregate creates a solid base for the pavers that will keep them from settling unevenly. This coarser aggregate allows water to move more freely to the soil below. A geo-textile fabric can be introduced between the soil and the coarse aggregate to keep weeds from sprouting up through the soil and disturbing the paving materials.

Havre de Grace, MD

The Coastal Plain intervention, represented in Havre de Grace, Maryland, is intended to remove pollutants from storm water. This is most actively done through an extensive constructed wetland feature that is intended as an extension of an existing wetland feature along the waterfront. Figure 77 describes how a wetland processes nutrients out of water and it is intended that the constructed wetland in Havre de Grace would function along these lines. Water is introduced to this system either as grey water from bathroom sinks, washing machines, and showers or as rainfall. The sun shining begins to break down nutrients and chemicals in this water through a process called

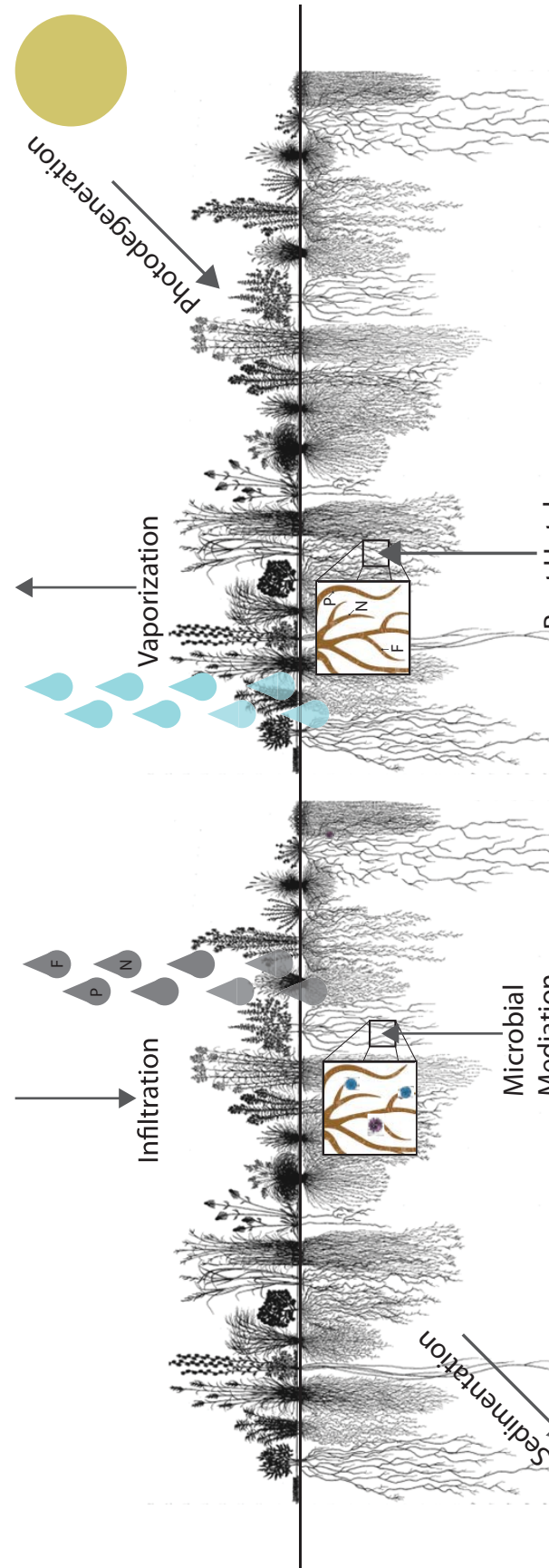


Figure 77: Wetland filtration process diagram.

photodegeneration. This is the same process that deteriorates paintings and makes paper yellow in the sun, but in this case it is acting on organic material that wants to be broken down. This water also infiltrates into the soil where it is either taken up by plant roots and used to help the plants grow or the nutrients are processed by microbes living in and around the plant roots. Part of the output of this process is more soil via a process called sedimentation. The end result of all of the aforementioned processes is water that vaporizes back into the atmosphere cleaner than it was introduced to the wetland.

In the Havre de Grace, Maryland design intervention, a constructed wetland that would embody all of these processes is the main landscape design intervention on the eastern half of the site. This productive landscape needs to be understood by visitors in order to communicate the relationship between the built and natural environments in the Coastal Plain, but at the same time visitors should not actually be able to walk through this environment. Havre de Grace has an existing waterfront boardwalk which connects the public parks as well as the primary institutions in the town. The boardwalk running along the north edge of the site plan in Figure 78 extends from that existing boardwalk in such a way as to allow people to view the constructed wetland and create connection to the new institution of the Chesapeake Bay Foundation outreach center.

The visitors' center itself is trying to be a part of its residential context and as such takes the large plan of the building and breaks it down into a set of successively smaller volumes much the same way that vernacular housing in the area is created by additively joining a series of volumes to create form. The overall displacement of form shown in Figure 79 draws inspiration from the telescope houses that were common on the eastern shore during its initial settlement. On the eastern shore a homesteading family would

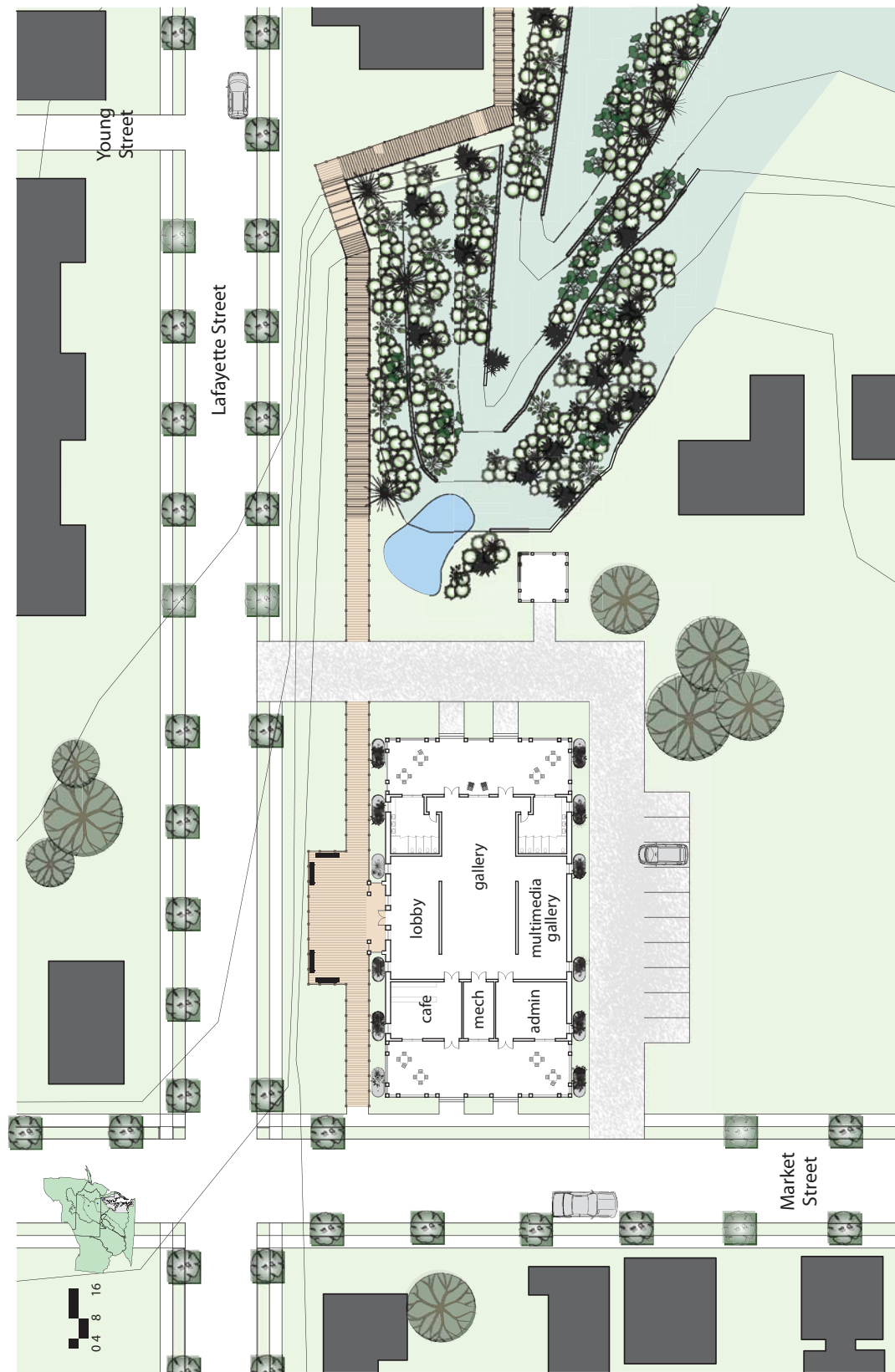


Figure 78: Plan of Havre de Grace, MD design intervention.

