ABSTRACT

Title of Thesis:	OUR WILD: ARCHITECTURE CATALYZING ECOLOGICAL REVITILIZIITON ON THE POTOMAC
	Jake Morris, Master of Architecture, 2018
Thesis directed by:	Lecturer, Brittany Williams, School of Architecture, Planning, and Preservation

As the global environment becomes increasingly unstable, our role in the ecosystem has become more critical than ever. By becoming stewards of the environment we can ensure a healthy world for future generations of humans and wildlife alike.

This thesis will focus on the Potomac River ecosystem and how a center for conservation and wildlife rehabilitation can engage and educate the public with the ecosystem they rely upon so heavily. Architecture defines our physical environment yet its influence is not bound to humanity, rather it has a defining role and impact on the greater ecosystem. Developing a design that works to remediate its site while simultaneously instilling a sense of environmental empathy on a communal scale can successfully begin the imperative process of revitalizing the Potomac River.

OUR WILD:
ARCHITECTURE CATALYZING ECOLOGICAL REVITILIZAITON ON THE POTOMAC

by

Jake Sharlin Morris

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
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Advisory Committee:
Lecturer Brittany Williams, Chair
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Dedication

To Chandler and Joey who left me with the greatest appreciation of nature and our wild fellows, I will treasure that always.

Acknowledgements

To my friends, who became my family, in studio. For making the academic experience a fun and memorable one.

To my family who supported me through my educational process, words cannot begin to describe how much I appreciate you.

To the great professors and teachers I've had over the years, your guidance and passion for what you teach has inspired me to become who I am today.

Table of Contents

List of Figures

List of Abbreviations/Terms

PRWA: Potomac River Watershed Area
SAV: Sub aquatic vegetation
Extirpation: Local extinction
Point Source Pollution: industrial, sewage, municipal waste
Nonpoint Source Pollution: herbicides, fertilizers, insecticides, run-off (oil, grease, chemicals), salt, urban, agricultural, construction (sediment)
Eutrophication: excess of nutrients causing dense algal growth, blocking light and limiting oxygen causing the death of sub aquatic plants and animals
ICPRB: Interstate Commission on the Potomac River Basin
Bioretention: The process where stormwater is collected into areas containing wetland grasses and other plants in and around a ponding area in order to slow down runoff and remove contaminants and other solids such as sediment from the water. It also provides habitat for wetland species such as waterfowl, amphibians, and fish.
Convection: The transfer of heat through the rise of hotter, less dense fluid matter and colder, denser fluid matter rushing in to the vacated space which is in turn heated by the energy source.
Radiant Heat: The emission of energy in rays/waves heating contacted matter.
Conduction: The transfer of heat through direct molecular collision.
Thermal Inertia: The ability of a material to retain heat energy as external temperature changes.
Evaporative Cooling: The lowering of air temperature as water is converted to a vapor, absorbing energy from the immediate atmosphere.

Chapter 1: The Potomac River

"What tales you could tell mighty river, if you would speak"-Edwin W. Beitzell[1]

Introduction

Three million years ago our distant ape-like ancestors were first beginning to utilize stone tools in Africa. At the same time, streams carrying water from the Appalachian Highlands to the Atlantic Ocean began to coalesce, forming the great Potomac River.[2] Today over six million humans reside in the Potomac River Watershed Area (PRWA), collecting over five million gallons of water from the river every day.[3]

Over the millennia, many aspects of humanity have changed, most strikingly our relationship with the natural world. Historically we were yet another species inhabiting our niche in an ecological system where our biological inputs and outputs resulted in an equilibrium, creating a stable environment. Today we have broken that system, creating far greater outputs in the form of pollution and waste while simultaneously encroaching upon and destroying the ecological systems relied upon by humanity for our most basic necessities. This thesis will explore how architecture can be used as a tool to stimulate users to become actively engaged in the wellbeing of their ecosystem.

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[1] Edwin Warfield Beitzell, *Life on the Potomac River TT -, TA -* (Abell, Md. : E.W. Beitzell, n.d.). vi.
[2] "USGS: The River and The Rocks (The Origin of the Potomac River Valley)," accessed November 1, 2017, https://www.nps.gov/parkhistory/online_books/grfa/sec4.htm.
[3] Interstate Commission on the Potomac River Basin, "Potomac Basin Facts - ICPRB," accessed November 1, 2017, https://www.potomacriver.org/potomac-basin-facts/.

The Ecological Cycle

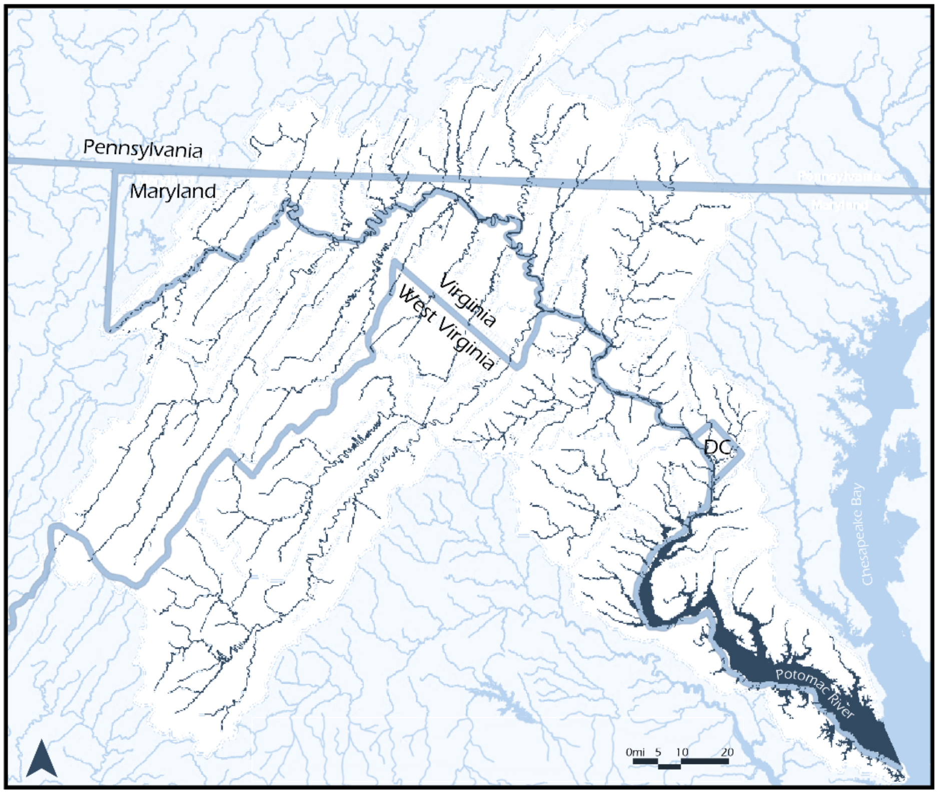

Figure 1: The Potomac River Watershed Area (Source: Author)

The PRWA covers 14,670 square miles[4] draining water from Pennsylvania, Maryland, Virginia, West Virginia, and Washington D.C. The Potomac once functioned as an extremely prolific ecosystem and provided a wild habitat where a diverse range species thrived amongst its shores. These species formed codependent relationships where nutrients entering the river worked their way up the food chain through plants and animals, eventually returning to the river where the cycle would begin anew.

[4] Kevin C Flynn, William T Mason, and Md.) Symposium on the Freshwater Potomac: Aquatic Communities and Environmental Stresses Symposium on the Freshwater Potomac: (1977 : College Park, *Proceedings of a Symposium in January 1977, at College Park, Maryland TT -, ICPRB Technical Publication ; 78-2; Interstate Commission on the Potomac River Basin. 78-2. Technical Publication ; TA* - (Rockville, Md., n.d.). 5.

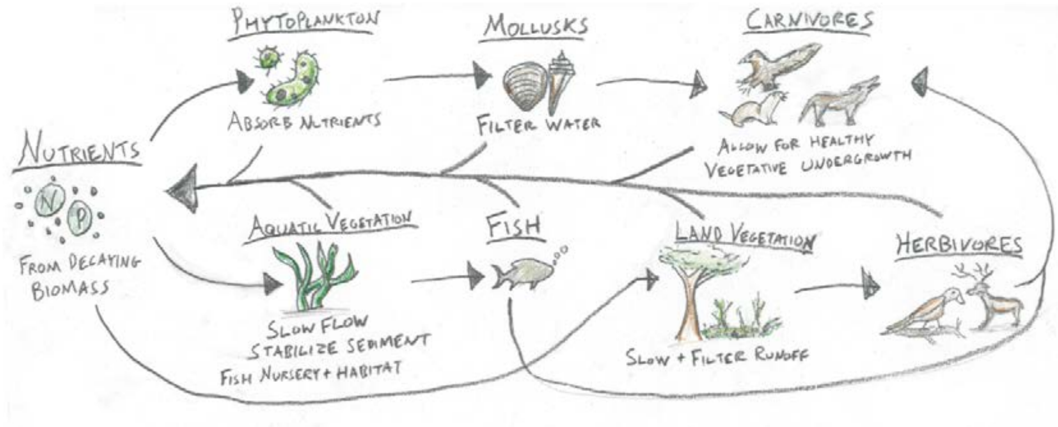

Figure 2: The Ecological Cycle (Source: Author)

In the pre-human Potomac River ecosystem the main source of nutrients came from decaying biomass releasing elements such as nitrogen and phosphorus into the land and water. These nutrients spur the growth of phytoplankton, land, and aquatic vegetation. Mollusks feed on plankton by filtering the water helping to keep it clear enough for light to reach the bottom, allowing for the successful photosynthesis of sub aquatic vegetation (SAV). Plentiful SAV provides a safe nursery habitat for young fish to feed and grow, safely hidden from predators.[5]

Back on shore, nutrients fuel the growth of forest vegetation, creating a diverse environment and diet for many species of herbivores and omnivores. A healthy population of carnivores ensures the herbivore population is kept in check allowing for a dense vegetative undergrowth. The undergrowth of the forest slows down and filters runoff, decreasing the damage and intensity of floods as well as

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[5] Harriette L Phelps, "The Asiatic Clam (*Corbicula Fluminea*) Invasion and System-Level Ecological Change in the Potomac River Estuary near Washington, D.C. TT -," *Estuaries TA* - 17, no. 3 (1994): 617.

absorbing excess nutrients. All the members of the river ecosystem rely on one another to sustain a successful cycling of nutrients through the food chain, creating an abundance of life in and along the Potomac.

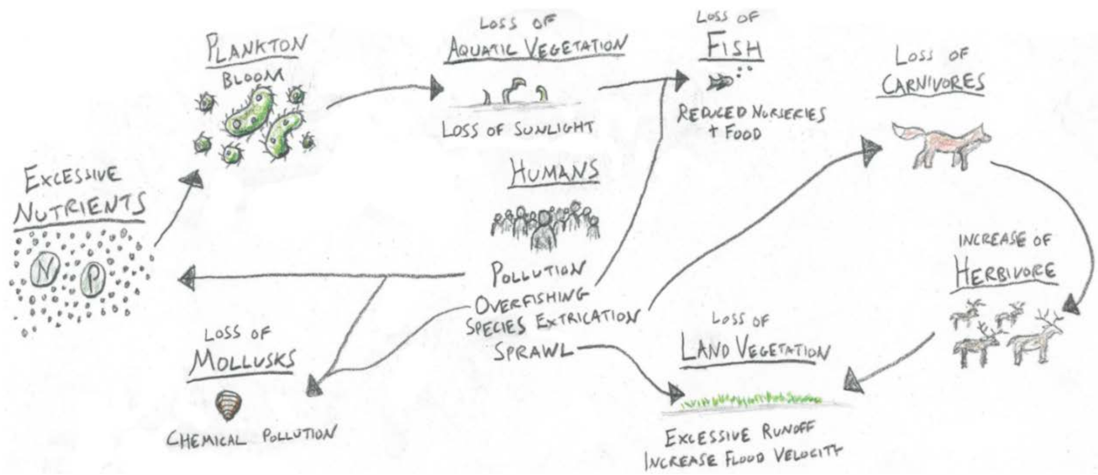

Figure 3: Human Impact on the Ecological Cycle (Source: Author)

Once humans settled in the PRWA the ecological cycle changed drastically. Pollution has become a significant input into the river ecosystem coming from both Point Sources (industrial, sewage, municipal waste) and Nonpoint Sources (runoff, oil, grease, chemicals, salt, urban, agricultural, construction sediment). Pollution results in an overload of nutrients causing eutrophication; a dense growth of plankton which reduces water clarity resulting in a loss of SAV, ultimately causing the fish population to plummet.[6] Mollusks, a typical control of the plankton and detritus in the water, no longer thrive in the Potomac due to chemical pollution and overharvesting.[7] Human urban and suburban development has removed a great deal of land vegetation

[6] Suzanne B Bricker, Karen C Rice, and Owen P Bricker, "From Headwaters to Coast: Influence of Human Activities on Water Quality of the Potomac River Estuary TT -," *Aquatic Geochemistry TA -* 20, no. 2–3 (2014): 292.

[7] Bricker, Rice, Bricker, "*Aquatic Geochemistry*", 302.

replacing native species with high maintenance, water reliant grasses and impervious surfaces. The removal of native forest and undergrowth results in excessive runoff, increased flood velocity, and a loss of nature's built-in filtering system. Additional vegetation is lost due to an increase of herbivore populations such as deer because of human's extrication (local extinction) of many carnivore species.

Modern architecture and construction are large contributors to human waste. In addition, design practices where architects seek to conform the environment around the building can be detrimental to local wildlife and vegetation. Such practices include the clearing of construction sites and essential removal of the natural landscape to make way for a manmade replacement. This act can release tons of sediment into runoff, contributing to effects equivalent to eutrophication in the river system. Wildlife habitat and native vegetation is also lost in this process resulting in a dramatic loss of biodiversity. These human activities and byproducts have resulted in a direct imbalance and disruption of the Potomac River's ecological system creating a shrinking, unhealthy environment for wildlife while polluting the very water so critical for our own survival.

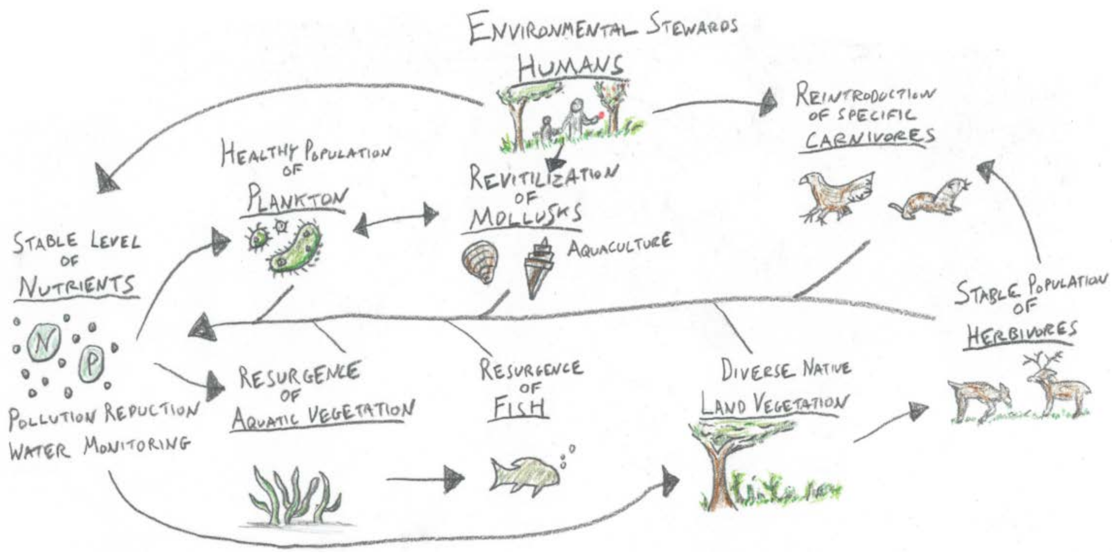

Figure 4: Humans as Stewards of the Ecological Cycle (Source: Author)

To create a thriving river for the wildlife and humans of the Potomac inhabitants must change their perception of their roles in the ecosystem. Humans can become environmental stewards to bring balance back to the ecological cycle. By reducing pollution and revitalizing the mollusk population, we can stabilize plankton populations, resulting in a resurgence of SAV, fish, and other wildlife dependent on them. Reintroduction of specific carnivorous species can control herbivore populations assisting in the health of forest undergrowth. Addressing the built environment and its role in the ecosystem will allow for a human habitat that supports a positive relationship with the river. Planting of native vegetation in developed areas can create key habitat and filter runoff. Creating small scale, wide-spread rain collection systems can decrease our reliance on water. Building with natural materials and implementing sustainable systems throughout our communities will decrease our reliance on the river and our impact upon it. By understanding the positive and negative ways our ancestors interacted with their environment, we can begin to determine the appropriate actions that can help restore the Potomac River for future generations of wildlife and people.

<u>Human History Along the Potomac</u>

Native Americans first settled along the Potomac River as far back as 10,000 years ago. These Hunter Gatherers would meet "for a good part of the year at a single base camp near the mouth of a tributary of the main river, where they could take advantage of large oyster beds or prime fishing locations."[8] Most of their diet consisted of shellfish, fish, deer, and plants.[9] By 900 C.E. natives began to form more sedentary communities.[10] Agriculture helped support a part of their diets at this time and the first significant human adjustments to the Potomac ecosystem began to take place as Natives began cultivating fields around settlements. Yet any environmental impact was fairly insignificant as Native populations only numbered in the thousands, spread throughout the entire PRWA. By 1500 C.E. Native hunter-gatherers who only farmed for a small portion of their food had transitioned to a more sedentary agricultural lifestyle at the same time European explorers began to arrive in the area.

European colonists had gained a strong foothold in the area by the late 1600s. Unfortunately due to "a combination of warfare, dispossession, and epidemic diseases, most of the Native peoples of the Potomac were gone by 1675, and the great

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[8] James D T A - T T - Rice, "Nature & History in the Potomac Country : From Hunter-Gatherers to the Age of Jefferson" (Baltimore : Johns Hopkins University Press, 2009), 21.
[9] Rice, "Nature & History in the Potomac Country: From Hunter-Gatherers to the Age of Jefferson", 22.
[10] Rice, "Nature & History in the Potomac Country: From Hunter-Gatherers to the Age of Jefferson", 22.

majority of the survivors were confined to reservations."[11] The port of Georgetown, Maryland was founded along the Potomac in 1751 and became a large exporter of the local burgeoning tobacco industry which replaced much of the PRWA's forest with plantations.[12] In 1790 the United States congress passed the Residence Act defining Washington D.C. as the nation's capital, supporting a population of 8,144 in 1800 and 681,000 in 2016.[13] Today 81% of the PRWA inhabitants live in urban areas, 84% of which are located in the Washington D.C. metropolitan area. Many diverse industries lay in the PRWA such as forestry and agriculture and "coal mining and pulp and paper production along the North Branch Potomac River; chemical production and agriculture in the Shenandoah valley; high-tech, service, and light industry, as well as military and government installations in the Washington metropolitan area; and fishing in the lower Potomac estuary."[14]

The transition from the Native's benign relationship with the river environment to a modern industrial and urbanistic relationship has led to an extreme loss of water quality and an increase in the struggle for life for the many species reliant on the river.

[11] Rice, "Nature & History in the Potomac Country: From Hunter-Gatherers to the Age of Jefferson", 130.
[12] National Park Service, "Washington, DC--Georgetown Historic District," accessed November 1, 2017, https://www.nps.gov/nr/travel/Wash/dc15.htm.
[13] US Census Bureau, "Population and Housing Unit Estimates" (n.d.), accessed November 1, 2017, https://www.census.gov/programs-surveys/popest.html.
[14] Interstate Commission on the Potomac River Basin, "Potomac Basin Facts - ICPRB."

Water Quality of the Potomac

A staggering amount of Potomac River water passes Washington D.C. with an average flow of seven billion gallons per day.[15] Proximity of so much water to urban and industrial activity has led to their direct degradation of the river water throughout the PRWA.

Yearly, over three billion gallons of raw sewage flow into the river from D.C.[16] and "the Potomac and its tributaries discharge an average of 2.5 million tons of sediment to the estuary."[17] This sediment mainly comes from construction sites in the PRWA, resulting in similar effects caused by eutrophication. The Interstate Commission on the Potomac River Basin (ICPRB) reports an increase in "total dissolved solids, chloride, and specific conductivity" which "harm aquatic life and increase water supply costs."[18] The ICPRB indicates these increases come from fracking, winter road salt, and the destruction of natural vegetation due to urban growth. The National Estuarine Eutrophication Assessment was conducted twice on the Potomac River (1999, 2007) "receiving a high-level eutrophication both times, with human-related loads considered high."[19] These nutrient loads come from both Point and Nonpoint Sources including "discharge from sewage treatment plants,

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[15] Interstate Commission on the Potomac River Basin, "Potomac Basin Facts - ICPRB."
[16] Brian Clark Howard, "Inside D.C.'s Massive Tunnel Project," *National Geographic*, last modified 2014, accessed November 1, 2017, https://news.nationalgeographic.com/news/2014/07/140703-combined-sewer-overflow-washington-storm-water-tunnel/.
[17] Kevin C Flynn, William T Mason, and Md.) Symposium on the Freshwater Potomac: Aquatic Communities and Environmental Stresses Symposium on the Freshwater Potomac: (1977 : College Park, *Proceedings of a Symposium in January 1977, at College Park, Maryland TT -, ICPRB Technical Publication ; 78-2; Interstate Commission on the Potomac River Basin. 78-2. Technical Publication ; TA* - (Rockville, Md., n.d.). 5.
[18] Claire Buchanan, Zachary Smith, and Andrea Nagel, "Long-Term Water Quality Trends in USEPA Region 3 (Mid-Atlantic)" (2017), accessed November 1, 2017, https://www.potomacriver.org/wp-content/uploads/2017/09/ICP17-5_Buchanan.pdf, 56.
[19] Bricker, Rice, Bricker, "*Aquatic Geochemistry*", 301.

atmospheric deposition onto terrestrial and aquatic surfaces, and runoff from urban and agricultural land uses."[20]

In the late 20th century the public became more aware of the degradation of their natural resources and Congress finally began enacting pollution regulatory laws such as the 1970 Clean Air Act, 1972 Clean Water Act, 1974 Safe Drinking Water Act, 1976 Toxic Substances Control Act, and 1977 Surface Mining Control and Reclamation Act. As a result of these laws, the ICPRB has reported a "strong downward trends in phosphorus" a "testament to the effectiveness of wastewater treatment plant upgrades and phosphate detergent bans in reversing eutrophication."[21]

Action from all residents of the PRWA is needed to continue the restoration of the Potomac. The ICPRB has stated that "source water protection is the first step to ensuring safe drinking water quality at the tap."[22] By aiming for high water quality in the Potomac not only will the water treatment process become easier and less expensive but the river will become healthier and more capable of supporting wildlife and humans alike. The first action that must be done to achieve this goal is educating the public, an act that can be maximized through a new and direct connection to the wildlife they coexist with.

