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Genesee Waterways Center

Andrea Stylianou
as3952@rit.edu

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GENESEE WATERWAYS CENTER

by

Andrea Stylianou

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COMMITTEE SIGNATURE PAGE

Dennis A. Andrejko, FAIA **Date**

Head, Department of Architecture

Thesis Advisor

Dr. Callie Babbitt **Date**

Associate Professor, Department of Sustainability

Thesis Committee Member

Nana-Yaw Andoh **Date**

Assistant Professor, Department of Architecture

Thesis Committee Member

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ABSTRACT

The Genesee Waterways Center, or GWC, is home to multiple competitive and recreational rowing programs and clubs, but lacks the appropriate facility to properly house and cater to its patrons and visitors. Rowing is an activity that values discipline and teamwork and has evolved into a sport that welcomes all those who are interested in joining. The GWC is located in Rochester, NY's Genesee Valley Park which brings many recreational visitors past or through the boathouse. GWC wants to provide the opportunity for all those interested, but faces three major problems: a disconnection with its surroundings, lack of a facility that can properly accommodate its patrons and visitors, and polluted water with excess algae for those who row.

Clean water is vital to the environmental and social health of a community. This thesis investigates the Genesee Waterways Center boathouse redesign to address the shortcomings of the existing facility to one that can properly accommodate its many programs and members, connect it to its surrounding site, and incorporate a water filtration system to participate in Rochester's educational efforts to clean and restore the Genesee River and weave it back into the fabric of the city. The goal of this re-design is to create a more accessible riverfront that energizes the area, restores the habitat and wildlife, unifies recreational opportunities, and enhances a variety of activities to elevate a sense of community.

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1. Introduction

The Genesee Waterways Center (GWC) is a boathouse located adjacent to the Genesee River in Rochester, NY, which hosts a number of community-based programs. Its mission is to bring people to the water and to provide unique recreational opportunities for the people of Monroe County. GWC is home to several competitive collegiate and high school rowing teams and offers learn-to-row programs, kayak clinics, and summer programs.

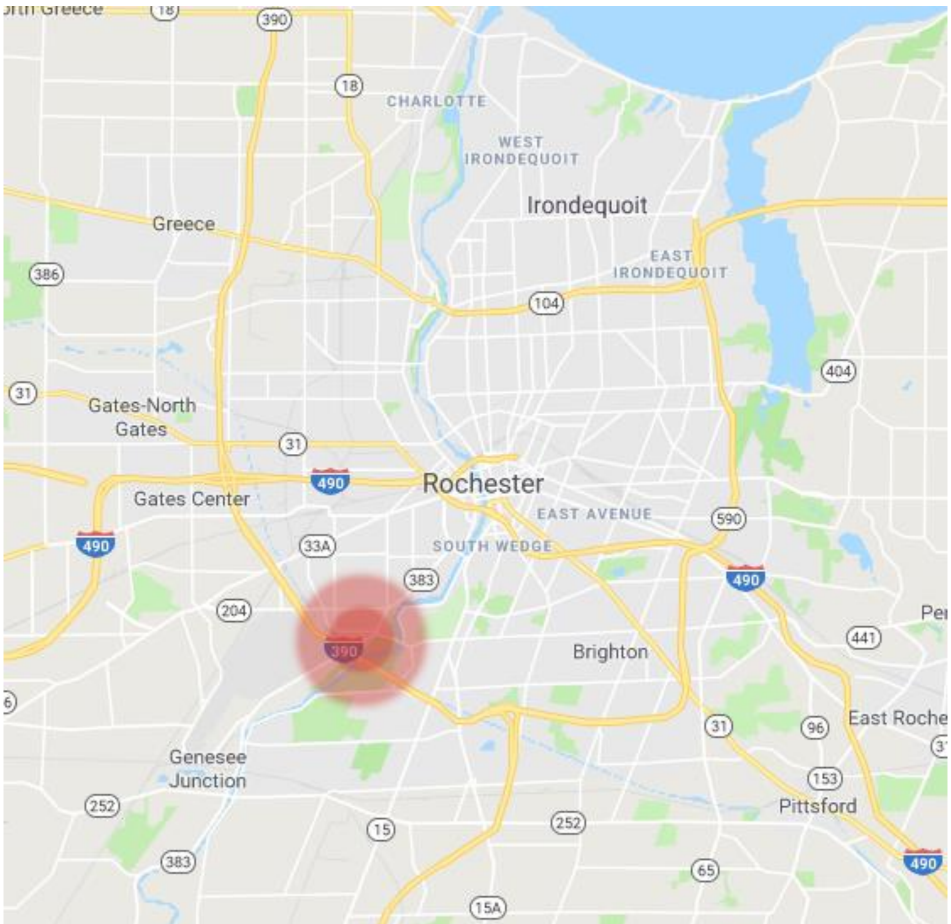

Figure 1: Location of Genesee Waterways Center, source: Google Maps

The GWC's current building was originally designed as an auto repair shop in the late 1970s. Approximately twenty years later, GWC opened its doors to local paddlers and rowers in partnership with the City of Rochester. GWC is located southwest of downtown Rochester, in

Genesee Valley Park, shown in *Figure 1*, along with the Genesee Valley Sports Complex. The two buildings act as entry points to walking and bicycle trails, baseball fields, tennis courts, and waterways.

Figure 2: Genesee Waterways Center, source: author

Shortly after GWC's opening in 1996, there were plans of a re-design to better accommodate its new residents. The new plans fell through, however, leaving a continuously growing program confined to the same space it opened up with twenty-one years ago, as seen in *Figure 2*.

Although GWC is meant to act as an entry point to many recreational opportunities, it has become a passing site instead of a destination. Unless visitors are specifically accessing the river, there is no other interaction with the water. This boathouse's role remains as a storage facility, taking away from GWC's mission of providing a community center.

Another problem GWC and its members face everyday is the current polluted state of the river. The Genesee River, a historically significant river in Rochester, is infamous due to contamination from industry use and agricultural run-off.[1] Much of this pollution has since ceased, but today's biggest concerns for the health of the river are sediment and phosphorus (P) pollution, which contribute to excess algae and bacteria. Rowers are exposed to the bacteria, leading to a number of health risks; increased sedimentation and eutrophication reduces water depth; and enhanced vegetative growth can block navigational and recreational use.[2]

In recent years, the city of Rochester has taken a number of steps towards building an environmentally healthy city. The city has a wide variety of green initiative programs that allow every type of audience to participate and to benefit from them. Few of the many green initiative programs include the Brownfield Cleanup Project that has taken place at various locations, the Clean Sweep program where thousands of volunteers collected thousands of tons of debris, recycling programs, and a handbook written by the city that guides developers, institutions, homeowners, and tenants through practical sustainable solutions. Local colleges like Rochester Institute of Technology and University of Rochester have their own programs to help contribute to Rochester's efforts. The two universities aim to be leaders in promoting sustainability through teaching, practicing, researching, and collaborating with individuals, organizations, government agencies, etc. to further educate others about the significance of sustainability.

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[1] "The Genesee River." City of Rochester. http://www.cityofrochester.gov/geneseeriver/.

[2] Makarewicz, Joseph C. and Nowak, Matthew J., "Genesee River Monroe County, New York" (2010). *Technical Reports*. 37. https://digitalcommons.brockport.edu/tech_rep/37

2. Problem Statement

The purpose of this thesis design is to propose a recreational facility that enhances activity through a more efficient and accommodating layout, acts as a water treatment station, and creates a sense of community. The Genesee Waterways Center and its surrounding site currently face the following social and environmental issues:

- Lack of facility, space, and equipment for competitive and recreational users.
- Contaminated river
- Lack of healthy human and water interaction

3. Project Mission

This thesis focuses on the requirements of a modern-day boathouse that integrates a sustainable design solution to lower the river's phosphorus levels. I am studying how the Genesee Waterways Center boathouse can filter the Genesee River of its phosphorus pollution because I want to find out how to integrate the GWC boathouse into the fabric of the city of Rochester by restoring its historic rivers and enhancing clean water that is vital to the environmental and social health of the city's community. "The built environment influences social behavior, promotes activity in and around the proposed architecture, and set a new standard for future generations, and athletic design."[3] The goal of this re-design is to create a more accessible riverfront that will work towards energizing the area, restoring the habitat and wildlife, and bringing together the recreationally-minded community.

[3] LaChance, Allison Marie, "Watt Community Rowing Center High-Performance Athletes Yield High-Performance Architecture" (2014). Thesis. Rochester Institute of Technology. Accessed from http://scholarworks.rit.edu/theses/8418

4. Background

4.1 Rowing

Though competitive rowing is one of the oldest and most traditional sports, it originally began as a means of transportation prevailing in ancient Egypt and in the Roman Empire.[4] Over time, the act of rowing transitioned into a competitive act on the European and Middle Eastern waterways, then became recreational, and was eventually introduced to the world of education. The sport spread to elite preparatory schools and universities all over the world. According to a former University of Maryland graduate student who focused her thesis on the Middle Branch Boathouse in Maryland, "Today, the sport is once again at a point of transition," as more rowing programs are focusing on their surrounding communities to "expose those to rowing who would not normally have the chance."[5] The sport of rowing, "also referred to as **crew**, is both a club and competitive sport that continuously stretches the physical and mental limits of athletes both on and off the water," teaching its rowers the value of discipline, teamwork, and community.[3] This sport is one that is a valuable community resource for health and community, making it a great addition to the fabric of Rochester's community.[6] Along with the many physical benefits, the social and personal values that are taught through rowing, "it instills notions of persistence and self-efficacy in both youth and adults."[6] Participants are also allowed to "experience their environment in a new way, fostering an appreciation of natural resources on the water."[6] Although "each team is unique in their coaching, rowing technique, and goals that encourages

[4] Britannica, The Editors of Encyclopaedia. "Rowing." Encyclopædia Britannica. August 15, 2018. https://www.britannica.com/topic/rowing-boat-propulsion-and-sport.

[5] Pless, Katlin Meredith. 2012. "The Middle Branch Boathouse: [Re]Bridging Water, Community & Sport." Order No. 1535105, University of Maryland, College Park. http://search.proquest.com.ezproxy.rit.edu/docview/1324128484?accountid=108.

[6] "Why Rowing?" Why Rowing. 2014 http://girowing.com/about/why_rowing.php#.Wj61cDKZOu4

success and teamwork," every crew has a boathouse that assists in supporting the program.[3]

This sport is one that requires a significant amount of equipment and storage for both indoor and outdoor seasons. **Rowing shells**, a narrow and long rowing boat designed for racing, vary in size, ranging in overall lengths from 27 feet to over 60 feet long, as they differ in the amount of rowers they carry, shown in Figure *3*.

Figure 3: Rowing Shell, source: author

The smallest shell holds one rower, a single, and the largest holds eight rowers and a coxswain, the steersman of the boat. In addition to the racing shells, each boat has a number of components that come along with it, such as oars, ranging from 9 to 12 feet in length, seats, footboards, and outriggers, which hold the oars into place. (Figure *4*) Throughout the outdoor season, a motorboat is always required to be on the water alongside the shells during practices and races, for coaches and race officials to provide instructions, but most importantly for safety purposes. During the winter season, all equipment, including shells and their components and all motorboats are stored away inside the boathouse. However, the rowing season does not end there. The winter season, December through March, rowing becomes more of an individual sport and rowers practice and compete using indoor rowing machines. Only one rower can use a machine at a time, requiring each crew to have multiple machines and a large enough space to keep them in, along with other large training equipment.

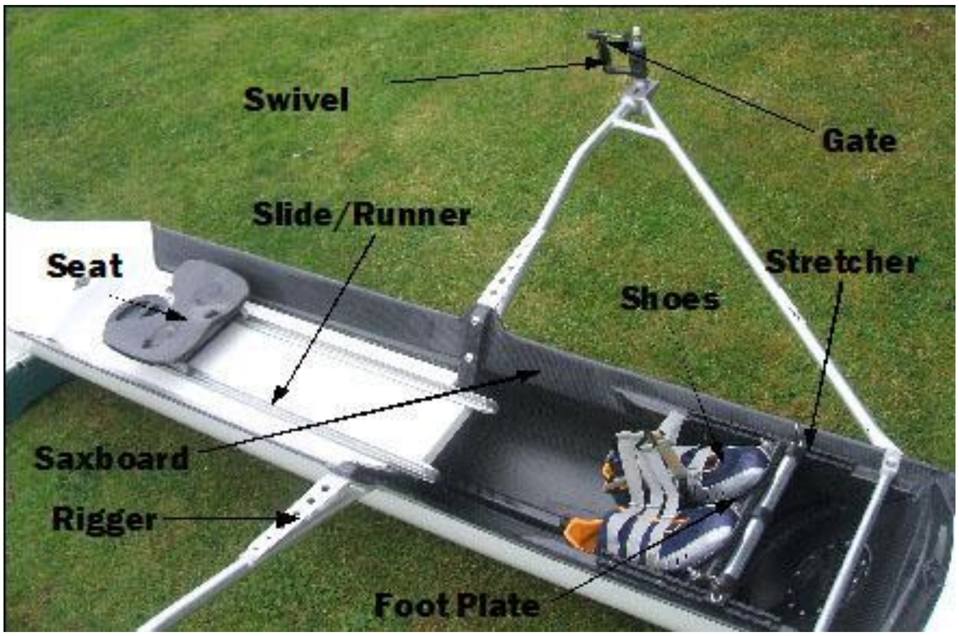

Figure 4: Inside a Rowing Boat, source: http://www2.gvsu.edu/ciunganc/Index.html

4.2 The Boathouse

The boathouse plays a significant role in the sport of rowing, especially for a community center that offers several recreational water sports to its visitors. While boathouses primarily existed as a space for storing equipment, its role has greatly evolved along with many other recreational facilities and sports arenas. Sports have changed greatly in the way they are viewed by spectators. "The boathouse no longer exists as simply a storage facility from which to view the water, but transforms the historical typology of the boathouse to incorporate both a place for viewing and being viewed."[5] As the sport and its spectators have evolved in the way they interact with each other, so must its home. The boathouse has a number of purposes, making it primarily a community center today. It is a space for teams to gather, socialize, and transition from land to water and back. It is also a place for recreational visitors to engage. Today, boathouses are a "staging plaza to prepare and receive boats," and a space for indoor training during the indoor season of rowing.[5] A variety of events happen in and around a boathouse throughout the year, making it a destination all year long for administrative work, training, preparation, regattas, or a series of racing events using rowed boats, summer camps, clinics, and social events.

This project envisions that The Genesee Waterways Center boathouse will transition from a storage facility with many disconnected programs that visitors stumble upon, to an open and inviting destination that reintroduces a connection between land and water for the community of Rochester. This boathouse will act as a connection between the different recreational communities, bringing together all types of people, and reconnecting people with the outdoors.[5] "The boathouse must address the relationship of the body to the waterfront, both through the movements of the sport, and through the relationship between spectator and sport.[5]

4.3 Genesee River Pollution

Since the 1950s, phosphorus levels have significantly increased in the Genesee River due to wastewater treatment plant discharges, runoff, and erosion after rainfall. While a limited amount of phosphorus is necessary for plant growth, an excessive amount can cause a dangerous form of pollution. The problem with too much sediment and phosphorus is that they are associated with coliform bacteria and with the speeding up of the process of eutrophication.

Eutrophication is the excessive richness of algae, which begins a cycle in rivers that becomes difficult for the ecosystem to escape. An excess in algae requires more oxygen. The growth of algae will continue until either oxygen or phosphorus becomes limited. As algae continues to grow, light is unable to penetrate below the water surface. As the amount of oxygen decreases, all oxygen-requiring organisms in the ecosystem are affected, causing deaths of fish species and other aquatic organisms. If the rate of deaths increases, then more oxygen is necessary for decomposition of fish species and other aquatic organisms and they are replaced by undesirable species. However, since oxygen has become limited, the system of the river becomes non-oxygenated and more changes occur, producing unpleasant odors and color changes. Increased sedimentation with eutrophication will also reduce water depths, enhance vegetative growth, blocking navigational waterways and impairing recreational use. Soil erosion is a major contributor to sped-up eutrophication process as bank erosion during floods can transport a lot of phosphorus from river banks and adjacent land to a stream of water. "Phosphorus also tends to attach to soil particles and thus into surface water bodies from runoff."[7]

NYSDEC's river guideline recommends phosphorus levels to be at 20 µg P/L (micro grams of phosphorus per liter). However, Genesee River's phosphorus levels were found to be at an average of 78.9 ± 14.9 µg P/L during a 2003-2009 report.[8]

Monroe County treats the Genesee River's wastewater through eight treatment facilities using a number of ways to purify wastewater from homes, businesses, and factories and send it back to Lake Ontario. Two of the facilities, VanLare and Northwest Quadrant are biological

[7] Perlman, Howard. "Phosphorus and Water." Phosphorus and water: The USGS Water Science School. https://water.usgs.gov/edu/phosphorus.html.

[8] Makarewicz, Joseph C. and Nowak, Matthew J., "Genesee River Monroe County, New York" (2010). *Technical Reports*. 37. https://digitalcommons.brockport.edu/tech_rep/37

treatment plants and use the same cleansing processes that occur naturally in lakes and rivers.[9] "Both facilities use chemical treatment, in the form of iron salts, to remove the nutrient phosphorus by precipitation."[9]

4.4 Genesee River Clean-Up Efforts

The restoration of the Genesee River has become a priority for the city of Rochester. Other than the City's efforts, several non-profit organizations have developed within the community to assist reaching the city's goal. Both the Genesee River Wilds and Genesee RiverWatch were created with the single goal of restoring and protecting the Genesee River.

Genesee River Wilds was formed in 2008 and set out to accomplish their goal of "improving the river's health, protecting it from future environmental threats, and enhancing its recreational potential" by "combining conservation, recreation, and business."[10] This non-profit organization is determined to make ecological improvements. Its members have been doing so by "adding forested riparian buffers along the upper Genesee River and its watershed that offer water conservation, wildlife habitat, and natural flood control while accommodating existing development."[10] In addition to environmental sustainability, this non-profit organization's purpose is to make social improvements as well. Their hope is that by adding parks, expanding bicycle and running trails, improving existing facilities and adding new canoe and kayak launches along the river, this will assist in increasing public interest and promoting a healthy interaction with the Genesee.

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[9] "Wastewater: Collection and Treatment by Monroe County-Operated Facilities." Monroe County Department of Environmental Services.
http://www2.monroecounty.gov/files/DES/Wastewater%20-%20Collection%20and%20Treatment%20by%20Monroe%20County-Operated%20Facilites.pdf
[10] "Genesee River Wilds Project." Genesee River Wilds Project. http://www.geneseeriverwilds.org/wp/.

Genesee RiverWatch has similar goals to Genesee River Wilds, to restore water quality as well as promote active involvement with the river. Their approach to restoring water quality differs in that they monitor the water quality monthly by gathering information and data and have created a network of “eyes on the water” to report pollution or improper land uses on waterways.

5. Literature Review

5.1 Boathouse Designs

Today, cities have become vehicle-dominant, leaving little space for the pedestrians and their recreational activities. This has had a great social and environmental impact on our surroundings. The demand for pedestrian-friendly cities is leading to an increase in the development of public outdoor spaces and their integration with the rest of the city. The articles below discuss the value of natural landscapes and access to natural resources within the city and why their restoration is necessary. Boathouses have evolved to become part of the natural landscape within and the articles below demonstrate how they also act as tools within public spaces.