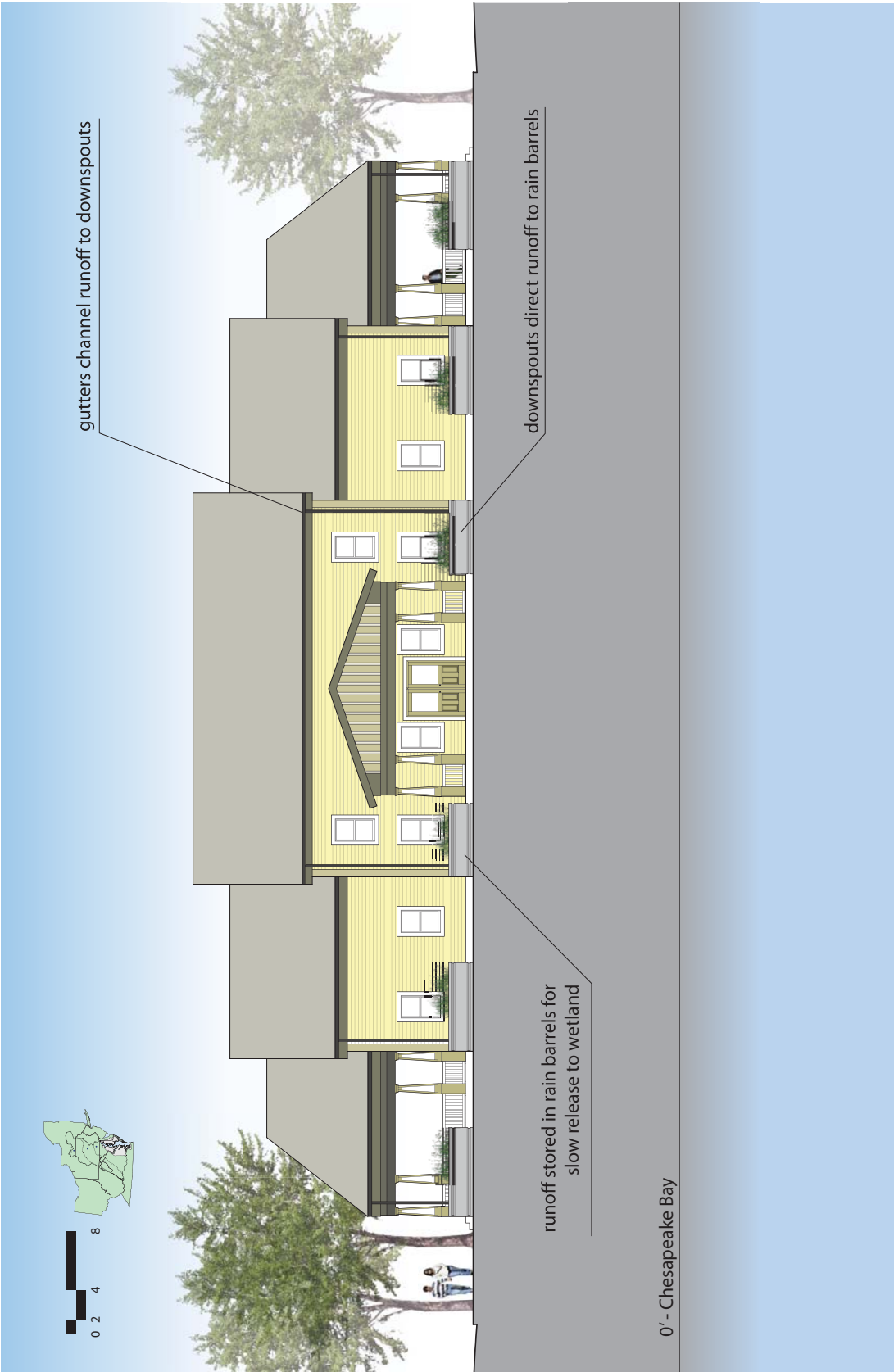


Figure 79: Elevation of Havre de Grace, MD design intervention.



Figure 80: Strolling along the boardwalk in Havre de Grace, MD.

acquire a piece of land and build the first initial house, the central portion in a design such as this one. The family would grow, children would be born, spouses would be added to the family, and instead of building a whole new structure, a wing might be added to one or both sides of the initial dwelling. In this visitors' center these are the two wing spaces which include additional gallery space as well as administrative and service functions. The house might continue to grow in this telescoping way such that the building always looked finished and complete but could also always be added to over time along clearly defined design guidelines and principles. The smallest additions to the building are the covered porches which give visitors to the center the opportunity to view nature from a sheltered place while still being a part of the great outdoors. These porches also fit into the larger character of Havre de Grace which, as a shore town, has a distinctive porch



Figure 81: Observing the wetland from the porch.

culture. Most residences in Havre de Grace feature front and side porches which are frequently populated with people taking time to visit with one another and watch the people going by.

Figure 80 illustrates the experience of walking along the boardwalk. From this vantage point the building serves as a backdrop for the celebrated wetland which would filter pollutants from water and provide habitat for native species. The opposite experience of the wetland feature would be that in Figure 81 which shows people enjoying the protection of the covered porch while being able to view both the wetland as well as the Chesapeake Bay in the distance.

Comparative Sections

In addition to the previously outlined design propositions, a set of sections was created to both describe the design solutions as well as to put them in conversation with one another, their relative groundwater resources, and the Chesapeake Bay. These sections in Figures 82 through 85 are taken through the respective site as well as an extensive amount of context between the sites and their most immediate body of water. The sections are also taken from the sky down through sea level showing the relationship between the Bay and each site. The elevation of the local body of water is also indicated on each drawing to show the relationship between each site's most immediate Chesapeake Bay tributary and each site. The cut through the ground is toned to represent the changing composition of the underground strata.

There are a myriad of relationships told by this set of drawings that describes the way the ecoregions of the Bay relate to one another and to water. The changing composition of the underground strata means that in each ecoregion of the Bay, water has a different path to take as it travels to recharge groundwater resources. In some locations where the underground soil is particularly dense it might be very difficult for water to percolate through that compacted soil. In other locations where the underground composition is coarser, water may be able to infiltrate more effectively to the aquifer. The composition of the ground strata also speaks to the ease or potential difficulties of creating suitable building foundations in these locations.