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[20] Bricker, Rice, Bricker, "*Aquatic Geochemistry*", 292.

[21] Interstate Commission on the Potomac River Basin, "Potomac Basin Facts - ICPRB," accessed November 1, 2017, https://www.potomacriver.org/potomac-basin-facts/.

[22] Interstate Commission on the Potomac River Basin, "Source Water Protection - ICPRB," accessed November 1, 2017, https://www.potomacriver.org/focus-areas/water-resources-and-drinking-water/drinking-water/source-water-protection/.

The Future of the Potomac River

This river runs through us. Humans are composed of up to 60% water, which means, those of us whose drinking water comes from the river are about two thirds Potomac.[23] The water flowing through your veins once passed by an assortment of animals swimming through dense aquatic grass forests along the river bottom. This connects us to each other, the river environment, and the animals that live there in a way that surpasses cultural or biological differences.

Though the river and its native inhabitants have been victims of human related pollution and extrication of the past few centuries, we can yet become the stewards of a healthy ecosystem. Public knowledge and activities utilized at the river and at home can directly contribute to a revival and flourish of the ecological resource so critical to our survival.

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[23] U.S. Geological Survey, "Water Properties: The Water in You (Water Science School)," last modified 2016, accessed November 15, 2017, https://water.usgs.gov/edu/propertyyou.html.

Chapter 2: Wildlife

"If you want to know what a man's like, take a good look at how he treats his inferiors, not his equals." J. K. Rowling[24]

<u>*Introduction*</u>

Once an equal member of the animal kingdom, humankind has gained an incredible power of influence over our fellow animals. Our actions have and continue to determine which species survive and which become consigned to the history books. Extinction is happening on a scale never before seen in the natural world. Historically "between one and ten species a year" would be lost due to "natural background extinction."[25] Today the UN Environment World Conservation Monitoring Centre estimate a loss of "one hundred thousand species" annually, equivalent to "273 species a day or 11 species an hour."[26] Yet by educating and involving the public, our influence can easily be turned to promote and ensure the survival and welfare of our fellow animals.

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[24] J K Rowling and Mary GrandPré, *Harry Potter and the Goblet of Fire TT -, Harry Potter: Year Four at Hogwarts; Year Four at Hogwarts; Rowling, J. K. 4. Year ... at Hogwarts ;; Rowling, J. K. 4. Harry Potter Series ;; Harry Potter ; 4. TA* -, First Amer. (New York : Arthur A. Levine Books, an imprint of Scholastic Inc., n.d.).
[25] Gill Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation TT -, Ashgate Studies in Environmental Policy and Practice; Ashgate Studies in Environmental Policy and Practice. TA* - (Aldershot, England ; Ashgate, n.d.), 4.
[26] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation,* 4.

Need

The Maryland Department of Natural Resources has documented "514 native Maryland animals...listed as endangered and threatened."[27] Habitat loss is "the main cause of species extinction today"[28] and is quite a problem in Maryland where there is an average of 594.8 people per square mile.[29] As the human population has grown and spread out, our encounters with existing wildlife has increased, often in problematic ways due to the lack of public familiarity and education with wildlife.

Although many North American species have been hunted to complete or regional extinction, several species have adjusted to live in and amongst the fringes of human development. In fact, a greater population of people in the North East United States are living closer to wild animals than any other time in history. For example, before colonization, "several million Native Americans and perhaps 30 million white tailed deer lived in eastern forests" while today "there are more than 200 million people and 30 million deer, if not more."[30] Due to our extrication of the deer's natural predators they have been able to flourish in the environment we have shaped for them. But our lack of knowledge and control of these animals has led to some problems. Deer will eat all the underbrush of a forest, taking away its ability

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[27] Larry Hogan and Mark Belton, *List of Rare, Threatened, and Endangered Animals of Maryland* (Annapolis, 2016), accessed November 8, 2017, http://dnr.maryland.gov/wildlife/Documents/rte_Animal_List.pdf.
[28] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation*, 11.
[29] US Census Bureau, "Population and Housing Unit Estimates" (n.d.), accessed November 1, 2017, https://www.census.gov/programs-surveys/popest.html.
[30] Jim Sterba, *Nautre Wars: The Incredible Story of How Wildlife Comebacks Turned Backyards into Battlegrounds*, 1st ed. (New York: Crown, 2012), xv.

to filter water and slow it down during floods.[31] Additionally, there "more than 1 million [deer vehicle collisions] annually" in the United States.[32] Besides deer, raccoons, coyotes, squirrels, foxes, rabbits, songbirds, and others have adapted to thrive in developed areas around the Potomac. This new scale of cohabitation has come with its fair share of problems, while the lack of public education and experience make it challenging to find the appropriate solutions.

Protecting and caring for our wildlife promotes greater biodiversity for our ecosystems. Biodiversity is critical for the health of any ecosystem as each member fills a certain role that keeps an environment functioning and productive. Architecture can play a key role in the protection of wildlife by becoming a medium of education and conservation in order to achieve a positive relationship with the wildlife we coexist with.

Wildlife Centers & Conservation

"One route by which we come to care about (and for) the environment is through caring about (and for) individuals that depend upon the environment."[33] *–Gill Aitken*

Wildlife rehabilitation is the act in which orphaned, injured, displaced, or sick animals are cared for and treated until they are well enough to be released back into the wild. Treatment of an individual involves the housing, feeding, and application of

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[31] Jim Sterba, *Nautre Wars: The Incredible Story of How Wildlife Comebacks Turned Backyards into Battlegrounds*, 1st ed. (New York: Crown, 2012), 106.
[32] Jim Sterba, *Nautre Wars: The Incredible Story of How Wildlife Comebacks Turned Backyards into Battlegrounds*, 1st ed. (New York: Crown, 2012), 213.
[33] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation*, 190.

medical aide while simultaneously limiting human contact in order to keep a character of wildness in the animal. This ensures an animal will remain wary and non-dependent on humans upon release.

The extrication and overall devastation of wildlife by American settlers and hunters spurred "conservationists in the late 19th century to begin a campaign to rescue wild populations by rebuilding habitat, creating refuges, and restocking."[34] The origins of wildlife rehabilitation began quite humbly with empathetic yet mostly untrained individuals operating out of their own homes. These impromptu facilities relied upon a small volunteer base functioning with very limited resources and knowledge to draw from. Museums as well as environmental education centers began to get involved in the field during the 1960s.[35] The publically broadcasted oil spills of the 1970s and rescue of affected marine animals began to raise enough concern to bring about the introduction of purpose-built rehabilitation centers staffed by professional wildlife handlers and veterinarians.[36] Secondary to wildlife care, these facilities eventually began to take on the role of public educators, creating and communicating knowledge on animals and their environments.

Education through wildlife rehabilitation can be achieved in a multitude of ways. Facilities will often take on veterinary students for a fellowship where they learn about and participate in the medical treatment of wild species. Knowledge gained from the caretaking of wildlife can be distributed for the purpose of

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[34] Jim Sterba, *Nature Wars: The Incredible Story of How Wildlife Comebacks Turned Backyards into Battlegrounds*, xviii.
[35] Kenneth B. Haas, "History of Wildlife Rehabilitation," *Wildlife Rehabilitation Today* (1998), accessed November 9, 2017, http://www.angelfire.com/nj/woundedknee/rehabhist.html.
[36] Kenneth B. Haas, "History of Wildlife Rehabilitation," *Wildlife Rehabilitation Today* (1998).

conservation and ecological science. When it comes to public education, keeping wild animals wild presents a significant challenge. Creative methods implemented by existing wildlife and environmental centers can be studied and built upon to develop an architectural methodology where education and rehabilitation are merged to create a more successful adaptation of the existing typology.

<u>*Precedents*</u>

City Wildlife

The only wildlife rescue and rehabilitation center in Washington D.C., City Wildlife, was opened in 2013 and rescues, treats, and releases hundreds of wild animals every year. The center runs out of a small portion of an old paper mill right next to the green line metro tracks in the northern point of the city.

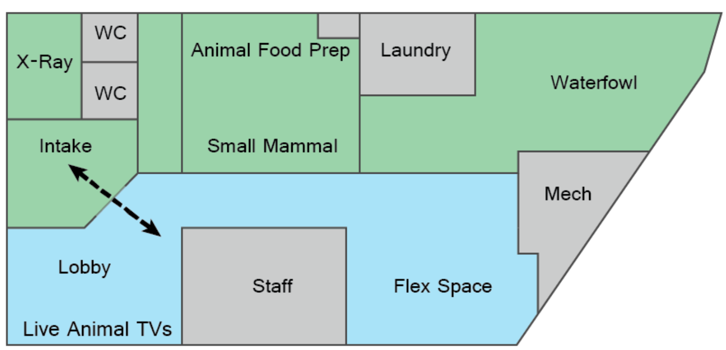

Figure 5: City Wildlife Plan (Source: Author)

The center was designed by retired architect, Anne Lewis, who is also president of the organization. She built with a very limited budget and has only completed one phase of the construction. However, Anne has still been able to include educational features in the small 800 square feet center. Members of the public entering the lobby area are greeted with two immediate connections to wildlife

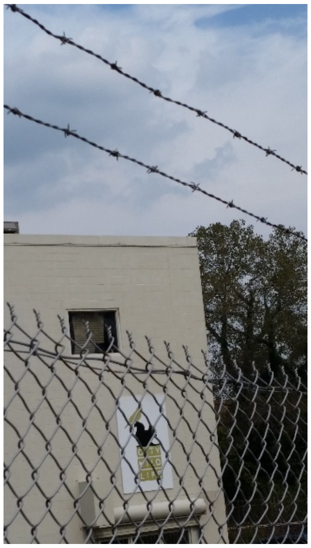

Figure 6: City Wildlife Entrance (Source: Author)

currently being treated. The animal intake room, which serves as an initial examination and medical treatment space, has a window to the lobby. This allows visitors to see into the inner workings of the center while limiting any sound coming from the reception and staff area that would unnecessarily stress the animals. The lobby also features televisions broadcasting live feeds from movable webcams showcasing an 'animal of the day.' This allows visitors to see animals up close and personal and even hear the cries and calls of these critters. Anne believes "the easiest way to let people see the wildlife is to mount a webcam in their cage and display the video on a screen in a public area" and that "technology is the best way to educate people" utilizing "interactive question and answer screens, or videos with our without explanations of real animals."[37] Being able to "webcam a surgery, for example" would mean "the viewers wouldn't even have to be in the same building."[38] Technology allows for a great amount of flexibility and versatility in the different wildlife activities the public can view and learn from in a very non-intrusive way.

Figure 7: City Wildlife Exam Room Window (Source: Author)

[37] Anne Lewis, e-mail message to author, November 8, 2017.
[38] Anne Lewis, e-mail message to author, November 8, 2017.

City Wildlife also runs a public outreach program called 'Lights Out DC' where volunteers walk a four mile route in the city during bird migratory seasons and collect dead or injured birds that have collided with glass. Statistics are collected to promote light reduction and glazing methods that help reduce bird casualties. Anne has stated that it is important for us to "nurture wildlife with the built environment instead of excluding it," a valuable lesson that should be applied to all realms of the architectural field.[39]

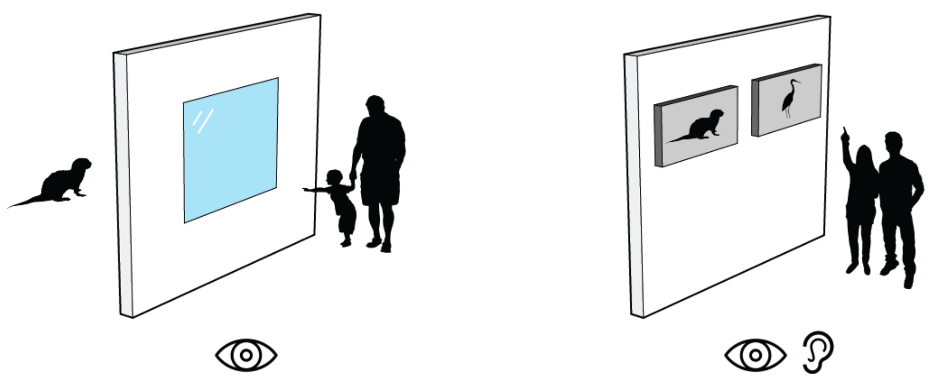

Figure 8: Public Education Methods at City Wildlife (Source: Author)

[39] Anne Lewis, interview by author, City Wildlife, Washington D.C., October 6, 2017.

PAWS Companion Animal Shelter and Wildlife Center

PAWS is a private, non-profit animal welfare organization based out of Lynnwood, Washington. The firms Jones & Jones and Animal Arts have designed a 26 acre complex in Seattle that features both companion animal adoption and wildlife rehabilitation. The unbuilt design features a main building where both companion and wild animals are brought in and given veterinary treatment before being taken to adoption areas and separate wildlife buildings/enclosures. The public has access to the main building and adoption areas as well as a series of paths meandering through several wetlands.

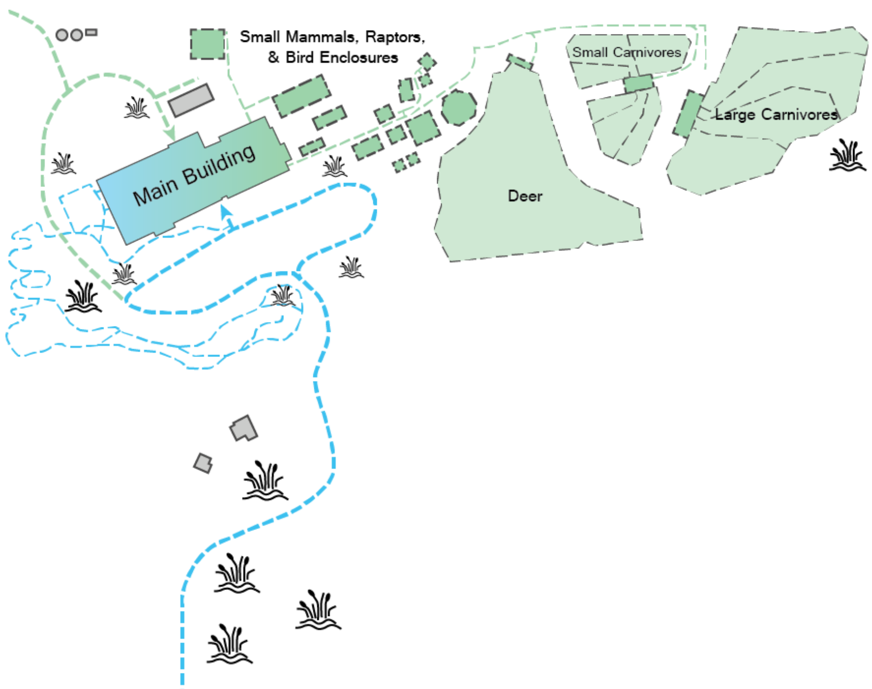

Figure 9: PAWS Companion Animal Shelter & Wildlife Center Site Plan (Source: Author)

The architects approach to site remediation via a series of constructed wetlands allows for a large amount of bioretention; the process where stormwater is collected into areas containing wetland grasses and other plants in and around a ponding area. This slows down the runoff and helps to remove contaminants and other solids such as sediment from the water. It also provides a clean habitat for wetland species such as waterfowl, amphibians, and fish.

While the wildlife rehabilitation areas of the center are not designed for any public interactions, the traversable wetlands provides the public with an exposure to a habitat where wetland wildlife, typically scarce in urbanized Seattle, can flourish. Being able to fully experience this habitat through sound, smell, and sight allows visitors to the center to connect with the wetland animals by sharing the same sensual experience of their physical environment.

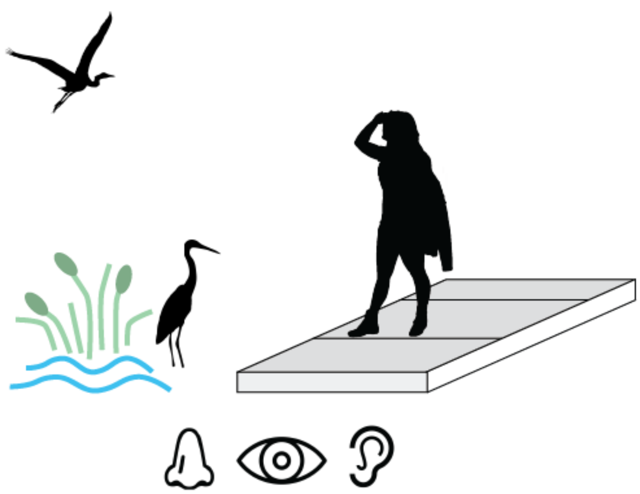

Figure 10: Public Interaction with Wetlands (Source: Author)

Wasit Natural Reserve Visitor Center

Located in the city of Sharjah in the United Arab Emirates, the Wasit Natural Reserve Visitor Center aims to protect the natural reserve and educate the public on the richness of the wetland ecosystem. Previously a waste water and trash dump, the 10 acre site now features 35,000 replanted trees, 350 species of birds, a rest area for 33,000 migratory birds, salt flats, and costal sand dunes in the center of a dense city.[40]

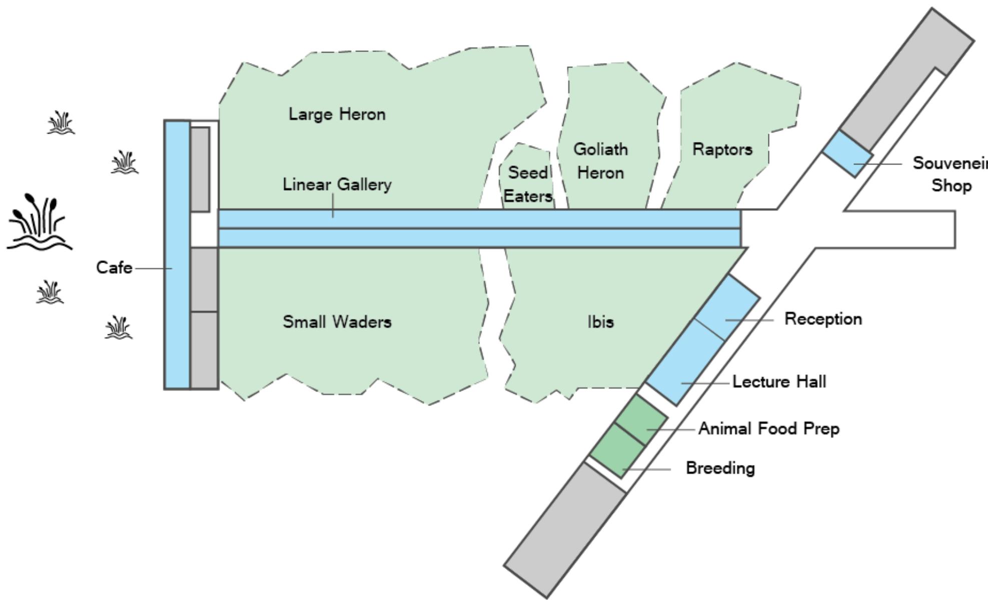

Figure 12: Wasit Natural Reserve Visitor Center Plan (Source: Author)

Figure 11: Wasit Natural Reserve Linear Gallery (Source: X Architects)

Figure 13: Wasit Natural Reserve (Source: X Architects)

[40] X-Architects, "Wasit Visitor Centre," accessed November 10, 2017, http://x-architects.com/x-architects/wasit-visitor-centre/100.

The 27,000 square feet visitor center has become a popular spot for bird watchers, researchers, and inhabitants of Sharjah looking for a break from the urban setting. The center includes an avian breeding program where wetland species are raised and introduced into the reserve. The center also has a souvenir shop and café for guests to enjoy. A lecture hall holds research and wildlife talks.

The main feature of the center is a linear gallery sunken into the surrounding bird enclosures which seamlessly merges the architecture into the exterior environment. This allows visitors to visually experience the birds' natural environment while simultaneously learning from exhibits on display in the gallery.

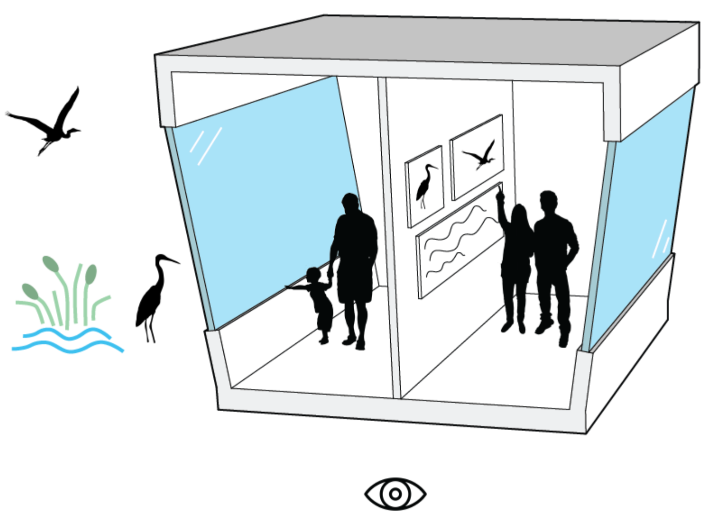

Figure 14: Wasit Natural Reserve Linear Gallery (Source: Author)

The Wild Animal Sanctuary

The Wild Animal Sanctuary located just north of Denver, Colorado, serves as a 720 acre refuge for over 450 animals who have been rescued from abusive and cruel situations in captivity. As a sanctuary, the organization provides large open habitat for rescued animals to live out the rest of their lives in peace. This project is the largest carnivore sanctuary in the world and contains bears, tigers, lions, wolves, jaguars, leopards, and coyotes.