5.1.1 Community Re-development & its Effect on the Waterfront

Brian Beresford wrote his thesis, “Thunderbird boathouse: a community development Fraser River-Middle Arm, City Centre Richmond,” to explore how the re-development of Richmond, British Columbia, would affect the riverfront. Beresford recognizes that with the way the city is redeveloping, the waterfront would gain more popularity and the boathouse community would need to adjust to the new improvements. Beresford uses his thesis to look into potential ways of developing the waterfront to “connect it to its existing and future landscape.”[11] The objectives of the thesis are outlined at the start to identify each goal and how they will be implemented. Beresford also identifies the city’s vision of the riverfront with a set of guidelines to inform his design decisions. After a site, city, and zoning analysis, Beresford presents three

[11] Beresford, Brian I. "Thunderbird boathouse: a community development Fraser River-Middle Arm, city centre Richmond." (2004).

design options and explains each option with its advantages and disadvantages. Although there is an existing boathouse simultaneously acting as a community facility, Beresford further develops the Thunderbird Boathouse to grow with its future landscape as well as its existing. Beresford concludes that this riverfront will become a "central social and cultural axis" in this urban environment, and emphasizes how the "culture, character, and sustainability of this region can continue into the future" if developed properly.[11]

5.1.2 Concerns About Urban Parks in Sustainable Cities

Anna Chiesura's article, "The role of urban parks for the sustainable city," discusses the many efforts that are made internationally to preserve the natural environment. Although green spaces are often limited in urban areas, Chiesura examines how natural areas provide positive services, including social and psychological. Natural areas that are well-preserved throughout cities is crucial for the well-being of its occupants. Research shows that natural elements are able to provide a reduction in stress levels and a sense of peacefulness, as well as a number of social benefits, "promoting the development of social ties and increasing social integration and interaction."[12]

The author's paper attempts to define what a sustainable city is by explaining that each city has its own criteria of what should be considered sustainable. Rather than delving into each environmental issue that can and should be solved, Chiesura focuses on the social and mental health of people and their general necessity of having clean, natural spaces to make their "city livable, pleasant, and attractive."[12] Chiesura interviewed a wide variety of people in the most popular park in Amsterdam, Vondelpark. The survey "addressed a broad range of issues,

[12] Chiesura, Anna. "The role of urban parks for the sustainable city." *Landscape and urban planning* 68, no. 1 (2004): 129-138.

ranging from motives for nature, nature's images, perception of environmental functions, environmental attitudes, and willingness-to-pay questions."[12] The results of this survey shows that natural spaces do in fact provide positive benefits to people, indicating that they "fulfill important immaterial and non-consumptive human needs."[12] However, Chiesura points out that although her results generally expressed people's need for green spaces, cities' natural spaces should have more diversity, such as vegetation and water for those with different interests. Different ages and perceptions of living environments affect "differences in reasons, activities, and feelings experienced in parks."[12]

5.1.3 Boathouse & Water Restoration Planning & Design Process

A planning study of Anacostia River's Boathouse Row has been developed by the District of Colombia Office of the Deputy Mayor for Planning and Economic Development and the Office of Planning in 2009. This land was transferred from the U.S. Government to the District of Colombia in 2008 as part of the Anacostia Waterfront Initiative. This planning study explains the overall goals of the project, its long-term vision, and gives a thorough explanation of the project's context, planning process, existing conditions, and the context of the site. Additionally, the study outlines the habitat areas on site, challenges and opportunities throughout the site, and the site's surrounding community. This full redevelopment project makes sure that environmental design techniques are used throughout the project to only improve the site by protecting it. Guiding and design principles are listed as a way to highlight the key users and design in a way that fully accommodates to them as well as welcome unexpected visitors. The overall goal of this project is to have "the site and its users contribute positively to the restoration of water recreation."[13] Two concepts are explored and discussed. "Concept 1 proposes that most of the existing uses remain on site and are expanded," which revolves around the issues of dredging, realigning, and widening the channel.[13] The second concept is focused on not dredging the Anacostia River, meaning that "motorized boat facilities may not be viable" in the long run.[13] In this case, these uses would need to be relocated and new structures would need to be built to support these uses.[13] The results of this planning study shows a more in depth plan of how each guiding principle will be executed, but does not decide on one specific concept. It is concluded that either concept would work as short-term solutions, but some overlap between the two would take place to reach long-term solutions.

5.1.4 Evolution of Boathouses

Jeffrey D. Peterson describes in his Foreword, "Boathouses: Buildings for Re-creation," the evolution of boathouses, both their purpose and general design, from 19th Century urban life to present day. Since the 19th century, boathouses became more prominent as industrialization grew, allowing more time for leisure as there was less physical labor. Boathouses were originally simple sheds exclusively used as storage spaces, but slowly transitioned into social spaces as collegiate rowing grew more popular in England and the U.S. in 1829. Rowing represented a moral ideal that the commission felt should be encouraged and required the architecture to reflect that.[14] "Strict spacing, orientation to the water, and dimensional requirements were enforced" over the coming years, but many variations were seen throughout the flourishment of boathouse construction, as it became a time of architectural competition amongst the clubs.[14] Traditionally, boathouses are designed with specific architectural features

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[13] "Boathouse Row Planning Study." District of the District of Columbia Office of Planning. October 2010. https://planning.dc.gov/publication/boathouse-row-planning-study-main-page.
[14] Peterson, Jeffrey D. "Boathouses: Buildings for Re-creation."

such as distinct rooflines, a gable roof, arched openings, and industrial motifs, among many other characteristics. Peterson gives many examples of boathouses that went against the traditional design. Although several of the mentioned boathouses were designed with flat roofs, these modern boathouses were still designed with bold and dramatic features, bringing a refreshing take on the design of boathouses. A recurring theme that is brought up throughout his foreword, is that boathouses have always brought us back or connected us to nature. Rowing was developed as a sport because it was used as a means of physical and spiritual escape from cities in the 19th century.[14] This temporary escape from urban life lead people to visit rural boathouses as part of recreational vacations.[14] Today, the construction of modern day boathouses brings an "awareness to the possible impacts of building on the water's edge," giving us a "greater responsibility to do it well."[14] Peterson states that rowing creates a new group of people "to whom the well-being of water becomes important," creating a new kind of connection to the waterfront, where the community cares about its waterfront.[14]

5.1.5 Public Spaces as a Revitalization Tool

"Planning the City Against Barriers. Enhancing the Role of Public Spaces," by Aleksandra Sas-Bojarska and Magdalena Rembeza, studies several issues brought on by technical barriers often found in cities, such as roads, railways, and infrastructures. A few of the many threats that are brought to cities include the destruction of the complexity of urban fabric, functional disadvantages, and environmental and landscape threats.[15] Sas-Bojarska and Rembeza argue that the city should be designed as one coherent system and unify public spaces with the urban fabric. This system can allow the city to become one linked network that

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[15] Sas-Bojarska, Aleksandra, and Magdalena Rembeza. "Planning the City Against Barriers. Enhancing the Role of Public Spaces." *Procedia engineering* 161 (2016): 1556-1562.

provides “opportunities for the movement of people and wildlife between them.”[15] Over time, many cities have become increasingly vehicle-dominant, where this article believes it should be more pedestrian-dominant. A few strategies are suggested to decrease any division amongst cities, including artistic strategies. Artistic strategies “give new perspective connected with stimulating community involvement,” “can be used as effective tools for the revitalization of spaces” through public participation, and “can support the sustainable road planning.”[15]

Two case studies were done examining the Charles River Esplanade in Boston, Massachusetts and Reagan’s Park in Gdansk, Poland. The two case studies show both sides, one where Boston’s public spaces are successfully integrated with its city, and how Reagan’s Park currently faces a large threat as a large road system is being planned. The Charles River Esplanade has many bridges, walkways, and river-park that ties the city’s every day walkways and cycling paths with the riverfront. The new roadway system that is being planned around Reagan’s Park will act as a barrier to a once open and accessible space also causing environmental, landscape, and social problems. Overall, this article emphasizes the importance of one, cohesive city with accessible public spaces that functions harmoniously.

5.1.6 Athletic Facilities as Gateway to Sustainability

Sports arenas and athletic facilities go through extreme amounts of water and energy usage, “even when they’re unused.”[16] “In the past decade, gyms and arenas have been recognized as sustainable gateway tools to raise awareness about the importance of sustainability” and Teal demonstrates that there is an abundance of opportunities for sustainable sports-related facilities.[16] The U.S. Green Building Council (USGBC) and Green Sports Alliance

[16] Teal, Derrick. “Stadiums Compete for Sustainability: Every Building, Even Stadiums, Can Be Made More Environmentally Friendly; Sometimes All it Takes is a Little Bit of Inspiration.”*Environmental Design & Construction.*October 1, 2013.

have collaborated with each other to show stadiums and athletic facilities that there are a number of sustainable options for them.

5.1.7 Water Restoration Through the Use of Architecture

Justin Agustin Manongdo used his thesis to bring awareness to the value of water and find a way to use architecture as a tool for collecting, protecting and respecting water. Manongdo's chosen site is the Ala Wai Canal in Waikiki, Hawaii, for his boathouse design, as Hawaii is known "to protect the land that which feeds us, not just physically but emotionally and spiritually."[17] These three words, "collect, protect, and respect," is the main theme throughout Manongdo's thesis. Manongdo begins by explaining the current availability of freshwater, where it is found or transported from, and how much climate change is affecting that. Throughout his thesis, Hawaii's value of freshwater is frequently discussed for health, personal hygiene, and agriculture, as well as how vital of a resource it is throughout the world.

Manongdo analyzed how humans connect water and landscape through the utilization of architecture by demonstrating a variety of strategies to collect, protect, and respect water, sun, and wind. He applied his frame to describe how water, sun, and wind are to be treated in the process of collecting, protecting, and respecting. Manongdo discusses "reactivating unused waterfronts or opportunity spaces" by studying waterfront precedents to apply to his own design and learn how it would bring people to these spaces.[17] He studied waterfronts and three types of architecture: resilient, tropical, and boathouse architecture. Each had strategies that were applied to Manongdo's boathouse design including strategies for Collect, Protect, and Respect. Five different strategies, such as bioswales, sidewalk stormwater management, bioretention pond, roof

[17] Manongdo, Justin Agustin. "Sustainable Island Water Culture: Collect, Protect, Respect." (2016).

water collection, and terracing are defined and explained in how they can "allow architecture to have water present."[17]

Bioswales, shown in Figure *5*, slow, collect, and purify polluted water runoff. As water goes through vegetation and soil, pollutants are captured, and water returns to its source.

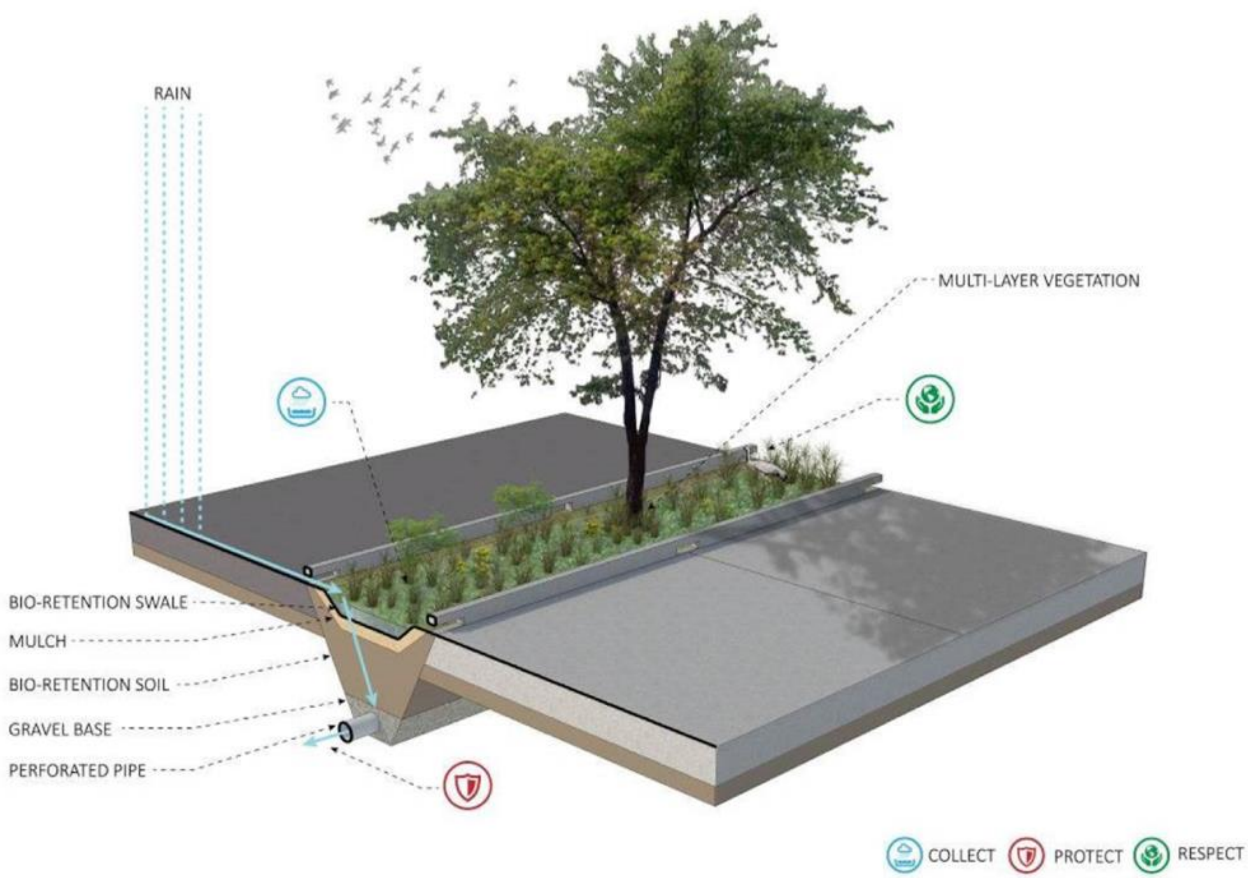

Figure 5: Bioswale, source: Jason Manongdo

The bioretention Pond, shown in Figure *6,* is a system that collects both rainwater and surface runoffs. Its purpose is to slow the process of water returning to its source but purifies the water before doing so.[17]

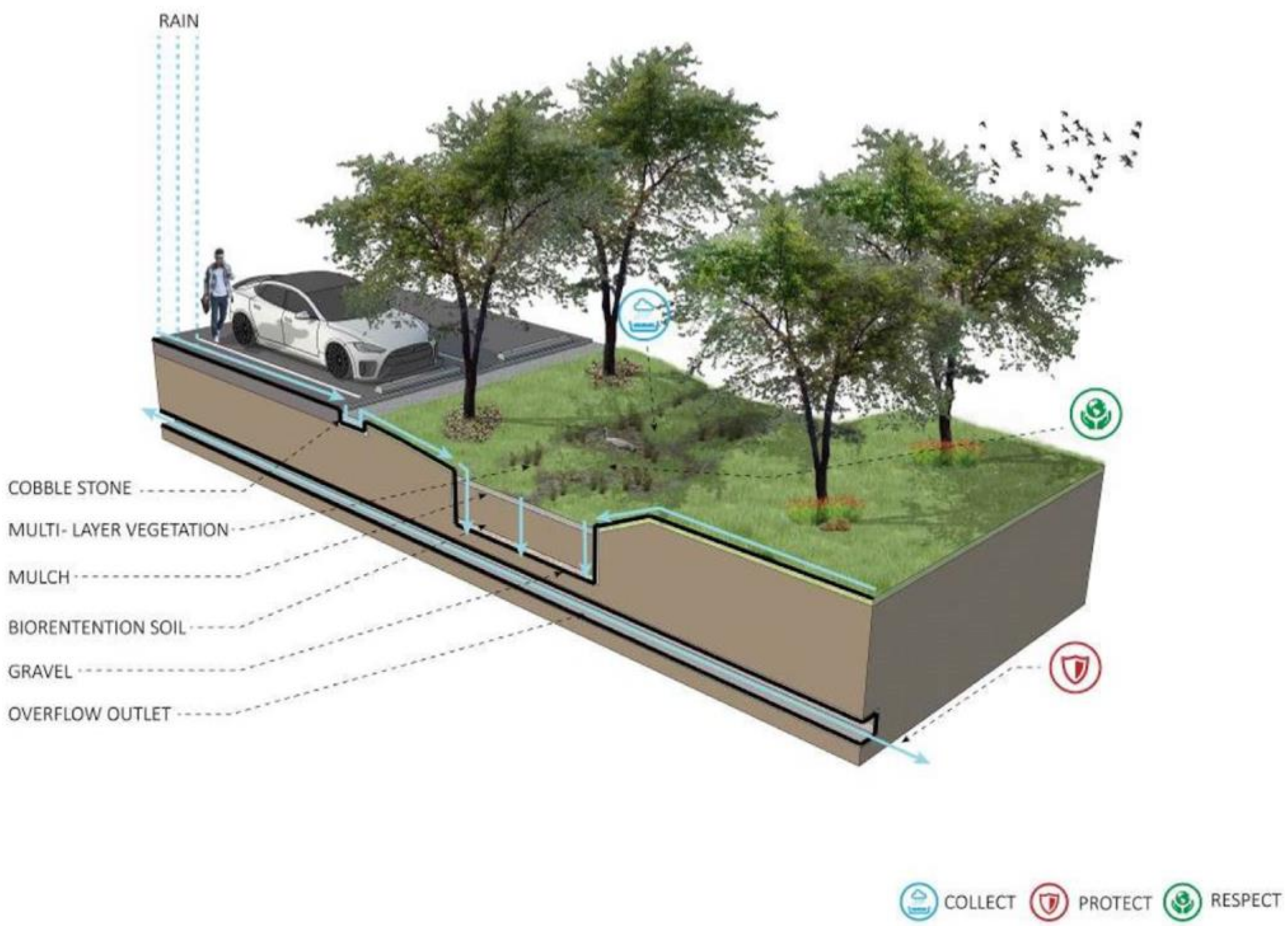

Figure 6: Bioretention pond, source: Jason Manongdo

Terracing is a Hawaiian strategy, shown in Figure *7*, that "diverts water and slows, purifies, and irrigates the plants within the system."[17]

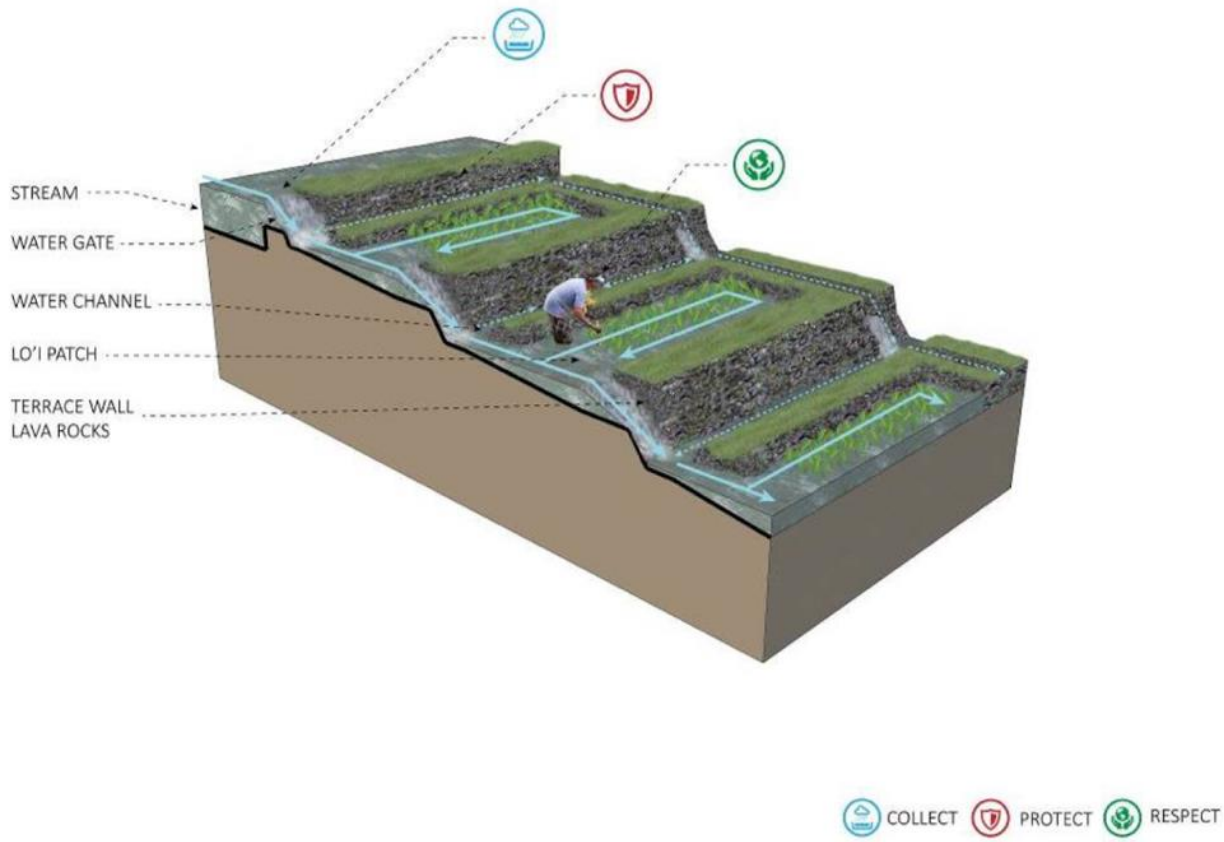

Figure 7: Terracing, source: Jason Manongdo

5.2 Water Restoration

The objective is to discuss the health of the water that surrounds boathouses and the many ways to filter phosphorus from water. To provide some background, it is important to understand the importance of healthy water ecosystems and the many methods that make water restoration possible. Though there are numerous technologies and techniques that filter phosphorus from water, each method requires its own particular materials, amount of space, and maintenance. Various methods of water purification have been researched including artificial filtration systems, small and large-scale systems, natural systems, and processes that mimic nature. In addition to learning about the many types of water filtration and comparing and contrasting which technology type is the best for its purpose, monitoring and evaluating water treatment systems allows us to fully understand how much of an influence these different systems can make, and which is the best fit for the Genesee River and its issues with phosphorus pollution.