The comparisons between where the local body of water lies and the elevation of the site show how likely a localized flood event might be. In Corning, New York the city elevation is very close to the elevation of the Chemung River while in Nanticoke,

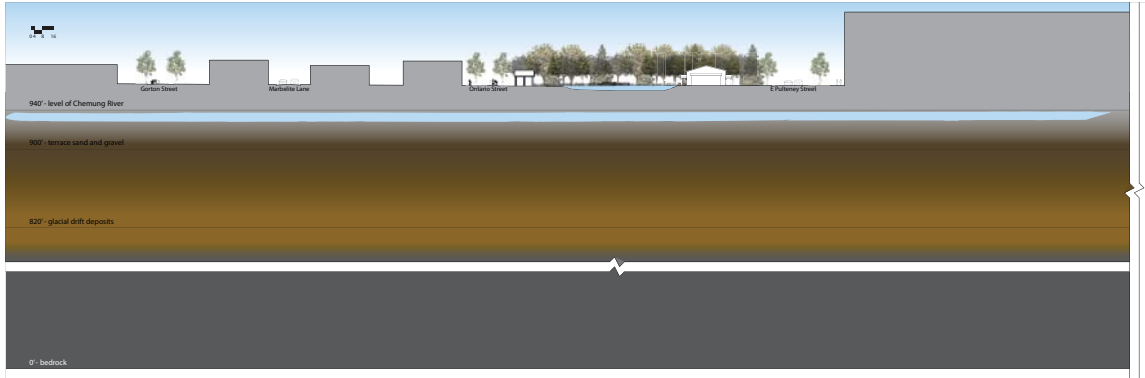


Figure 82: Section through Corning, NY design proposition with underground context.

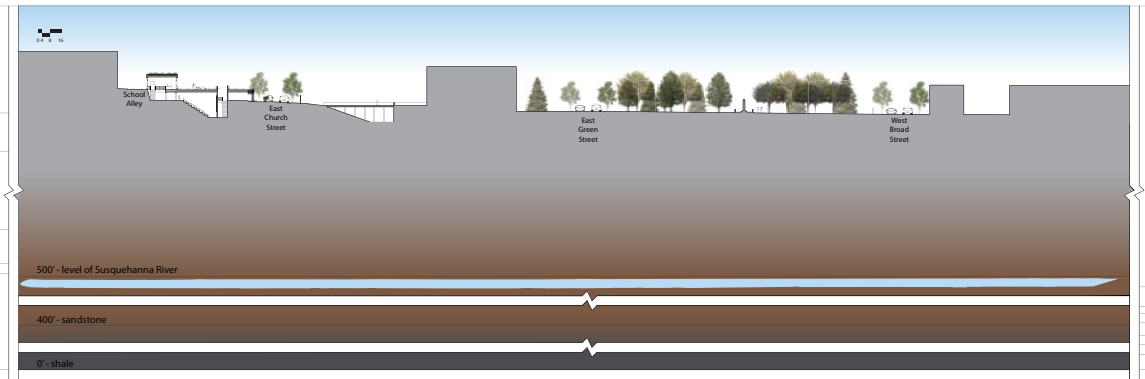


Figure 83: Section through Nanticoke, PA design proposition with underground context.

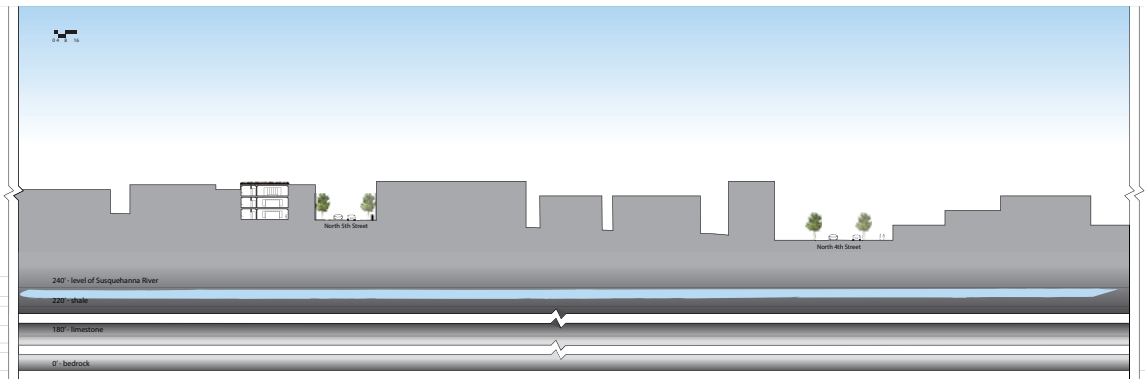


Figure 84: Section through Columbia, PA design proposition with underground context.

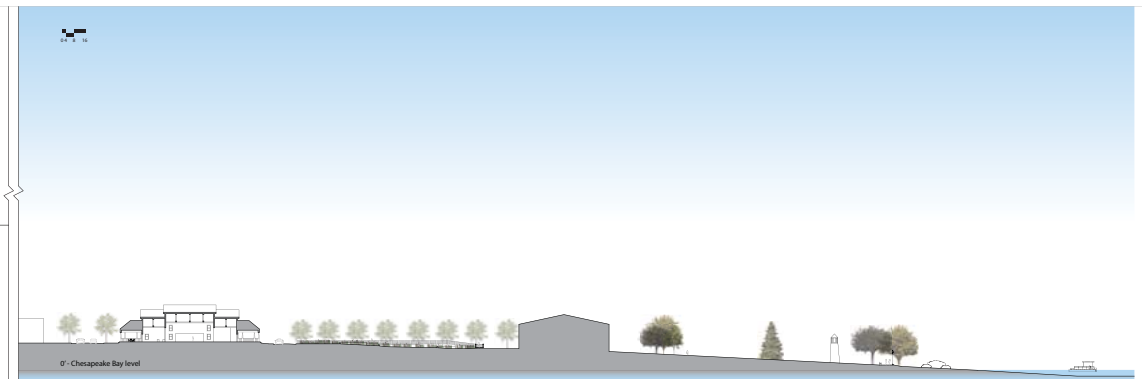


Figure 85: Section through Havre de Grace, MD design proposition with underground context.

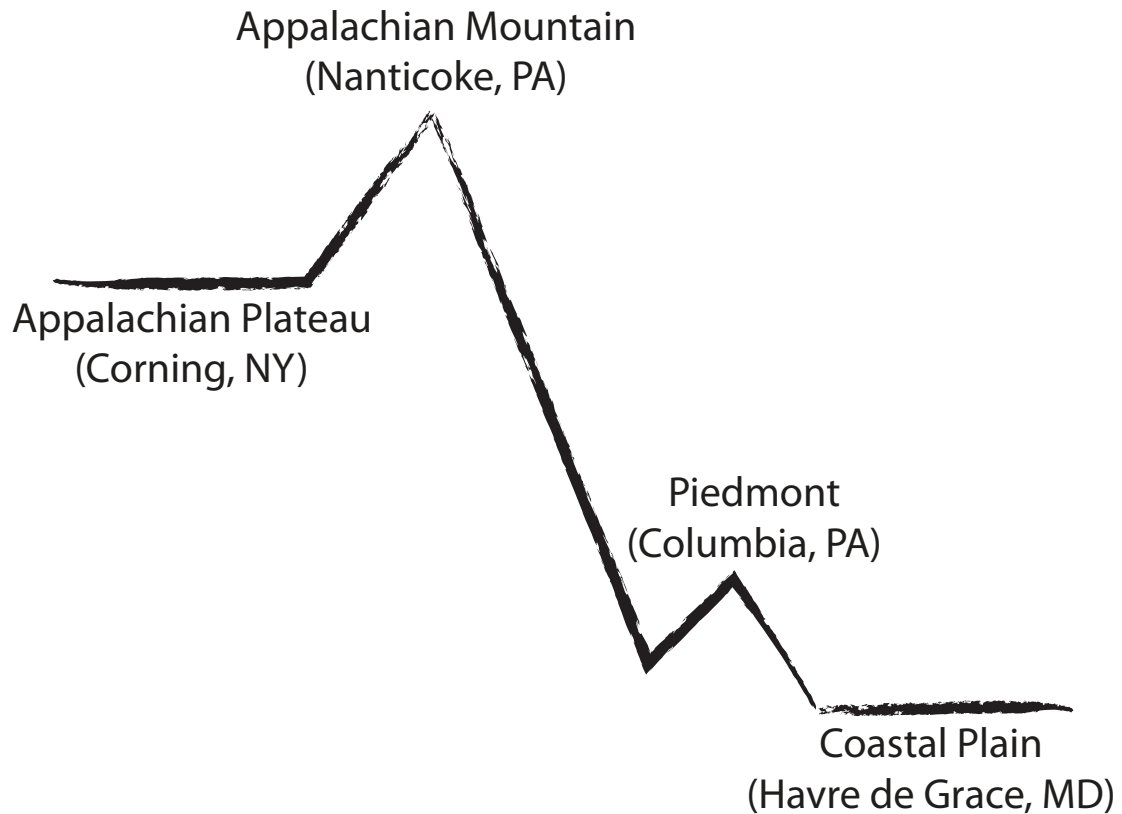


Figure 86: Watershed transect diagram.