Figure 16: The Wild Animal Sanctuary Site Plan (Source: Author)

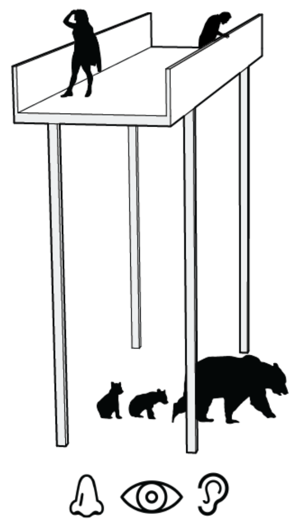

Figure 15: Elevated Walkway at the Wild Animal Sanctuary (Source: Author)

The site features a large welcome center where visitors can access the longest elevated walkway in the world; over a mile and a half in length. This gives the public expansive views of the rescued animals while sharing in their experience of the wide open Colorado plains. By elevating the public from the wildlife, the architecture is able to reduce the stress animals can experience from visitors which is often the norm in a typical zoo. The open aspect of the walkway grants visitors a sensually connected experience where they can hear and see the sanctuary's animals whilst limiting any possible disturbances to them.

Figure 17: Grizzly Bear by Walkway (Source: The Wild Animal Sanctuary)

Wildlife Center of Virginia

Opened in 1982, the Wildlife Center of Virginia aims to provide healthcare to native animals of the state. Since opening, they have treated over 70,000 animals, including 200 different species, and shared the lessons they have learned over the years with 1.5 million adults and children in Virginia.[41]

Figure 18: The Wildlife Center of Virginia Site Plan (Source: Author)

[41] The Wildlife Center of Virginia, "About the Center," accessed November 11, 2017, https://www.wildlifecenter.org/about-center.

The center operates out of a 5,700 square foot main building which includes veterinary spaces, offices, a library, and an outreach area. Directly behind the main building are enclosures for non-releasable raptors and opossums; accesible to the public for education purposes. Beyond these are enclosures only accesible by staff that house birds, reptiles, and mammals undergoing rehabilation in anticipation of release.

Any wildlife rehabilitation organization operating for as long as The Wildlife Center of Virginia will eventually encounter wildlife suffering from chronic illnesses, crippling injuries, or other conditions that prevent them being able to survive independently in the wild. There are three fates for these animals. One is humane euthanasia. Another is that the animal is kept at the center to act as a surrogate parent to help teach appropriate behaviors and care for injured or orphaned young of the same species. Certain animals are used for educational purposes while living out the rest of their lives with the care of trained professionals. These animals can be used to familiarize locals, especially children, with the native wildlife. Through this type of learning, visitors can begin to understand how to behave and act when interacting with wildlife. In addition, this often physical, up close interaction, can leave a lasting impression on visitors instilling within them a sense of responsibility for their shared environment.

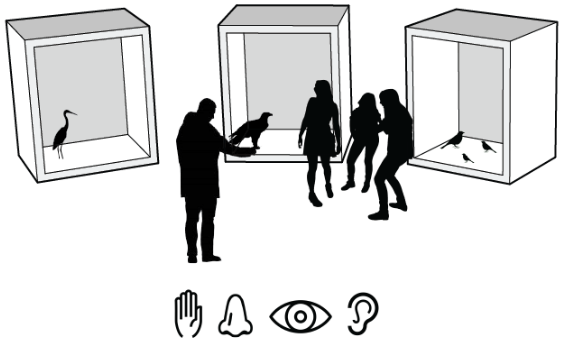

Figure 20: Public Education at The Wildlife Center of Virginia (Source: Author)

Figure 19: Education Enclosures (Source: The Wildlife Center of Virginia)

<u>*Success of Wildlife Care*</u>

While no wildlife center exists along the Potomac today, there have been many stories of wildlife protection and rehabilitation success both locally and around the world. These efforts have helped to ensure individuals of wild species are able to fulfill their ecological roles as it is only "when these are in operation that wild entities can reach their full potential."[42]

Wildlife rehabilitation is a practice that is currently being carried out in many countries around the world. There are approximately "16,000 wildlife casualties [that] are taken into captivity for treatment annually in Britain" while "in the Netherlands,

[42] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation*, 79.

wildlife hospitals are estimated to deal with over 30,000 birds a year, a high proportion of these being released."[43] Many centers in Britain such as the Lower Moss Wood Educational Nature Reserve and Wildlife Hospital fund themselves by "providing educational visits to (mainly) schoolchildren at its seventeen-acre woodland site" where "efforts are made to focus children's attention on the importance of protecting local habitats."[44] In Borneo, orangutans who have been confiscated from illegal animal trading on the black market are "held in groups of 10 to 15 animals so that they can develop a social structure, and then taken as a group to a suitable area of forest where there are no longer wild populations" and released.[45] These widespread and diverse efforts are critical to protecting the environment and its members at a global scale.

Along the Potomac, efforts have been planned and enacted to help raise fish populations to healthy, precolonial levels. The first European explorer to sail up the Potomac in 1608, Captain John Smith, reported an "abundance of fish, lying to thick with their heads above the water" and that "neither better fish, more plenty, nor more variety for small fish, had any of [them] seen in any place so swimming in the water."[46] Since then, overfishing, pollution, and eutrophication have caused a plummet in fish populations. For example, Sturgeon, a species of fish that can live up to 150 years and grow to be 14 feet long, have become completely extricated from the

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[43] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation*, 120-121.
[44] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation*, 128.
[45] Aitken, *A New Approach to Conservation : The Importance of the Individual through Wildlife Rehabilitation*, 123.
[46] Tilp, Frederick. 1978. *This Was Potomac River*. First edition. Bladensburg, Md.: Tilp, 3.

Potomac. They became “the most popular export to England in a pickled condition” and Captain John Smith reported people catching up to “thirty sturgeons in one night at the site of Georgetown harbor.”[47] The ICPRB has plans to “stock captive Atlantic sturgeon” in order to eventually create a “healthy, captive brood stock of genetically diverse sturgeon adults that will provide larvae and juvenile fish for restoration stocking.”[48] Restocking of extricated species of the Potomac can even merge with public and educational realms. Elementary students, for example, played an important role reintroducing the American Shad, “once one of the east coast’s most abundant and economically important fish,” back into the Potomac.[49] Students would raise the shad fry in their classrooms and release them into the river in the spring. With the assistance of students, the ICPRB and U.S. Fish and Wildlife Service have reported that “the number of adult shad returning to spawn has increased tenfold.”[50] These plans and accomplishments mark a new era where the restoration and conservation of the Potomac has become an important goal for both public and private groups.

Architecture has a key role to play in these efforts as conservationists work to protect and promote the wellbeing of wildlife. The built environment can be designed to enable the acts of rehabilitation, reintroduction, and conservation of native species, alongside of the integration of public efforts and education. An intimacy with nature can be instilled upon individuals through observation and participation, acts that can

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[47] Tilp, Frederick. 1978. *This Was Potomac River*. First edition. Bladensburg, Md.: Tilp, 21.
[48] Interstate Commission on the Potomac River Basin, “Potomac Basin Facts - ICPRB.”
[49] Interstate Commission on the Potomac River Basin, “The Potomac River American Shad Restoration Project” (n.d.), accessed November 11, 2017, www.potomacriver.org.
[50] Ibid.

be facilitated through design principles that promote a strong physical connection to the environment and a continuum of natural and built living systems.

Chapter 3: Attainable Natural Building & Sustainable Systems

"We often forget that we are nature. Nature is not something separate from us. So when we say that we have lost our connection to nature, we have lot our connection to ourselves." -Andy Goldsworthy

Introduction

Architecture has become the ultimate definer of humanities physical environments in the modern era. Yet the influence of architecture is not bound to humanity alone, rather it has an influential role to play in the greater ecosystem.

Design defines the relationship between architecture and its immediate surroundings. By creating a methodology where architecture works positively with the natural environment, design can enable active engagement of the ecosystem by directly drawing upon site specific materials and natural systems to create strong physical and functional connections. By making these methods understandable and easily attainable to the general public, environmentally responsible architecture can move past conception and become widely utilized throughout our communities. A study of regional architectural history can begin to reveal the foundations of such a methodology through the understanding of common built forms developed prior to the industrial era.

Native American Regional Architecture

For over 10,000 years Native Americans of the PRWA gathered in small villages used as a base camp for hunting and gathering expeditions.[51] These villages were often compromised of an encircling defensive palisade and several homes called yeahawkans.[52] These structures were constructed with "bowed saplings lashed together to frame oval buildings with rounded roofs, then covered with layered bark or mats sewn from reeds."[53] Mats covered the entrances that let fresh air in while a hole at the top of the building allowed smoke from the central fire to escape.[54] 12-20 people would live in yeahawkans that typically measured of 10-16' wide, 20-30' long, and 10' high.[55] Yeahawkans would usually be "sited under trees for additional shelter."[56] Early explorers like Englishman John White described the shelters as being "as warme as stooves in all weather."[57]

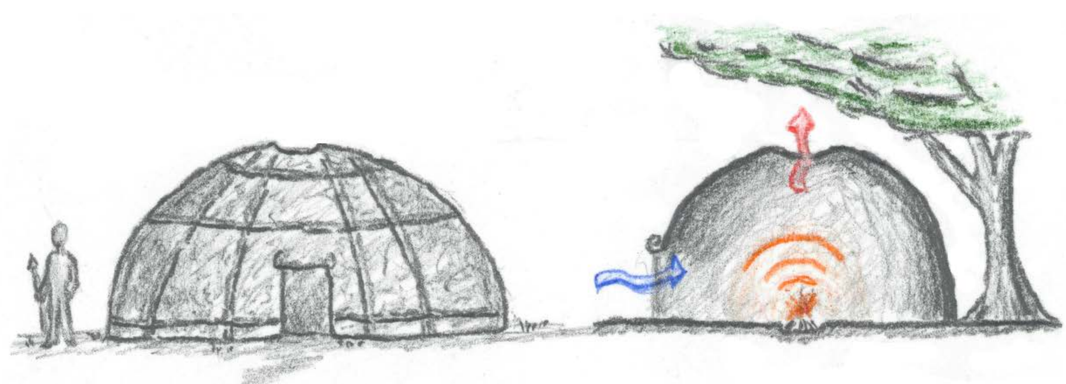

Figure 21: Yeahawkan Elevation & Section (Source: Author)

[51] Rice, "Nature & History in the Potomac Country: From Hunter-Gatherers to the Age of Jefferson", 37.
[52] Rice, 37.
[53] Rice, 37.
[54] Rice, 37.
[55] Rice, 37.
[56] Rice, 37.
[57] Rice, 37.

Natives relied solely on the manipulation of raw materials found in abundance around their villages to create homes that utilized simple systems in order to provide protection from the natural elements. Radiant heat coming from the central fire warmed the interior air of the yeahawkans causing it to rise and escape through the top opening while drawing cooler air through the open entrance through a process called convection. This would allow for an exchange of fresh air but loss of heat resulting in the need to keep the fire constantly lit. By siting their homes under trees, Natives were able to add a natural element of protection from wind and rain. The basic manipulation of resources provided by their local environment enabled Natives to develop an architecture suitable to their lifestyle of direct dependence on immediately available natural resources.

Colonial Regional Architecture

Colonists in the 17th and 18th centuries brought simple construction techniques developed in their homelands to the Americas. The very first settlers lacked the time and means to create the more complex brick or wood framed houses of Europe. Instead they used immediately available materials to create shelters that were able to see them through their first years in the New World.

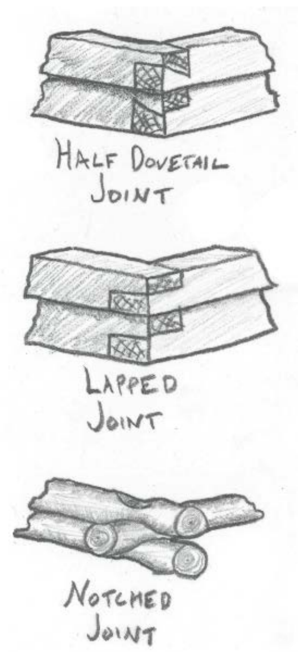

Figure 22: Wood Joints (Source: Author)

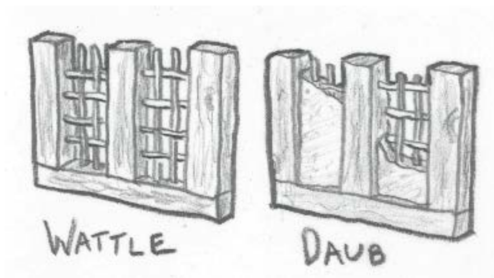

Figure 23: Wattle & Daub (Source: Author)

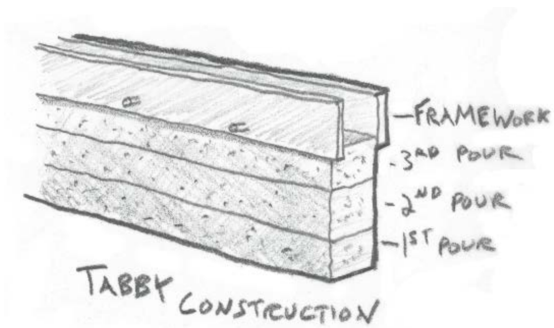

Figure 24: Tabby Construction (Source: Author)

Axes and other tools brought over the Atlantic by the colonists enabled them to create rudimentary structures such as cottages. These cottages were constructed mainly of lumber, “with frames of hewn planks or squared timbers, covered by broad boards laid flush, or smaller lapped clapboards.”[58] Simple wood joints were often utilized in place of nails and screws. Colonists also covered woven branches or reeds with some combination of clay, earth, straw, and dung; a construction technique known as wattle and daub. This could be used to make entire walls or seal the gaps between timber pieces.[59] The concrete mixture of lime

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[58] Hugh Morrison, *Early American Architecture : From the First Colonial Settlements to the National Period TT -, TA -* (New York : Oxford University Press, n.d.), 11.
[59] Hugh Morrison, *Early American Architecture : From the First Colonial Settlements to the National Period*, 11.

from crushed and whole shells, sand, ash, and water known as Tabby was also popular in humid and coastal regions of the colonies, especially notable for its longevity, durability, and reusability.[60] The resulting slurry was poured into a formwork in a similar manner to rammed earth to create walls, columns, arches, bricks, floors, or roofs and often finished with stucco (lime, sand, and water).[61]

The utilization of immediately available materials in ways that involved little to no processing allowed colonists to create shelters they depended on for simple survival. In addition, these basic building methodologies were very accessible to colonists; meaning neighbors helped neighbors to construct their homes without the assistance of specialized professionals. This factor, plus the abundance of local building materials, allowed the colonists to build and secure a permanent foothold in the Americas.

Combining regional materials with sustainable systems is the next step in order to develop a typology that reaches optimum synergy between the built form and the environment.

Air Regulation

The act of air regulation, including through ventilation and temperature control has been practiced by humans and other animals for many thousands of years. These methods have been largely set aside since the advent of air conditioning and cheap electrical energy. Yet humanities reliance on fossil fuels to

[60] Lauren B Sickels-Taves and Michael S Sheehan, "An Introduction to Tabby" (1999), accessed November 19, 2017, http://atlantapreservation.com/buildingmaterials/TabbyInfo.pdf.
[61] Sickels-Taves, Sheehan, "*An Introduction to Tabby*".

create comfortable interior climates with no relationship to the outdoors has resulted in environmental problems on a global scale and alternative methods must be sought after and applied. A combination of historic passive design methods and modern technological adaptations can be studied to find an ideal combination that is most suitable for a building site's specific climate.

Many species of ants and termites build their nests in such a way that allows for natural ventilation. One particular species that does this is the South American leafcutter ant (*Atta laevigata*) whose underground tunnel system can extend up to six meters and support upwards of eight million adults.[62] These ants utilize what is known as 'induced flow' where wind flowing over the mound results in a lowering of air pressure at the peak causing air to flow out of top passages and into the lower ones.[63] The shape of the mound allows for this effect regardless of the direction of the wind. Additionally, these nests made of and into the earth utilize thermal mass to retain the warmth of the sun in the day and release it at night. Nest temperatures are stabilized throughout the seasons by reaching deep down where, at around six meters, air temperature becomes a constant 50-60 degrees year round. These simple methods of ventilation through convection, solar radiation collection via thermal mass, and geothermal

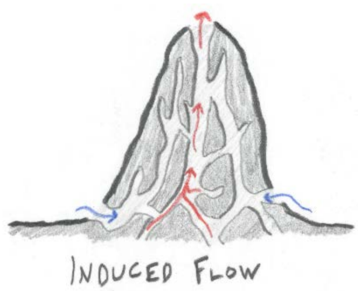

Figure 25: Ventilation of Ant Mound (Source: Author)

[62] Michael H Hansell, *Built by Animals : The Natural History of Animal Architecture TT -, TA -* (Oxford ; Oxford University Press, n.d.), 22.

[63] Hansell, *Built by Animals : The Natural History of Animal Architecture*, 24.

temperature stabilization allow many species of ants and termites to take advantage of the simple physical properties of their environment to create a moderated, shelter capable of supporting millions of residents.

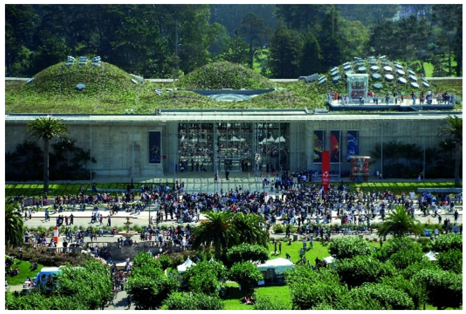

Figure 26: California Academy of Sciences (Source: RPBW Architects)

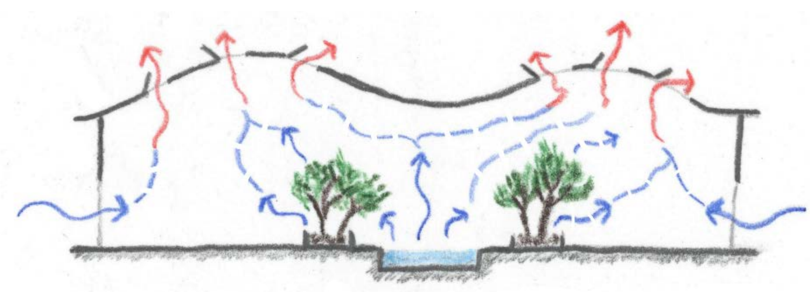

Figure 27: Ventilation in the California Academy of Sciences (Source: Author)

The California Academy of Sciences, designed by Renzo Piano, is an exemplary example of modern architecture that uses technology and passive design to manipulate physical principles to create a well ventilated, comfortable building. The roof, composed of a series of domes covered in autochthonous plants, has a multitude of automated skylights which open and close to ventilate the building through convection; drawing hot air out the top of the domes and cool air through the sides of the building. Additional cooling takes place as the interior water feature is converted into a vapor, lowering the air temperature through a process called evaporative cooling. Through a phenomenon called thermal inertia, the moist soil of interior vegetation retains a low temperature throughout the day further cooling the building. The California Academy of Sciences successfully combines a series of natural and mechanical systems to create and regulate a cool interior environment for a building sited in a hot, arid climate.

Natural Lighting

Solar illumination can lighten our dependency on electrical energy and optimize synergy with the human circadian rhythm and visual system. In the United States, electrical lighting currently accounts for 20% of total electrical energy consumption.[64] A number of studies, including one conducted by scientists at the Lighting Research Center in Troy, New York, have found that daylit spaces increase occupant production and comfort while supporting the factors that are needed to regulate the circadian rhythm.[65] Many mechanisms and methods have become widespread in the field of architecture that seek to bring natural light into the built environment.

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[64] Eileen. Haas, *Natural Lighting TT -, TA* - (Harrisville, N.H. : SolarVision Publications, n.d.), 7.
[65] Lighting Research Center, "ASSIST Recommends | Solid State Lighting | Programs | LRC," accessed November 21, 2017, http://www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp.

Figure 28: Solar Tubes at Dingpu Metro Station (Source: J.J. Pan & Partners)

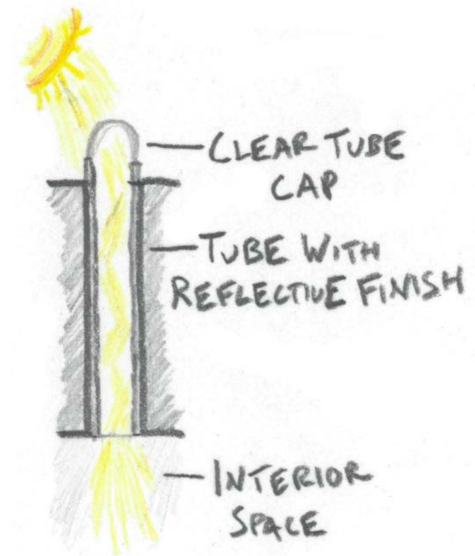

Figure 29: Vertical Solar Tube (Source: Author)

One of the greatest challenges of naturally lighting a space is getting light into deeper spaces that may be completely enclosed in a building. Light can be brought into these areas through the use of solar tubes; enclosed reflective shafts that take light from above and bounce it down into a space. Vertical solar tubes at the Dingpu Metro Station in Taiwan bring direct light deep underground. The use of this technology brings natural light into an underground typology typically separated from the exterior world above. Similar to vertical solar tubes, light-wells and skylights can penetrate the skin of a building to bring light into a space where window light may not be present or sufficient.

Horizontal solar tubes can be utilized to bring ambient light into a space by bouncing direct light off of a ceiling into the space below. The Steam Canoe in Toronto, Canada has been built with horizontal solar tubes to bring ambient light into a structure designed to shelter occupants from frigid winter weather. This technique is similar to light shelves which bounce light coming in through windows onto ceilings, allowing light to penetrate deeper and more evenly into a building.

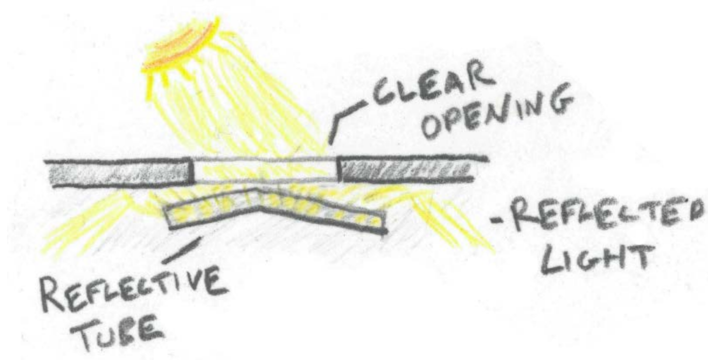

Figure 30: Horizontal Solar Tube (Source: Author)

During hot summer months, light penetration can rapidly heat up interior spaces, requiring an efficient control of solar infiltration to achieve a balance between natural light and comfortable temperature. Modern programming technology has allowed for automated screens such as the ones attached to the Al Bahar Towers in Abu Dhabi. These parametric screens expand and contract to control the amount of light coming into the skyscrapers. This helps reduce interior heat generated by solar radiation as well as the occupant's reliance on costly air conditioning. Similar to automated screens, roof overhangs can be calculated and constructed for specific geolocations to block high altitude summer sunlight and let in lower altitude winter light. This passive design technique can reduce summer heat gains while still allowing for the warming advantages of sunlight in the cold winter months.