5.2.1 Selecting the Appropriate Wastewater Treatment Technology

In a Water Demand Management Workshop, Harald Schölzel and Rhonda Bower have written a report with all the proper criteria that explains how a small-scale wastewater treatment technology should be chosen. Their list of criteria consists of: effluent quality, water supply, land space, maintenance and operation, cost, electrical requirement, and topography. In addition to summarizing why each of these criteria are important in choosing a technology, Schölzel and Bower have created a technology rating sheet that compares each technology. The sheet is organized by primary, secondary, tertiary, and advanced treatment categories to compare each technology equally, as demonstrated in *Figure 8*. The technologies discussed in this report are mostly designed for sewage treatment, but the process of logically selecting the best sustainable water treatment technology can still be applied to this project.

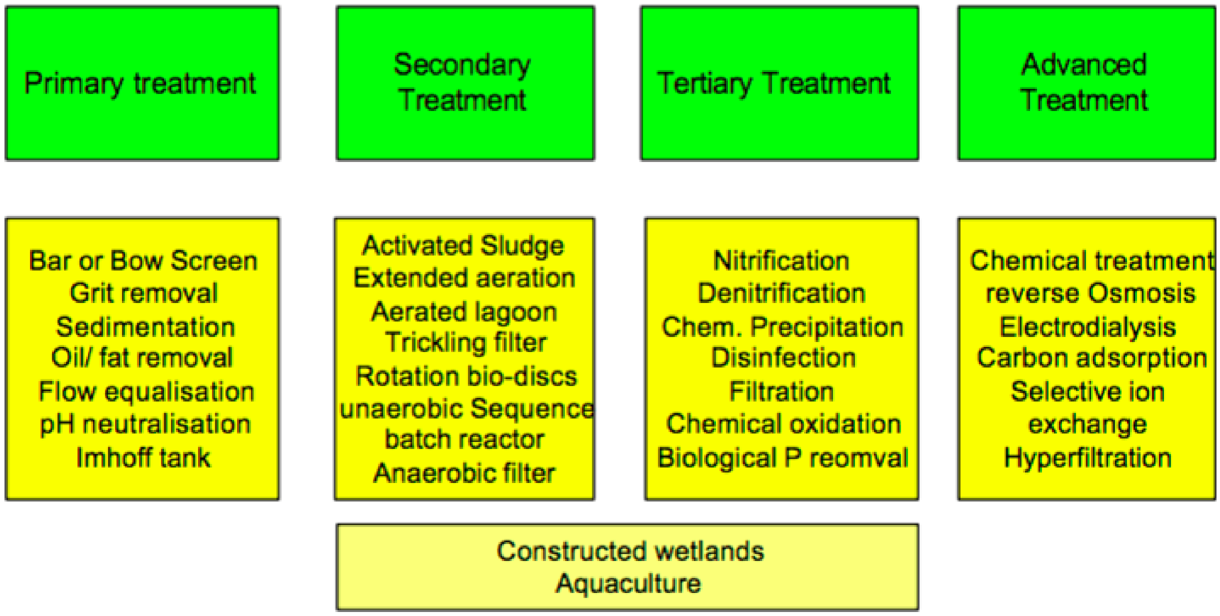

Figure 8: Treatment categorization and technologies, Source: Veenstra and Alaerts (1996)

Each technology might require a different amount of land space, rated low, moderate, or high. This depends on a number of criteria such as how large the equipment is, how many components are required, and how much space it needs to operate. Land space availability is often limited and cannot be negotiated, which is why it much be taken into consideration when selecting the appropriate technology. Next, maintenance and operation play a major role when choosing a technology, as there is "a certain degree of maintenance and skilled workforce to perform maintenance and operational duties."[18] It is important to choose the proper level of maintenance and operational duties that is right for that project site and its users seeing as the

[18] Schölzel, Harald and Rhonda Bower. *Small Scale Wastewater Treatment Plant Project: Report On Project Criteria, Guidelines and Technologies.* Suva, Fiji: SOPAC Technical Report, 1999.

chosen technology relies on both for it to work properly.[18] Mechanical equipment requires a certain amount of supervision, even at the lowest level of operation and maintenance, to keep the system updated and prevent it from becoming non-operational. This also means the users responsible for M & O must be thoroughly educated in how the system functions and what it would need if it is not operating properly. Cost and topography are also important on the rating list, although topography is "site specific." Cost includes cost of construction, running costs, and maintenance costs, which can help determine which technology type is chosen. "However, people sometimes take the option of a less-than-adequate system that does not perform satisfactorily giving out poor quality effluent for the sake of cutting costs."[18] Topography also has an influence over which technology is chosen as it "can be more effective producing better-quality effluent" and "allow easier implementation of wastewater technologies" or do just the opposite.[18] Table *1* below shows how each technology is arranged to be rated and compared to each other.

Table 1: Example Rating Table

Technology	**Criteria**					
Process Type	*Effluent Quality*	*Water Supply*	*Land*	*O & M*	*Cost*	*Electricity*
	Low (L)/ Moderate (M)/ High (H)	Yes/No	L, M, H	L, M, H	L, M, H	Yes/No

5.2.2 Monitoring & Evaluating Selected Water Treatment Method

Richard P Beverly's book focuses on the full process of building a water treatment plant from start to finish. Beverly emphasizes the importance of beginning with preliminary designs and explains the value of starting with a simple small-scale, manageable pilot study. He explains in detail every step that is necessary in a pilot study and the risks that the designer takes without doing a pilot study. Along with focusing on the type of treatment process that will be used and the cost of construction, Beverly discusses establishing methods of how waste will be disposed of. "In some cases, the disposal of the chemical waste governs the type of treatment processes to be used."[19] Next, he discusses the many filter types that can be used in water filtration, their operational design issues, treatment processes and monitor controls, having an operator who fully understands how to use all controls manually and automatically, and lastly, how to properly conduct water quality evaluations. Richard Beverly's information is extremely useful in that it allows the designer to fully understand what goes into creating a water treatment plant and all the important steps that must be taken before, during, and after the treatment plant's construction. Throughout his book, Beverly goes through every step and issue the designer might come across through their design, but does not mention the significance of the size of a water treatment plant at full-scale. He does, however, discuss bench-scale/jar testing that helps identify the proper operating range of a plant, showing that both large and small-scale water treatment systems are capable of making an impact.[19]

5.2.3 Small Scale Water Purification Solution

Strauss Water's Maze is a "micro-scale" water purification device that is meant to be installed in homes. This device has become a necessary product in "remote areas around the world and even industrializing nations like China, India, and Brazil," where they do not have the "confidence in the safety, quality, and availability of the water that comes out of their tap."[20]

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[19] Beverly, Richard P. *Water treatment process monitoring and evaluation.* Denver: American Water Works Association, 2012.

[20] Lo, Chris. "*Water purification: High-tech, small scale.*" Water Technology, 2011. http://www.water-technology.net/features/featurewater-purification-high-tech-small-scale/

The Maze is an “all-in-one” purifier that removes or reduced contaminants such as, heavy metals, volatile organic contaminants, arsenic, and microbiological contaminants, and prevents the development of bacteria and viruses. This “micro-scale” device shows that a large system is not always the solution, but small-scale systems can make just as great of a difference, as there is a strength in numbers.

5.2.4 The Process of a Largescale Wastewater Treatment Plant

The Stickney Water Reclamation Plant (SWRP) is the largest wastewater treatment facility in the world located in Chicago, IL and owned and operated by the Metropolitan Water Reclamation District. This treatment plant serves 2.3 million people in a 260 square mile area and is capable of treating up to 1.44 billion gallons of water per day. This wastewater treatment plant “mitigates flooding and converts wastewater into valuable resources like clear water, phosphorous, biosolids, and natural gas.”[21] This wastewater treatment plant uses processes similar to the natural processes that occur in rivers in addition to physical and biological processes combining air, gravity and microorganisms.[21] There are three phases of treatment: primary, secondary, and tertiary. The whole process of converting raw sewage to clean water takes about 12 hours to be processed, cleaned, and released.[21]

Primary treatment begins with water entering the plant and filtering out large debris through course screens. Water is pumped by gravity and flows throughout the treatment plant to six 132-foot long aerated grit tanks and nine 160-foot diameter primary settling tanks removing fats and oils to separate the solids from the water. The solids are then pumped to go through their own treatment process where they become biosolids, an alternative to chemical fertilizers.[21]

[21] "Stickney Water Reclamation Plan." MWRDGC. https://www.mwrd.org/irj/go/km/docs/documents/MWRD/internet/protecting_the_environment/Water_Reclamation_Plants/pdfs/FactSheet_WRPs_Stickney.pdf.

"By the end of primary treatment, 60-80% of the solids have been removed."[21] Secondary treatment is where microorganisms help remove organic material from the wastewater. Air is pumped through the water to aeration tanks, as microbes need oxygen. The water enters settling thanks where remaining solids fall to the bottom and clean water flows out the top of the tank. Next, clean water is released into the Chicago Sanitary and Ship canal.

This wastewater treatment plant is "regulated under the Environmental Protection Agency's National Pollutant Discharge Elimination System (NPDES) permit program," where rigorous standards are set and must be met.[21] This treatment plant facility has received several awards from the National Association of Clean Water Agencies and its work as also resulted in an increase in "recreation on the waterways, such as kayaking and canoeing, a rebounding aquatic habitat and increases in fish species."[21] Stickney WRP "is recovering valuable resources and is expanding the use of biosolids throughout its region."[21]

5.2.5 Restoring All Types of Aquatic Ecosystems

Clean-Flo International is a company that focuses on restoring water bodies using custom engineered technologies that work with nature. They focus on bringing healthy aquatic ecosystem backs to polluted, overgrown and dying water bodies. Clean-Flo International recognizes that each water body is different and custom engineer each design to meet the specific needs and requirements to achieve complete water body restoration. Clean-Flo uses six different applications of restoration and aeration: pond lake, reservoir and river restoration, wastewater treatment, and aquaculture. "Clean-Flo International has developed a water restoration process for river improvement and stream restoration that brings river water from the bottom to the surface, as beneath the surface of a river is a stagnant body of water, so that the entire river is oxygenated by the system and the atmosphere."[22]

The Clean-Flo River Restoration System uses inversion and oxygenation to enable beneficial bacteria, insects, and fish to thrive on the bottom. This allows "beneficial bacteria to feed on organic matter, and organic sediment is biodegraded into carbon dioxide and water."[22] As insects feed on organic matter and bacteria and fish feed on insects, there is an overall improvement in fish health and growth rate. "In any water body, when the bottom is oxygenated, phosphorus and nitrogen in the water column is bound to the sediment where it becomes food for the beneficial bacteria and insects."[23] "Utilizing the Clean-Flo Continuous Laminar Flow Inversion and Oxygenation aeration system and water treatment process for river improvement and stream restoration, all parameters of water quality greatly improve. The river water then becomes very clean and suitable for natural use."[23] One example of Clean-Flo International's River Restoration Project includes Helpe Mineure River case study.

Nonetheless, the Helpe Mineure River case study, although helpful in learning more about Clean-Flo's general water maintenance process, focuses on reducing ammonia and COD levels. After speaking with a Clean-Flo representative, Clean-Flo's process in reducing P levels for a large-scale body of water, like the Genesee River, was discussed and carefully explained, allowing for a more specific understanding. If there are excess P levels in water, an environment needs to be created with maintained dissolved oxygen levels and then utilize bio-augmentation to ensure a productive Food Chain is maintained so the excess P is directed into productive metabolism.[23] However, a river can create some difficulty as there is no retention time with the

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[22] CFadmin. "River Restoration and Water Aeration Systems |." CLEAN-FLO. March 10, 2017. https://www.clean-flo.com/systems/river-restoration/.

[23] David Shackleton, email message to author, July 17, 2018.

water flowing. Clean-Flo suggests that corrective interventions should be introduced along a significant distance down the river or divert the water into a retention basin to treat and reduce P before allowing the water back into the river.[23] Another suggestion made by Clean-Flo includes the installation of solar panels or water paddles. The water paddles are driven by the flow of the river to generate electricity, which would be used to power a compressor to drive the aeration units in the river.[23]

5.2.6 Applying Biomimicry to Architecture for Natural Water Filtration

When it comes to water filtration, there are a number of artificial systems that help clean out water of contaminants, but there are also a number of ways that "mimic nature and its ability to purify while controlling its flow."[24] Thomas Button explores the many ways that biomimicry can be applied to architecture, including naturally managing and filtering water in site design. Man-made ecosystems are created "through the use of bio-swales, green-roofs, rain gardens, tree trenches, and roadside plantings."[24]

Button discusses several ways that plants can be used as natural filtration systems, including the "Biolytix® water filter," "BioHaven® Floating Islands," and "Algal turf scrubbers." Button explains that the "Biolytix®" is a "system that utilizes the wastewater from a building and uses plants, stones and bacteria as a filter before releasing the water into the environment," as seen in *Figure 9*.[24]

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[24] Button, Thomas. "Biomimicry: A Source for Architectural Innovation in Existing Buildings" (2016). Thesis. Rochester Institute of Technology. http://scholarworks.rit.edu/theses/9174.

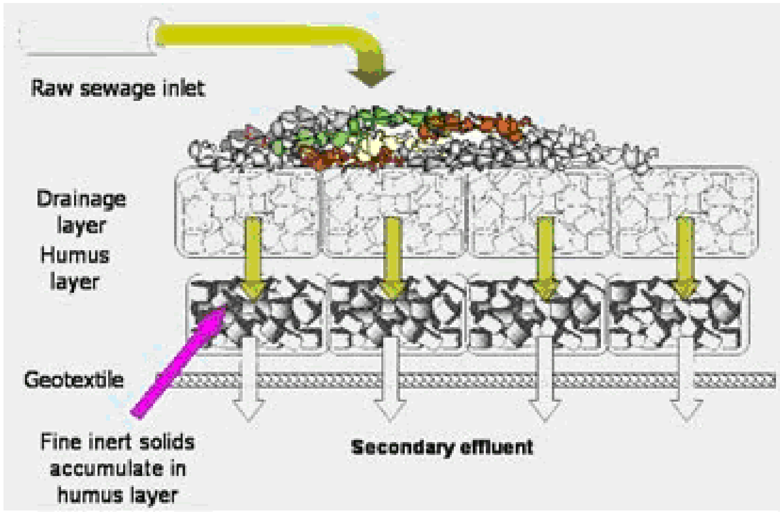

Figure 9: Biolytix water filter process, source: Biolytix

The floating islands are designed to sit atop waterbodies to aid in removing and preventing water from further exposure to excess nutrients and that are harmful to water ecosystems, illustrated in *Figure 10*.[24]

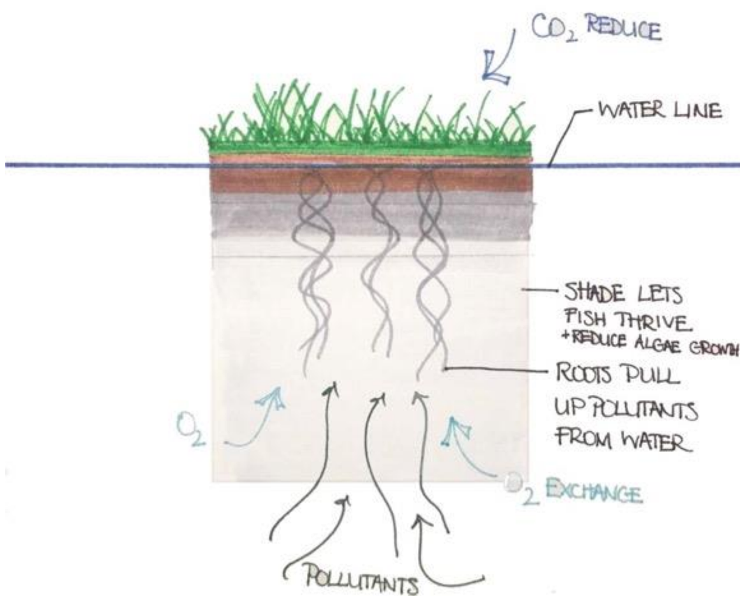

Figure 10: BioHaven Floating Island, source: author

6. Case Studies

6.1 Boathouse Case Studies

The following case studies explore a variety of boathouses that push the sustainability agenda through proposed concepts and established projects that face comparable problems to the Genesee Waterways Center.

6.1.1 Studio Gang

Studio Gang, an architecture firm in Chicago, IL, has designed two separate boathouses that once faced similar problems as GWC faces today. The two boathouses are located along the Chicago River. Like the Genesee River, the Chicago River is long-polluted and neglected. The city of Chicago began to take steps towards a revitalization plan in Chicago to transform the river ecologically and recreationally, using four boathouses that sit adjacent to the river as cornerstones.[25] Studio Gang re-designed the WMS Boathouse at Clark Park in 2013 and the Eleanor Boathouse at Park 571 in 2016, with the overall goal of a creating a healthy river.

The WMS Boathouse (*Figure 11*) and Eleanor Boathouse (*Figure 12*) are home to a variety of different programs including rowing teams and clubs, learn to row programs, yoga classes, etc. In addition to improving the river ecologically, Studio Gang's designers also aimed to improve the community's health by making the riverfront a "destination for recreation."[25]

[25] "WMS Boathouse at Clark Park." Studio Gang. http://studiogang.com/project/wms-boathouse-at-clark-park.

Figure 11: WMS Boathouse at Clark Park, source: Steve Hall © Hedrich Blessing

Figure 12: Eleanor Boathouse at Park 571, source: © Tom Harris

The new boathouses allowed for an expansion of their programs and the materials used creating a system that filters the water before returning to the river. The boathouses' roof design, "roof drainage elements and site design together function as its stormwater management system, diverting 100 percent of runoff from the sewer," as illustrated in the roof diagram in (*Figure 13*).[25] Chicago's method uses a more natural approach of reducing pollution through the use of native plantings, beds of gravel, and rain gardens that retain and filter stormwater on-site before slowly releasing it to the ground and river.