Pennsylvania, the city sits far above the local water table. What is interesting here though is that both of these sites are significantly elevated from the level of the Chesapeake Bay. Even in a location where sea level rise would be reasonably unnoticed, changes in rising water might be felt because of changes in the immediate body of water.

This section also helped to inspire the watershed transect diagram in Figure 86 which shows a diagrammatic transect section through the watershed. In this diagram the Appalachian Plateau is diagrammed as a flat land at the top of the watershed. Moving south, the Appalachian Mountains spike the elevation in the watershed and transition quickly to a much lower elevation in the Piedmont. Along the Piedmont there is another small, localized rise which corresponds with the fall line which gave the cities of the Piedmont their initial reason for being. The Coastal Plain, furthest south in the

watershed, is again a flat plateau which lies most immediately adjacent to the Chesapeake Bay.

The design solutions described above along with these comparative sections were designed to achieve four theses. The Corning, New York intervention was to retain nutrients and promote biodiversity. The Appalachian Mountains site in Nanticoke, Pennsylvania was to recharge the underground aquifer. The urban site in Columbia, Pennsylvania was to illustrate ways our built environment can reduce runoff and in the Coastal Plain city of Havre de Grace, Maryland, the design intervention was to remove pollutants from the water. These four schemes each independently function to achieve these goals but when taken together answer the larger questions this thesis posed about how the built environment can be a better mediator of the water cycle in order to improve the health of Chesapeake Bay and its watershed.

Chapter 5: A Design Language for Water

Following the design work outlined above which was presented publicly on April 25, 2011, it became clear that while there were seeds of great things to come in all of the design propositions presented that the thesis would benefit from further development of a design language for water. To achieve this language, six architectural elements were chosen and rules were developed about how these elements should be incorporated into design work to create buildings throughout the Chesapeake Bay watershed that speak to this interest in water-based design.

Green Roof

Green roofs serve to reduce runoff, collect and store water, and create microclimate. When specifically designed for storm water management green roofs should abide by three guiding design principles, two of which are illustrated in figures 87 - 88. First and foremost, green roofs must be placed on roofs with 4 - 6 hours of unobstructed daily solar access. Even shade-loving plants require sunlight to grow, and without this solar requirement met, the plants of the green roof will have limited ability to successfully survive. In addition to this solar requirement, green roofs that aim to retain as much water as possible should ideally be flat as shown in figure 89. The greater the slope on the roof the greater tendency precipitation has to flow down the slope causing erosion of the soil and limiting the ability of the plants to take up nutrients from the water and slow the rainfall down. Green roofs at maximum can have a 10 degree slope as shown in figure 90. Steeper slopes such as that illustrated in figure 91 should not be designed for green roofs. Whenever possible, green roofs should be designed using native species.

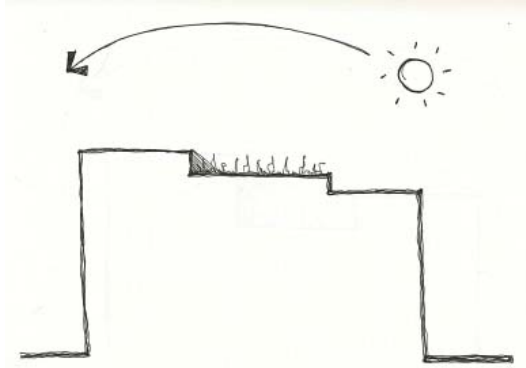


Figure 87: Appropriate solar access for a green roof.

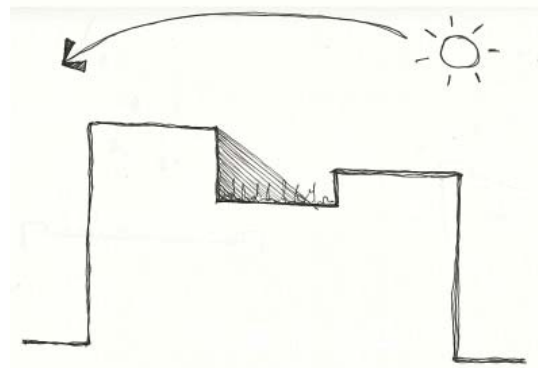


Figure 88: Inappropriate solar access for a green roof.



Figure 89: Appropriate slope for a green roof.

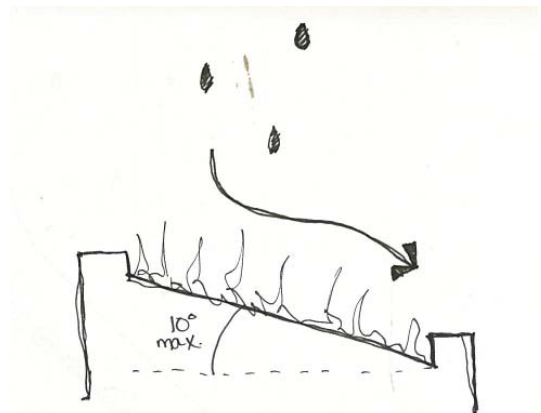


Figure 90: Maximum slope for a green roof.

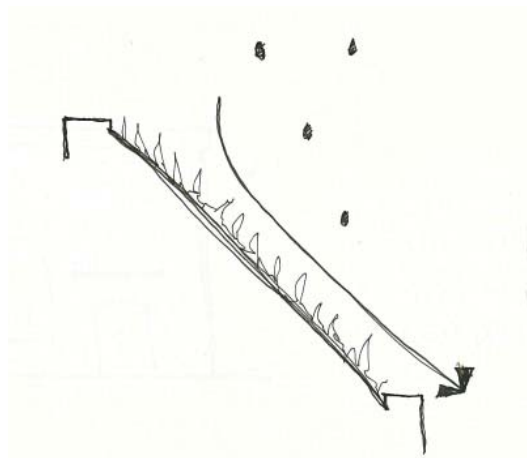


Figure 91: Inappropriate slope for a green roof.

Rain Barrels

Rain barrels are connected to the gutter system of a building and reduce runoff by collecting it and storing it in a sealed container. In order to use this technology to its best advantage in a water-based design intervention, three rules should be followed. Rain barrels get a poor reputation as being unattractive. To celebrate rain barrels in architecture, they should be created in hierarchical materials and forms with significant placement on the building elevations. Designed in this way, a rain barrel is elevated from its service function and is celebrated as a design object. Rain barrels have obvious mechanical functions which can include unattractive connections, valves, and other maintenance ports. All reasonable steps should be taken to conceal these mechanical functions in order to preserve a rain barrel as a design object. The water stored in rain barrels will likely be used in irrigation. To aid the end user of a building, rain barrels should be placed adjacent to the landscape areas that will utilize the collected rainfall as shown in figure 92 not at a great distance as illustrated in figure 93.

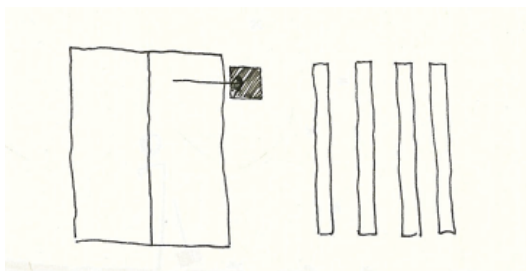


Figure 92: Rain barrels adjacent to location for water usage.