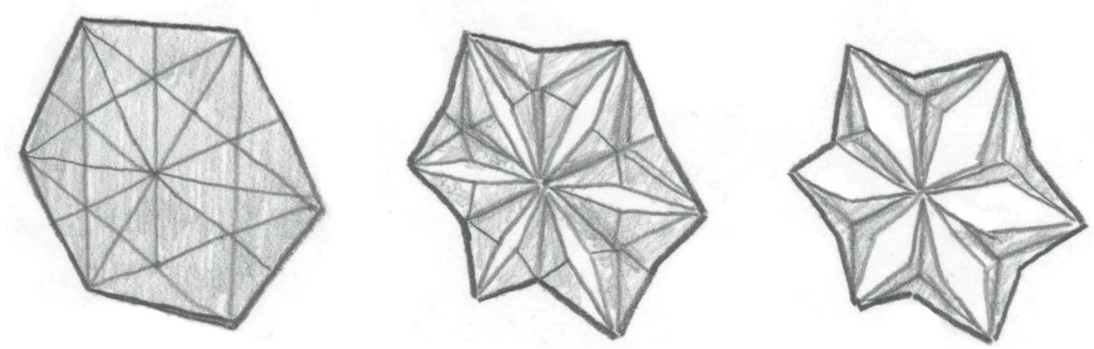

Figure 31: Automated Screen at the Al Bahar Towers (Source: Author)

The many techniques used to bring natural light into a building can be altered and scaled to suite the particular programmatic and site related needs of any design to reduce dependency on electricity and increase well-being and overall user experience.

Energy

Smaller scale energy generating mechanisms can work with site specific environmental resources to provide sustainable energy for building use. Electricity generated through hydro, wind, solar, and vegetative means are becoming increasingly efficient and affordable, making them great candidates for power generation for the average user.

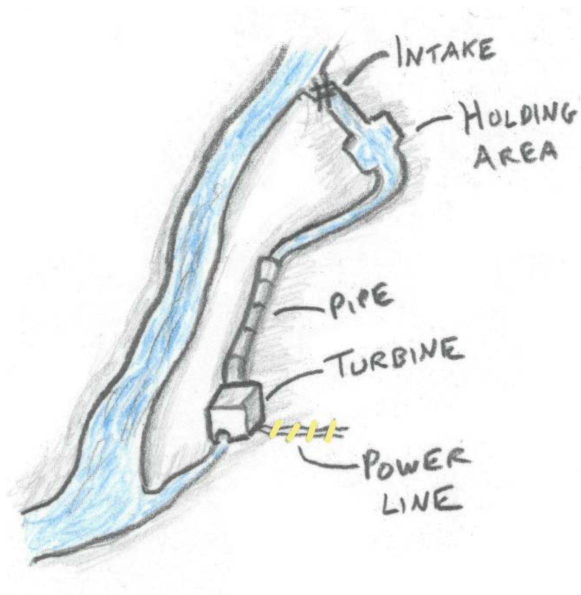

Figure 32: Micro-Hydro Energy System (Source: Author)

Humans have utilized hydropower for thousands of years to mill grain, cut stone, saw lumber, and more. Today water can be used to generate electricity as it is directed to flow past turbines connected to electromagnetic generators which in turn produce power. Micro-hydro energy can generate power for individual buildings at a scale that does not disrupt the environment in the manner of hydroelectric dams which block off whole rivers. These systems start with water intake from a river or stream, typically with some form of protection to filter out debris such as metal bars. Water then flows to a holding area where suspended particles can settle to the bottom. From here the water follows a channel or immediately enters a pipe. The pipe will direct the water downhill to meet the turbine after which it can be returned to the source. The amount of generated electricity is dependent on “the distance of the fall, the speed of the flow, and the number of liters per second flowing through the system."[66] Sluice gates or valves can be installed at the intake to divert or shut off water in order to conduct maintenance on the turbine.

Wind turbines are becoming quite popular in the field of sustainable energy production and accounts for approximately 2% of energy consumed in the United States.[67] The kinetic energy of the wind spins turbine blades around the rotor to create mechanical energy which in turn generates electricity. Turbines such as the Aeroleaf®, produced by Newwind in France, are small scale vertical axis turbines that can supply power at an immediate yet small scale. One of Newwind's WindTrees® (equipped with 63 Aeroleaves®) can supply "83% of the electrical consumption of a French household."[68] These small scale turbines generate power through the use of a "(rotor) magnet assembly, which is rotated by a blade moving across a power circuit (stator)."[69] Small scale turbines such as this do not produce the same level of noise as large turbines nor do they pose such a high level of risk to bird populations. In addition, their scale and power output makes them incredibly accessible to the individual user/household.

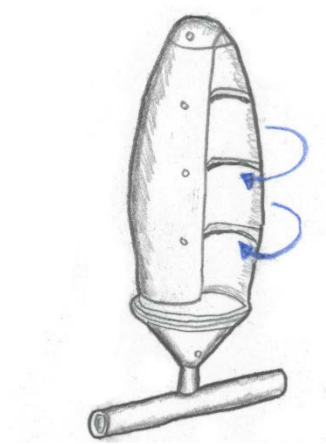

Figure 33: Vertical Axis Turbine (Source: Author)

[66] Emma. Judge and Intermediate Technology Development Group., *Hands on Energy, Infrastructure and Recycling : Practical Innovations for a Sustainable World TT -, TA* - (London : ITDG, n.d.), 12.
[67] Institute for Energy Research, "Wind - IER," accessed November 21, 2017, http://instituteforenergyresearch.org/topics/encyclopedia/wind/.
[68] Newwind, "AEROLEAF®," accessed November 21, 2017, http://www.newwind.fr/en/innovations/#vent-slider.
[69] Ibid.

Solar powered energy production is increasing rapidly in the United States as evidenced by the seventeen-fold national production increase of 1.2 gigawatts in 2008 to 30 gigawatts produced today, enough to power 21 million homes.[70] The photovoltaic cells that solar panels are composed of have two layers of semiconductors, a negative and positive. The semiconductors absorb photons from the sun and transmit it to direct current electricity which is sent to an inverter that converts the power to alternating current which is then stored in batteries, directed straight into the house, or fed into the electric grid. Solar panels come in many different sizes and can be applied to many areas of a building. These factors in addition to today's more widespread use and affordability of solar panels have made them much more accessible to the general public.

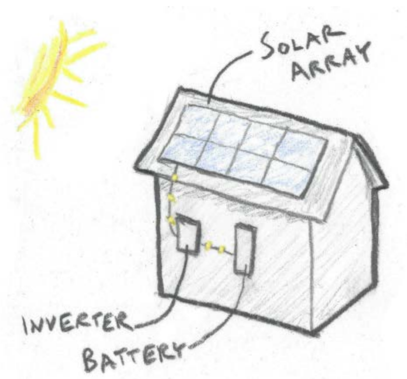

Figure 34: Solar Powered Home (Source: Author)

[70] Department of Energy, "Solar Energy in the United States," accessed November 21, 2017, https://energy.gov/eere/solarpoweringamerica/solar-energy-united-states.

Biophotovoltaics (BPV) is an emerging field of energy production where power is generated from the natural electricity produced by plants. An advantage of BPV over solar photovoltaics is that they are cheaper to create, self-replicating, self-repairing, and biodegradable. The Institute for Advanced Architecture of Catalonia has developed a façade system that is comprised of modular clay moss planters. Electricity is generated as the moss produces organic matter through photosynthesis. Some of this matter is released through its roots to the soil below where a symbiotic bacteria break it down into several byproducts, including electrons that are then captured by a 'soil' of hydrogel and carbon fibers.[71] However further bioengineering must be conducted to allow for maximum electron production by plants and bacteria to make them as efficient as solar photovoltaics. There is a great potential of BPV in areas with limited solar exposure (such as northern regions) where plants like moss can still thrive. The modularity of planters gives it the ability to easily scale to serve diverse built environments. BPV can have an important secondary function as a food source. The simplicity of this system allows for easy maintenance and set up, increasing its potential by simply being very appropriate for an average household.

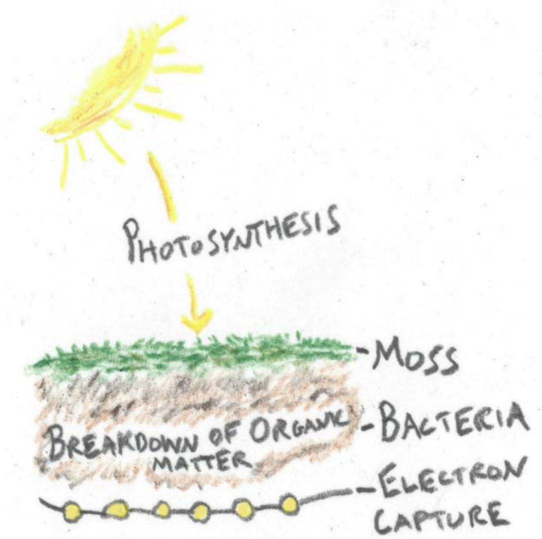

Figure 35: Microbial Fuel Cell (Source: Author)

[71] Elena Mitro, "Moss Voltaics," accessed November 21, 2017, http://elenamitro.com/my-product/moss-voltaics/.

Educating the public on the multitude of small-scale renewable energy sources can in turn allow these systems to become prevalent throughout global communities as individuals learn which of these highly attainable technologies, or combinations thereof, will be the most efficient and productive for one's particular environment.

Water

The control of water, be it for stormwater management or building and landscaping use, has become an integral aspect of modern architectural design. Rainwater collection and mitigation can help reduce pollution entering our waterways and provide free water for occupant use while decreasing their reliance on municipal sources.

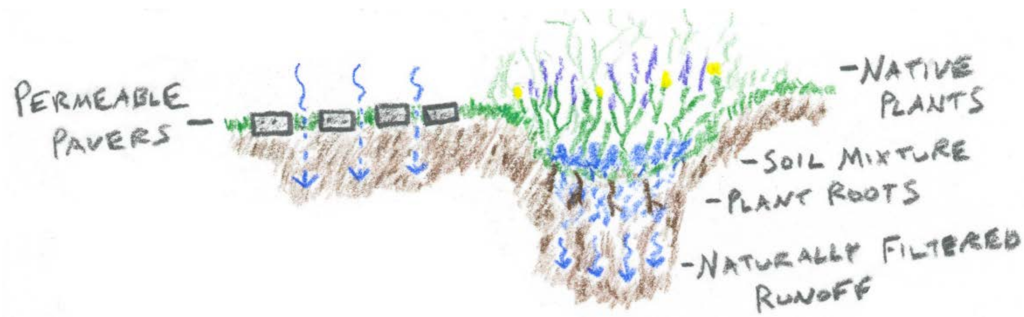

Figure 36: Porous Pavers & Rain Garden (Source: Author)

The sprawl of the built environment has led to an incredibly high amount of impervious surfaces including roads, driveways, roofs and more. During rainstorms a large amount of water runs off of these surfaces and directly into our drainage systems, carrying pollutants such as fertilizers, pesticides, oils, and others into our drinking sources. Rain gardens can be built at any scale to absorb excess rainwater and filter 30% more water than the conventional lawn.[72] They typically consist of

[72] Virgil Shockley et al., "Rain Gardens in Maryland's Coastal Plain" (n.d.), accessed November 27, 2017,

native plants in some mixture of gravel, soil, and mulch often located in a low point of the landscape where water will naturally flow. Rain gardens can also provide much needed habitat to local wildlife. In addition to rain gardens, porous paving of vehicular and pedestrian areas can allow for the infiltration of water into the ground. Typical porous paving consists of a latticework of solid surfaces and permeable ones although porous concrete, asphalt, and paving stones have been developed in the field of material sciences. Rain gardens and porous paving can alleviate our impact on the local water sources humans and wildlife rely on.

Rainwater collection is becoming more widespread as filtration systems become more affordable and sized to the average household. Instead of gutter systems directing water into lawns or directly into sewers, the water can be stored in rain barrels or tanks to be immediately used for landscape irrigation and appliances where water does not come into direct contact with people such as toilets. Collected rainwater can also be filtered to be used in household appliances and can become a great local source of drinking water for the inhabitants.

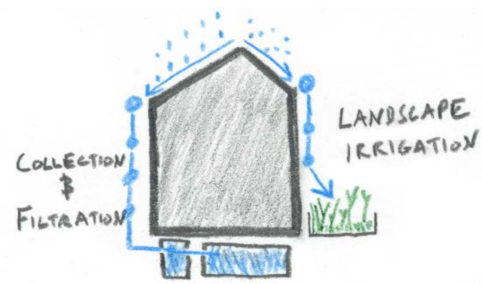

Figure 37: Rainwater Collection (Source: Author)

These methods to slow down and clean stormwater entering our waterways and make use of rainwater are examples of the advancement of modern architecture where environmental considerations are changing the common built forms and

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https://web.archive.org/web/20110419210439/http://www.aacounty.org/DPW/Highways/Resources/Raingarden/Rain_Gardens_MD_Coastal_Plain.pdf.

functions of our landscapes and building systems to not only benefit humans but also the ecosystems we occupy.

<u>Communal Building</u>

Local building projects can encourage a sense of community amongst a group of individuals who live in the same neighborhood. These projects can range from community gardens, neighborhood rain gardens, homes, and even bridges. Some more advanced projects may require the help of specialized professionals such as architects and engineers who can introduce modern technologies as a basis for simpler construction with local materials attainable by the regional citizens. The communities shared participation of the creation of the project can instill a sense of ownership and help individuals develop a skill set for maintenance and creation of future projects. Hybridizing modern technologies and methods provided or taught by specialized professionals with local building materials can encourage the advancement of building that is deeply entwined with the local ecology and its human inhabitants.

Figure 39: Students Building Goat Enclosure (Source: Yutaka Kobayashi)

Figure 38: Students & Teacher Feeding Goat (Source: Yutaka Kobayashi)

Figure 40: School Scale Ecological Cycle (Source: Author)

Yutaka Kobayashi, a Japanese artist, has helped construct and orchestrate several ecological installations at elementary schools both in Japan and the United States. These installations feature enclosures for small farm animals such as goats or chickens that are built by the students with Yutaka's assistance. They then become the custodians of the animals; feeding, milking, and helping to raise newborns. Yutaka introduces the children to a visible and understandable ecological cycle that they take an active role in; "organic surplus (leftovers from the school dining hall) is used to nourish the animals; the manure, broken down by micro-organisms, returns to the inorganic and is used as fertilizer for the plants, which by means of photosynthesis convert inorganic molecules into organic ones."[73] One of his projects in Japan follows local vernacular architecture with a framed wood structure and a movable transparent skin, commonly seen in Japanese homes. Not only do these projects teach the children about local building methodologies at a scale they can accomplish, but becomes a keystone in their environmental education "through the production of a real experience" which can be "transferred and applied to everyday life, encouraging citizens to take greater responsibility for the environment and to develop networks of connections among educators, students, and citizens."[74]

[73] Alessandro. Rocca, *Natural Architecture TT -, TA* - (New York : Princeton Architectural Press, n.d.), 100.
[74] Alessandro. Rocca, "*Natural Architecture TT,*" 95.

Figure 41: Original Bridge (Source: Edward NG)

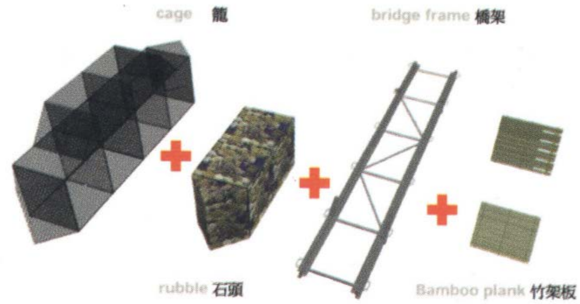

Figure 42: Bridge Components; Metal Cage, Rubble, Steel Frame, & Bamboo Palettes (Source: Edward NG)

In Maosi, a rural village in Gansu, China, architect Yan Yung Edward NG helped locals create a bridge for 300 school children who cross the river on a daily basis. Typically, villagers would create a bridge with local materials including mud, straw, and branches which would be swept away every year by the summer rains. These bridges were very unstable and children often fell into the river. Once a mother and child lost their lives crossing the bridge, Yan Yung decided to help the villagers construct a permanent one that would be able to withstand annual floods. The bridge was designed to be constructed in "a way that all parts have very low costs and can be transported and assembled with a minimum of mechanical devices, operated by volunteers without the need for professional training."[75] The final bridge was constructed with metal cages filled with stone rubble, heavy enough to act as solid foundations, connected with a steel frame overlaid with bamboo palettes and hand rails. This combination of a modern steel structure and local materials resulted in a bridge constructed by locals under the guidance of a professional that would be safe

[75] Alessandro. Rocca, "*Natural Architecture TT*," 177.

for children to cross all throughout the year and could be easily maintained and used by the villagers for many years to come.

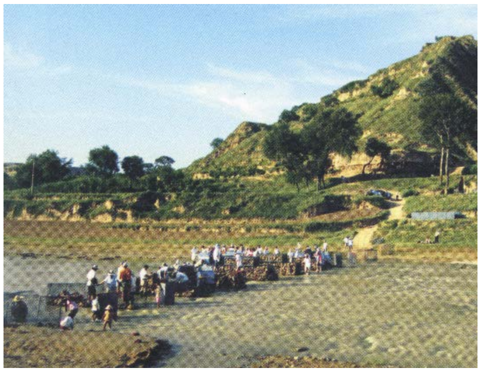

Figure 44: Villagers Building New Bridge (Source: Edward NG)

Figure 45: Children Crossing New Bridge (Source: Edward NG)

<u>The Integration of Nature in the Built Environment</u>

The assessment of one's environment can result in a knowledge of historical building methodologies and materials that, when combined with modern technology, can fully utilize the available natural systems to produce comfortable, energy efficient buildings which function synergistically with the immediate ecosystem. Architectural design often segregates the world of human habitation from that of wild animals but when designed to work with the elements of the local ecology instead of disrupting them, architecture can begin to take on an active role in the creation and function of the local habitat and begin to integrate itself seamlessly with the greater ecosystem. By actively engaging the public through substantive experiences, local communities can begin to adapt the methods and technologies to achieve this goal on a larger scale and encourage individuals to become more responsible for their environment. This necessary advancement of architecture will result in built environments that allow for the healthy convergence of the natural and man-made.

Chapter 4: The Chesapeake & Ohio Canal

"He often used to say there was only one Road; that it was like a great river: its springs were at every doorstep and every path was its tributary. 'It's a dangerous business, Frodo, going out of your door,' he used to say. 'You step into the Road, and if you don't keep your feet, there is no telling where you might be swept off to.'"

- J.R.R. Tolkien

<u>*Construction of the Canal*</u>

The Potomac River is one of the wildest in America, riddled with waterfalls, rapids, whirlpools, and strong currents that make boating and trading on the river an incredible and even deadly challenge. Early Americans desired to secure a trade route west from Washington D.C. to the Ohio Valley before New York in order to make the Capital a competitive port. The first man to take on this task was the hero of the Revolutionary War and first American President, George Washington.

Washington founded the Potomac Company in 1784 with the goal to create five skirting canals to bypass Great Falls, Little Falls, House's Falls near Harpers Ferry, Payne's Falls of the Shenandoah River, and Seneca Falls in Maryland. All were completed 18 years later in 1802, three years after Washington's death. These canals allowed 60'x 10' rafts called gondolas to carry "furs, grain, lumber, flour, and, less often, mountain whiskey" from western Maryland to Georgetown.[76] Yet these boats were too poorly constructed to make the trip back up the river and were

[76] Kytle, Elizabeth. 1983. *Home on the Canal*. Cabin John, Md.: Seven Locks Press, 12.

consequently sold as lumber in Georgetown. Shallows left exposed by the drier months of the year made navigation possible "for not more than 45 days a year."[77] Traders could not keep a consist schedule, users lost business, and the Potomac Company lost the tolls it relied upon to make ends meet.

In 1822 the Committee on the District of Columbia submitted a report to congress on the importance of connecting Washington to the west by a canal and in 1823 the first Chesapeake and Ohio Canal convention took place.[78] By 1821 3.62 million dollars had been secured for the canal, with money provided by Congress, D.C., Georgetown, Alexandria, Maryland, Shepherdstown, and numerous private citizens.[79] The canal was planned to be 60 feet wide and six feet deep with a constant downstream current of two miles per hour.[80] On July 4, 1828 construction on the canal was commenced at the head of Little Falls, at the same time of the groundbreaking ceremony of the Baltimore & Ohio Railroad, which would eventually make the C&O obsolete.

To build the canal, laborers were recruited abroad, with the majority from Ireland and Germany. The immigrants began back-breaking work for low wages averaging $10 a month while constantly suffering from outbursts of diseases such as cholera.[81] Work went slowly and funds frequently ran out, resulting in several petitions to the federal government and state of Maryland by the company for additional funding. By 1831, the section from Georgetown to Seneca was opened and

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[77] Kytle, *Home on the Canal*, 12.
[78] Kytle, *Home on the Canal*, 19.
[79] Kytle, *Home on the Canal*, 21.
[80] Kytle, *Home on the Canal*, 24-25.
[81] Kytle, *Home on the Canal*, 34-35, 42.

by 1839 the canal reached Hancock, Maryland.[82] The B&O Railroad reached Cumberland in 1842 yet the C&O remained competitive due to significantly lower rates.[83] Finally after 22 years of incredibly hard work through numerous economic issues, labor troubles, construction problems, and disease, all 185.7 miles of the Chesapeake and Ohio Canal were completed on October 10, 1850.[84]

Operation

Once completed, the C&O Canal operated from 1850 to 1924, a short lifespan for such a great national project. During this time canal boats "became uniform in size," 90-92 feet long and 14 feet wide with a "stable at the bow, the hay house in the middle, and the cabin at the stern" typically with 14 hatches to cargo space capable of storing 120 tons of goods.[85] Many families operated these boats which always had someone steering while another drove the mules. Mules tugged the boat from the adjacent towpath. Boats had two or three mules with one tugging while the other recuperated on board. Over the decades scores of mules were pushed to lameness and not cared for properly due to their cheap cost and ease of replacement.[86] Mule-power made for a typical seven day trip from Cumberland to Georgetown.