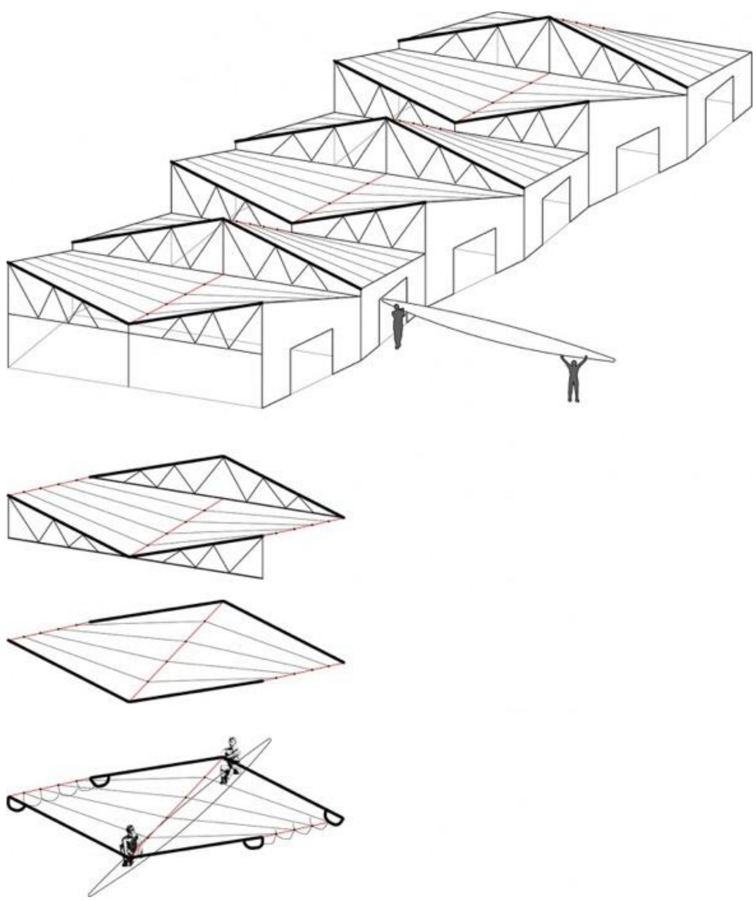

Figure 13: WMS Boathouse Roof Diagram, source: © Studio Gang

Another project by Studio Gang is the Memphis Riverfront Concept completed in 2017. Two of the three principles this project was based on was to restore the natural conditions and ecology of the Mississippi River and create a connective network of Memphis, Tennessee's characteristics of people, culture, and existing urban spaces along the river (*Figure 14*).

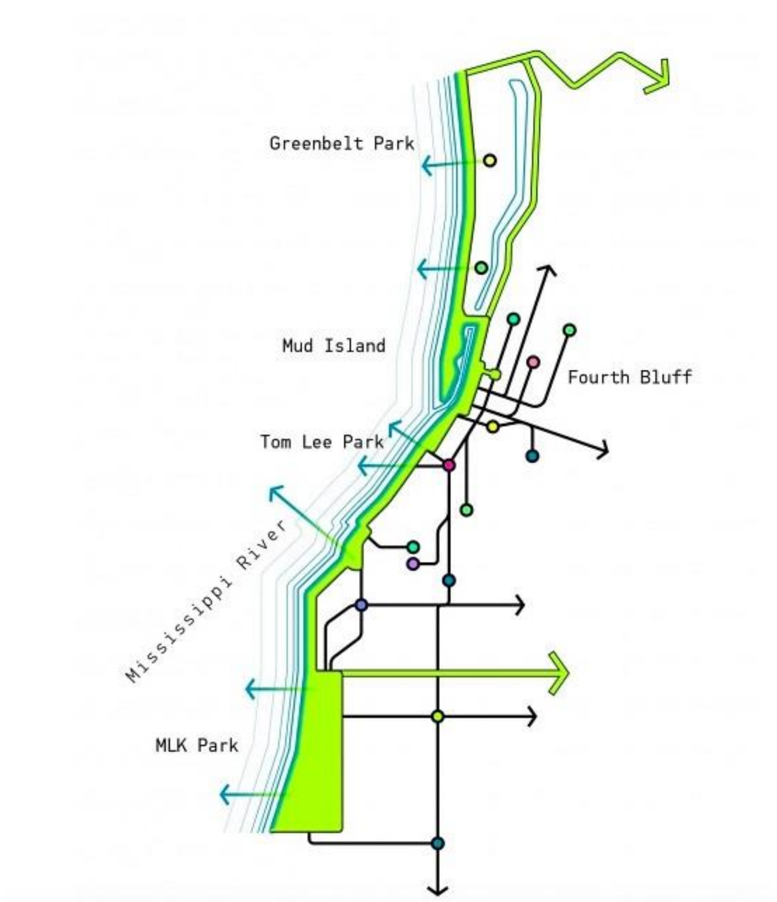

Figure 14: Masterplan Overview, source: © Studio Gang

There was a major focus on five zones along the river. Each zone was opened up with new walkways through their once overlooked communities with a variety of recreational activities and pop-up events (Figure *15*). A new boathouse, boardwalk, and shady grove was planted by the community, bringing new life in addition to improved streetscape that draws people to the riverfront.[26] Existing parks, paths, and public spaces have been connected, making them more accessible. An Eco Hub has been constructed within one of the zones that has a variety of new plantings and structures to amplify the river ecology. The Eco Hub offers teaching and learning to the public as it is also a partner of University of Memphis and with the Memphis Zoo. The Hub provides a hands-on research center for freshwater ecological and science studies.

Figure 15: Memphis Riverfront Concept Rendering, source: © Studio Gang

6.1.2 Indiana University South Bend Boathouse

Sarah Fortson, a former architecture student of Ball State University, focused her thesis on Indiana University's Boathouse in South Bend alongside the St. Joseph River and East Race. The goal of her boathouse design was to maximize physical and visual access to the river using traditional boathouse facility organization. Fortson's research shows the typical arrangement of

[26] "Memphis Riverfront Concept." Studio Gang. http://studiogang.com/project/memphis-riverfront-concept.

spaces, as well as traditional architectural characteristics of interior and exterior boathouses. Fortson lists the four types of spaces found in a boathouse's program and how they are organized. The four general types of spaces are training areas, social and support areas, storage areas, and exterior spaces. Training and social and support areas are commonly found on the upper levels, whilst storage areas are placed on the lower levels for maximum access to the water, seen in *Figure 16*. Architectural characteristics often seen in boathouses are arched openings, multi-material construction, and industrial motifs.

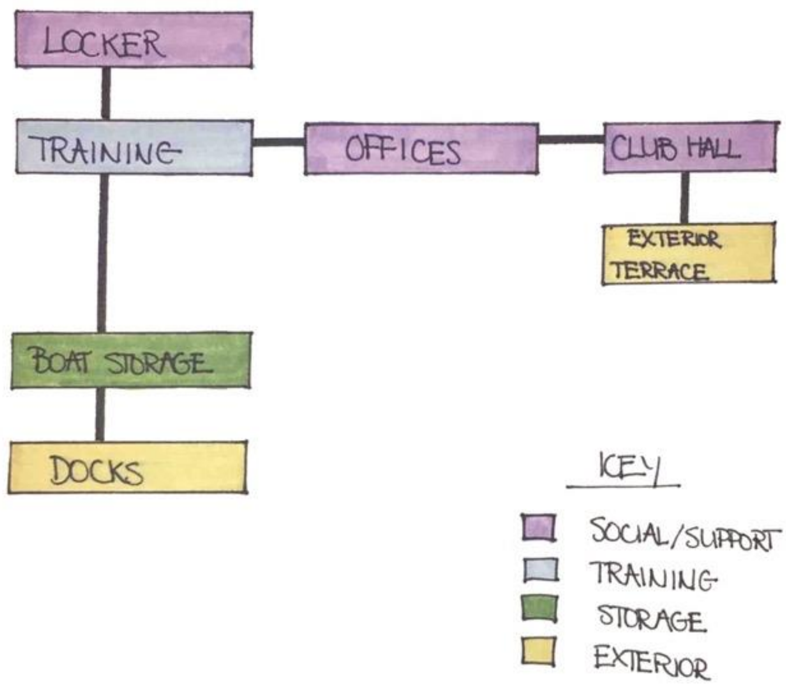

Figure 16: Bubble diagram- Traditional boathouse organization, source: author

Fortson's boating facility was designed with hopes of providing a hub of activity along her proposed continuous park that would also accommodate and enhance the drama of traditional ceremonies of competitive boating and allow spectators to join in on the experience along with the athletes.[27] Through her project's design, she also believes it is necessary to emphasize social relaxation and physical exertion simultaneously, exhibit pride of the kayak and rowing clubs, maximize physical and visual contact with the river for both athletes and guests, link interior and exterior spaces and campus to the river. Fortson's design is organized in such a way that maximizes views of the river and brings the exterior inside by traditionally placing social and training spaces on upper levels with balconies and large windows, as shown in *Figure 17*. This provides all with maximum possible views of the river and allows natural light to pour into the space. The club social hall provides a space for dining and lounging, emphasizing social relaxation, while still in a facility that promotes the importance of physical exertion by having training spaces, both on and off the water, club trophies and recreational path that surrounds the boathouse on full display. The boathouse itself acts as a link between the university's campus to the river in a ceremonial way. The boathouse's entrance was designed as a ramp, symbolizing the docks during the launching of boats, which is traditional in competitive rowing, and "emphasizes the importance of ceremony, circulation, and transition."[27]

[27] Fortson, Sarah B. 1992. "Indiana University South Bend boathouse and training facility for kayaking and rowing: architecture as a stage for activity." Ball State University. n.d.

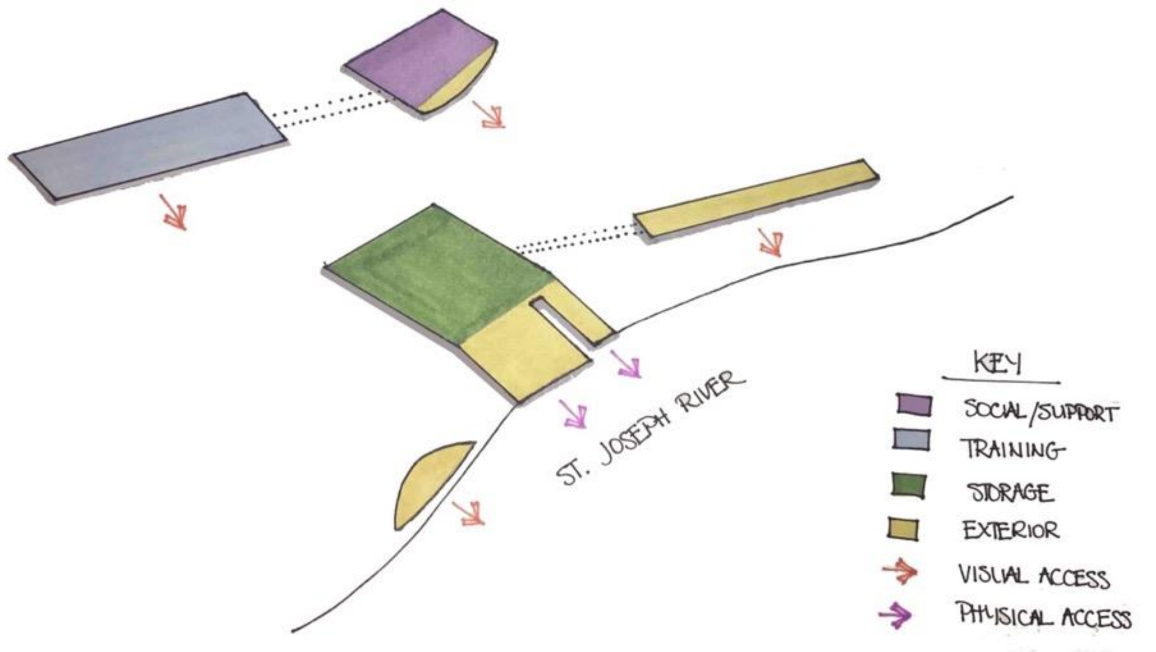

Figure 17: Indiana University South Bend Boathouse Analysis, source: author

6.2 Phosphorus Filtration Case Studies

Next, a variety of phosphorus removal methods and systems have been explored to learn how each is constructed and its overall impact. Their results are analyzed and discussed to understand if any could be successfully applied to the Genesee River.

6.2.1 Removing Phosphorus from Drainage Waters

A study was done by four associate professors from Oklahoma State University and University of Maryland in 2013 looking into landscape filters that would remove dissolved phosphorus in runoff before reaching streams and lakes. They found that industrial by-products are typically land-filled, can easily be re-used in improving surface water quality by adsorbing phosphorus from passing water.[28] For this case study, "several phosphorus removal structures

[28] Penn, Chad, Josh Payne, Josh McGrath, and Jeff Vitale. "Designing Structures to Remove Phosphorus from Drainage Waters." Extension. November 13, 2013. http://articles.extension.org/pages/67669/designing-structures-to-remove-phosphorus-from-drainage-waters.

were constructed in residential and agricultural watersheds."[28] Industrial by-products such as flu gas desulfurization gypsum and steel slag were used, two phosphorus sorbents, within the filters, allowing them to be replaced after they lose their effect and representing a true removal of the phosphorus, rather than temporarily blocking it.[28] "The phosphorus removal filters were placed in locations known to produce high dissolved P concentrations in runoff."[28] After eight months of monitoring water flow and the filters and testing sixteen different sorbing materials, one filter was able to remove about 25% of the dissolved phosphorus that had entered the structure. The structure was found to be effective for about seven to eight months and was able to handle flow rates over 100gpm.

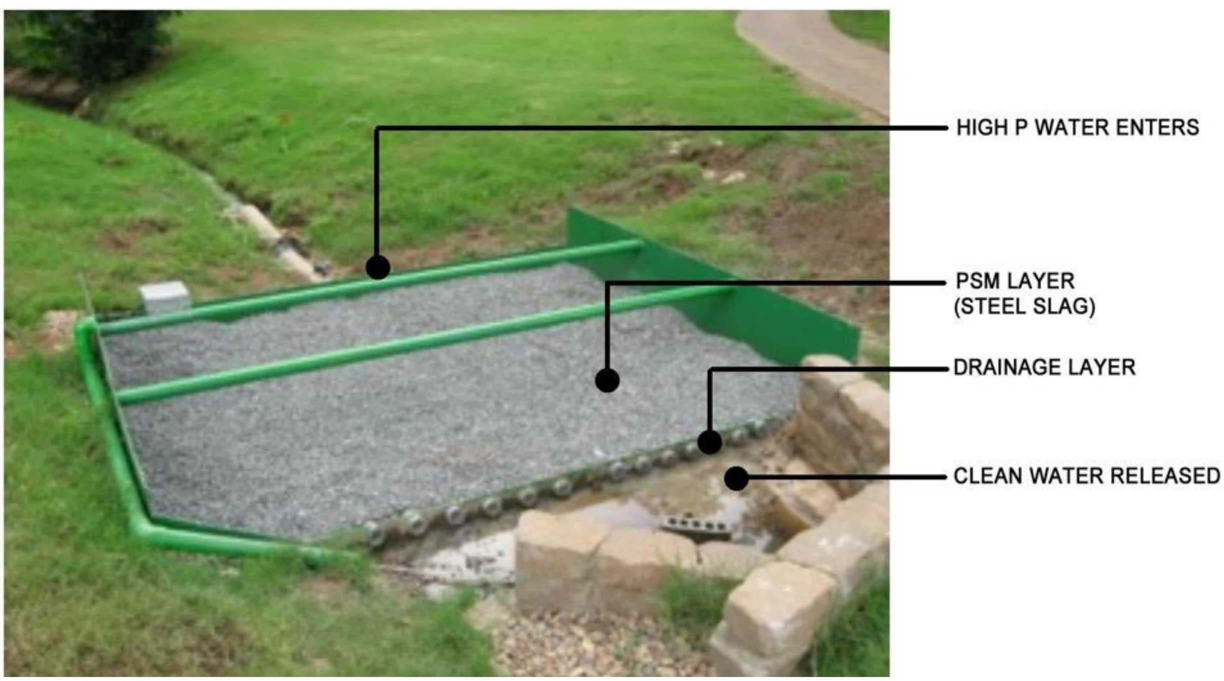

Figure 18: Phosphorus removal structure located at Stillwater Country Club, source: http://articles.extension.org/pages/67669/designing-structures-to-remove-phosphorus-from-drainage-waters.

A phosphorus removal structure, shown in *Figure 18* and *Figure 19*, can be constructed in many different ways yet still be effective, as long as they contain the four basic principles:

a. Solid media with high affinity for P, commonly known as a "P sorption material," or PSM.
b. PSM is contained and placed in a hydrologically active area with high dissolved P concentrations.
c. High dissolved P water is able to flow through the contained PSM.
d. The PSM is removable and replaceable after it's no longer effective.[29]

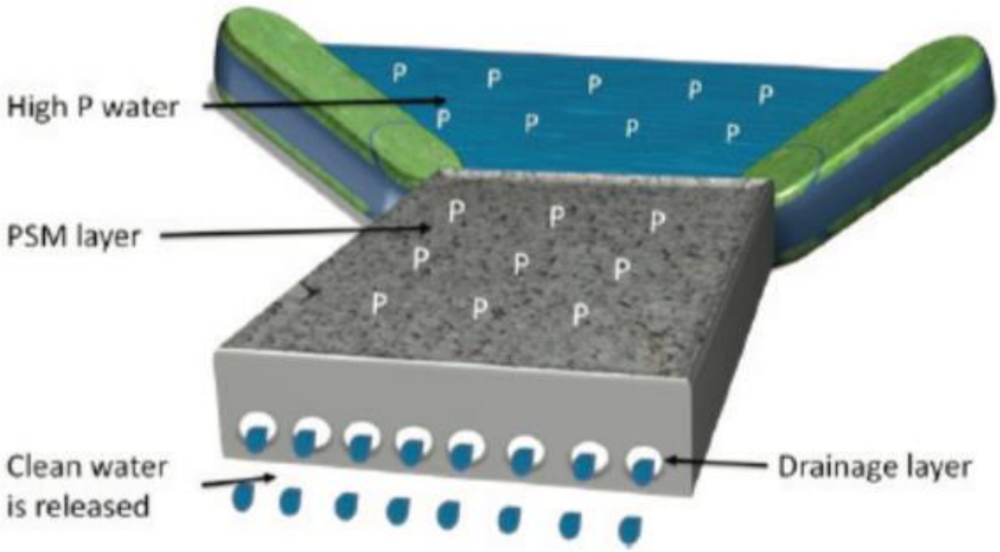

Figure 19: Phosphorus removal structure diagram,
source: http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-9345/L-447%20Phosphorus%20Removal.pdf

[29] Oklahoma State University. *L-447 Phosphorus Removal Structures*. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-9345/L-447%20Phosphorus%20Removal.

6.2.2 USGS Water Filtration System

In 2012, a team from the U.S. Geological Survey (USGS) began designing a fully functional phosphorus water treatment system. This filter system "uses discarded mining by-products, called mine drainage ochre," allowing the system to be cost-effective as well as environmentally friendly.[30] In 1999, USGS scientists found that ochre, a natural, porous mixture of clay, sand, and ferric oxide, is an effective primary filtering agent to remove phosphorus from water.[30]

The USGS filter is constructed of large tanks, made of inexpensive, off-the-shelf components rather than custom fabricated, that each hold about 600lbs of mine drainage ochre. Phosphorus infused water is piped to the top of the tank using a gravity flow process, allowing it to pass through the ochre and filtered water is released out of the bottom of the tank.[30] Between the first prototype's design in 2012 at the USGS Leetown Science Center, it has taken a total of five years to develop a large-scale filtration system, seen in *Figure 20*, that is "capable of filtering more than 100 thousand gallons per day."[30]

Figure 20: Phosphorus removal treatment plant, source: USGS

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[30] "New USGS Filter Removes Phosphorus from Waste Water." USGS. July 19, 2017. https://www.usgs.gov/news/new-usgs-filter-removes-phosphorus-waste-water.