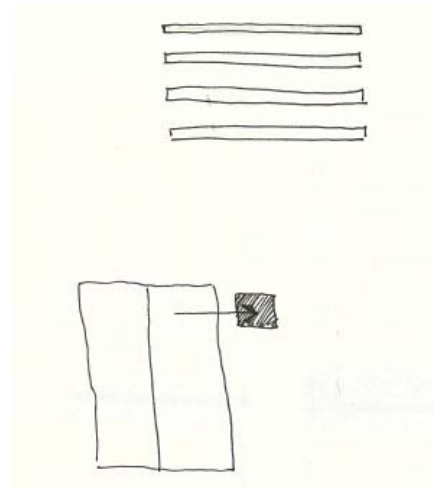


Figure 93: Rain barrels placed distant from location for water usage.

Permeable Paving

Permeable paving allows water to percolate into soil where it initially hits the earth instead of becoming runoff and being reintroduced to the ground in a distant location. In order for permeable paving to be a successful part of a design intervention for water is important to take three issues into consideration. If the site has significant snowfall that requires the frequent use of mechanical equipment to remove snow, permeable paving is a poor design solution for creating walking surfaces. Permeable paving is long-lasting, but it also can be broken and knocked apart by the force of heavy machinery. Permeable paving is better suited to temperate climates with minimal snowfall where the snow can be removed manually with shovels. Permeable paving is an appropriate design solution for creating pedestrian pathways as seen in figure 94 but is not recommended for parking areas in water-based designs. Runoff from parking spaces

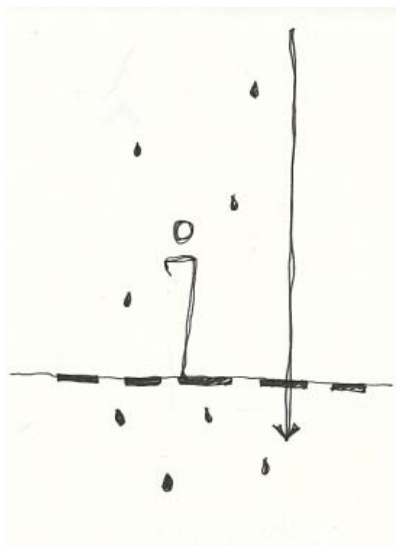


Figure 94: Permeable paving for pedestrian pathways.



Figure 95: Landscape swales to mediate parking runoff.

contains a greater concentration of pollutants than pedestrian walking surfaces and should be directed to appropriate landscape swales as shown in figure 95. Finally, permeable paving is correctly installed when it is laid atop a well-compacted base that minimizes the opportunity for uneven settlement.

Constructed Wetlands

Constructed wetlands are a landscape architecture element which utilize plants to filter pollutants naturally out of grey water and rainfall. This landscape is a productive one in which the plants are working and as such should not be disturbed by foot traffic. Architecture involving constructed wetlands should include circulation which allows significant views of the wetland but should not include pedestrian paths through this landscape as shown in figures 96 and 97. This sort of movement along the edge of the wetland minimizes human interaction with organic content in the water and keeps people from disturbing the plants which are actively working to eliminate pollutants. Constructed wetlands should also be designed in alternating areas of water movement and retention as shown in figure 98. Stagnant water attracts undesirable bugs and as a result some amount of water movement is beneficial, but the water must also be periodically retained in order to let the nutrients in the water be absorbed. Alternating these two design types balances the competing needs of the constructed wetland. As with any landscape, native plants should be used whenever possible in order to minimize irrigation needs and avoid invasive species.

Green Walls

Green walls introduce landscape elements into the vertical plane and can both reduce runoff as well as create microclimate. Green wall systems should always be

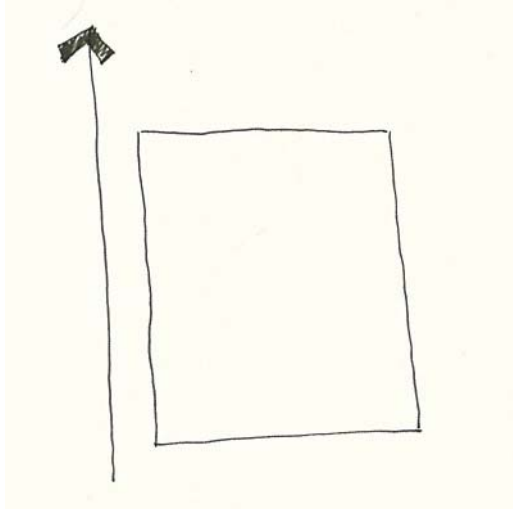


Figure 96: Circulation along edges of constructed wetland is advisable.

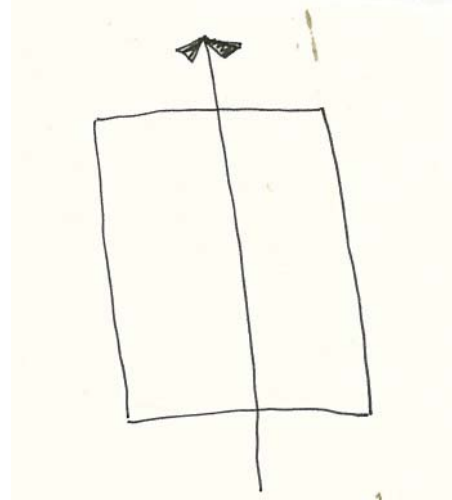


Figure 97: Circulation through the center of the constructed wetland is not advisable.

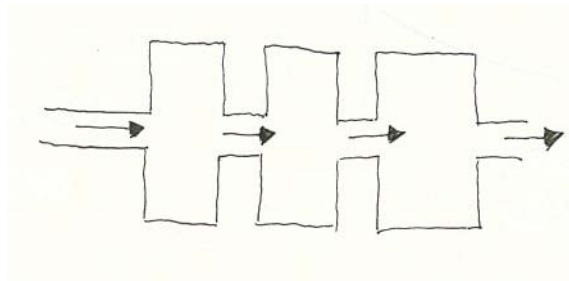


Figure 98: Constructed wetlands should be created to alternate areas of water movement and retention.

installed concurrently with a drip irrigation system run through the structure of the green wall. Installing such a system minimized maintenance of the plants after installation and helps to preserve the health of the plants. When such a system is fed by runoff from the roof, the green wall is eliminating runoff from traveling off site. Similar to green roofs and illustrated in figures 99 and 110, a green wall should be installed on vertical surface

with 4 - 6 hours of unobstructed daily solar access in order to promote plant growth. Green walls on north walls of buildings in the northern hemisphere are historically reasonably unsuccessful. Ideally a green wall should face south in the northern hemisphere. Similar to the other growing interventions described, native plants should be used whenever possible.

Scuppers

Scuppers are an articulated moment in architecture where water's path from the sky to the earth is highlighted. In order to make the most of this expression, scuppers should be placed prominently along building or site circulation paths to insure that building users are aware of this movement. Scuppers should also be created out of hierarchal materials in order to be highlighted against the building and landscape. As shown in figures 101 and 102 rain chains are an appropriate solution if the drop from the scupper is a great distance if minimizing splashing is desirable. Alternatively, this

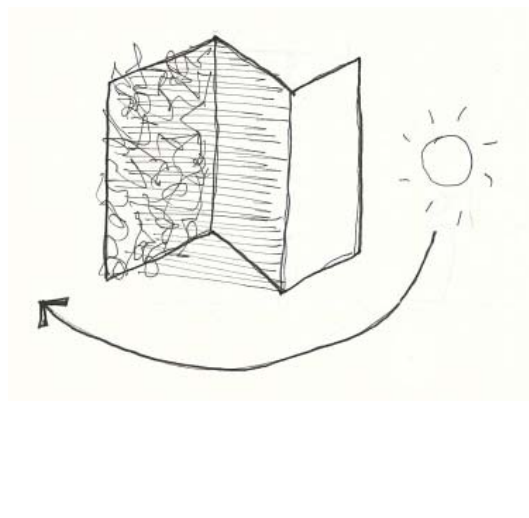


Figure 99: Appropriate solar access for a green wall.