Figure 46: Mules at the C&O Canal (Source: U.S. National Park Service)

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[82] Kytle, *Home on the Canal*, 84.
[83] William Davies, *The Geology and Engineering Structures of the Chesapeake and Ohio Canal* (Glen Echo, MD, 1999), ix.
[84] Walter S Sanderlin, *The Great National Project. TT -, Johns Hopkins University Studies in Historical and Political Science ; Ser. 64, No. 1. TA* - (New York : AMS Press, n.d.), 159.
[85] Kytle, *Home on the Canal*, 84.
[86] Kytle, *Home on the Canal*, 85-86.

Figure 47: Lockhouse at Pennyfield Lock (Source: Author)

The canal was built with 74 locks operated by locktenders (often accompanied by their families) living in lockhouses along the canal. Here they lived rent-free, with an acre of land for gardening, and a wage of $150 a year.[87] Locktenders often worked around the clock, letting in boats and collecting tolls throughout all hours of the day. The canal was divided up into long sections each run by a Superintendent who oversaw repair gangs and level walkers who "covered 20 to 24 miles of canal a day, keeping sharp eyes out for leaks."[88]

The first items to be transported down the canal were flour, wheat, corn, lumber, lime, stone, and some coal.[89] Yet the most continuous income for the canal was the sale of water, with the Georgetown "millers, founders, and textile manufacturers [as] the canal company's main customers."[90] Eventually coal became the main and most profitable product for the canal company, with limited early

Figure 48: Coal Loading in Cumberland (Source: Kytle)

[87] Kytle, *Home on the Canal*, 87.
[88] Kytle, *Home on the Canal*, 66-67, 87.
[89] Kytle, *Home on the Canal*, 89.
[90] Kytle, *Home on the Canal*, 91.

competition from the B&O Railroad whose original cars were only equipped to carry lighter loads such as passengers.[91]

The Civil War (1861-1865) caused damage to both the canal itself and the trade carried out along it. Located on the frontline, Confederate and Union forces fought for control of the area and canal properties were often turned into hospitals, morgues, and army encampments.[92] The Confederate army attacked the canal time and time again, damaging dams, locks, and aqueducts and stealing mules. Yet the frequent disruptions did not stop the trade for long and by the end of the war the company had "raised employees' pay…and by 1865 the company had paid off all its debts."[93]

The golden years of the canal took place during the first half of the 1870s when about one million tons of cargo were transported yearly by as many as 540 boats.[94] The company brought in net annual gains at an average of a "quarter of a million plus."[95] The high volume of traffic resulted in long stretches of boats waiting to pass through locks or load/unload cargo, sometimes reaching 60-80 boats in length.[96] Steamboats were introduced to the canal in 1875 and continued to navigate the canal until 1889.[97] During June of 1877 a two month boater strike caused many shippers to give their business to the B&O Railroad. Later that year the worst flood in 150 years ended the boating season early and did tremendous damage to the entire

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91 Kytle, *Home on the Canal*, 94.
92 Kytle, *Home on the Canal*, 96.
93 Kytle, *Home on the Canal*, 100.
94 Thomas F Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland TT -, TA -*, 2nd ed. ([Shepherdstown, W. Va.] : American Canal and Transportation Center, n.d.), 17.
95 Kytle, *Home on the Canal*, 105.
96 Kytle, *Home on the Canal*, 102.
97 Kytle, *Home on the Canal*, 105-106.

canal.[98] Numerous floods throughout the years caused damage and unpredictability for trade along the canal. Additionally, droughts could stop boats for weeks at a time. Winter heralded an annual closing of the C&O and winter floods caused extra damage as ice crushed through the canal. The strikes, seasonal damages, inconsistent trading schedules, and loss of business to the B&O Railroad led to the end of the golden period during by the 1880s.

A series of depressions and floods throughout the 1880 and 1890s led to the end of profitability for trade carried out after 1890. The B&O Railroad acquired the canal company in 1889 when it entered receivership after the catastrophic Johnstown flood.[99] This prevented the Western Maryland Railroad from extending its track to the coal fields which would have led to direct competition the B&O Railroad. In 1902 the canal was run by the Canal Towage Company, which was owned by the B&O Railroad. This ownership brought about the end of individually owned boats and zero tolerance for "rough and rowdy" boatmen and their strikes.[100] Coal now accounted for 99% of the canals business yet rapidly declined from 171,062 tons transported in 1914 to 56,505 tons in 1923. This was a direct result of the increasing economic and physical efficiency of

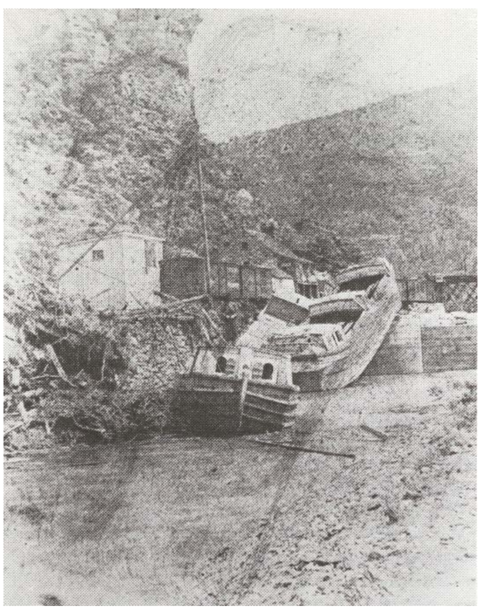

Figure 49: 1889 Flood Damage at Lock 33 (Source: Kytle)

[98] Kytle, *Home on the Canal*, 108.
[99] Kytle, *Home on the Canal*, 114.
[100] Kytle, *Home on the Canal*, 117.

the B&O Railroad.[101] The canal suffered so much damage by the flood of 1924 that it was never repaired sufficiently to reopen and funding completely ran out at the onset of the Great Depression. The Chesapeake & Ohio Canal, one of the greatest feats of American engineering, was permanently closed for trading after 74 years of operation.

Historic Infrastructure

74 lift locks, 11 stone aqueducts, 7 dams, numerous waste weirs, bridges, stop gates, stop locks, river locks, guard locks, culverts, and a 3,118 foot tunnel made up the different mechanisms and structures that together were necessary for the canal to function.

The combined 74 lift locks raised the canal from sea level in Georgetown to 610 feet in Cumberland. These locks allowed downstream boats to enter through the upper gate which would close behind them. Then valves in the lower gate opened to adjust the water depth to that of the next lock. The lower gate would then open to allow the boat to pass through. This process was reversed for canal boats travelling upstream.

[101] Unrau, Harland D. "Historical Resource Study: Chesapeake & Ohio Canal." [US Department of the Interior, National Park Service]. Retrieved 2013-05-02.

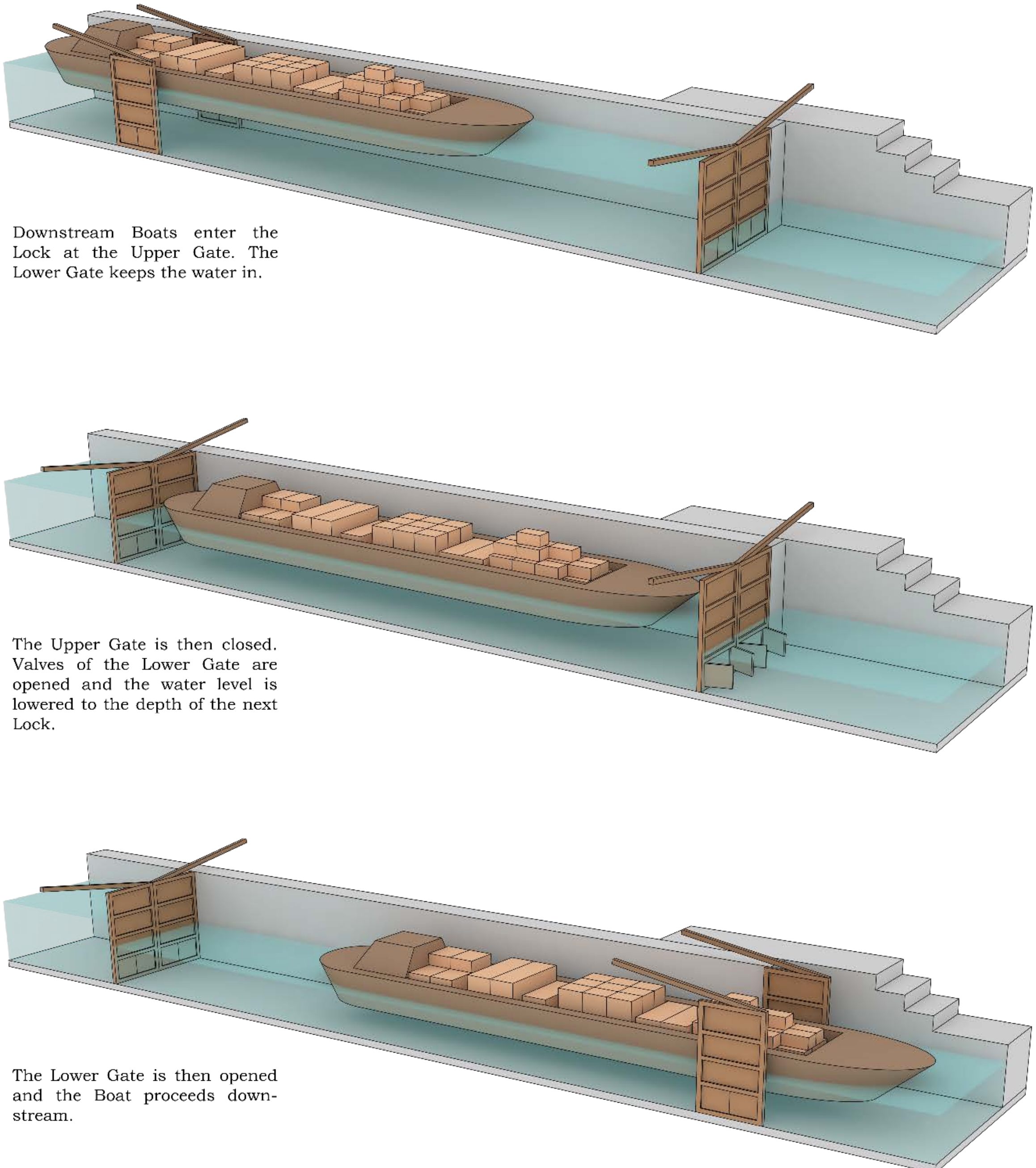

Figure 50: Lift Lock in action. (Source: Author)

Waste weirs allowed excess water from emptying locks or storms to discharge further down the canal or back into the river in order to maintain water level and flow speed. Stop gates, stop locks, and guard locks were located along the C&O to “divert floodwater and to cut off flow” in the canal if there was a breach in the embankment.[102] The seven dams along the river were used to feed the C&O by raising the level of the Potomac which would cause water, moved by gravity, to enter the locations of the canal that were below river level. River locks would control the amount of water entering the canal from the river. Culverts were built to allow streams and creeks to flow underneath the canal. Aqueducts were the larger version of culverts and crossed bigger streams.

Figure 51: Culvert north of Pennyfield Lock (Source: Author)

At its time the canal was such a fantastic feat of human engineering that it pushed global boundaries with record setting structures. The Georgetown canal incline was the "largest incline in the world at the time and a model was exhibited at the World's fair in Paris in 1878 as one of the United States' best efforts in the field of civil engineering."[103] This system brought boats to a higher level of water without the need of a lift lock, instead using originally a turbine and later a steam engine for power. The Cabin John Bridge was originally built in 1864 as an aqueduct (now a roadway) and was the longest single-span masonry arch in the world.[104] In 1879 the canal company constructed a telephone line from Georgetown to Cumberland with "48 telephone instruments, making it the longest commercial telephone line in the world."[105]

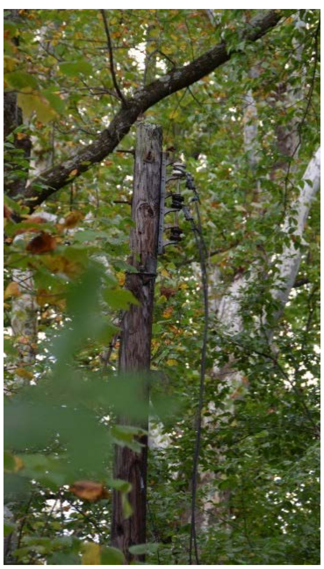

Figure 52: Telephone Pole near Riley's Lock (Source: Author)

[102] Davies, *The Geology and Engineering Structures of the Chesapeake and Ohio Canal*, xiii.
[103] Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland*, 19.
[104] Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland*, 30.
[105] Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland*, 44.

Although it had its fair share of troubles, the engineering of the C&O and corresponding structures gave the canal a proud legacy that is still cherished today.

<u>A National Historic Park</u>

The B&O Railroad suffered tremendous economic losses during the Great Depression and was forced to sell the C&O Canal to the US Government in 1938 for 2 million dollars.[106] The Park Service immediately got to work and restored the waterway from Washington to Seneca, opening that portion of the canal as part of the National Capital Parks System in 1939.[107]

In 1954 a proposal to turn the canal into a highway was brought to congress and a plan was laid out by the Army Corps of Engineers and published with support in the *Washington Post*. Supreme Court Justice William O. Douglas wrote to the editorial writer about the aspects of the canal that could not be experienced from a car such as "muskrats, badgers, and fox…strange islands and promontories through the fantasy of fog…whistling wings of ducks" and even invited the editor to walk the canal with him, believing "he would return a new man."[108] This walk became known as the Douglas Hike and included 58 people, 9 of which (including Douglas) walked the full 184.5 miles in seven days.[109] The *Washington Post* changed its stance on the matter and Douglas soon formed the C&O Canal Association which lobbied for protective legislation and created plans to preserve and protect the canal.[110]

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[106] Kytle, *Home on the Canal*, 121.
[107] Kytle, *Home on the Canal*, 122.
[108] Kytle, *Home on the Canal*, 123.
[109] Kytle, *Home on the Canal*, 123.
[110] Kytle, *Home on the Canal*, 123.

President Eisenhower made the canal a National Monument in 1961 and ten years later the *Chesapeake and Ohio Canal National Historic Park Act* was passed, securing the canals survival as a National Historic Park. The National Park Service and volunteer organizations such as the C&O Canal Association work to maintain the canal which draws visitors from all over the country. There are currently six visitor's centers along the canal and access points at almost all of the 74 historic lock sites. Locals and tourists alike enjoy walking, running, boating, climbing, camping, biking, and more.

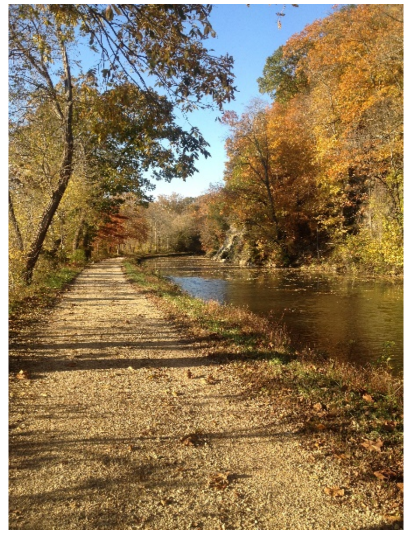


Figure 53: C&O Canal (Source: Author)

Modern infrastructure can be found in and around this National Historic Park, continuing its legacy of innovative feats of engineering. Several water reservoirs lie alongside the canal, from the Georgetown Reservoir in D.C. to Ridgedale Reservoir in Cumberland. The Potomac Water Treatment Plant produces up to 283 million gallons of water per day and is one of 10 water treatment plants located by the canal, serving the millions of citizens residing nearby.[111] The seven modified historic dams divert water to these plants while others service hydroelectric plants such as the Honeywood Power

Figure 54: Pump Station for Rockville water supply, near Swains' Lock (Source: Author)

[111] Washington Suburban Sanitary Commission, "Water Filtration," last modified 2015, https://www.wsscwater.com/education-and-recreation/about-water/water-filtration-1.html.

Plant in Fallingwaters, West Virginia. Not far from the capital is the US Naval Surface Warfare Center, equipped with massive indoor pools for naval ship and submarine testing. Much like the original C&O Canal, these modern marvels of engineering service the people of the PRWA using the power and water of the Potomac River.

Figure 55: Beaver seen near Pennyfield Lock (Source: Author)

During the working days of the canal, people saw wildlife as a nuisance and the company would even give "a reward of 25 cents for each muskrat killed on the line of the canal."[112] Workers often killed otters, beavers, and other small mammals mistaking them for muskrats, resulting in a decimation in these animals' populations along the canal. Overhunting of this period also led to an incredible depletion and extirpation of local wildlife in the area. Today fishing and hunting permits and seasons are carefully regulated to allow for the proliferation of the remaining animals. The C&O National Historic Park aims to protect wildlife and give animals some habitat in this buffer zone that separates the river and the surrounding suburban sprawl. The area along the canal now features several nature preserves, a waterfowl sanctuary, wildlife management areas, and a State Forest near Cumberland. The modern canal has set the stage of a highly engineered historic built environment that has begun to converge with the reemerging wild.

[112] Kytle, *Home on the Canal*, 67.

The canal, once a busy trading route turned National Historic Park, can itself be seen as a massive adaptive reuse project. Along the waterway are many examples of old structures used anew. The Great Falls Tavern, for example, was once a lockhouse, turned into a tavern, hotel, private club, grocery, and finally now functions as a museum about the canal.[113] Dam 4, once used to regulate the amount of water entering the canal, was refitted in 1913 and updated in 1994 to generate hydroelectric power.[114] Six lockhouses have been fixed up and refurbished as rentals where visitors can take a step back in time for one to three nights. Yet many of the old locks are simply used as access points to the canal; forgotten places that yet hold a great potential for the communities around them.

[113] Thomas F Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland*, 66.

[114] Ranger Curt, "The Power of Water," last modified 2014, https://www.canaltrust.org/discoveryarea/dam-4/.

Chapter 5: Riley's Lock

Figure 56: Boat Entering Riley's Lock (Source: Kytle)

<u>*History of Lock 24*</u>

Lock Number 24, known as Riley's Lock, was constructed from 1830 to 1831 and is the only lock on the canal that doubles as an aqueduct. The Seneca Aqueduct (Aqueduct Number 1) is 113 feet long and carried the canal over Seneca Creek.

The lock's namesake, the Riley family, operated lock 24 from 1892 to until the canal closed in 1924.[115] Besides managing the lock, the Riley's raised and sold produce and rented out rowboats for people to fish with.[116] Locals from Rockville and Gaithersburg would often visit the area to fish and stayed in cottages nearby.[117] The children would swim, fish, have picnics, play ball, and help with the chores in the

[115] Kytle, *Home on the Canal*, 73.
[116] Kytle, *Home on the Canal*, 229.
[117] Kytle, *Home on the Canal*, 234.

garden and at the lock. The family lived in lockhouse number 16, a three story house made of the local Red Seneca Sandstone mined from the nearby quarries.

A boat basin lies on the canal to the west of the aqueduct (measuring 340 feet across at its widest point) with six sandstone quarries along its northern shore. Red Seneca Sandstone was quarried here for the Potomac Company as early as 1774, supplying stone used for the canal locks on the Virginia side of Great Falls.[118] The stone quarried here supplied material for the C&O and Alexandria canal and many buildings in Washington D.C. including the Smithsonian Castle. The stone taken from these quarries was pulled by mules down a narrow gauge tram to be cut at the Seneca Stone Cutting Mill at the east end of the basin. The mill cut at a rate of 1" an hour and worked on stone brought from several quarries in the area including Goose Creek, Virginia and Whites Ferry, Maryland.[119]

Figure 58: Riley's Lock Lockhouse, made of Red Seneca Sandstone (Source: Author)

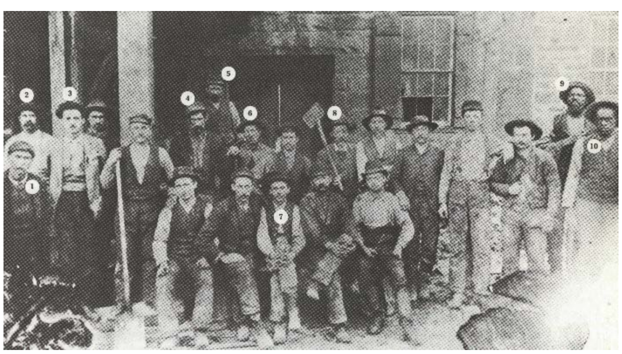


Figure 57: Workers at Seneca Stone Cutting Mill, circa 1890 (Source: Kytle)

[118] Davies, *The Geology and Engineering Structures of the Chesapeake and Ohio Canal*, 106.
[119] Thomas F Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland*, 57.

Other structures located near the lock included the locktenders shanty, a country store across from the lock, Darby Flour Mill and grain warehouse below the lock, and Old Tschiffely Mill, close to River Road. The mills supplied flour from locally grown wheat to D.C. while the country store sold groceries to boaters and local families.

During the Civil War Riley's Lock was raided by Colonel J.E.B. Stuart of the confederate army on June 27, 1863.[120] The confederates were able to burn a boat but no lasting damage was done to the lock itself.

In 1971 a catastrophic flood raised Seneca Creek 8 feet and sent houses, boats, and trees downstream blocking up and eventually destroying the westernmost arch of the Seneca Aqueduct.[121]

Figure 59: Seneca Aqueduct (Source: Author)

[120] Davies, *The Geology and Engineering Structures of the Chesapeake and Ohio Canal*, 105.
[121] Thomas F Hahn, *Towpath Guide to the Chesapeake & Ohio Canal : Georgetown Tidelock to Cumberland*, 59.

Location, Demographics, & Regional Information

Figure 60: Riley's Lock on the C&O Canal (Source: Author)

Riley's Lock lies 22.82 miles from the start of the canal in Washington D.C. The surrounding counties and cities of Maryland and Virginia include Montgomery County, Loudoun County, Fairfax County, Alexandria, Arlington, and Washington D.C. Together these regions hold a population of 3,621,460 people.