6.2.3 Blue Water Technologies Phosphorus Removal

Hayden Wastewater Research Facility, a research facility for Bluewater Technologies, was constructed in April 2005 in Hayden, Idaho with the main purpose of "showcasing phosphorus removal and developing future advanced water treatment processes."[31] The plant provides wastewater treatment for the local community, but this system is also capable of treating groundwater in addition to wastewater. The BluePro system uses a unique approach by using a controlled, cost effective system by using advanced control techniques and patented nutrient removal systems. Compared to its competitors, the BluePro system uses a lower amount of chemical dosage throughout the entire treatment plant.

The BluePro sand filter, shown in *Figure 21*, uses a continuous backwash sand filter process where the influent is distributed across the filter to the bottom of the sand column. The water is filtered as it moves up the filter and sand coated with hydrous ferric oxide (HFO) attracts and reacts with the phosphorus. Sand sinks to the bottom of the tank to an airlift device and "phosphorus-laden media is transported into the washbox where discharged HFO coating and adsorbed contaminates are separated from the media."[32] The velocity of the water in the washbox was carefully designed to allow contaminates to be carried away while the media falls into the filter bed. "Freshly scrubbed media from the washbox is recoated with HFO as the cycle begins again."[32]

All waste is removed from the filter through backwash allowing it to be recycled. Recycling backwash upstream provides the added benefit of phosphorus to go through the

[31]Newcombe, Remy. "New System Optimizes Sand Filter Phosphorus Removal." WaterWorld. http://www.waterworld.com/articles/print/volume-22/issue-2/feature/new-system-optimizes-sand-filter-phosphorus-removal.html.
[32] "BluePRO Reactive Filtration for Phosphorus and Metals." Nexom. http://nexom.com/blue-pro/.

treatment system more than once, further guaranteeing the removal of phosphorus.[32] Through the use of this system, BluePro consistently achieves low phosphorus or metal levels."[32] However, this removal system is only capable of filtering between 10,000 gpd to 1 MGD (millions of gallons per day). While this could be an effective approach for a smaller sizes body of water, the Genesee River's flow rate is approximately 1,981,140.8 gpm, meaning this system would not be an effective solution for this location.

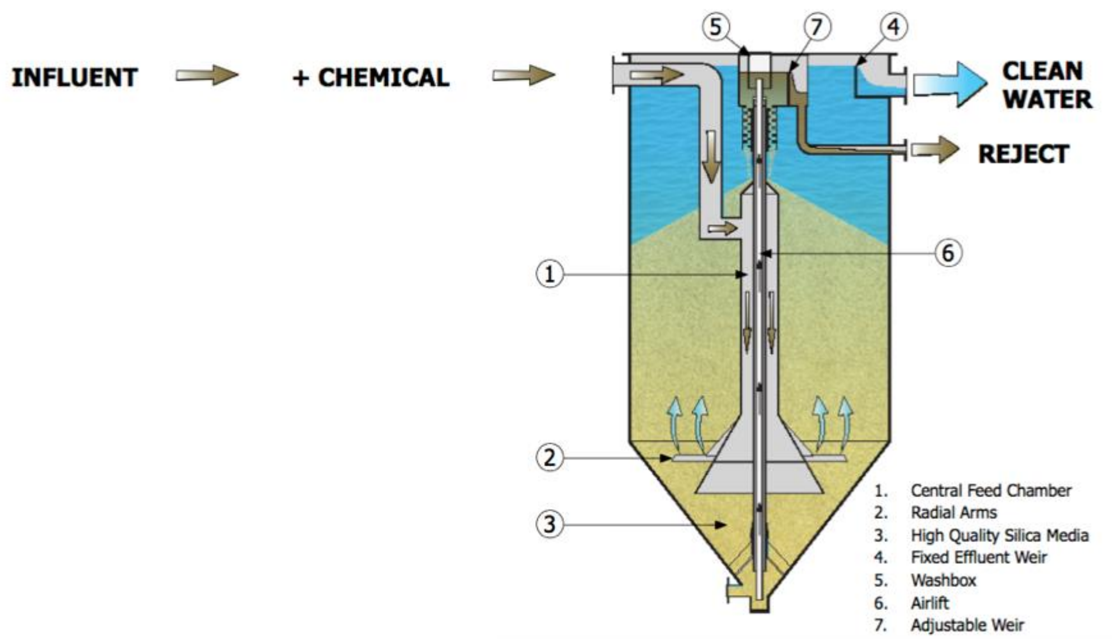

Figure 21: BluePro Sand Filter, source: Nexom

6.2.4 Helpe Mineure River, Fourmies, France

Similar to Rochester, NY, Fourmies, France has a large textile industry with factories and manufacturers, their Helpe Mineure River was greatly affected. As the river passes through the rural town, COD and ammonia are increased, and oxygen is decreased, putting the water in the unusable category.[33] In the early 1970s, the town began to restore the river through a series of actions including: "suppress direct discharges into the river, continue to upgrade storm runoff, extend the sewage system, and improve the quality of treatment at the wastewater treatment plant."[33] However, after all their efforts, results showed that oxygen levels were still too low after passing through Fourmies.

Clean-Flo International joined Fourmies's efforts in reoxygenating the river from Fourmies to Rocquigny, about 30 miles south of Fourmies. Since the river is too shallow to aerate directly, "Clean-Flo proposed to dam the river, divert it into a retention pond, aerate the water, and return it to the river. Reoxygenation of the river was then instituted using the Clean-Flo process of inversion/oxygenation," which would reduce both COD and ammonia.[33] The retention pond, illustrated in *Figure 22*, was designed to have a minimum retention time of 5.5 hours at maximum flow, as it takes about 5.5 hours for the river to flow from Fourmies to Wignehies. COD and ammonia are not reduced enough in the retention lagoon, but "by discharging partially oxygenated water back into the river, ammonia and COD could be improved by the time the water reaches Wignehies."[33]

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[33] Laing, Robert L., and Carlton J. Rausch. "Aeration And Pollutant Abatement In The Helpe Mineure River, Fourmies, France." *Lake and Reservoir Management* 9, no. 1 (1994): 98-102. doi:10.1080/07438149409354735.

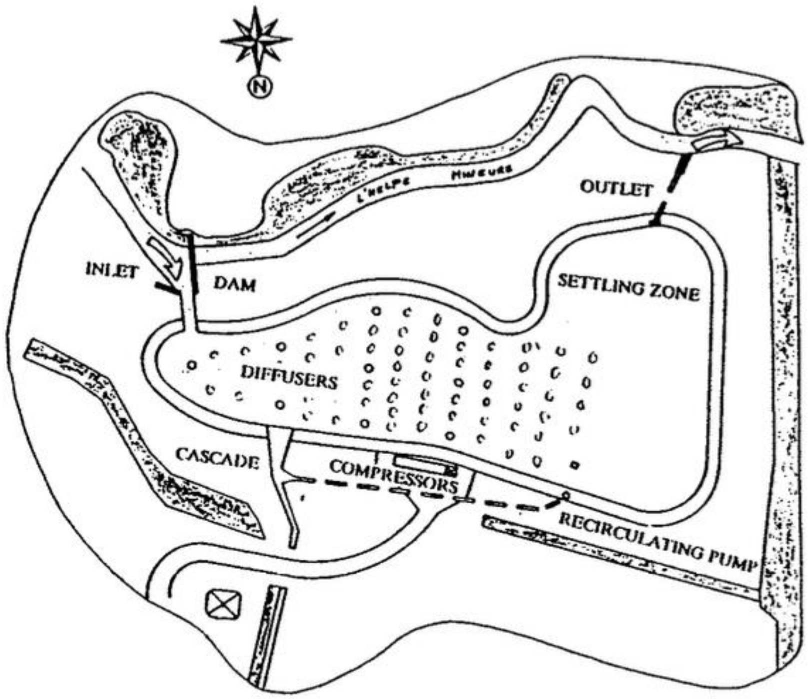

Figure 22: Reoxygenation lagoon for the Helpe Mineure River at Fourmies, France (drawing not to scale), source: "Aeration And Pollutant Abatement In The Helpe Mineure River, Fourmies, France."

The retention lagoon, was designed to hold between 33,000- 53,000 gallons of water. There are 8 Clean-FLo inversion/oxygenation systems, consisting of 64 bottom air-diffusers placed evenly throughout the lagoon and a small settling tank near the outlet. A water pump circulates 100 l/s of water "from the end of the aeration section back to the beginning of the diffuser area, where it is discharged down a cascade to be recirculated."[33] 14- 100% of water is reoxygenated a second time, depending on the flow rate. "Pumped water is discharged to the top of a stream bed that slopes rapidly down to the lagoon," adding additional aeration as it flows back to into the lagoon.[33]

The general results of Clean-Flo's inversion/oxygenation process were:

The appearance of fish and benthic organisms in both the river and the retention pond.

Increase in oxygen saturation from 20% to 70-100% in the river during low flow, as the water leaves Fourmies. It was determined that after aeration, there was a change in objectionable odor during low flow to no odor, and the water is now much clearer downstream. Additionally, COD, TKN, and ammonia levels were reduced throughout the entire aimed miles of the river. [33]

7. Building Analysis

7.1 Traditional Boathouse Layout

The traditional boathouse is designed and organized in a very specific way that allows building users to circulate through it has smoothly and efficiently as possible. The "ultimate goal" of a boathouse is to emphasize "activity" and "physical exertion," while "promoting social relaxation."[34] Themes of movement and rhythm are incorporated into the design to "exhibit pride" by "enhancing the drama of the traditional ceremonies and pageantry of competitive boating."[34] Along with the themes of movement and rhythm, Fortson discusses that a boathouse's design is meant to maximize physical and visual contact with the river, linking the interior and exterior.[34]

Characteristics often found in a boathouse include: distinct rooflines, symmetrical plans, multi-paned windows, squat towers with horizontal lines, arched openings, multi-material construction, incorporation of imagery of ships and cranes, and industrial motifs.[48] The basic organization of the boathouse's plan places storage on the lower level and training and social spaces located on the upper level, allowing easy access to the river for boaters, and a view of the river from the upper level for both athletes and spectators. Although boathouses have had these traditional elements since the 19th century, Ivy League boathouses have added to the design criteria by organizing their spaces in their own specific way. Ivy League boathouses also locate boat storage on the lower level and locker and exercise spaces on the upper level, but are designed asymmetrically, which is seen along the historic Boathouse Row on the Schuylkill

[34] Fortson, Sarah B. 1992. "Indiana University South Bend boathouse and training facility for kayaking and rowing : architecture as a stage for activity." Ball State University. n.d.

River in Philadelphia. However, both traditional and Ivy League boathouses accentuate nature, daylight, and views.

There are four types of spaces found in a boathouse, each playing a major role and having a relationship with the other: training spaces, social and support spaces, storage, and exterior spaces.

7.1.1 Training Spaces

"The training room is a space for athletic performance and where concentration on individual activity is emphasized."[34] Adjacent spaces are the locker rooms and coaches' and trainers' offices, as illustrated in Figure *23*. The locker room is meant to be a central meeting location, comfortable atmosphere for the athletes, and exhibit team pride. Natural lighting should be used in all three rooms to enhance the space, as well as help create a pleasant environment and offices and training room should have a view of the river to inspire and link interior with exterior, as well as enhance a pleasant environment.[34]

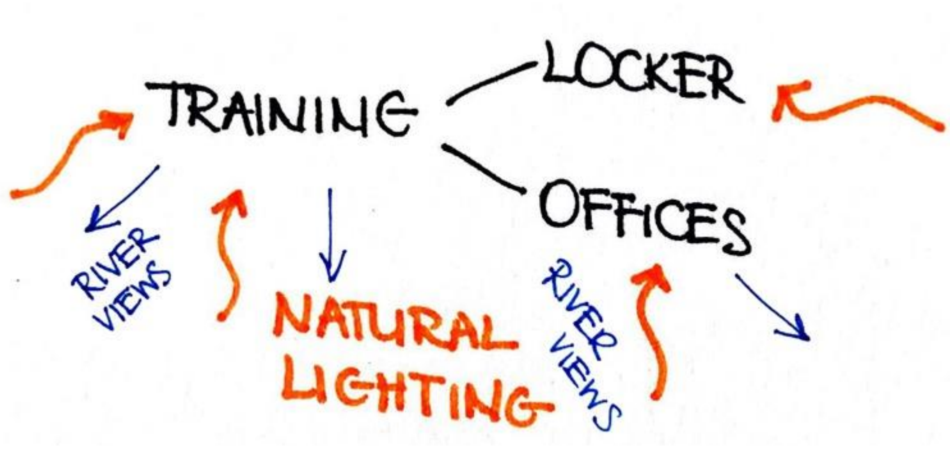

Figure 23: Training Room Analysis, source: author

7.1.2 Social and Support Spaces

Social and support spaces are meant to introduce newcomers into the world of rowing and welcome back athletes to their home space. These are spaces for non-athletic activities and include the entry, club social hall, and trophy room, which "exhibit team pride, while providing a dramatic entryway into the facility."[34] The flooring in these rooms are traditionally wood, symbolizing the structure of the boat shell. Natural lighting and the view of the river is maximized. Adjacent spaces to the entry, social hall, and trophy room are the club offices and exterior terraces, shown in Figure *24*.

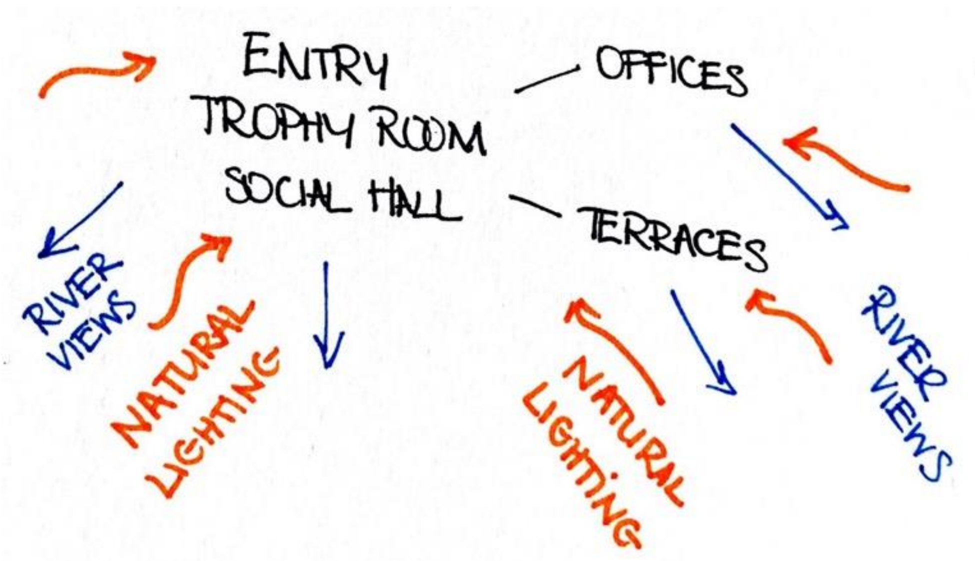

Figure 24: Social & Support Analysis, source: author

7.1.3 Storage

"The ceremony of taking the boats to the water begins in the boat storage space."[34] A visual connection from the boat storage area to the river is both traditional and efficient when transferring the boats and equipment to the water. Inside the boat storage space, the shells are displayed on racks, one above the other. The adjacent spaces are typically the riverfront docks, trailer parking area, and boat repair areas, demonstrated in Figure *25*. It is important these particular spaces are adjacent to one another, as the boats require frequent access to and from the river and the trailer to transport boats and equipment to and from regattas.

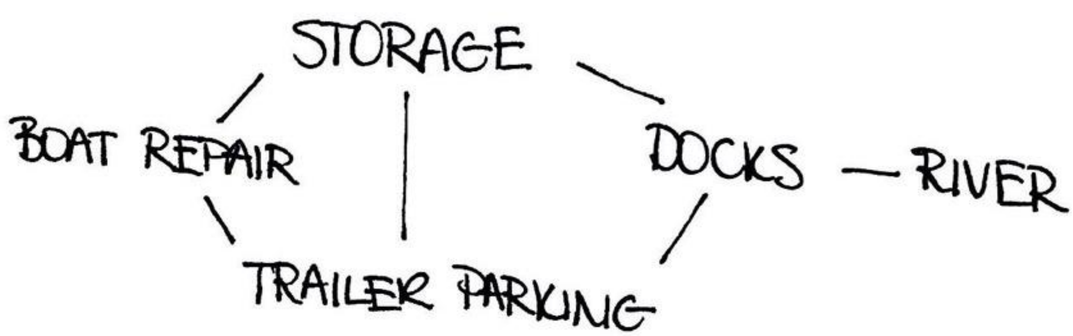

Figure 25: Storage Analysis, source: author

7.1.4 Exterior Spaces

"The docks are a vital link between the facility and river, creating a stage for interaction and for the ceremony of boat racing."[34] Spaces adjacent to the docks are the exterior terrace, "an extension of the club social hall providing an elevated view for spectators," and an outdoor viewing area, shown in Figure *26*.[34] The exterior spaces of a boathouse are just as important to the boathouse as the inside spaces. Exterior spaces are used as: a gathering space for spectators and athletes, a path for other recreational people, a preparation area when athletes are traveling and packing the trailer with equipment, a training space, and a pathway for competitors and recreational users to and from the water.