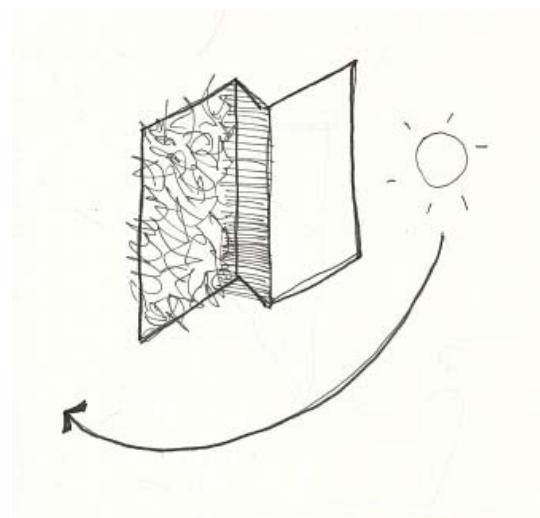


Figure 100: Inappropriate solar access for a green wall.

splashing could be celebrated to further communicate the nature of water's movement through the built environment.

While this design language is not a complete catalog of the elements available to designers interested in created buildings for storm water management, it does start to set the stage for how a language of this nature could continue to be developed. Other elements that could be added to this catalog include: rain chains, storm water planters, cisterns, landscape swales, Archimedes' screw, ponds or pools, filter strips, aqueducts, gutters and downspouts, sand filtration, terracing, french drains, damming, and rain screens. This thesis has also confined its interests to technologies utilized outside the building, but a catalog of other elements related to water in the built environment would include the opportunities of solar thermal systems, composting toilets, water fountains, washing machines, dishwashers, and a host of other equipment in buildings which utilizes water in order to function properly.

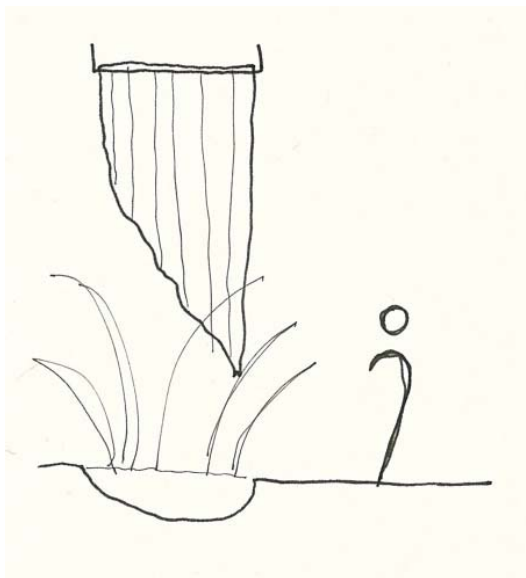


Figure 101: Scuppers without rain chains create splashes.

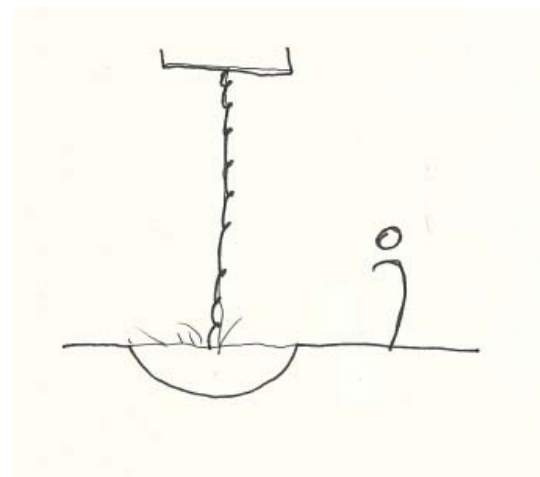


Figure 102: Scuppers with rain chains minimize splashes.

Chapter 6: Conclusions

While most architectural theses at the University of Maryland School of Architecture, Planning, and Preservation seek to solve the challenges of a singular design problem defined with one site, one building, and one tectonic, the intention of this thesis was broader: to define articulately what differences exist across the landscape of the Chesapeake Bay watershed and how architecture must adapt to meet those varying conditions for the health of the watershed as a whole. The point was to compare the designed environments created within the ecoregions and understand why what might be vernacular and appropriate for water in the Appalachian Plateau might be an entirely inappropriate design response for the Coastal Plain or any one of the other comparisons articulated in Chapter 4. The maturity of the design development is not as deep as it could have been had one structure been studied singularly, but the richness of the story to be told about the architecture of the Chesapeake Bay watershed comes not from the development of one building, but rather the complex interrelated stories of a set of buildings that must respond uniquely to the changing conditions of the landscape.

What came out of this thesis most fundamentally is a changed understanding of the water cycle and our relationship to it. The idealized understanding of the water cycle articulated in Figure 2 changed profoundly as a result of this design work and Figures 103 and 104 propose updated ways of looking at the water cycle. Figure 103 shows an updated and yet still idealized look at the water cycle. What had previously been understood and diagrammed as a single closed loop cycle is now understood to actually be a concurrent set of closed loop cycles happening at variety of scales.

As became evident through this design research, water is a design issue at every

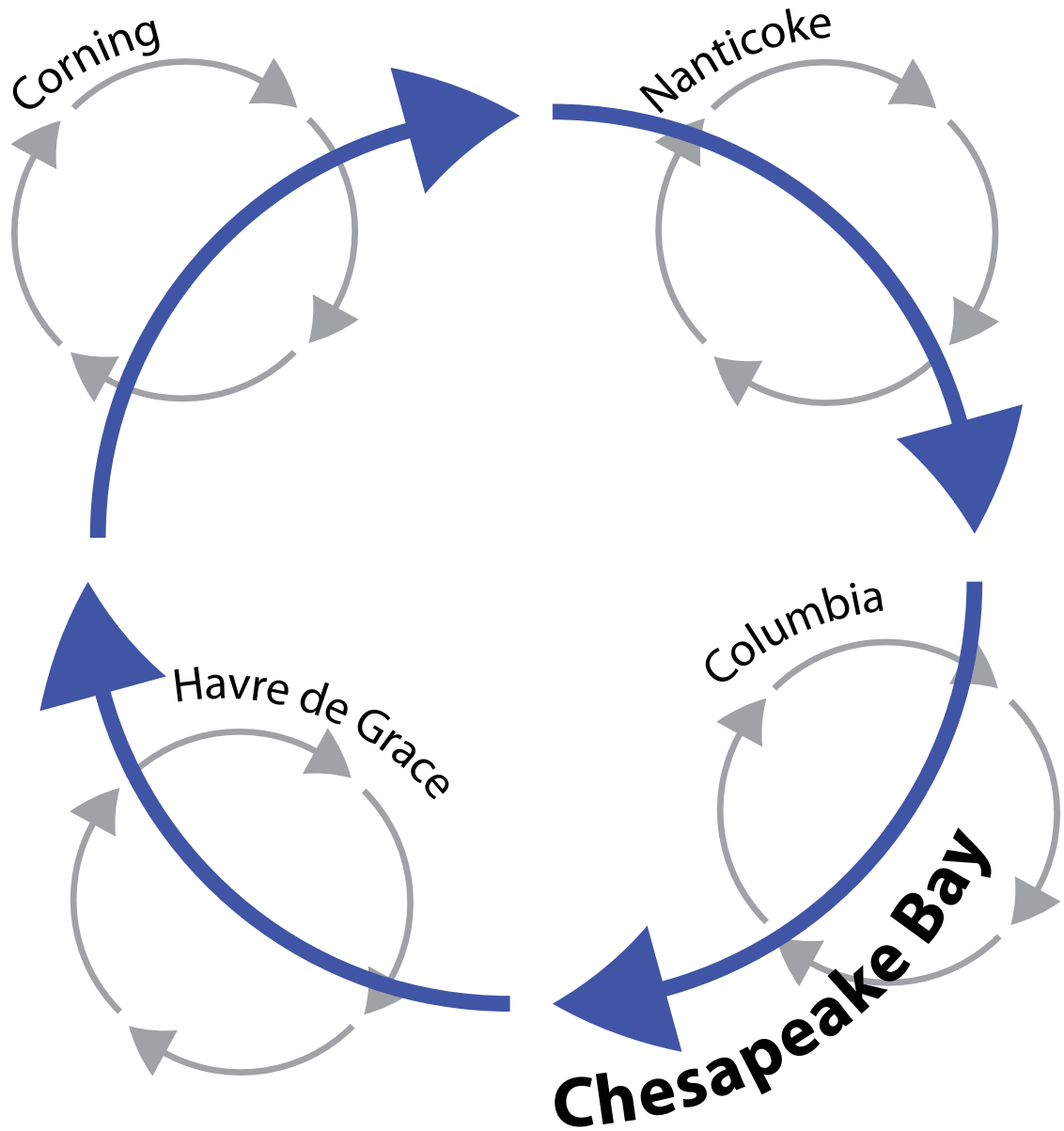


Figure 103: Water cycle diagram. Unlike the idealized water cycle diagram, this image shows a set of water cycles happening concurrently at a variety of scales.