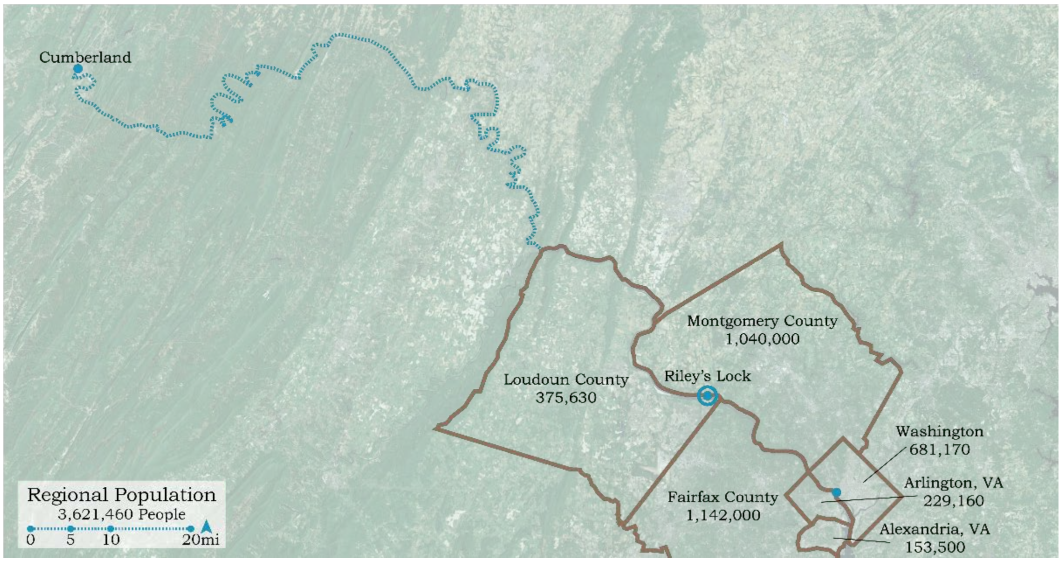


Figure 61: Regional Population around Riley's Lock

Riley's lock lies amidst several population centers, (seen in figure 62) all within a 20-45 minute drive. Within this area are three wildlife centers. Owl Moon Raptor Rescue in Boyds, Maryland specializes in birds of prey (owls, hawks, eagles, etc.). Second Chance Wildlife Center operates out of a house in Gaithersburg, Maryland and rehabilitates sick and injured animals. City Wildlife in Washington, D.C. rehabilitates small animals found in the urban environment.

Figure 63: Regional Population Centers (Source: Author)

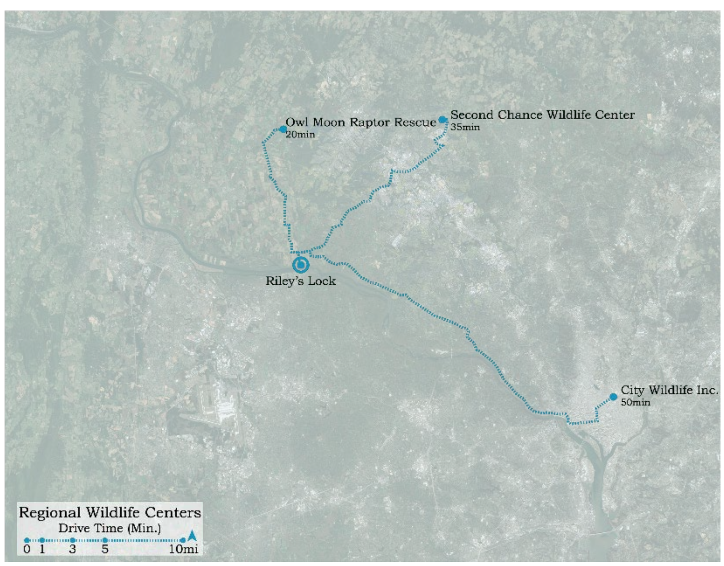


Figure 62: Regional Wildlife Centers (Source: Author)

Within a three mile radius of the site there are four parks/wildlife management areas. McKee Beshers Wildlife Management Area lies to the west of the site and contains 2,000 acres of farmland, forest, and regulated wetlands. Across the river in Virginia is Seneca Regional Park, a 450 acre protected forest. To the east of the site, past Violette's Lock, is Blockhouse Point Conservation Park, a 630 acre forest with civil war ruins. Across the canal from this park is Diersson Waterfowl Sanctuary and Wildlife Management Area, a 40 acre wetland with two man-made ponds and several nest boxes for waterfowl.

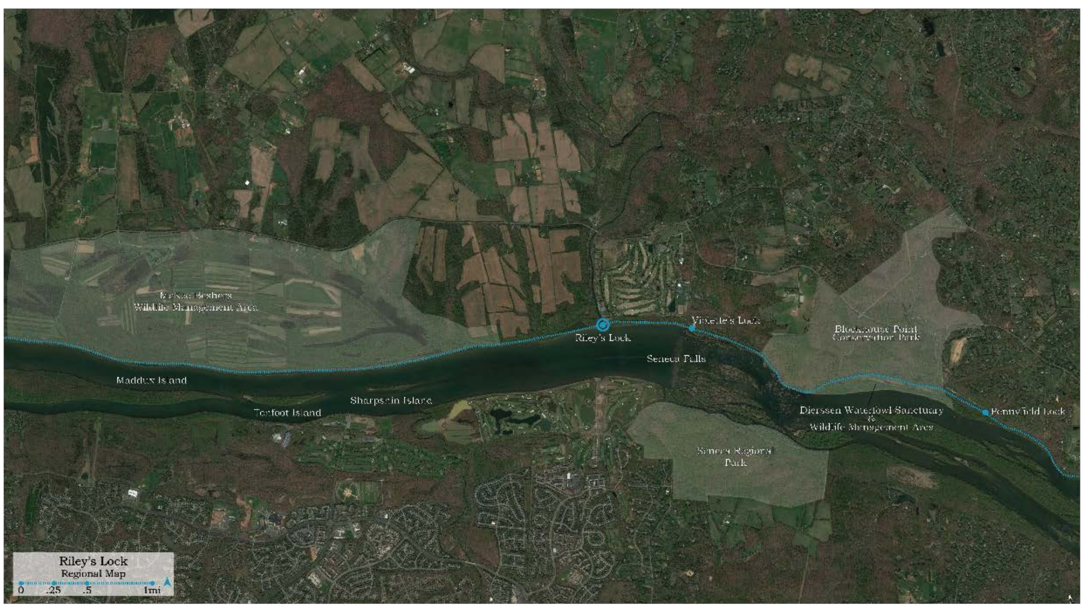


Figure 64: Regional Map (Source: Author)

Site Features

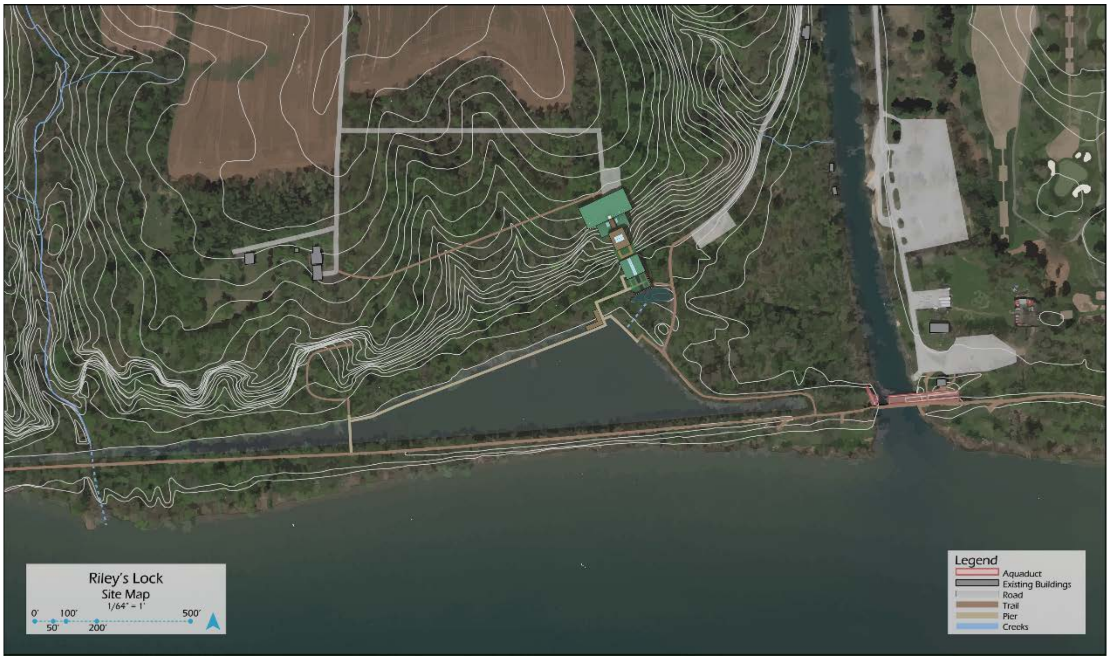


Figure 65: Site Plan (Source: Author)

When looking at the site between Breton Woods Golf Course (East) and Bulls Run Creek (West) one can find several historical features. Upon arrival at the site visitors can see the old aqueduct canal lock and lockhouse. Following the towpath west one will find the boat basin, 340 feet across at its widest point. Down a side trail lies the ruins of the Seneca Stone Cutting Mill, an industrial building reclaimed by nature. North of the mill lies a hill with a 60 foot elevation gain from the basin to the top. Following the hill down to the west end of the basin one finds the overgrown

Figure 66: Seneca Stone Cutting Mill Ruins (Source: Author)

quarries where Red Seneca Sandstone was once mined. Above the quarries are two historic farmhouses. The easternmost two quarries lie beyond Bull Run Creek which passes under the canal through Culvert #35.

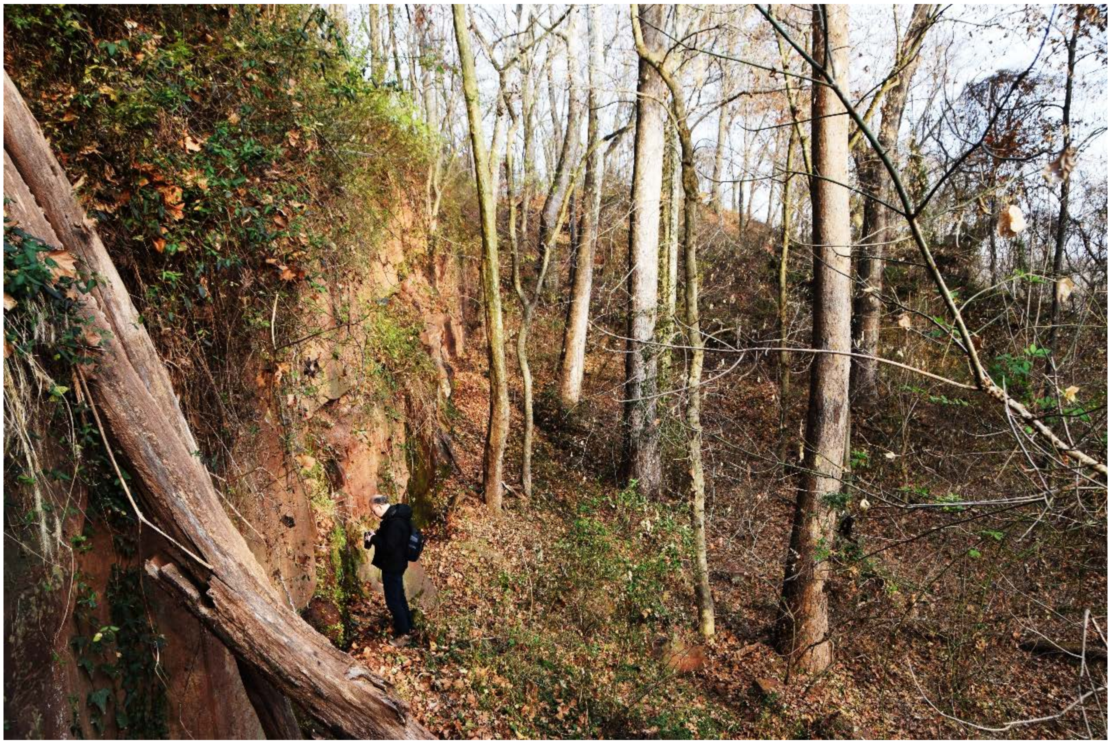


Figure 67: Seneca Sandstone Quarry (Source: Author)

The forests of the site can be divided into three categories. The Riverine Buffer lies between the canal embankment and the Potomac and is the first to be flooded when water levels rise. The Midland Forest can be found on the flood plain beyond the canal and within the 30 foot 100 year storm event flood level. The Upland Forest lies atop the hill beyond the quarried and boat basin and is a great viewpoint out onto the river when the trees are bare in the winter.

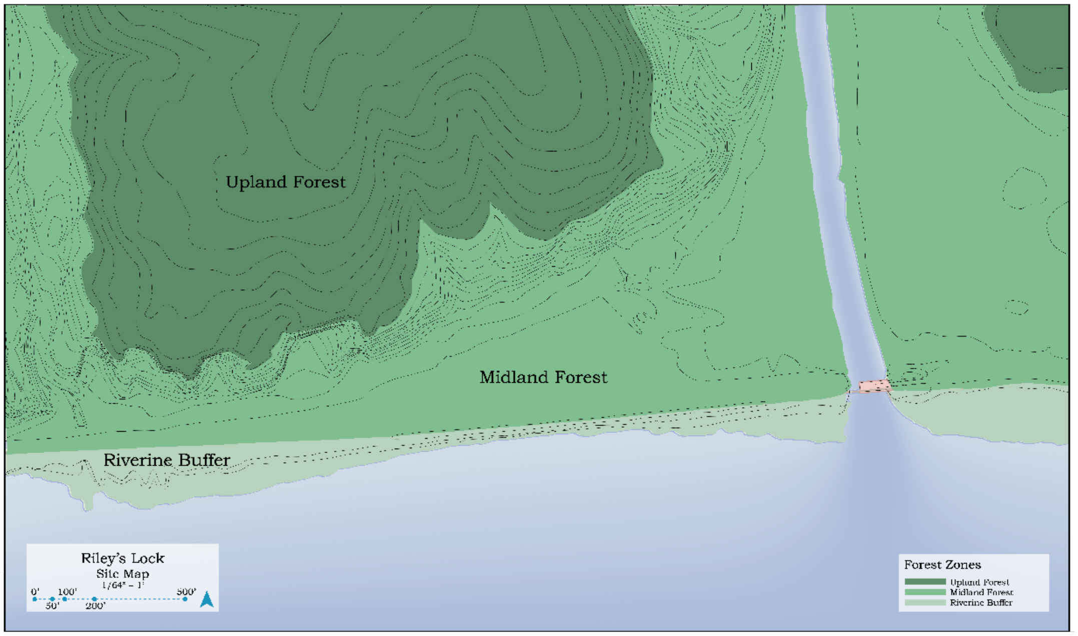


Figure 68: Forest Zones (Source: Author)

Figure 69: 30' 100 Year Flood Event (Source: Author)

Site Inhabitants

The stretch of the C&O Canal by Riley's lock and surrounding site is host to many different visitors including human and wildlife alike. The diverse environment of the area allows for many different forms of recreation to historical reenactment and education at the old lockhouse to biking, hiking, and walking along the tow path. Nautical visitors take the creek, canal, and river to sail, kayak, canoe, jet ski, fish, and more. The stretch of river by the site is approximately 2,000 feet wide with a slow current which makes it very accessible to all levels of boaters. The two greens adjacent to the point where Seneca Creek enters the Potomac is set up with picnic tables and grills for cookouts and plenty of space for camping.

Figure 70: Activities around Riley's Lock (Source: Author)

A wide range of wildlife can be found in the river and forest habitats around Riley's Lock. Many species of waterfowl such as the Great Blue Herons and Mallard will feed in the Boat Basin, Seneca Creek, and Potomac. Raptors such as the Red-Tailed Hawk, Turkey Vulture, and Bald Eagle can be seen flying in the sky above the river. Along the shore of the river one can spot dozens upon dozens of mollusk shells. During the summer the river is thick with hydrilla, an aquatic grass that has begun to overpopulate the river due to fertilizer runoff. In the river boaters can spot a number of fish species including carp, catfish, smallmouth bass, and sunfish. Many species of mammal roam the forest and feed in the river such as the beaver, otter, raccoon, squirrel, deer, fox, coyote, opossum, and more. Despite the plethora of animals one can spot around Riley's Lock, many species have been permanently extricated from the area while others have only returned in small numbers, a fraction of their precolonial population.

Figure 72: Great Blue Heron (Source: Author)

Figure 71: White-Tailed Deer (Source: Author)

Site Potential

The C&O Canal is a living example of humanities attempt to tame a wild environment that has since been partially reclaimed by nature. The canal that was laboriously built along the Potomac River in order to secure a trading route to the west could not provide the economic resources necessary to maintain so many different forms of infrastructure required for the C&O to function. These structures have since fallen into ruin and disuse, allowing native plants and animals to repopulate this stretch of historic industry. Today wildlife coexists with people who are able to easily visit the otherwise inaccessible river environment due to the tow path and locks built by the C&O company.

The site around Riley's Lock can be seen as the convergence of wildlife and the built environment as wildlife moves back into this area once dominated by trading boats and mining activities. A great variation of historic and natural elements allow for many opportunities of engagement and education with the Potomac River environment and the animals that live there in ways that can be beneficial to both humans and wildlife. Riley's Lock is an ideal stage for residents of the PRWA to take part in the revitalization of the ecosystem in order to develop a healthier relationship with the river.

Chapter 6: Programming

Overview

The Seneca Conservancy will aim to actively encourage and fulfill a broad range of environmental revitalization to the PRWA. To achieve conservation at multiple scales, the center will feature a design focusing on the following three pronged approach:

1. **Individual** care through Wildlife Rehabilitation/Reintroduction
2. **Site** Revitalization through Water Treatment, Research, & Experimentation
3. **Public** Education through Wildlife & Environmental Learning

These three tactics will intertwine through the development of a series of architectural designs that will stimulate users to become actively engaged in the wellbeing of their ecosystem.

Wildlife Rehabilitation Center

The Wildlife Rehabilitation Center will programmatically be divided between two functions that will feature several moments of overlapping spaces.

The primary function will be a more private architecture where staff treat injured and sick wildlife through a series of veterinary treatment and animal recovery spaces, both indoor and outdoor.

The secondary function of the center will include public programming where visitors can learn about the native wildlife being treated at the center. This will include a central area where visitors can see food being prepared for animals, a window into the surgery room, and a window into a smaller treatment room.

Separated from the hospital building, visitors will be able to watch live streams of animals being treated or recovering through a series of televisions. An area for hologram projections will also be provided to allow visitors to interact with animals they may not be able to in the wild.

Research Center

The research center will be made up of a series of laboratories, open workspace, and meeting rooms. This will be where experimentation, research, and monitoring of the Potomac and site Basin will be performed with the aims to achieve a healthy river ecosystem. Workspace will be allotted for administrative tasks related to both the upkeep of the Conservancy as well as public outreach.

The data that is collected here will be used and made public in an effort to remediate not just the Potomac River, but waterways all around the nation and potentially the world.

This area will be designed with public tours in mind so visitors can get a look into the active work being done by the employees of the Seneca Conservancy.

Environmental Education

A combination of outdoor and indoor programming will be designed with the goal to instill a sense of empathy and environmental connection to visitors coming from surrounding communities of the Potomac. These areas will allow for visitors to learn about ways they can live more sustainable lives and have a positive role in their local ecosystems.

Around the Basin this will consist of a water-walk and trail loop that will allow visitors to walk around the Basin on their own or on a tour and learn about the different animals and wildlife that live there and our effect upon them. Closer to the building site there will be a sheltered pier where different mollusks including mussels and clams will be grown in an effort to place them in the Basin and Potomac where they can begin to repopulate and clean the water.

In the building visitors will have the chance to come back out to the forest to an area that has been specially planted with native fauna. Visitors can learn about the different characteristics of these plants and perhaps take this knowledge back home with them and begin to landscape with vegetation more appropriate for the Maryland climate.

Finally visitors will have the opportunity to visit an observation deck and look out onto the Potomac River and Basin. Through these great views visitors can gain an appreciation for the scale of the river habitat.

Historic Education

The Seneca Stonecutting Mill ruins will be partially left open to the forest that has reclaimed it with minimal interventions such as designated paths. The other half will have a pavilion insertion where visitors can learn about the history of the C&O and Seneca Stonecutting Mill & Quarries.

Chapter 7: Design

"I am the Lorax. I speak for the trees.

I speak for the trees, for the trees have no tongues.

And I'm asking you, sir, at the top of my lungs

What's that THING you've made out of my Truffula tuft?"

- Dr. Seuss

Design Introduction

This thesis came about from the great appreciation of our planet's wild places and the drastic disconnect between these places and the built up cities where most humans reside. Despite this disconnect, our society relies heavily upon these places for such basic necessities as food, material, water, and even joy. Yet we are not the only ones dependent on these places, we share them with a plethora of other living beings. However our role in the ecosystems we share has caused wildlife populations to plummet at a never before seen rate. The completed Seneca Conservancy seeks to combine active stewardship of the Potomac River and its wild inhabitants with public education in order to connect the surrounding communities to the river they rely so heavily upon.

Site Design

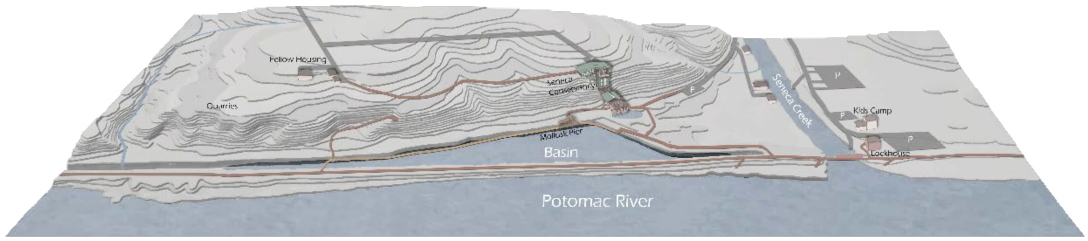


Figure 73: Site Aerial (Source: Author)

Access to the Seneca Conservancy can be found at the far right of the Site Aerial (above) through the roads and parking lots leading up to Riley's Lock. Visitors can also access the Conservancy by the mill road on the opposite side of Seneca Creek. A new trail loops around the Basin where visitors can reach the Conservancy, Basin, Quarries, and C&O Canal towpath. Employees of the Conservancy can access Fellow Housing and a private entry to the building through a road in the upland forest to the far left of the Site Aerial (above).