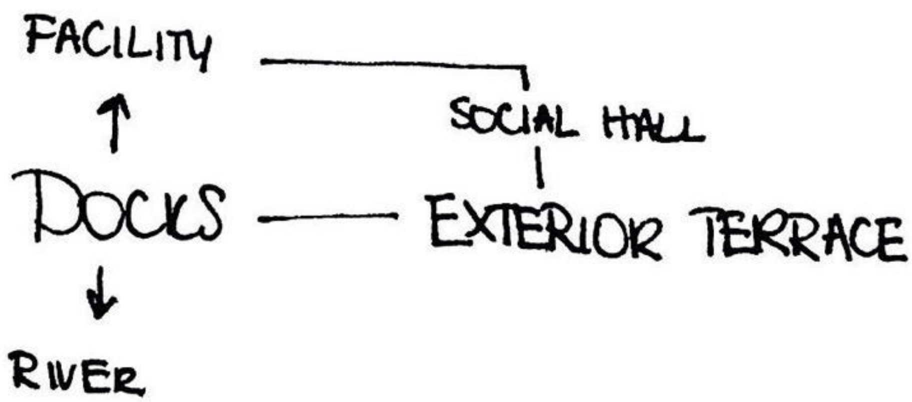

Figure 26: Exterior Analysis, source: author

The images below show all four categories of spaces, training, storage, social/support, and exterior, organized in their specific arrangement to show how they relate to each other on the GWC site *(Figure 27, Figure 28).*

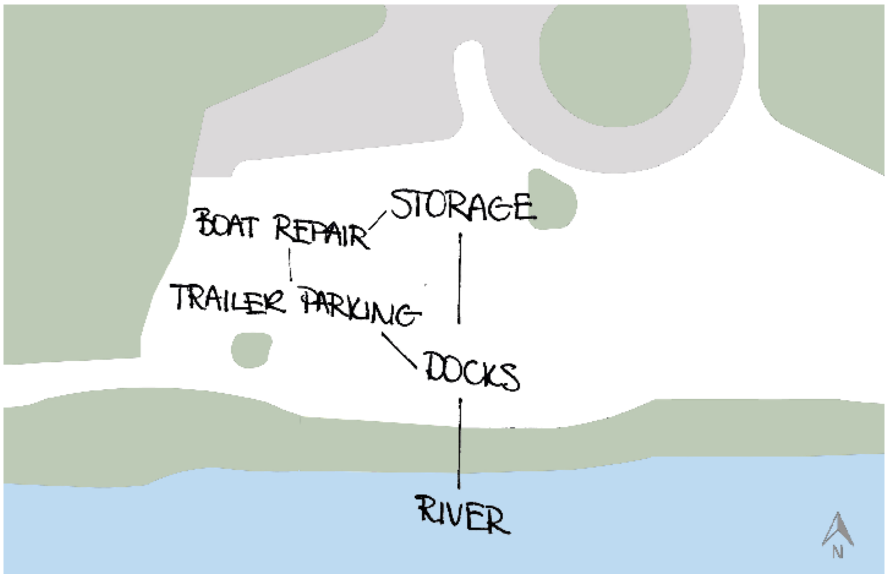

Figure 27: First Floor Arrangement, source: author

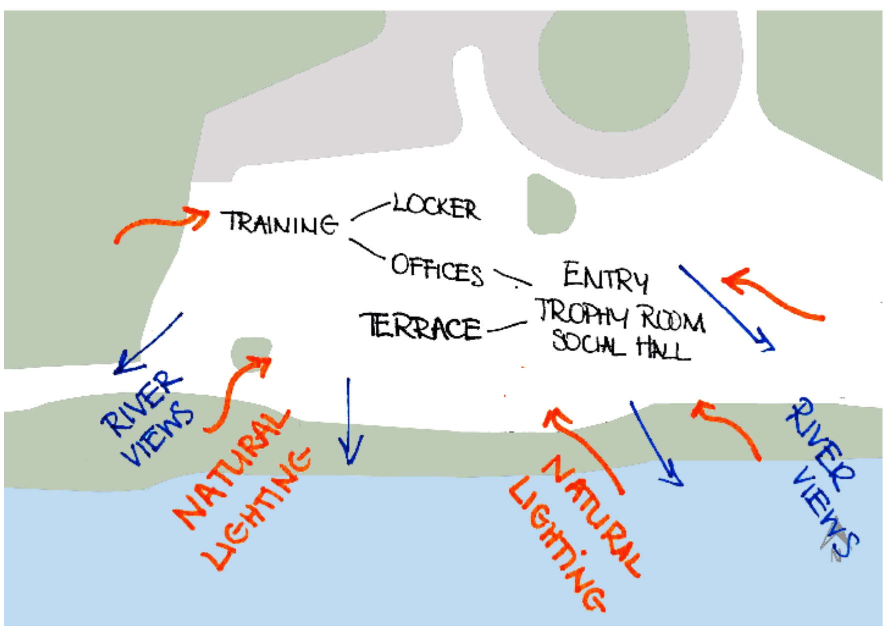

Figure 28: Second Floor Arrangement, source: author

8. Literature Review & Case Study Analysis

Having discussed a number of cases about both boathouse designs and water restoration, this section analyzes how specific elements from these articles might apply to the Genesee Waterways Center and its surrounding site. The following analyses provide examples that will assist in properly re-designing the GWC in a way that benefits its community and addresses each goal of this thesis. This section also examines how each of the discussed phosphorus filtration methods can or cannot work for this site and what more the GWC would require to better fit that method for this project.

GWC faces similar concerns to the Thunderbird boathouse as it needs to develop in a way that it can connect to its existing site and accommodate its existing users. However, GWC also needs be redeveloped in a way that will allow itself to grow with the redeveloping City of Rochester and accommodate its future landscape and visitors. Although Beresford was able to use the city's vision of the riverfront in his design process, he was unable to directly learn the community's vision. This thesis project has researched the GWC community's vision. The advantage of having the community's vision allows this project to gain direct information of what the community is missing, what is working, what is not working, and what it hopes to contribute.

Chiesura's article found that natural spaces have the potential to bring positive social and environmental benefits to their environments. The Genesee Waterways Center is located in a city that is making great strides in its sustainability initiative. Rochester as a whole has been addressing its many environmental concerns, including the restoration of the Genesee River, where the GWC sits adjacent to. The city has no shortage of parks, most of which have biking and running trails, but few with waterfront access. Diversity in parks should exist to reach as many of the public's interests possible. This project attempts to bring that diversity through the GWC's re-design, making the boathouse and its waterfront a highlight, a destination, and accessible for its visitors.

The planning study done by the District of Columbia's Office of Planning is a helpful model for planning and designing the GWC's redesign. Analyzing the existing site, its surrounding community, its long-term vision, and overall goals will help to inform the GWC's redesign in a way that allows it to fully respond to its needs and will not stray from its goals. The GWC project is not as large as the Anacostia Waterfront Initiative, but the organization of its planning is a helpful guide listing every portion of the project that should be kept in mind.

The typical boathouses that have been studied for this project were designed with traditional architectural features like Jeffrey Peterson mentions. Peterson's article brings to light the many modern boathouses that took a new approach to the traditional guidelines of a boathouse's architecture, as seen in *Figure 29*. Rochester's more historic neighborhoods have continued to use traditional architecture, but its newer and re-developing communities have utilized more contemporary and industrial design features throughout the architecture. The modern boathouse designs discussed in Peterson's Foreword can be utilized in this project's design as well, as GWC surrounding neighborhoods are less traditional and more industrial. This project's hope is to create a new connection to the waterfront like Peterson mentions, but to do so that responsibly connects us back to nature.

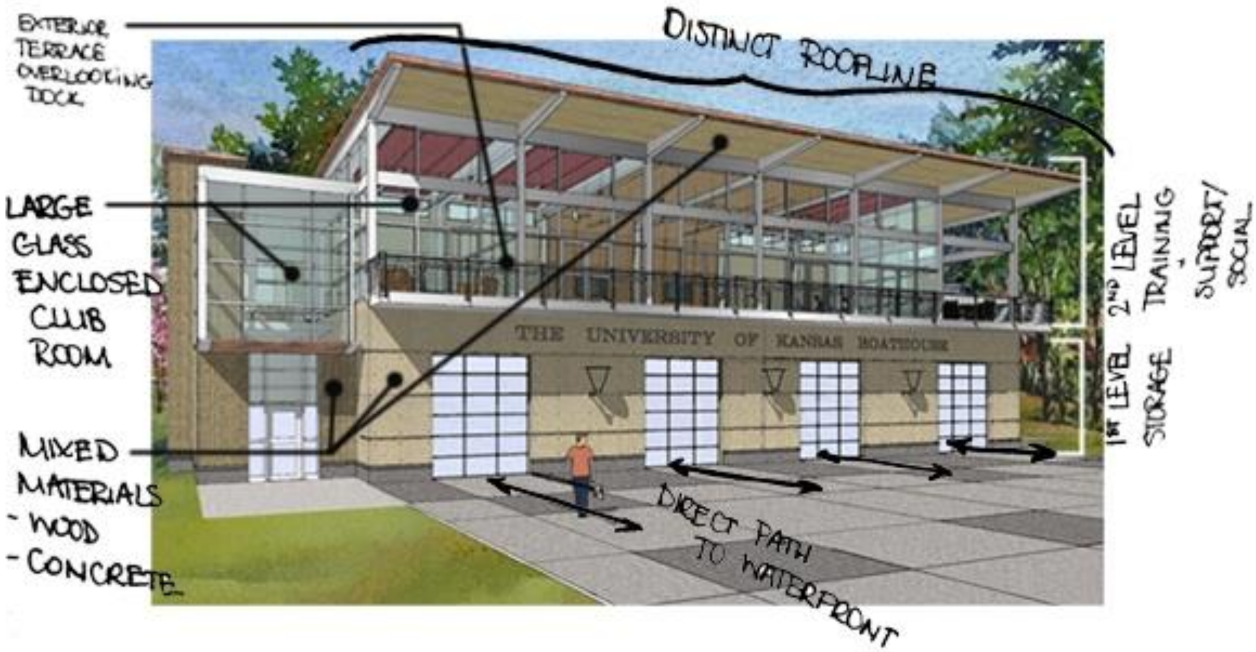

Figure 29:University of Kansas Boathouse Analysis, source: Jeffrey Peterson

Currently, the Genesee Waterways Center is a facility that not many know about. Bicycle and running paths cross it, several baseball and tennis courts surround the facility, and there is a neighboring sports complex. There are many activities scattered throughout the park, but the Genesee Valley Park is disconnected and is missing the harmony Sas-Bojarska discusses. Connecting the water to its landscape is not the only goal in this project, but the connection between the boathouse itself to its landscape is also missing. The GWC should act as one coherent system with the waterfront it uses daily and the park it is located it in.

Though this project only focuses on a boathouse within a public park in Rochester, the Genesee Valley Park, the same ideals discussed in Sas-Bojarska's and Rembeza's article apply to the GWC. It is important that the boathouse is designed in a harmonious and cohesive way that creates an enjoyable environment for its users. There is less division in this proposed design by grouping together the same types of spaces together and laying out the spaces in a way that transitions from public to private as users enter and move through the building.

Jason Manongdo's thesis is very helpful for this thesis project because it suggests ways to reactivate the use of the waterfront and connect the water to its landscape by collecting, protecting, and respecting the water. Manongdo is less concerned about boathouse users and more about the boathouse's relationship with the water, sun and wind. His thesis looks at how to use the boathouse as a tool for water restoration and uses its surrounding site as part of the restoration process. This thesis will go further into researching how the boathouse itself can become the tool for collecting, protecting, and respecting the water that passes through from the Genesee River by simultaneously creating a relationship with water and sun (see *Figure 30*). Nonetheless, Hawaii's value and appreciation of water is a message Rochester, NY should be reminded of, as the Genesee River was abused for years from industrial contamination.

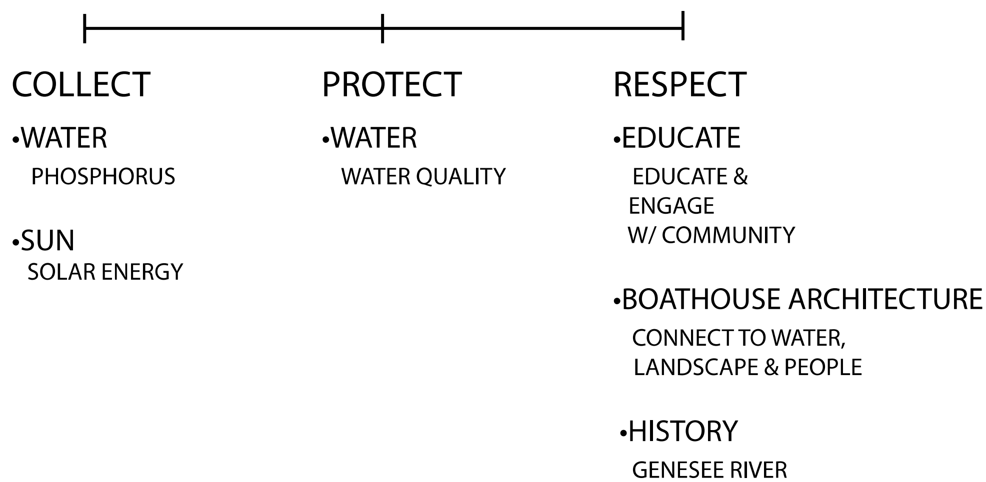

Figure 30: Characteristics of Collect, Protect, Respect, source: Jason Manongdo

The Stickney Water Reclamation Plant is the first treatment process discussed that is capable of handling the capacity of the Genesee River. However, this is not just a treatment system, but an entire treatment facility with two plants, a number of large tanks and encompasses 413 acres of land to treat about 1 million gallons of water a day. While SWRP is a great example, this project needs a treatment system that is much smaller scale so GWC can handle and integrate into its own site without it requiring such a large amount of space. However, as pointed out by Strauss Water, one small or large system on the Genesee River might not resolve all of its phosphorus levels, but it is a possibility that placing a number of small-scale phosphorus purification systems might make a greater difference and help reduce a large number of phosphorus levels.

Seeing as the GWC boathouse is such a small point on the Genesee River, which continuously channels such large volumes of water, a retention basin will be too large of a project and responsibility for GWC to take on its own, but also may not necessarily make a significant impact from this one point. However, the Genesee River is large enough and deep enough to handle corrective interventions installed throughout the course of the river before and past the GWC. This solution at the GWC alone would make a small contribution to re-oxygenating the river water, but could make a more significant impact if these water paddles were placed along the Genesee River.

The “BioHaven® Floating Islands” could be useful in managing any wastewater or runoff from the GWC and its surrounding site. It is a means of using plants as an “integrative site element for managing water” and is mainly designed for smaller water bodies.[24] It is unlikely that it will play a large role on its own in the Genesee River, but can act as a secondary method to further assist in water filtration. Where the algal turf scrubber uses algae to remove excess nutrients, this method would not be useful in the Genesee River, as there is an excess amount of algae already due to the high levels of phosphorus and is part of the issue. However, the other two systems that Button discusses, can be useful for the issues that the Genesee River faces.

9. GWC Sustainable Solutions

Today, boathouses act primarily as community centers where members and spectators can socialize and train. It is no longer a space strictly for storing equipment, but the gateway to the waterfront where recreational users transition from land to water and back. The architecture of boathouses has greatly evolved since its beginning and even more so in recent years, as the sport itself has come to a point of transition. The general organization and principle architectural elements of boathouses have largely remained the same, but they have been redefined to align with modern-day requirements and uses. Seeing as water is a vital resource and a key element in the sport of rowing, it is important that the water quality is kept at an optimal level for the health of the environment and its users. Although a limited amount of phosphorus is necessary, too much can be harmful to an ecosystem and create an excess in algae and decrease in oxygen. Over time, there has been a wide range of developed technologies that can reduce phosphorus and maintain its levels. Based on the findings presented above, the GWC's proposed design provides a social link to its surrounding site and can properly accommodate its programs and an environmental sustainable solution that contributes to lowering the Genesee River's phosphorus pollution. While the boathouse itself cannot individually address the phosphorus levels, it can contribute to reducing levels as well as provide a model for other organizations in the community that may begin to interact with the river.

9.1 Current Boathouse

Genesee Waterways Center is situated in the Genesee Valley Park adjacent to the Genesee River, at the intersection of Scottsville Road and Elmwood Avenue, shown in Figure *31* and Figure *32*.

Figure 31: Location of Genesee Waterways Center, source: Google Maps

The Genesee Waterways Center is accessible by several bicycle and running trails that lead to the boathouse and by vehicles. While two of the trails, Erie Canal Heritage Trail and Genesee Riverway Trail, run along the river, some of the entry points of Genesee Valley Park begin at Elmwood Ave and Genesee Street, welcoming its surrounding neighborhood (shown in Figure *32*). The boathouse is surrounded by baseball diamonds, soccer fields, and tennis courts, but also has a direct road for cars leading from the Elmwood Ave that includes a large parking lot.

Figure 32: Genesee Valley Park, source: Google Maps

Currently, GWC faces many design issues, as it was not built to serve as a boathouse. Some renovations have been made over time as temporary solutions, but they are not enough to properly sustain its programs. Many of the necessary spaces seen in traditional boathouses are missing and the current layout is disconnected and disorganized. The key characteristics of any traditional boathouse are nonexistent in GWC's home, as there is only one level, no distinct roofline, and no themes of rhythm or movement. While the construction is made up of mixed materials, most of it is concrete blocks seen in the interior, fluted concrete exterior walls and wood is seen on the upper exterior of the building, seen in the below images, *Figure 33* through Figure *36*.

Figure 33: Panoramic View of GWC, source: author

Figure 34: GWC Entry from Parking Lot (North Elevation), source: author

Figure 35: GWC South Elevation, source: author

Figure 36: GWC Small Storage, source: author

While today's boathouse is meant to be an open and inviting building, the GWC is a cramped, small building with a narrow and dark hallway leading to a number of closed doors, Figure *37*. Despite the many entry points around this building, it is a confusing and uninviting space.

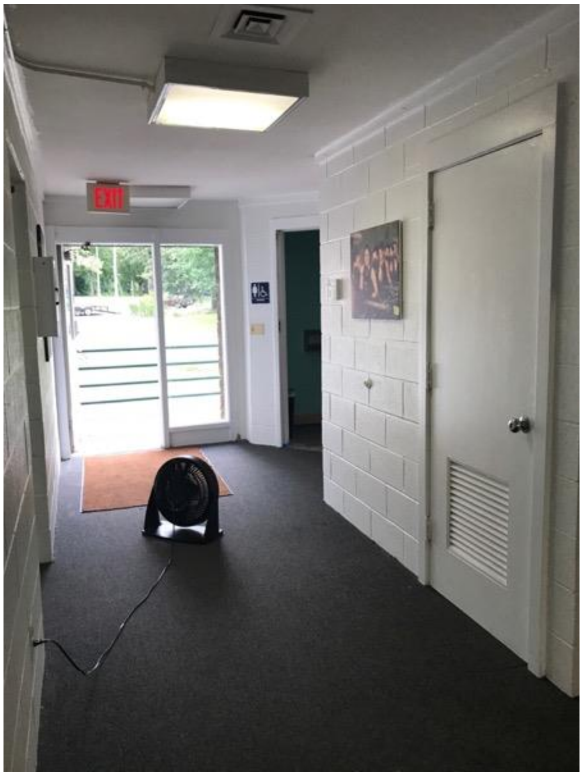

Figure 37: Entryway of GWC, source: author

Figure 38: GWC Training & Club Social Hall, source: author

Beginning with the training and support spaces, there is one room that acts as both the training room and club social hall shown in *Figure 38* above. This space has small windows with minimal views of the river that is right across from the room, taking away the inspiration, pleasant environment, and the clear link between interior and exterior. There is no storage space to put any equipment when the room is used as a social hall, meaning the equipment remains stacked in the room as seen in the above image, which can be dangerous and obstructive. The materials that make up this room are the same materials used throughout the rest of the building's interior, white painted concrete blocks and a grey carpet. The offices are located directly next to the training room and Fortson's other suggested, and significant, space, the locker room, is nonexistent. There are restrooms, but they are located in the opposite corner of the building and act as one of the many entry points into the building, seen in *Figure 37*.

GWC greatly lacks social and support spaces inside and out. The boathouse has many entry points as shown in *Figure 40*. This facility does not have one main entry but has entryways directly to the main office, the manager's office, the restrooms, which are also accessible from inside, the hallway that leads to a number of closed doors inside, and both storage spaces. Visitors who are unfamiliar with the building can easily walk through any door and would be easily confused as to where they are and where the main space is. Bikers and runners who pass by are not given the opportunity to walk through and engage with the building if they need to use the restrooms, but will simply use the bathroom door from the exterior and leave without any interaction.

Newcomers are not introduced to the world of rowing and see very little team pride, symbols, or relation to rowing or kayaking other than the many brochures displayed in the main office, a few small signs by the teams' cubbies, and one sign that hangs outside the fence bordering the trailer parking area. The two offices, the main office and manager's office are located directly across the river and adjacent to the docks and small storage space. The offices are in the opposite corner of the building from the larger storage space and trailer parking area, which also becomes an outdoor storage space for the kayaks during the warmer months. The storage space is traditionally one unified space, rather than several divided up areas, and as Fortson stated, visually connected to the river for efficiency.[34] Efficiency is a major issue in the world of rowing, as there is a lot of large and heavy equipment that is brought back and forth to the water. Each boat has numerous components to it and when getting on and off the water it is important that rowers are quick to allow other teams through in a timely matter and to not exhaust themselves carrying all equipment. Currently, one storage space is adjacent to the docks, but the other is on the opposite side of the boathouse. The storage spaces are cramped and cluttered with every type of equipment used, including rowing shells, oars, parts and accessories, and motorized boats, shown in *Figure 39* below.