scale precisely because the water cycle occurs at every scale. The cycle of evaporation, condensation, and precipitation happens locally in every ecoregion of the Chesapeake Bay watershed, but also happens at the regional scale of the Chesapeake Bay. The water cycle also happens at larger scales with bigger spheres of influence at national and international scales. This understanding of the water cycle adds a level of complexity

to the idealized diagram that more accurately describes the global, regional, and local system that is being designed for when an architect chooses to design for water. This more complex understanding allows a designer to not only think more sustainably about designing, but also dictates that when thinking of water the best design solution must not only be right for the immediate site, but also be right for the larger regional site. This is particularly critical in the Chesapeake Bay watershed because of the Bay's subtle nutrient and salinity composition.

Figure 104 illustrates another way knowledge has increased as a result of this thesis's design work. This diagram represents what tracing a drop of water through the Chesapeake Bay watershed might look like, which, surprisingly, starts to look quite similar to the design process spiral. A drop of water which falls at the top of the underlying transect diagram, on the Appalachian Plateau, might be recycled indefinitely at the top of the watershed. A drop of water might forever be processed and reprocessed at the top of the watershed and never actually make it to the Bay, especially if measures are taken in designing the built environment of that ecoregion to try to retain water that is incident on the site. Alternatively, a drop of water might progressively move through the ecoregions, periodically getting caught up in the mountain ridges of both the Appalachian Mountains ecoregion and the Piedmont, before finally reaching the Bay.

The bottom line is that through careful design work, architects can create built environments specific to the ecoregions of the Chesapeake Bay that would allow a loop to happen repeatedly on the same site without losing the precipitation to those downstream. Obviously a certain amount of movement downstream is desirable - the Coastal Plain is in part as nutrient-rich as it is because water traveling down the waterways of the

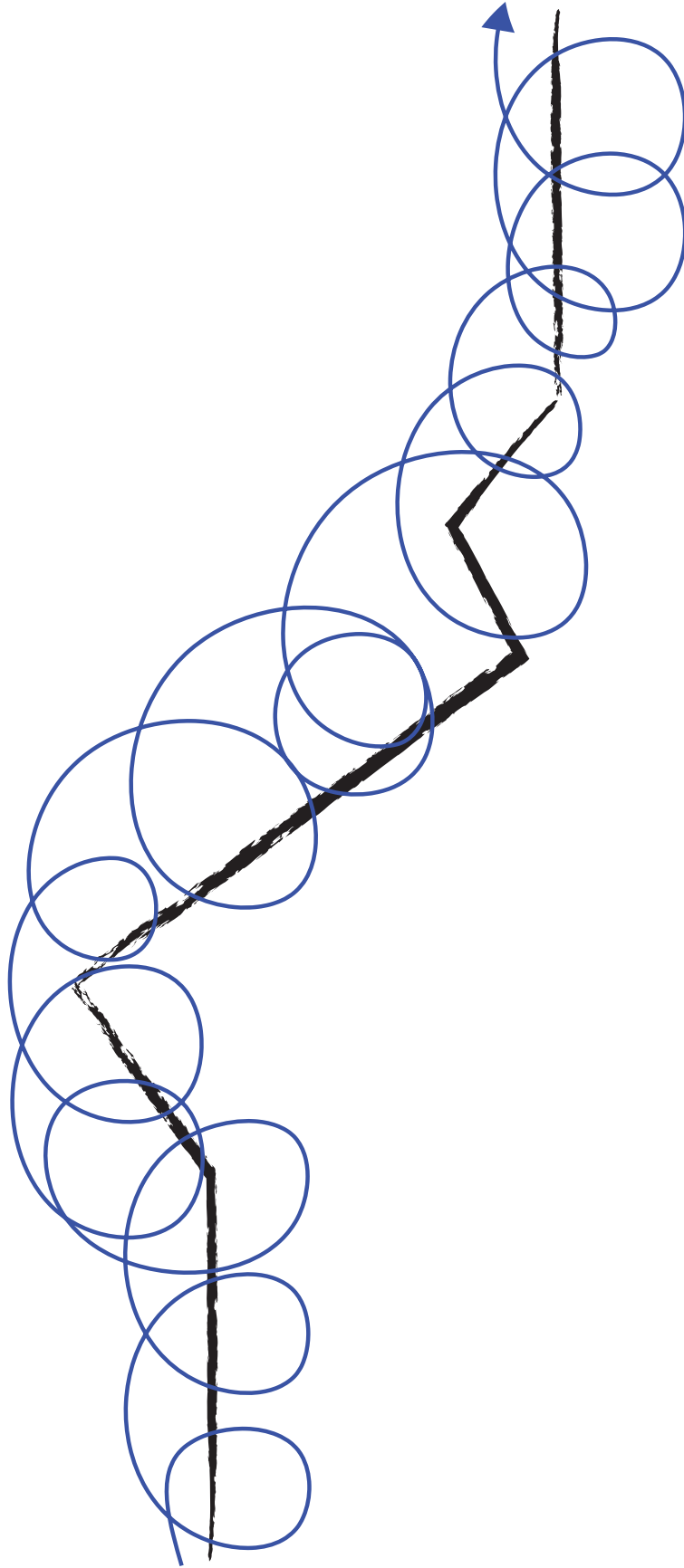


Figure 104: Tracing a water drop along the watershed transect. This loop interestingly begins to look like the design process loop.

watershed picks up nutrients in its path, but at present so much of the precipitation on the Chesapeake Bay watershed becomes runoff and reaches the Bay so laden with nutrients that the Bay can not filter them out and behave effectively as an ecosystem. With proper design solutions in combination with the host of other efforts that are under way to help preserve the Bay's health, the Chesapeake Bay might be able to refresh itself from the onslaught of chemicals and nutrients that have been flushed into this ecosystem.

This work is significant because it sets the framework for a new understanding of ecological design education. Architecture students are always told not to draw a box around their site because it closes off the mind's understanding of the greater context the work fits into. The point of most educators is that to create a good building urbanistically, a student must think about the larger site context a structure is to fit into. This thesis proposes that even enlarging the student or architect's view of the site to include the immediate context is not thinking big enough to achieve a truly green design. Designing ecologically sustainable buildings requires holistic consideration of the natural systems and processes that work on the site. When designing for water, this means thinking and designing on the scale of the watershed as well as on the scales of the building and the detail.

Natural systems work on a multiplicity of scales for which designers must concurrently understand and design. This work could be envisioned as the first of a family of works that might also include analysis and design work considering the energy cycle and the carbon cycle. Understanding the frame of reference relevant in designing for these natural cycles and processes might help to lead the way forward in green design in a way that is not style specific but instead has a firm foundation in principles that can

be applied in a variety of architectural styles.

While this thesis marks a significant achievement in a growing understanding of ecological design, it is a stepping stone to a life's work. Much of the work described here has opened up a myriad of alternative possibilities for both design and research work that could keep a team of architects busy creating for a lifetime. It is hoped that in the future this work will be carried forward in built case studies beyond the University of Maryland's 2011 entry into the Solar Decathlon and that, with time and practice this work will grow to include a host of built structures that embody the principles described here.