Building Massing

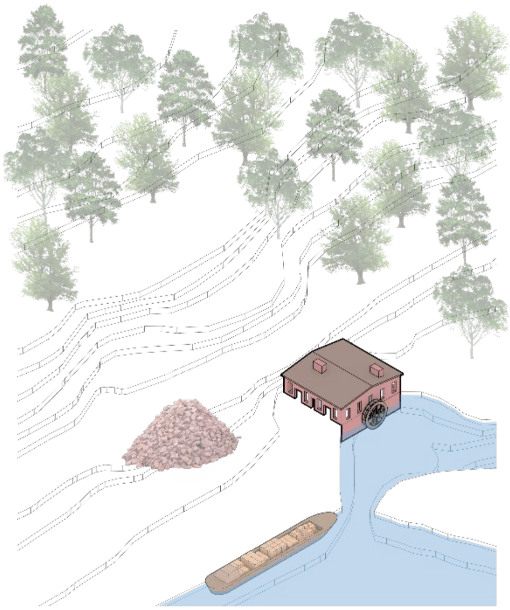


Figure 75: Mill c. 1837 (Source: Author)

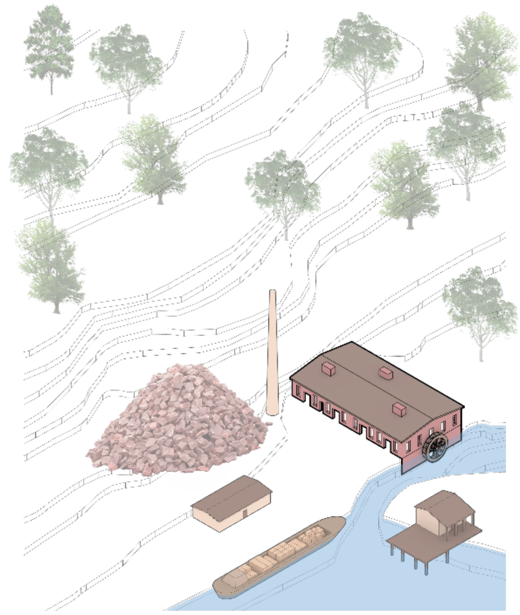


Figure 74: Mill c. 1855 (Source: Author)

The segmented expansion of the Seneca Stonecutting Mill inspired the following strategy for developing the buildings mass to reach the top of the adjacent hill, allowing certain programming to be well out of reach of the flood plain below.

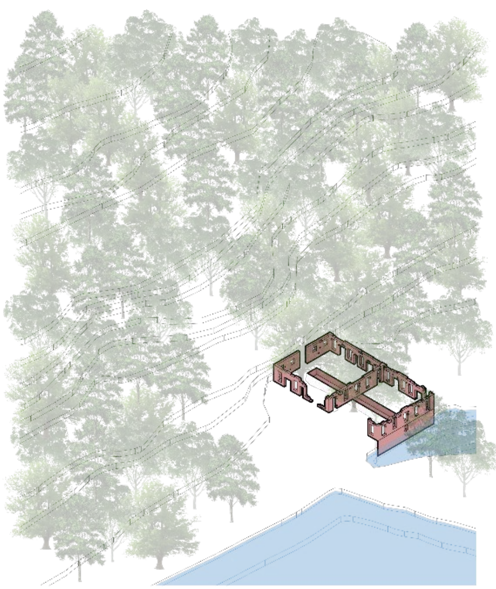


Figure 77: Mill Ruin 2018 (Source: Author)

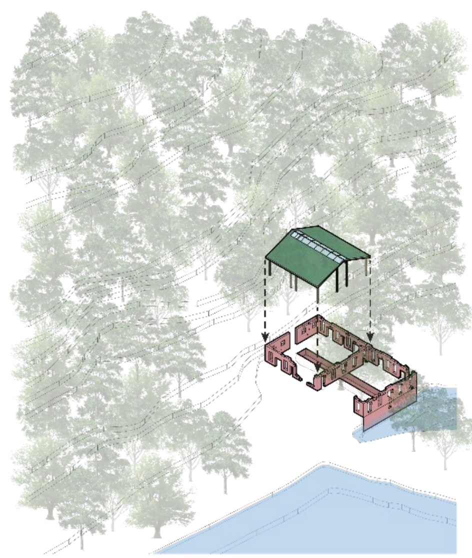


Figure 76: Pavilion Insertion (Source: Author)

To begin the design of the Seneca Conservancy, a pavilion was inserted into half of the existing ruins.

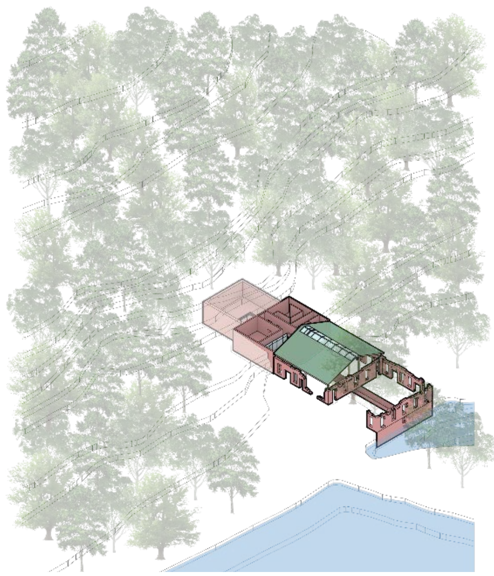


Figure 79: Grotto Extension (Source: Author)

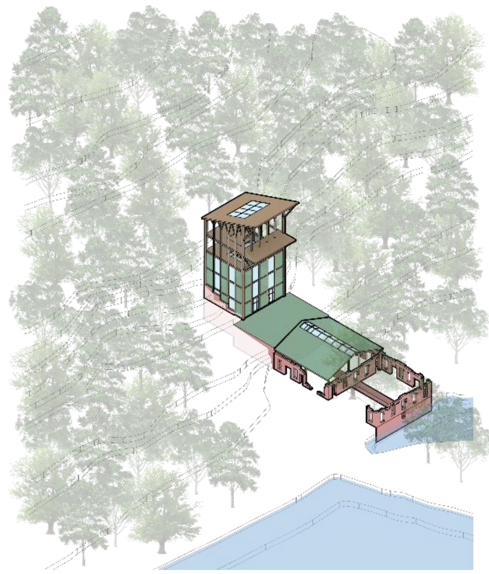


Figure 78: Lookout Tower (Source: Author)

The ruins are extended back into the hillside in a new sandstone structure, the Grotto. Atop the first half of the Grotto is a landscaping area, behind which the Lookout Tower extends beyond the forest canopy.

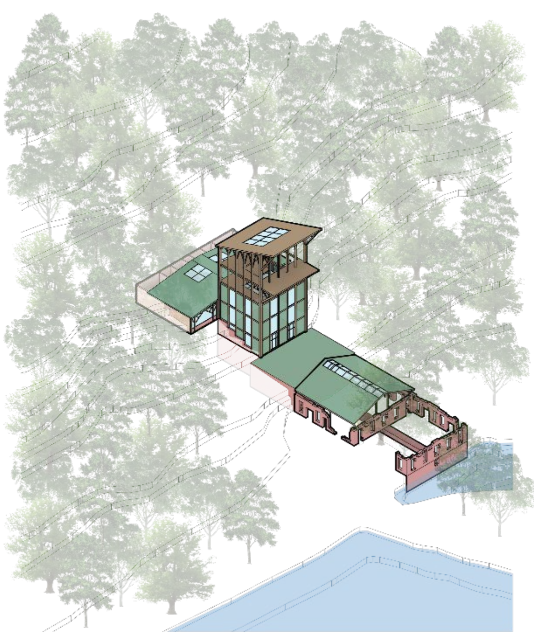


Figure 80: Research Insertion (Source: Author)

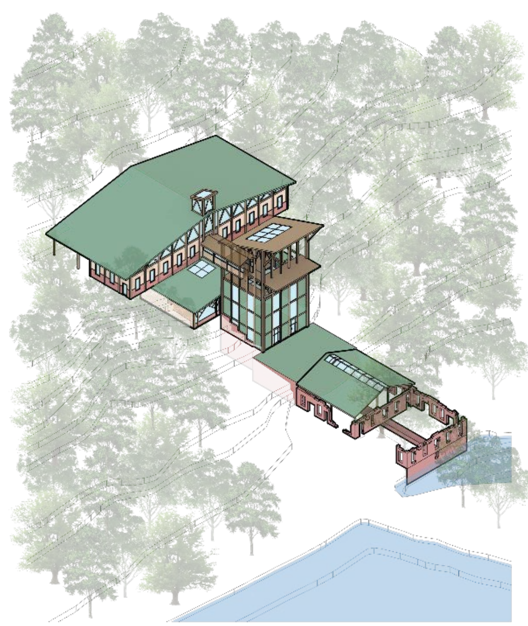


Figure 81: Hospital Terminus (Source: Author)

Behind the Lookout Tower, a Research Center is partially inserted into the hillside. Atop of this is the final element of the Seneca Conservancy, the Wildlife Hospital.

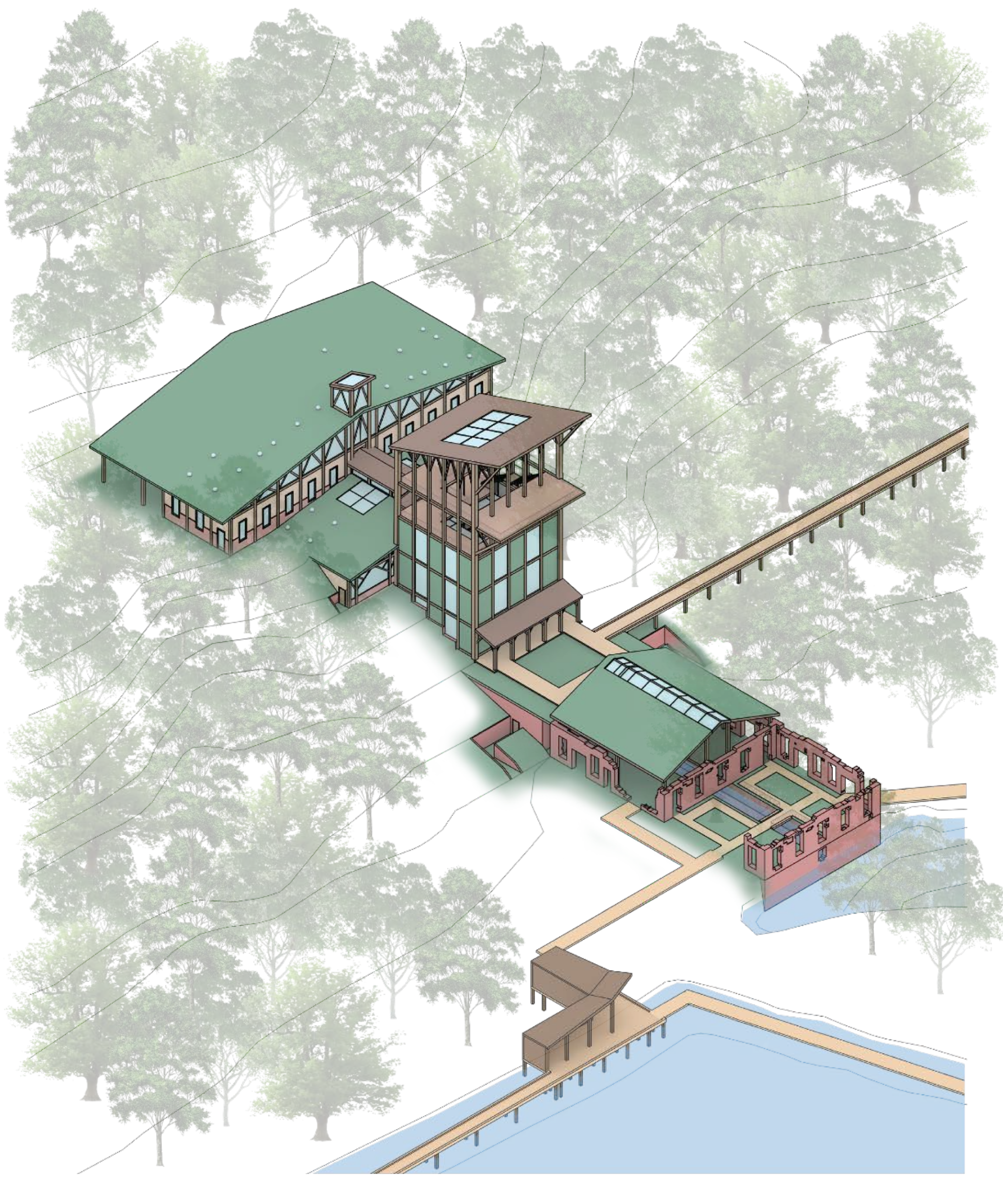


Figure 82: Final Massing with Landscape Elements (Source: Author)

The completed Seneca Conservancy is a result of a modern interpretation of the segmented expansion of the original structure in addition to the simple movement of boats changing level in the locks up and down the C&O Canal.

The resultant building has several features that extend out into the landscape. One path leads from the C&O towpath to the ruins while another, elevated trail, extends from atop the Grotto back towards Seneca Creek. From the ruins another trail extends, linking the building with the water-walk around the Basin.

Water Cycle & Other Sustainable Strategies

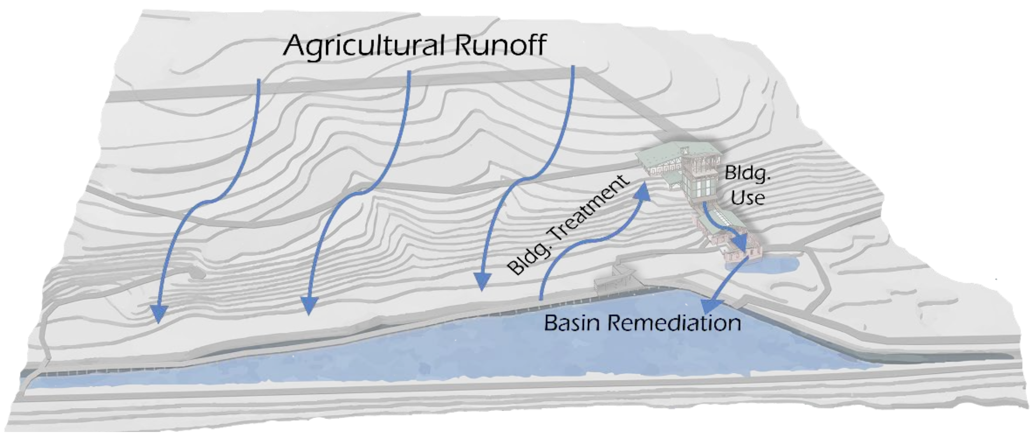


Figure 83: Site Water Cycle (Source: Author)

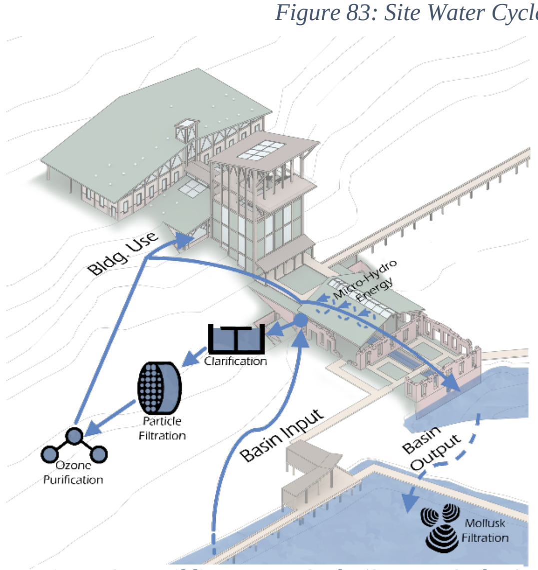


Figure 84: Building Water Cycle (Source: Author)

The Seneca Conservancy is designed to treat the water of the adjacent Basin in such a way as to serve as an example as what the elimination of pollutants in runoff would look like in the greater Potomac.

At a site scale, agricultural runoff would be captured and pumped into the building, treated, and released back into the basin to create a remediated habitat for wildlife and human recreation. Looking closer at the process in the building, water being pumped in goes through a series of filtration processes including clarification, particle filtration, and ozone purification. Part of this is then used for building purposes while most gets channeled out of the building, powering micro-hydroelectric turbines in the ruin, and finally coming back out into the Basin.

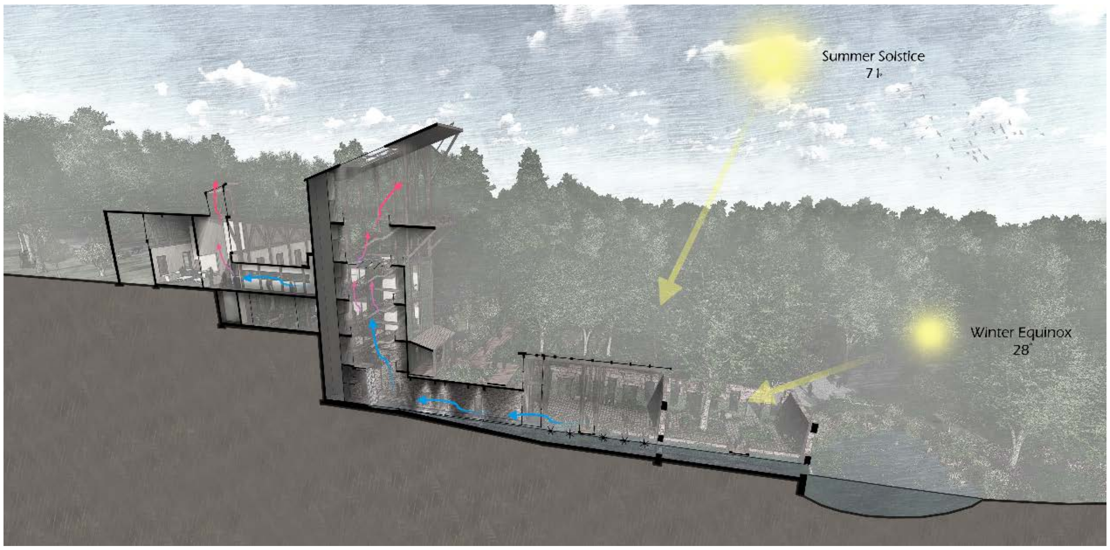


Figure 85: Solar Angles & Air Convection (Source: Author)

The building itself is designed to accommodate a steady flow of air through the process of convection. Operable glazing throughout the building allows for the for less dense, hotter air to flow out of the main tower and hospital tower making way for cooler, denser air to take its place.

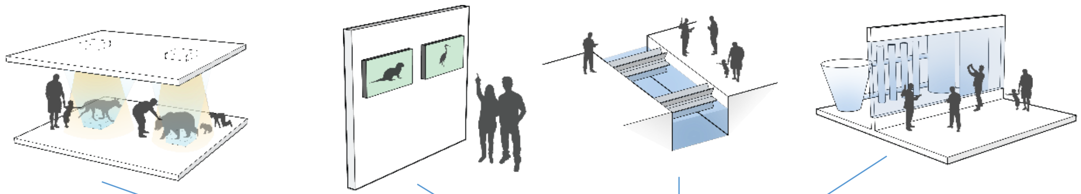
The southeastern orientation of the building allows for winter light to penetrate into the southern facades during the colder seasons when the forest canopy is dormant. During the hotter months, sunlight is both blocked by carefully placed eaves and overhangs and simultaneously filtered by the forest canopy.

Seneca Conservancy Program Walkthrough

Figure 86: Building Section (Source: Author)

Approaching from the Basin, visitors have the opportunity for outdoor education (figure 87) and to learn about the mollusks being grown at the pier (figure 87). Moving into the ruins, visitors can see the micro-hydroelectric turbines powering the filtration process of the building and the basin (figure 88). Once in the Grotto visitors can walk by a room dedicated to the filtration machinery (figure 88). Beyond this are two rooms where technology allows for a connection to wildlife through live streams of animals being treated at the hospital above (figure 88) and through holograms allowing visitors to interact with projections of animals they may not encounter in the wild (figure 88).

Figure 89: Wildlife Streams, Holograms, Micro-Hydro Energy, & H2O Filtration (Source: Author)



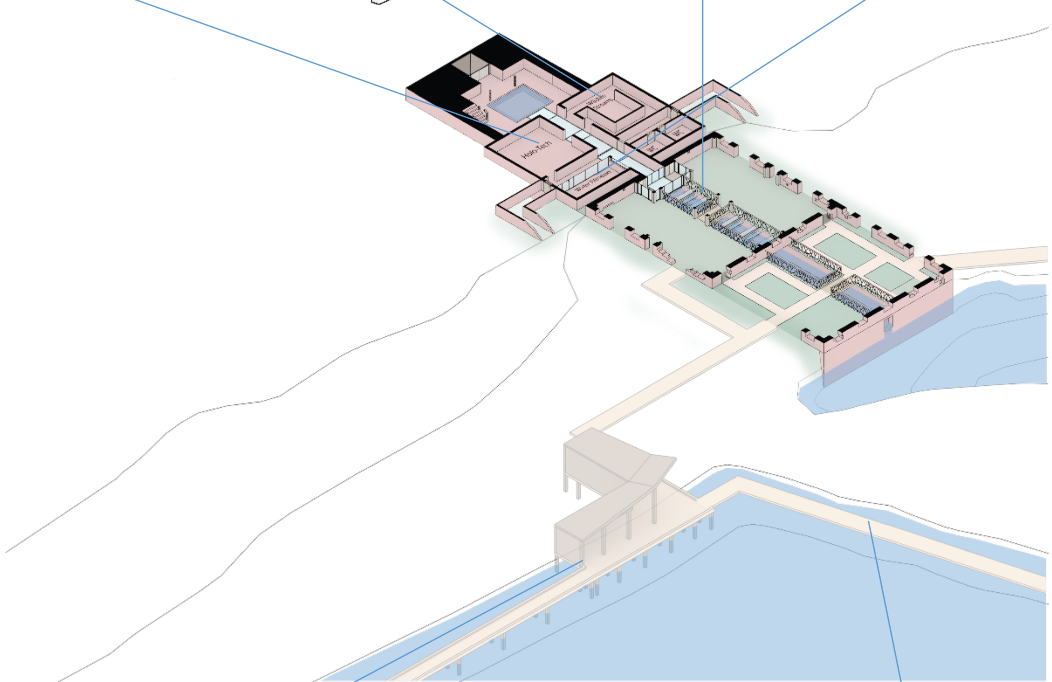


Figure 87: 1st Level - Grotto & Ruin (Source: Author)

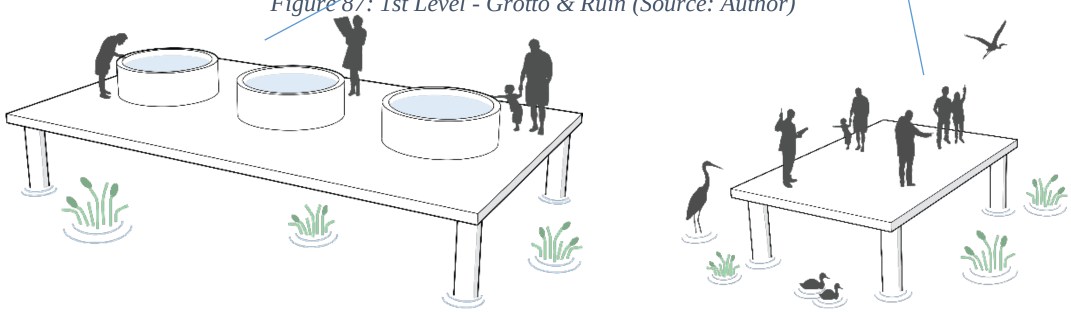


Figure 88: Mollusk Restoration & Outdoor Ed. (Source Author)

The 2nd level of the building features the Potomac Garden (figure 91). Here visitors can learn about the native fauna of the Potomac River Watershed Area and perhaps take this knowledge back to their communities to shift to more sustainable landscaping with plants appropriate for the local climate.