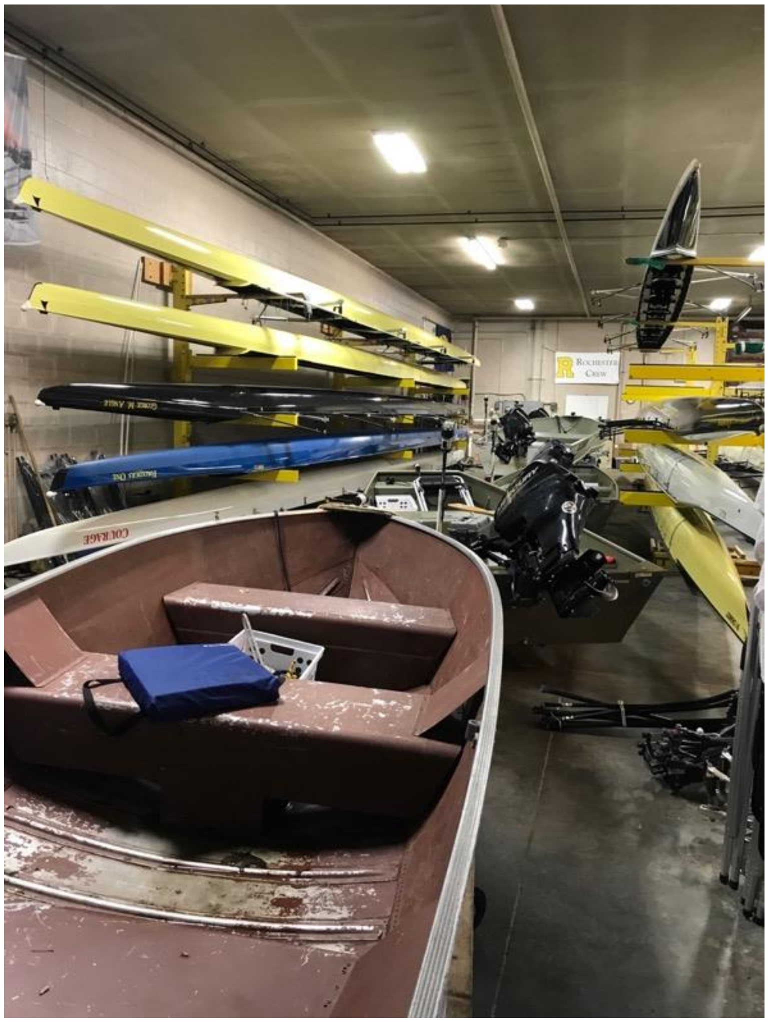

Figure 39: GWC Boat storage, source: author

Secondly, both doorways of the storage areas are parallel to the river and docks, neither having a visual and physical connection to the river nor an efficient pathway. The ramps to the docks add to the already inefficient and inconvenient pathways, as they are out of the way and not a direct path for the rowers to deliver their shells and oars to the river, which are already difficult to navigate due to their sizes.

Lastly, the GWC lacks in its exterior spaces. Spectators and athletes do not have designated outdoor spaces for gathering or viewing. The exterior spaces that are highlighted in *Figure 40* shows an exterior storage and trailer parking space on the west side of the boathouse and three docks along the river. The running and bike path that come from the surrounding park passes past the south side of the boathouse, but there is no stopping space for these temporary visitors to engage with the river or boathouse. Another issue the GWC often faces is that the bike and running trails that pass the boathouse interfere with the GWC's path to and from the river. While cyclists and runners have the right of way, it becomes dangerous when rowers, kayakers, or canoers are attempting to maneuver their large and heavy boats to or from the river through the already difficult pathway and also need to worry about cyclists on the same trail. Rowing shells must be carried slowly and with care, as they are expensive and heavy. Though there are signs on the public trail asking cyclists to walk their bikes, most cyclists do not heed the signs, causing traffic pattern issues.

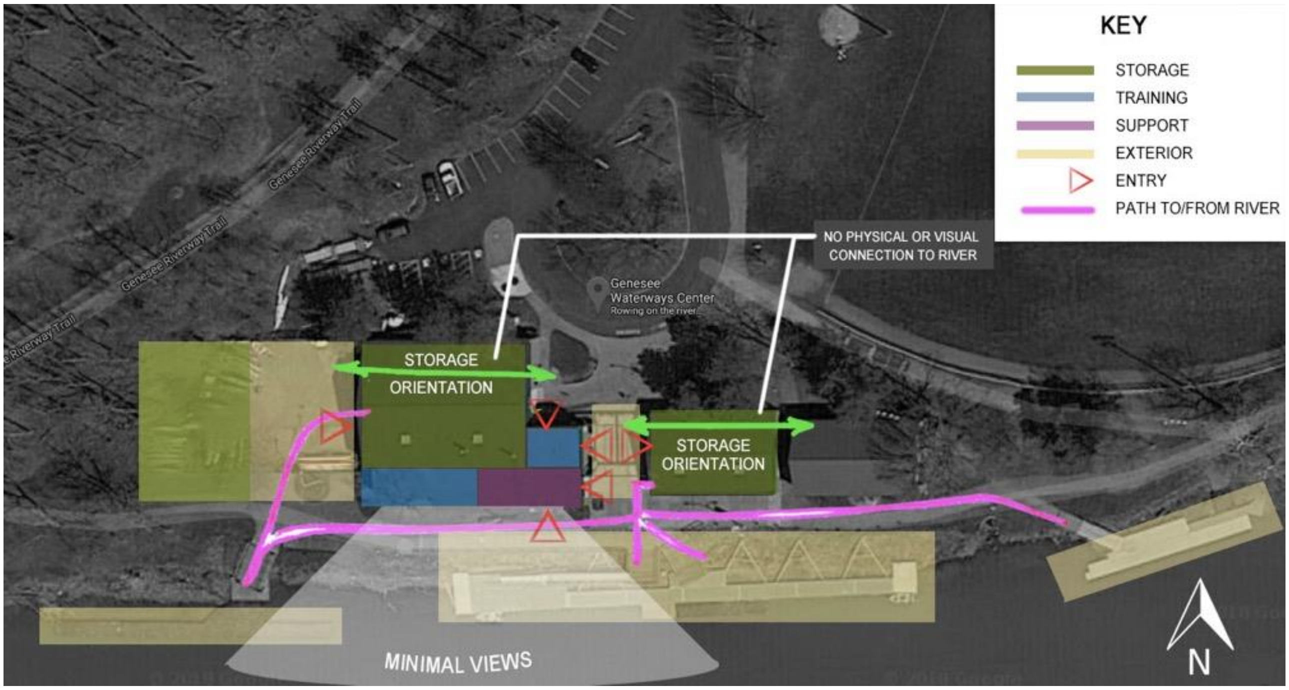

Figure 40: GWC Building Analysis, source: author

The GWC has a number of necessary spaces that are missing from the facility, as illustrated in the site analysis in *Figure 40*. The structure, materials, and floor plan prevent GWC's programs from growing and creating a relationship with the city of Rochester. The current state of the boathouse's architecture does not provide the support the athletes need for motivation, inspiration, or a sense of pride. Instead, the programs are isolated and disconnected, like the facility is to the rest of its surroundings. There is little connection between the boathouse and river or the boathouse and its own sports. The link between the interior and exterior is absent due to the lack of natural materials, the lack of physical and visual contact with the Genesee River, and minimal daylight reaching the interior, even though the south side of the building is exposed to the most amount of sunlight, shown in *Figure 41*. The broken up and disconnected layout neither enhances activity nor social relation within the facility and creates a barrier between the spectator, participants, and river, rather than create an interaction.

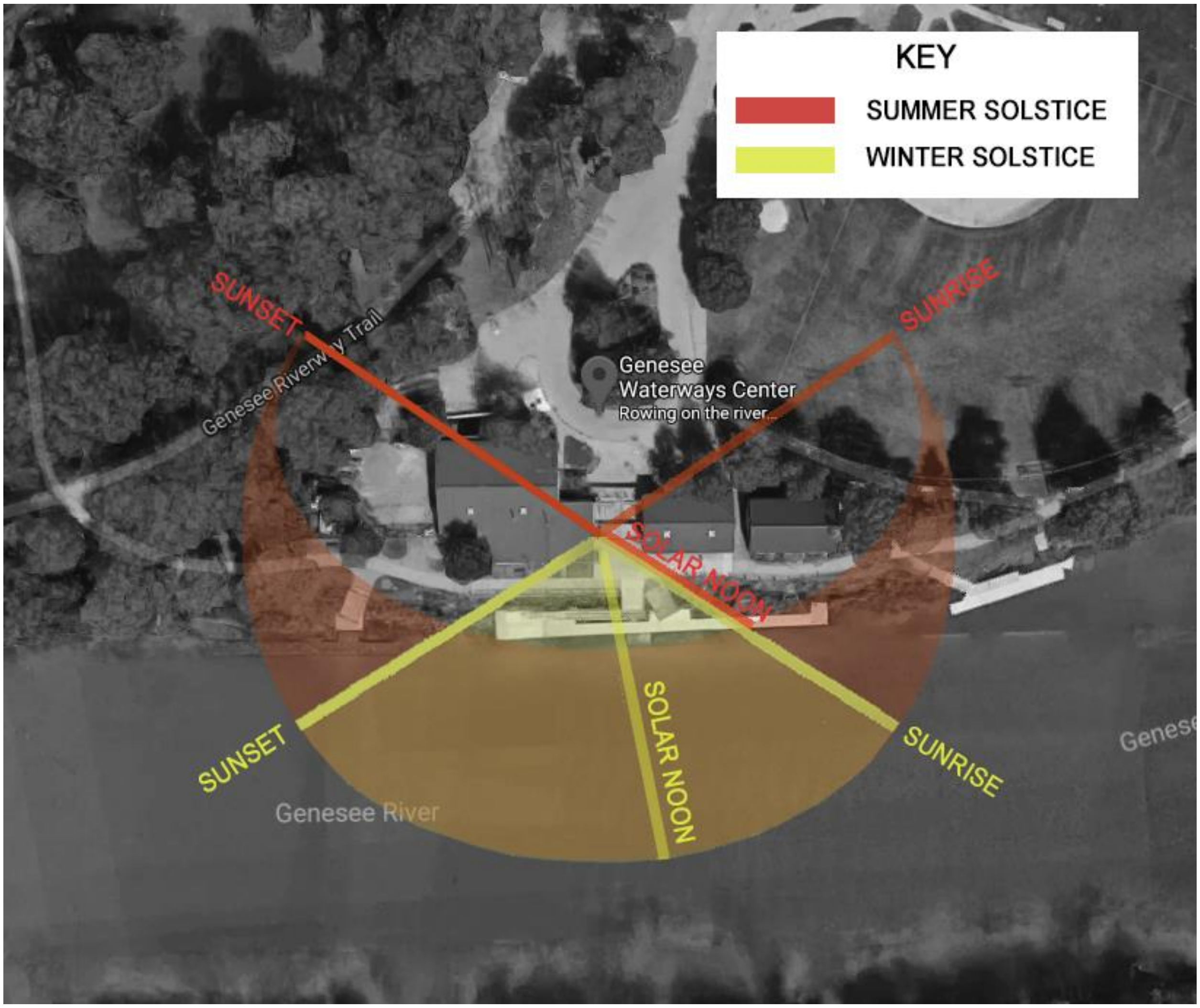

Figure 41: Solar Analysis, source: author

The GWC currently has about 60 program members who visit weekly. Kayak renters will bring a total of 80 participants during the week and upwards of 100 partakers during weekends. Occasionally, the Genesee Valley Sports Complex (GVSC) next door hosts events during the weekends, bringing a total of about 300 people who stop by the GWC docks. There are a few traffic issues the boathouse staff and members often face as the public trail and GVSC’s events, such as the triathlon, pass in front of the GWC boathouse, causing many traffic pattern issues during practice time.

This section has shown that the Genesee Waterways Center has a disorganized and disconnected floor plan and is missing the key architectural features that help to identify a boathouse. Many needed spaces are missing from this building, such as locker rooms, an appropriate training room and social hall, an outdoor training space, support spaces, and boat storage spaces that are not big enough to store all the boats and equipment. Additionally, there is a weak relationship between the boathouse and the Genesee River, with minimal visual and physical connections, as the interior receives little daylight, and the boat storage spaces are aligned parallel to the river. Without an opening perpendicular to the river adds great difficulty of maneuvering racing shells that range between 27 to 62 feet in length.

The table on the following page shows the key features expressed in the above case studies that should be incorporated into any boathouse to properly accommodate today's boathouse, its programs, and its competitive and recreational users. As shown in Table *2*, the current design of the Genesee Waterways Center only features two of the nine general core requirements that are found in boathouses traditionally along with the evolved and further developed boathouses of today.

Table 2: Current GWC design features

Core elements of a boathouse	Existing GWC
Max. physical & visual access to river from boathouse	
Typical arrangement of 4 spaces	
Two levels	
Traditional architectural characteristics: multi-material construction	x
Spectator areas	
Emphasis of physical exertion	
Emphasis of social relaxation	
Surrounding recreational path	x
Natural light inside boathouse	

9.2 Proposed Boathouse

The proposed re-design of Genesee Waterways Center is a schematic design that shows the reorganization of the spaces and a second-floor addition to align it with the tradition of boathouse design. The traditional boathouse that is being introduced to GWC is the proper organization of the essential spaces, illustrated in *Figure 42*, and architectural characteristics. Boathouse architectural styles have greatly evolved overtime, but its layout has largely remained for the purposes of efficiency and community, exemplified in more detail in *Figure 43*.

The solutions to the concerns of GWC's current state are as follows:

- Layout reorganization
- Addition of appropriate spaces and architectural characteristics
- Build stronger relationship between boathouse and river through physical and visual connections
- Build a healthier relationship between river and people by using rowers and boathouse as the tool to power the integrated water treatment technology
- Improve the boathouse's relationship to its surrounding site and natural landscape through the use of materials

9.2.1 Program

The design solution for the Genesee Waterways Center will include the following training, exterior, storage, and social and support spaces listed below. They are all spaces that are either typically found and required in boathouses or spaces that are desired by the GWC community that would better support their club members, staff members, and programs. The redesign of this boathouse is not a new structure, but a reorganization of the spaces within the existing structure plus the addition of spaces and a floor level, a change in interior and exterior materials and architectural features that better reflect those of a typical boathouse as researched above.

Rowing Shell Storage
Kayak Storage
Mechanized Boat Storage
Entry
Docks
Trailer Parking
Outdoor Training Space
Indoor Spectator Area
Exterior Terrace

Daycare
Public Bathrooms
Offices
Conference Room
Multi-purpose Room that doubles as
Training and Club Social Hall
Locker Rooms
Kitchen
Storage Rooms

The bubble diagram phase helped develop the design of the floor plan based on the need for a particular sequence of rooms and how those spaces relate to the building's orientation (*Figure 42*).

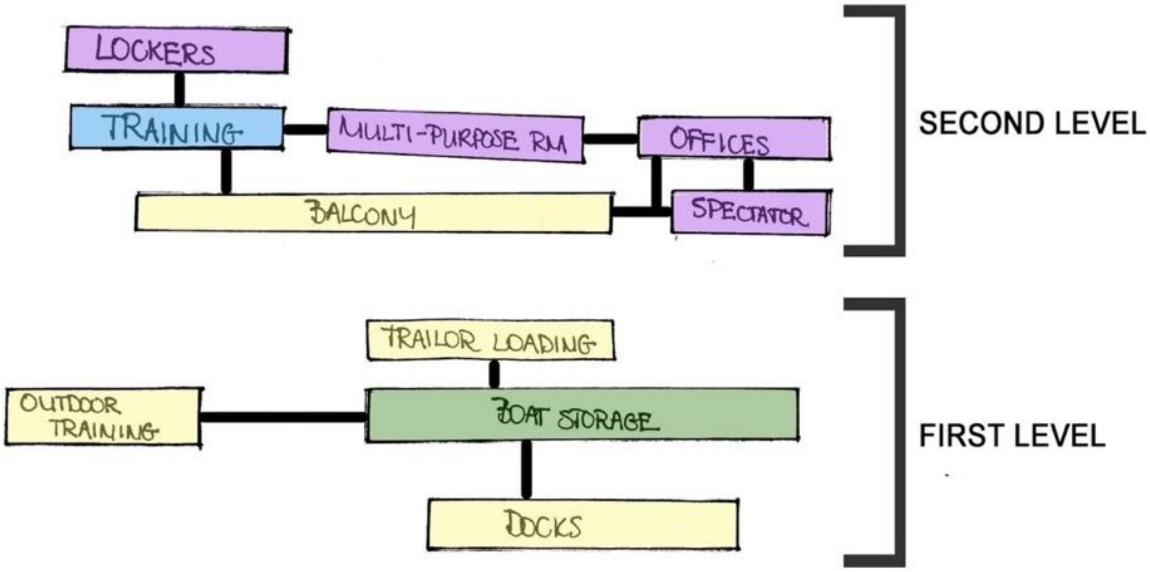

Figure 42: Bubble Diagram, source: author

9.2.2 Ground Floor

This proposal for re-design includes one large space for storing rowing shells and equipment, a smaller and separate storage space for motorized boats and one detached space, which currently exists, dedicated to kayak equipment (see *Figure 50*). All three spaces will have a direct visual and physical connection to the river as they will be placed directly adjacent to the river and their doorways will open leading straight to their designated docks for maximum efficiency. Next, the ground floor will be comprised of a grand entry space that leads upstairs to the second floor with a direct view of the river. The entry space will be used to introduce visitors to the world of rowing through a showcase of community events and members' achievements. Ground floor exterior spaces will include docks, an outdoor training space, existing bike and running path, and existing trailer parking and loading space. Lastly, the dock locations are not only for the rowers to carry their equipment with more ease, but also a more distinct sign to cyclists and runners that there is activity ahead where they should be aware and walk their bikes or slow down for safety.

9.2.3 Second Floor

The GWC is currently one level, but this thesis proposes a re-design to create a more traditional boathouse that can accommodate the appropriate spaces. The second floor design will include all support spaces including a conference room, the club social hall that doubles as the training room with locker rooms adjacent, kitchen, public restrooms, offices, a daycare, indoor spectator area, and a viewing balcony. The spaces on this floor were arranged in a way that transitions from public to more private spaces that are exclusive to club members, beginning from the indoor and outdoor viewing areas and ending with the daycare. The second floor spaces were also organized in a way that gives the key spaces, spectator area, offices, and multi-purpose room, the maximum view of the river and the docks below. Though this design provides a viewing space of both the north and south sides of the river, the design has a more emphasized view of the south side since the GWC rowers and kayakers usually row towards that direction.

9.2.4 Architectural Features

The GWC's current exterior characteristics do not exhibit the typical characteristics often found in the architecture of boathouses. This re-design proposes multi-material construction and a more distinct roofline that represents the rhythm of waves in water. The exterior materials proposed consist of wood cladding and fluted concrete, reflecting both the surrounding nature and the materials of the existing boathouse. The interior materials, shown in the renderings Figure *58* and *Figure 59*, are primarily wood but also feature concrete flooring in the entry and ground floor storage spaces, repurposing the demolished walls from the current GWC.