Appendix A: Water-Related Resources

Through the course of this thesis a plethora of resources have been studied that have increased my understanding of the water cycle, architecture, and the relationship between the built and natural environments. In trying to tell the clearest, most concise narrative of this thesis, a number of these resources were not included as part of the story and as a result are not included in the bibliography. What I present below is a catalog of other information relevant to water and architecture with the hope that the next person who takes interest in building for the Chesapeake Bay watershed will have a good place to start telling their own story without having to start entirely from the beginning as I did.

Built Precedents for Water-Based Design

Phillip Merrill Environmental Center. Annapolis, Maryland. SmithGroup, Inc.
Gannett/USA Today Headquarters. McLean, Virginia. Kohn Pedersen Fox.
Adam Joseph Lewis Center. Oberlin, Ohio. William McDonough and Partners.
Sidwell Friends Middle School. Washington, DC. Kieran Timberlake.

Internet Resources on Water, the Chesapeake Bay, and Related Topics

Center for Watershed Protection: <http://www.cwp.org>
Chesapeake Bay Foundation: <http://www.cbf.org>
Chesapeake: Bay on the Brink: <http://chesapeake.news21.com/blog/>
Chesapeake Bay Program: <http://www.chesapeakebay.net/>
CHESTORY: The Center for the Chesapeake Story: <http://www.chestory.org/>
One Drop Foundation: <http://www.onedrop.org/en/drop-experience.aspx>
Water.org: <http://www.water.org>

Print Resources on Water, the Chesapeake Bay and Related Topics

Barlow, Maude and Tony Clarke. "Water Must Be Made a Public Resource" in *Global Resources*. New York: The Gale Group, 2008.

Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. New York: Perennial, 1997.

Biswas, Asit K. "Water Scarcity is Not a Global Problem" in *Global Resources*. New York: The Gale Group.

Central City Concern. *Achieving Water Independence in Buildings: Navigating the Challenges of Water Reuse in Oregon*. March 2009.

Cramer, Gary W. "The Poetry of Stormwater." *Landscape Architecture*. March 2006, pages 50-60.

Environmental Protection Agency. *Evaluation Report: Saving the Chesapeake Bay Requires Better Coordination of Environmental and Agricultural Resources*. 20 November 2006.

Fothergill, Alastair. *The Blue Planet: Seas of Life*. London: British Broadcasting Corporation, 2007.

Hassett, Brooke, Margaret Palmer, Emily Bernhardt, Sean Smith, Jamie Carr, and David Hart. "Restoring Watersheds Project by Project: Trends in Chesapeake Bay Tributary Restoration." *Frontiers in Ecology and the Environment*. Vol. 3, No. 5, pages 259-267.

Kibert, Charles J. *Sustainable Construction: Green Building Design and Delivery*. Hoboken, NJ: John Wiley & Sons, Inc., 2005.

Lonergan, Steve. "Water Scarcity is a Global Problem" in *Global Resources*. New York:

The Gale Group, 2008.

McDonough, William and Michael Braungart. *Cradle to Cradle: Rethinking the Way We*

Make Things. New York: North Point Press, 2002.

Roaf, Susan. *EcoHouse*. Boston, MA: Architectural Press, 2001.

U.S. Fish & Wildlife Service. *Native Plants for Wildlife Habitat and Conservation*

Landscaping: Chesapeake Bay Watershed. 2003.

Van der Ryn, Sim and Stuart Cowan. *Ecological Design*. Washington, DC: Island Press,

1996.

Zaretsky, Michael. *Precdents in Zero-Energy Design: Architecture and Passive Design*

in the 2007 Solar Decathlon. New York: Routledge, 2010.

Bibliography

- Addington, D. Michelle. "Good-bye, Willis Carrier." In *The Green Braid*, edited by Kim Tanzer and Rafael Longoria, 160-172. New York: Routledge, 2007.
- Banham, Reyner. *The Architecture of the Well-Tempered Environment*. Chicago: University of Chicago Press, 1969.
- Bates, Bill. *Images of America: Havre de Grace*. Chicago: Arcardia Publishing, 2006.
- Bradsby, Henry C, ed. *History of Luzerne County, Pennsylvania*. Chicago: S.B. Nelson & Co., Publishers, 1893.
- Chesapeake Bay Program. "Bay Geology." The Bay Watershed. <http://www.chesapeakebay.net/baygeology.aspx?menuitem=14604>.
- . "Facts & Figures." Facts and History. <http://www.chesapeakebay.net/factsandfigures.aspx?menuitem=14582>.
- . "Physical Characteristics." About the Bay. <http://www.chesapeakebay.net/physicalcharacteristics.aspx?menuitem=14657>.
- "City Profile - History." *Havre de Grace: Unique on the Chesapeake*. http://www.havredegracemd.com/city_profile_history.php.
- Colburn, Virginia, Elizabeth H. Amoss, and Kathryn W. Mike. *A Bicentennial Sketch*. Havre de Grace, Maryland: Susquehanna Publishing Co., Inc., 1976.
- Columbia Borough, "History," *Borough of Columbia, Pennsylvania*, <http://psabcontent.com/columbiapa/content/history.php>.
- Dimitrioff, Tom. "Settlement." *History of Corning, NY*. http://www.corningny.com/visitors_history.shtml.
- . "Canals." *History of Corning, NY*. http://www.corningny.com/visitors_history.shtml.

---. "Industry." *History of Corning, NY*. http://www.corningny.com/visitors_history.shtml.

---. "The Flood." *History of Corning, NY*. http://www.corningny.com/visitors_history.shtml.

---. "Post Flood." *History of Corning, NY*. http://www.corningny.com/visitors_history.shtml.

Edmonson, Brad. "Corning's Choice." *Preservation* 53, no. 4 (2001): 42-44.

Fisher, George W. and Jerry R. Schubel. "The Chesapeake Ecosystem: Its Geologic Heritage." In *Discovering the Chesapeake*, edited by Philip D. Curtin, Grace S. Brush, and George W. Fisher, 1-14. Baltimore: The Johns Hopkins University Press, 2001.

Flow: How Did a Handful of Corporations Steal Our Water? DVD. Directed by Irean Salina. New York: Oscilloscope Pictures, 2008.

The Gombach Group, "Columbia Historic District," *Living Places*, http://www.livingplaces.com/PA/Lancaster_County/Columbia_Borough/Columbia_Historic_District.html.

---, "Columbia Borough," *Living Places*, http://www.livingplaces.com/PA/Lancaster_County/Columbia_Borough.html.

Heschong, Lisa. *Thermal Delight in Architecture*. Cambridge, Massachusetts: The MIT Press, 1979.

History of Nanticoke. <http://www.nanticokecity.com/history.htm#HISTORY>.

Janosov, Robert A. "Concrete City: Garden Village of the Anthracite Region," *Pennsylvania Heritage*, Summer 1997, 32-39.

Jay, Peter A., ed. *Havre de Grace: An Informal History*. Havre de Grace, Maryland: The Susquehanna Publishing Company, 1986.

Lawrence, Susannah. *The Audubon Society Field Guide to the National Place of the Mid-Atlantic States*. (New York: Pantheon, 1984), 180-184.

Luzerne County, "City of Nanticoke," *Luzerne County Living*, http://www.luzernecounty.org/living/municipalities/city_of_nanticoke.

Michener, James A. *Chesapeake: A Novel*. New York: Random House, 2003.

Murphy, Pat. "The Energy Impact of Our Buildings." *New Solutions*, Number 11, January 2007, 1-12.

Perlman, Howard. "Summary of the Water Cycle," *The Water Cycle*, <http://ga.water.usgs.gov/edu/watercyclesummary.html>.

Rudofsky, Bernard. *Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture*. Garden City, New York: Doubleday & Company, Inc., 1964.

U.S. Department of Energy. *2008 Buildings Energy Data Book*. Washington, DC: GPO, March 2009.