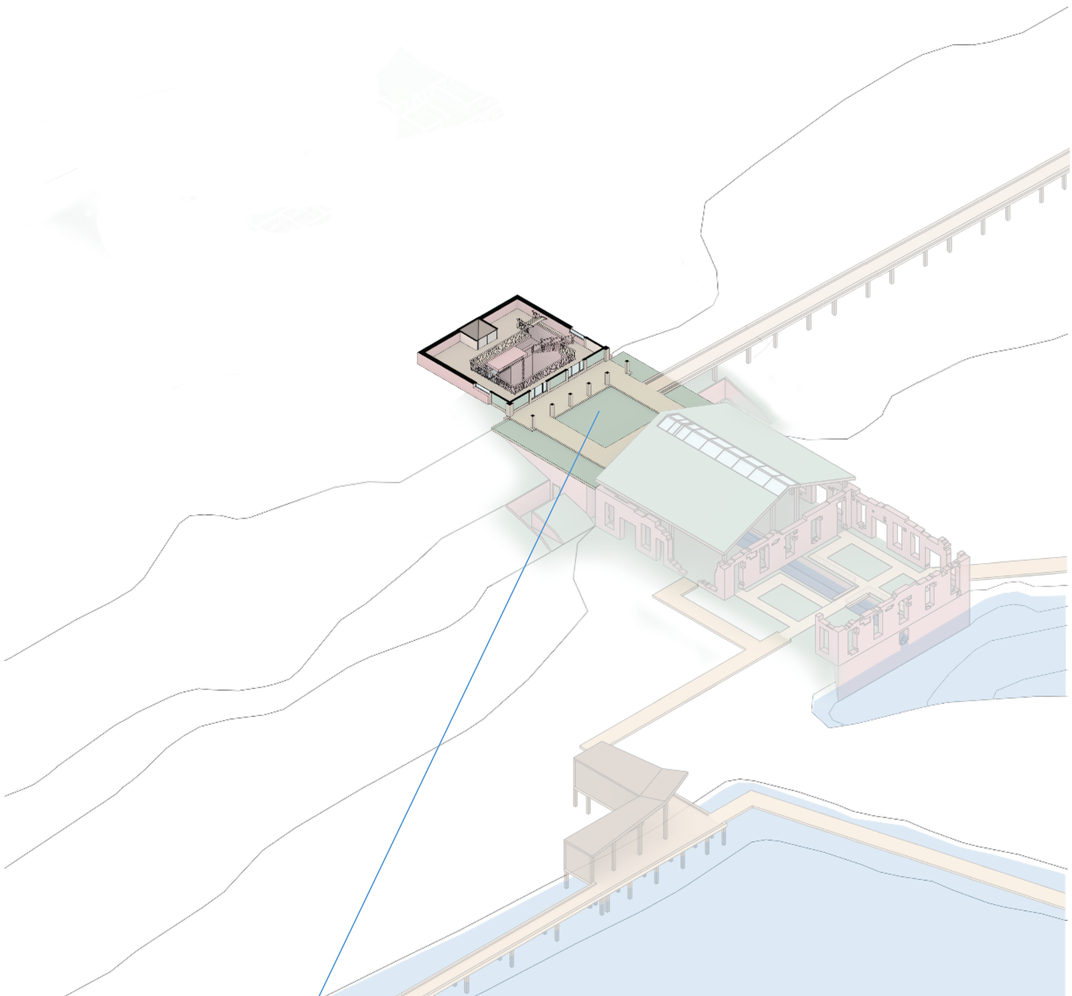


Figure 90: 2nd Level - Potomac Garden (Source: Author)

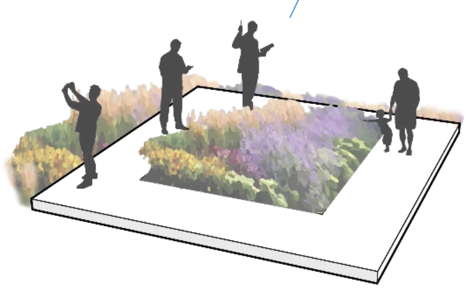


Figure 91: Native Fauna Ed. (Source: Author)

The 3rd level of the building consists of the Research Center. Here, a series of labs (figure 92), open workspaces, and meeting rooms are centered on a central light-well that doubles as a gathering space for workers. Visitors on special tours can loop through this area and see the work being done to create a healthy Potomac River.

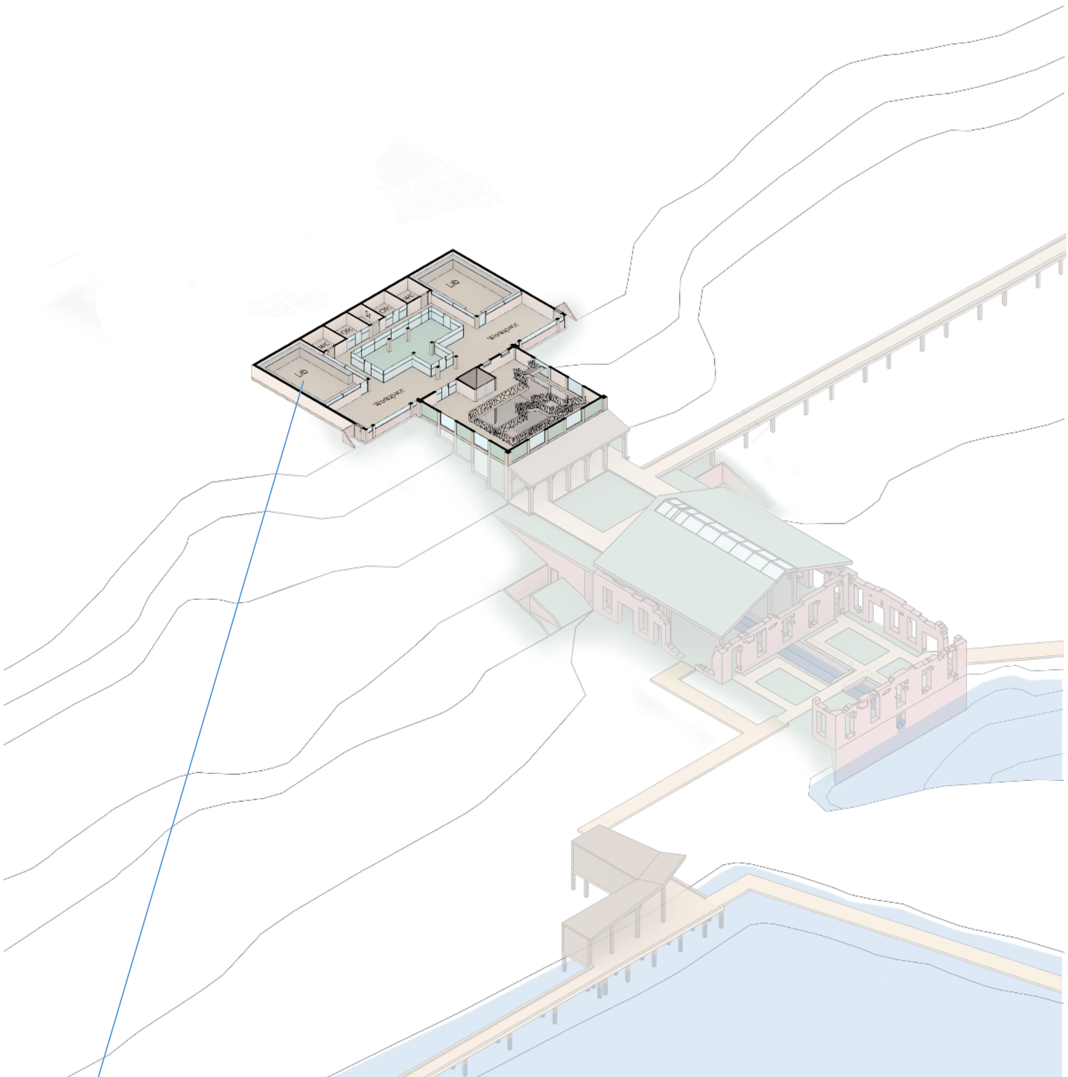


Figure 92: 3rd Level - Research Center (Source: Author)

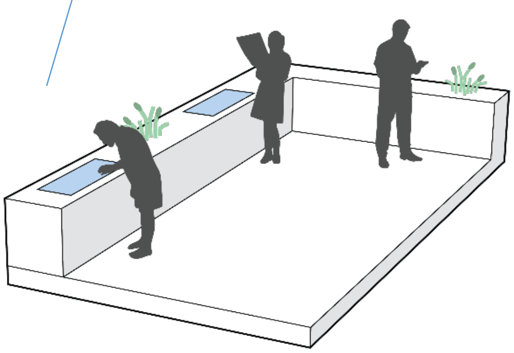


Figure 93: Research & Monitoring (Source: Author)

On the 4th level of the Seneca Conservancy, visitors can find the Wildlife Hospital. Here they can view animals being treated and see the process of food preparation.

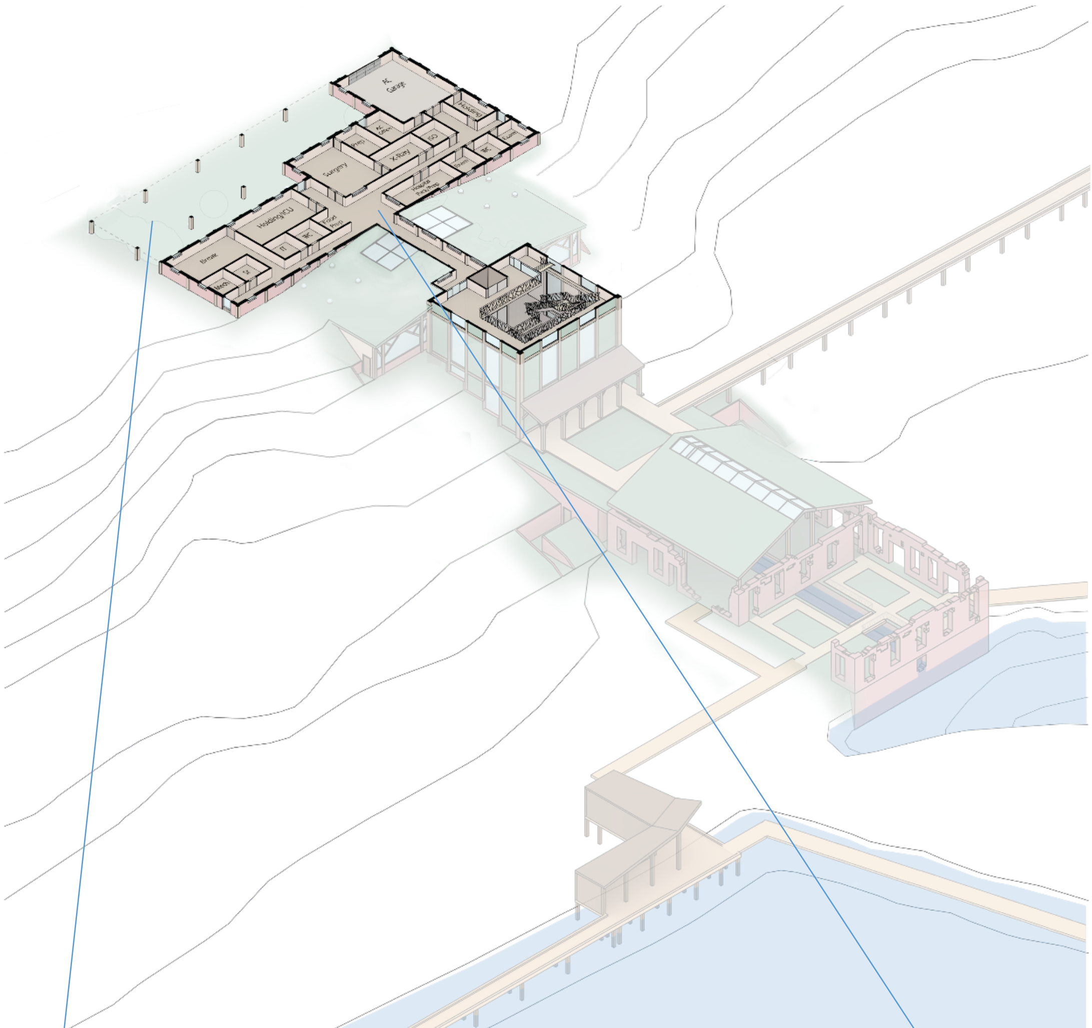


Figure 95: 4th Level - Hospital (Source: Author)

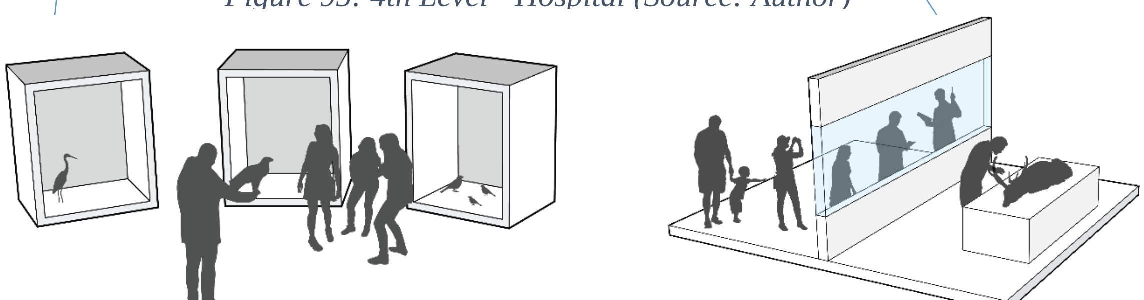


Figure 94: Wildlife Education & Care (Source: Author)

On the 6th level of the building visitors finally reach the Lookout Tower. Located above the forest canopy, views encompass the Basin and Potomac River below, revealing the scale of the local river habitat.

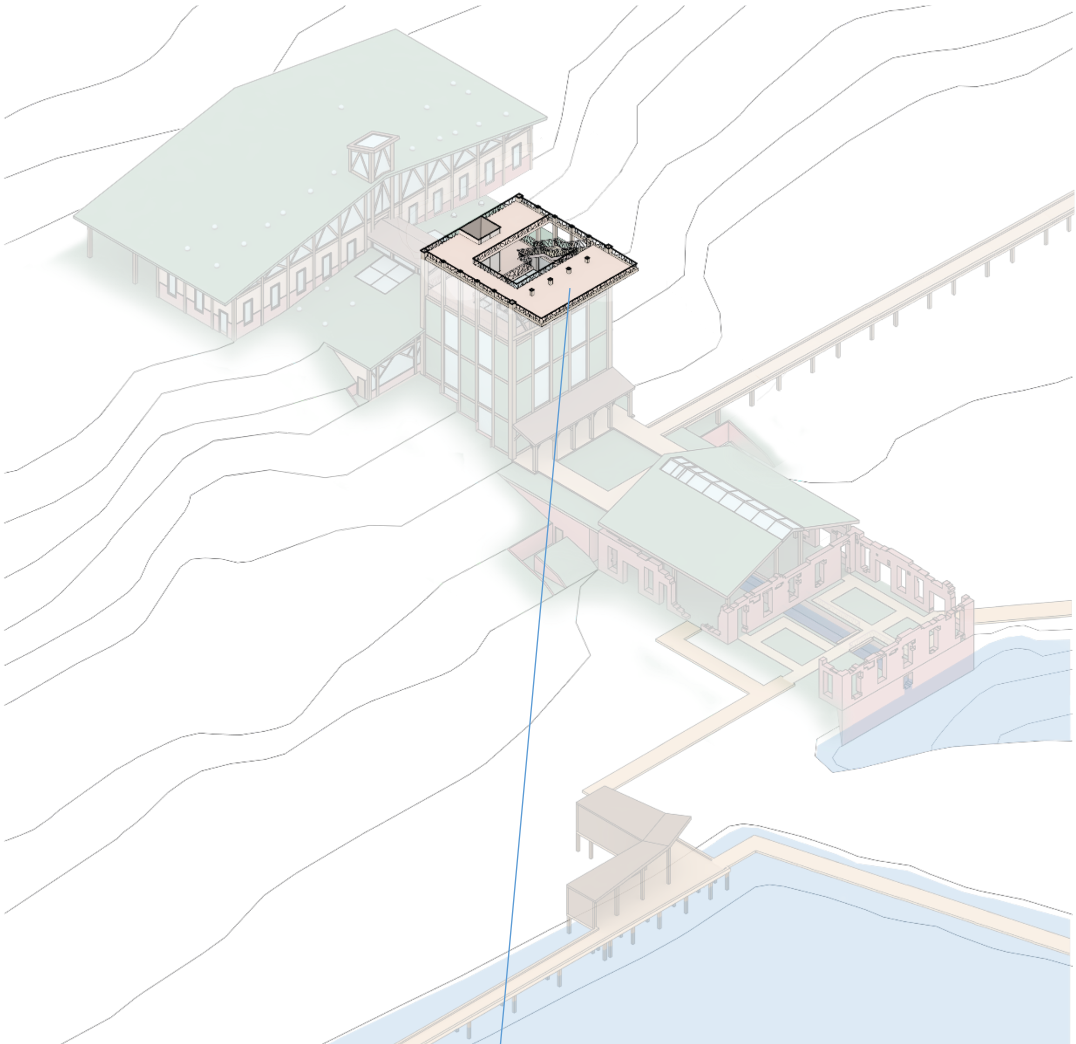


Figure 96: 6th Level - Observation Deck (Source: Author)

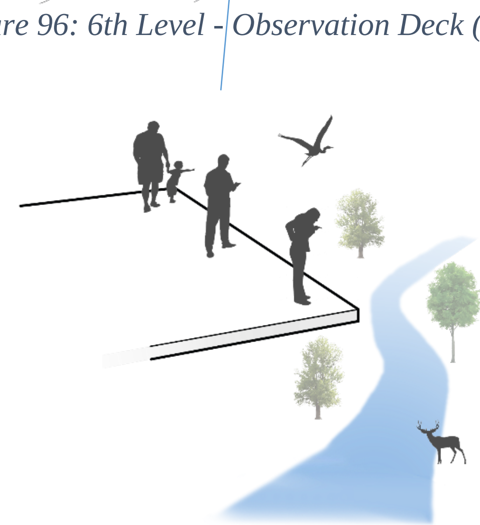


Figure 97: Observation Deck (Source: Author)

Design Conclusion

The design of the Seneca Conservancy seeks to bridge the ever growing gap between our society and the few remaining wild places of planet Earth. Through a series of programming dedicated to the active remediation and study of the Potomac River ecosystem, the effects of pollution on the river can begin to be alleviated, restoring the health of the river not just for humanity but for the wildlife we share it with. Educational aspects of the building and surrounding site are designed to instill a sense of empathy and a deeper connection to the Potomac through a combination of real experience and ecological education. In the end, this design practice seeks to create a basis from which all architecture can begin to engage its environment in such a way that encourages users to enact positive change in their ecosystems.

Figure 98: Approach from C&O (Source: Author)

Figure 99: Ruin Garden (Source: Author)

Figure 100: Ruin Pavilion (Source: Author)

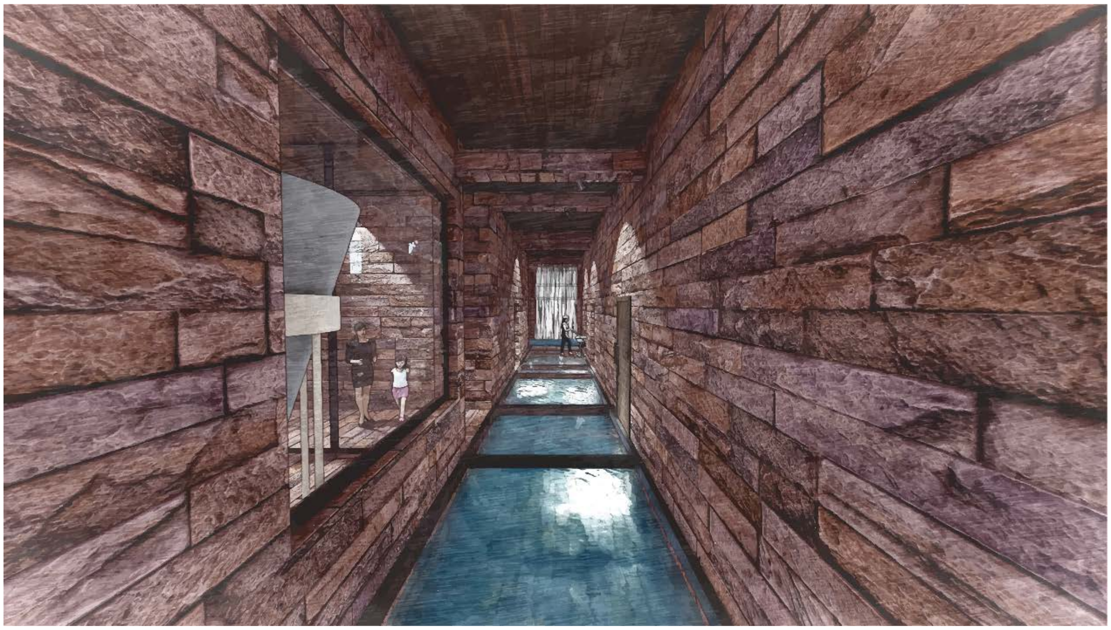


Figure 101: Grotto Hallway (Source: Author)


Figure 102: End of Grotto at Tower Base (Source: Author)

Figure 103: Inside the Tower (Source: Author)

Figure 104: Seneca Conservancy Aerial (Source: Author)

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