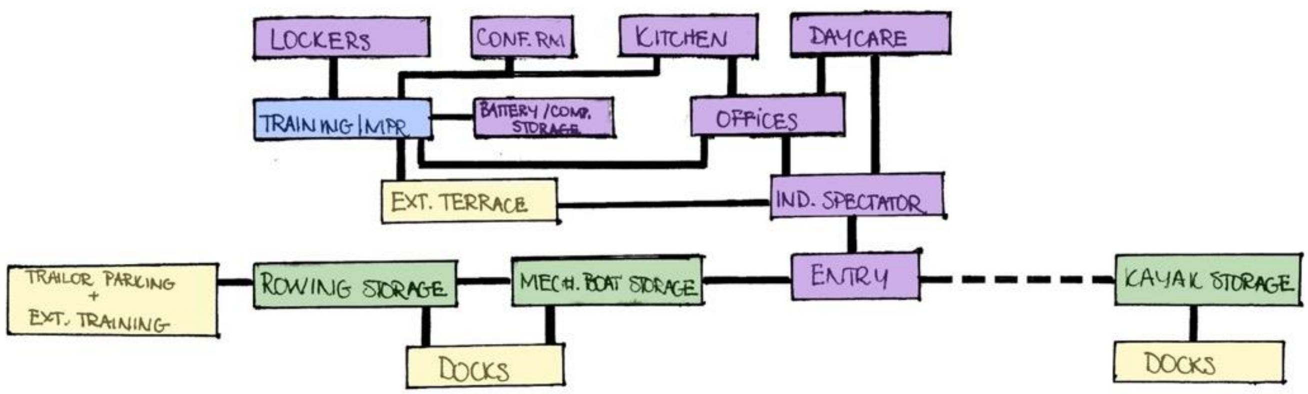

Figure 43: Bubble Diagram, source: author

Table 3 below shows a comparison of the existing design of the GWC versus its proposed design. The existing boathouse features very little of the key parts that make a successful boathouse with today's necessities taken into consideration. However, the proposed design make an effort to incorporate all of the requirements outlined by the previously discussed case studies that align with GWC's desires and goals.

Table 3: Comparison of Existing & Proposed GWC Design

Core elements of a boathouse	Existing GWC	Proposed GWC
Max. physical & visual access to river		x
Typical arrangement of 4 spaces		x
Two levels		x
Traditional architectural characteristics: multi-material construction	x	x
Spectator areas		x
Emphasis of physical exertion		x
Emphasis of social relaxation		x
Surrounding recreational path	x	x
Natural light inside boathouse		x

<u>9.2.5 Educational Experience</u>

One of the goals of this project was to integrate a P pollution solution for the Genesee River into the GWC's proposed design in a way that provides an educational experience for the boathouse's patrons. As shown in *Figure 52*, the GWC's proposed lobby has a designated space where the aeration system's compressor, energy converter, and energy storage systems would be located and displayed, demonstrating and explaining to passersby the purpose of these technologies, how they work, and GWC's environmental contribution to the community of Rochester. The technologies display is located at the entrance of the lobby, inviting guests into the building, introducing them to the world of rowing and to the GWC community. Additionally, since the rowers are contributing to powering the aeration system, it would be a useful tool for them to have a visual display in their training room that informs them of how much energy they have generated, emphasizing both physical exertion and community, two significant features frequently stressed amongst boathouses.

Second, there is an alternative renewable energy source to make up the remaining energy required to power the aeration system that would not be generated by GWC's athletes. Rather than locate the solar panels on the roof, they will be located on the south side of the building outside of the entry space, as illustrated in Figure *50*. The solar panels will be located on the ground, exterior of the boathouse where spectators can first begin their exploration of the GWC and its program's goals and contributions. By placing the solar panels outside, this would lead to new visitors inside and potentially new members.

Lastly, the many technologies and systems are located throughout the interior and exterior of the Genesee Waterways Center are all connected to each other. Instead of hiding the many wires and pipes in the walls, ceilings, or underground, this project proposes to expose them for the public to view, allowing people to further understand how the technologies are connected and how they work. The wires within the boathouse that connect the rowing machines from the training room and the solar panels to the technologies displayed in the entry are exposed on the walls and ceilings. The pipe connected from the compressor to the diffuser is exposed in the entry's floor and outside within the ground leading to the diffuser. A glass pane rests above the pipe at the level of the surrounding sidewalk and entry flooring so that the pipe is visible to the public through the glass but the floor level is not disrupted to create a tripping hazard. Additionally, there is a screen in the display room that shows a live feed of the diffuser as it operates underwater to show the end result of the rowers' and solar panels' energy generation.

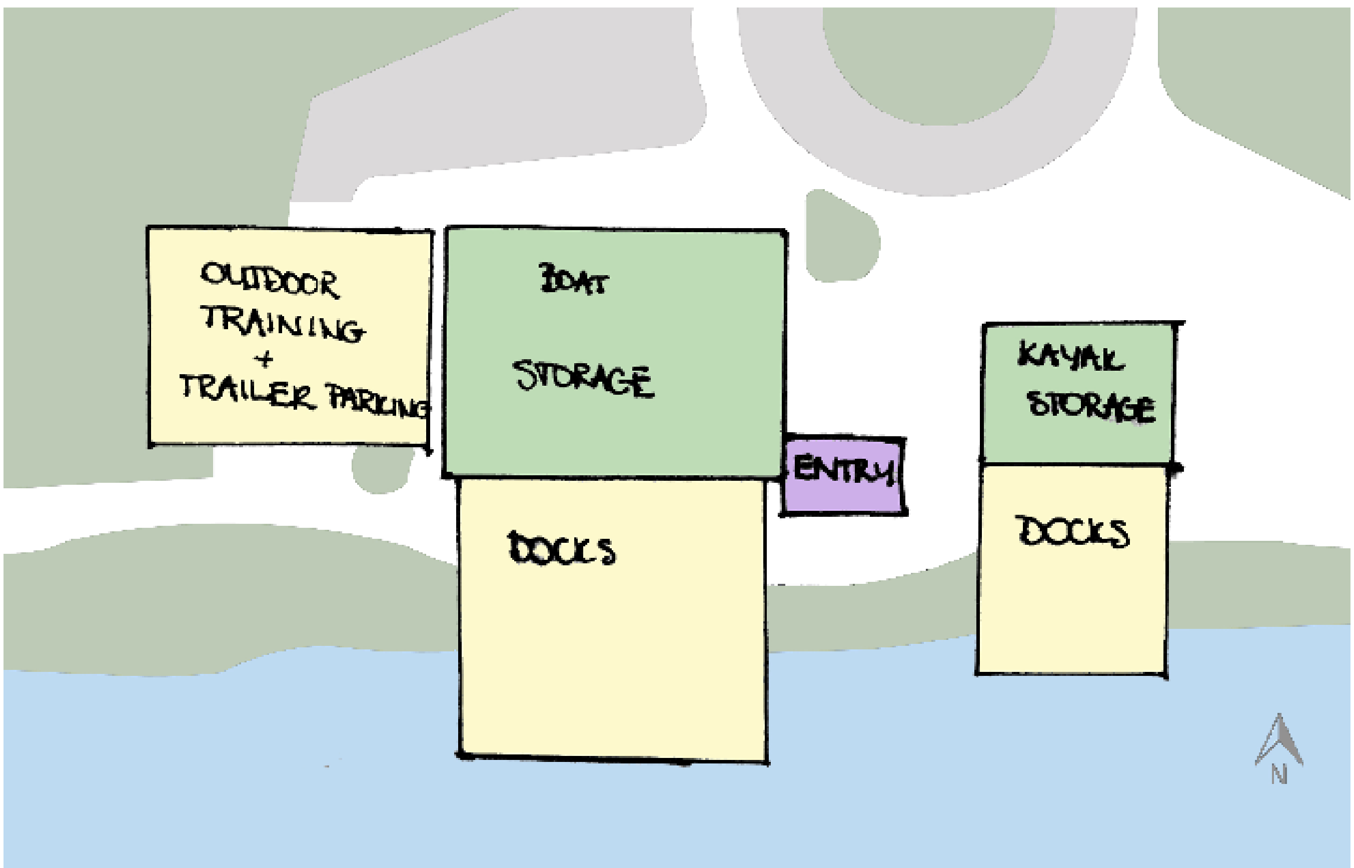

Figure 44: First Floor Process, source: author

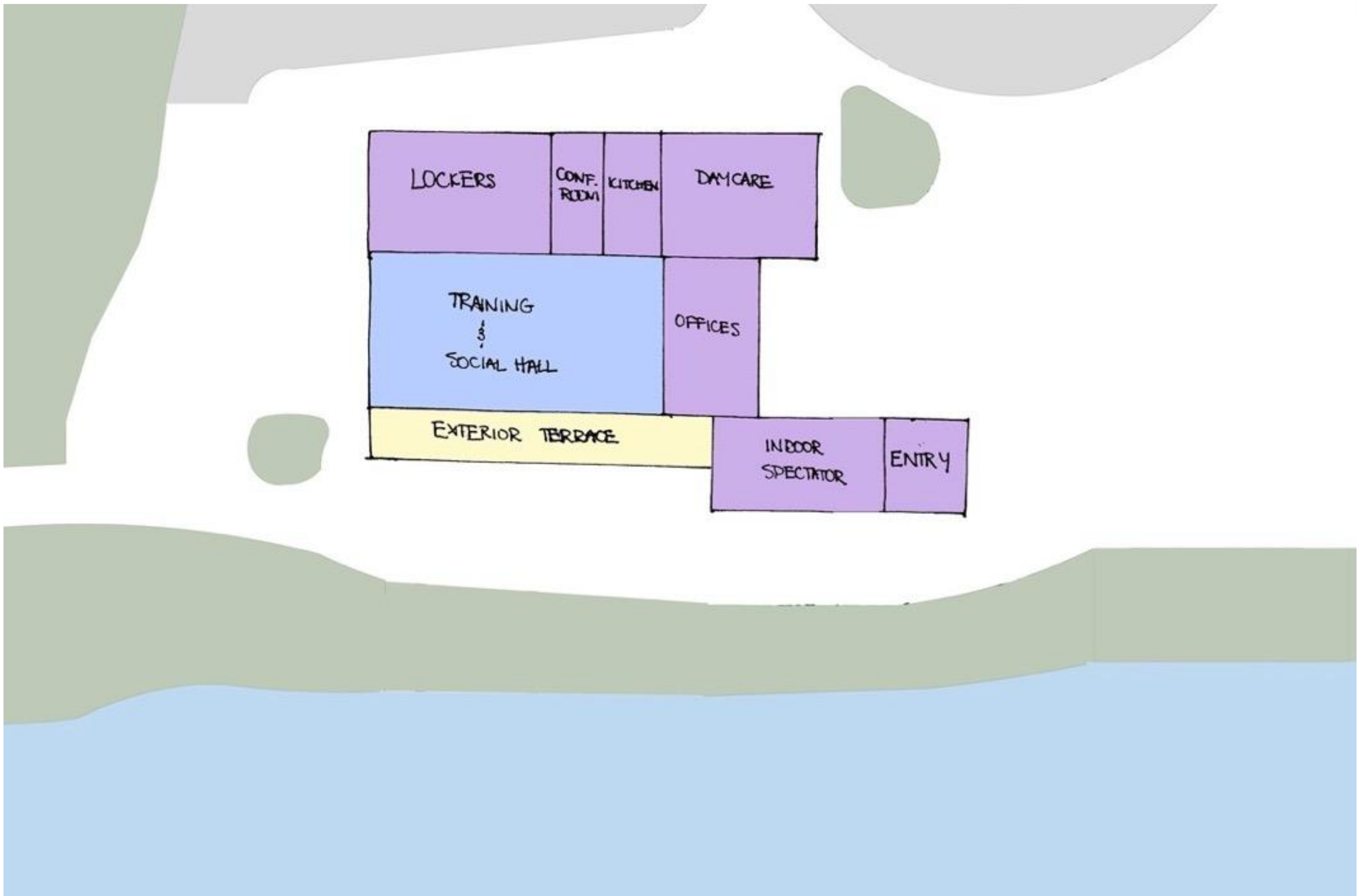

Figure 45: Second Floor Process, source: author

Figure *44* and Figure *45* show the process in how the GWC's new layout began to form its shape from the bubble diagrams. After researching the proper layout of how a typical boathouse is designed and the types of spaces that the GWC currently lacks and is in need of, a more accommodating boathouse was designed within the existing form of the boathouse with several changes and additions. The spaces that require direct physical waterfront access, the most views of the river, and natural light, such as the training room/social hall, offices, and spectator areas, were placed on the south side of the building with their required adjacent spaces in their appropriate locations on the north side of the building. Both storage spaces that are currently oriented parallel to the river and the large storage space that is currently on the north side of the building, have been reoriented perpendicular to the river and moved to the south side directly adjacent to the river for efficiency and convenience. The outdoor training space and trailer parking area has remained the existing location of the current trailer parking area. The parking lot of this space is narrow and a circular driveway, which does not leave enough space for new trailer parking without interfering with parking spaces and the driveway. The current outdoor area has enough space for trailer parking, prepping or repairing boats, and outdoor training without disrupting the public trail and allows the athletes to a private, focused space.

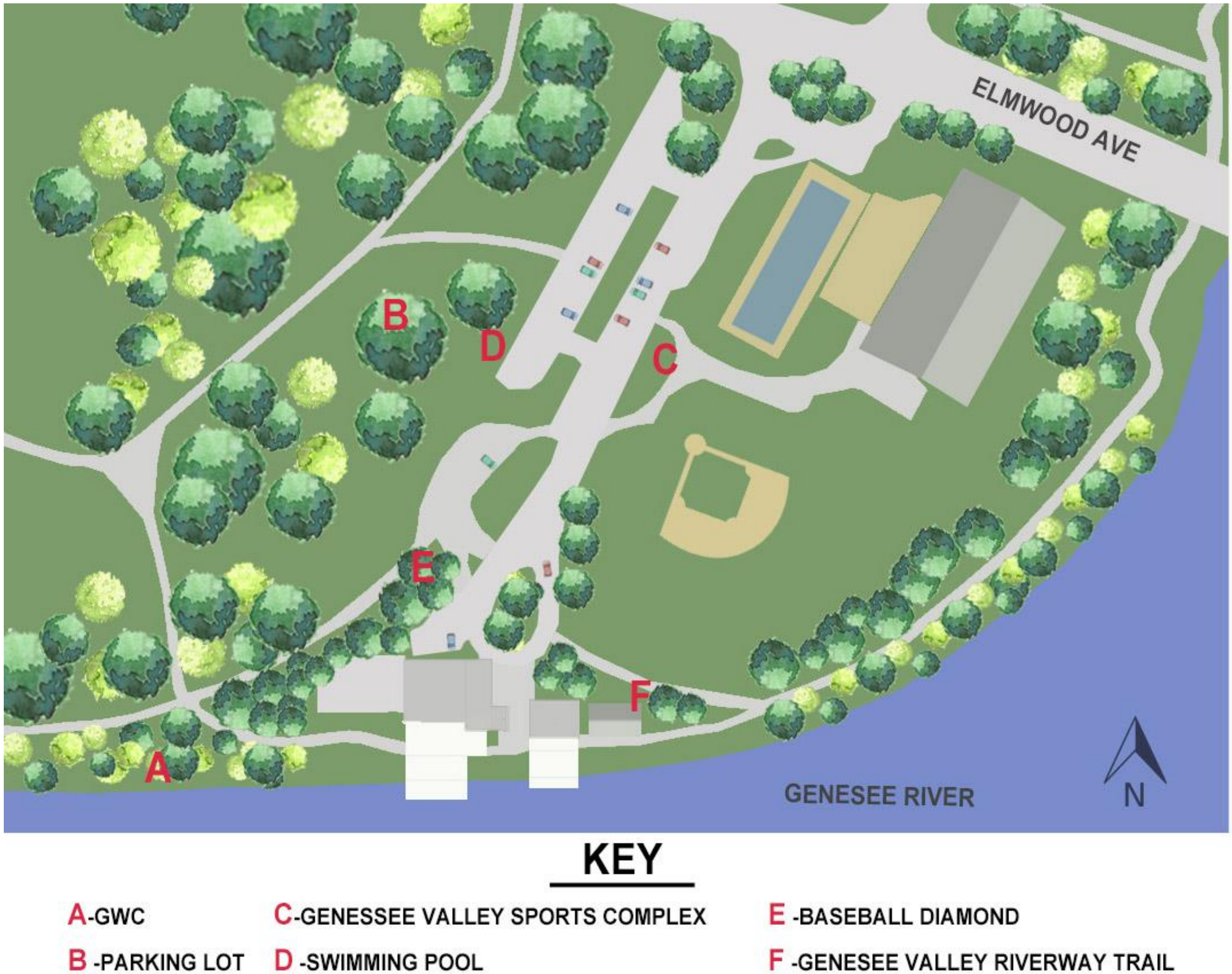

Figure 46: Site Plan (not to scale), source: author

Figure 47: Roof Plan (not to scale), source: author

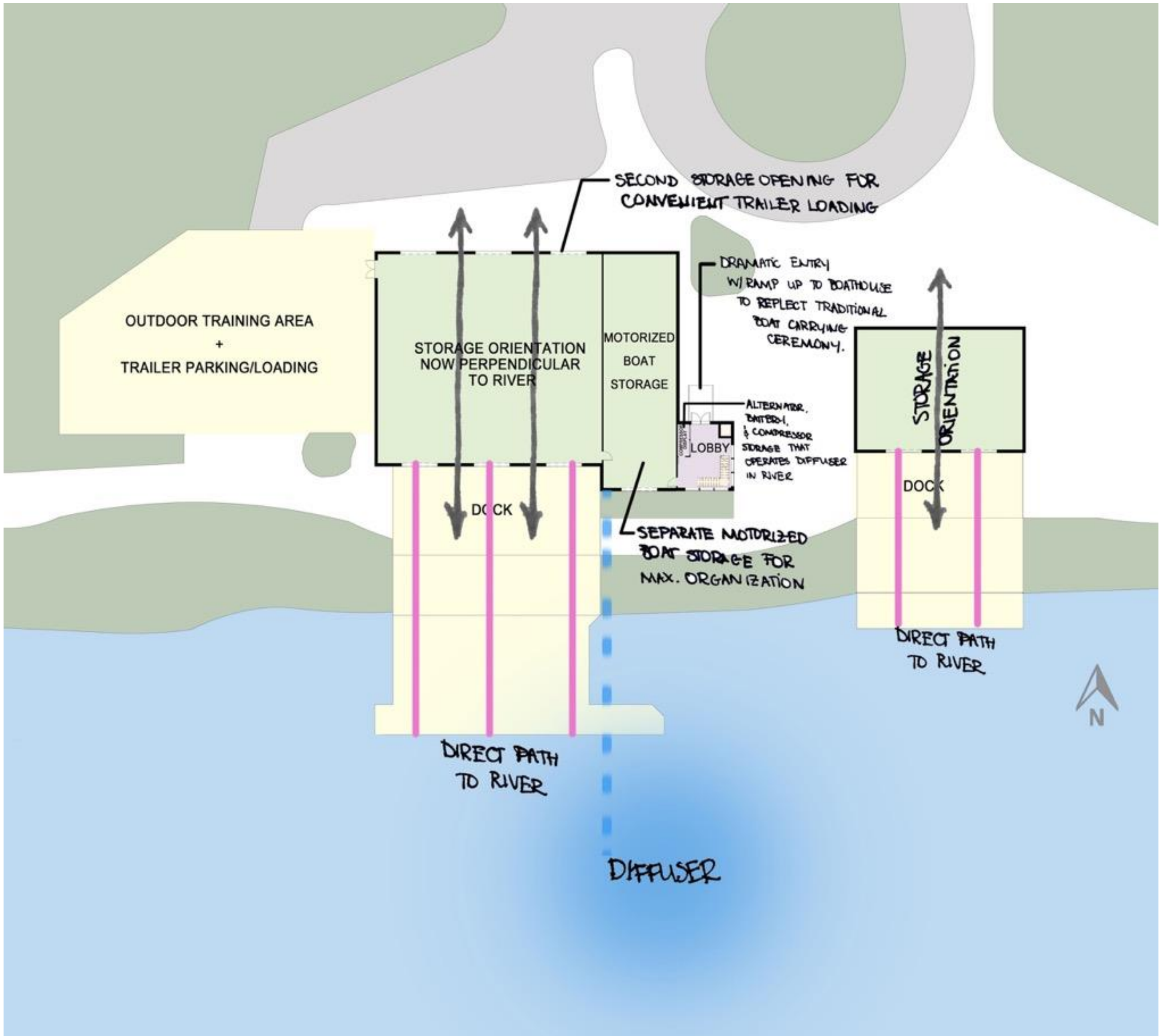

Figure 48: Ground Floor Analysis (not to scale), source: author

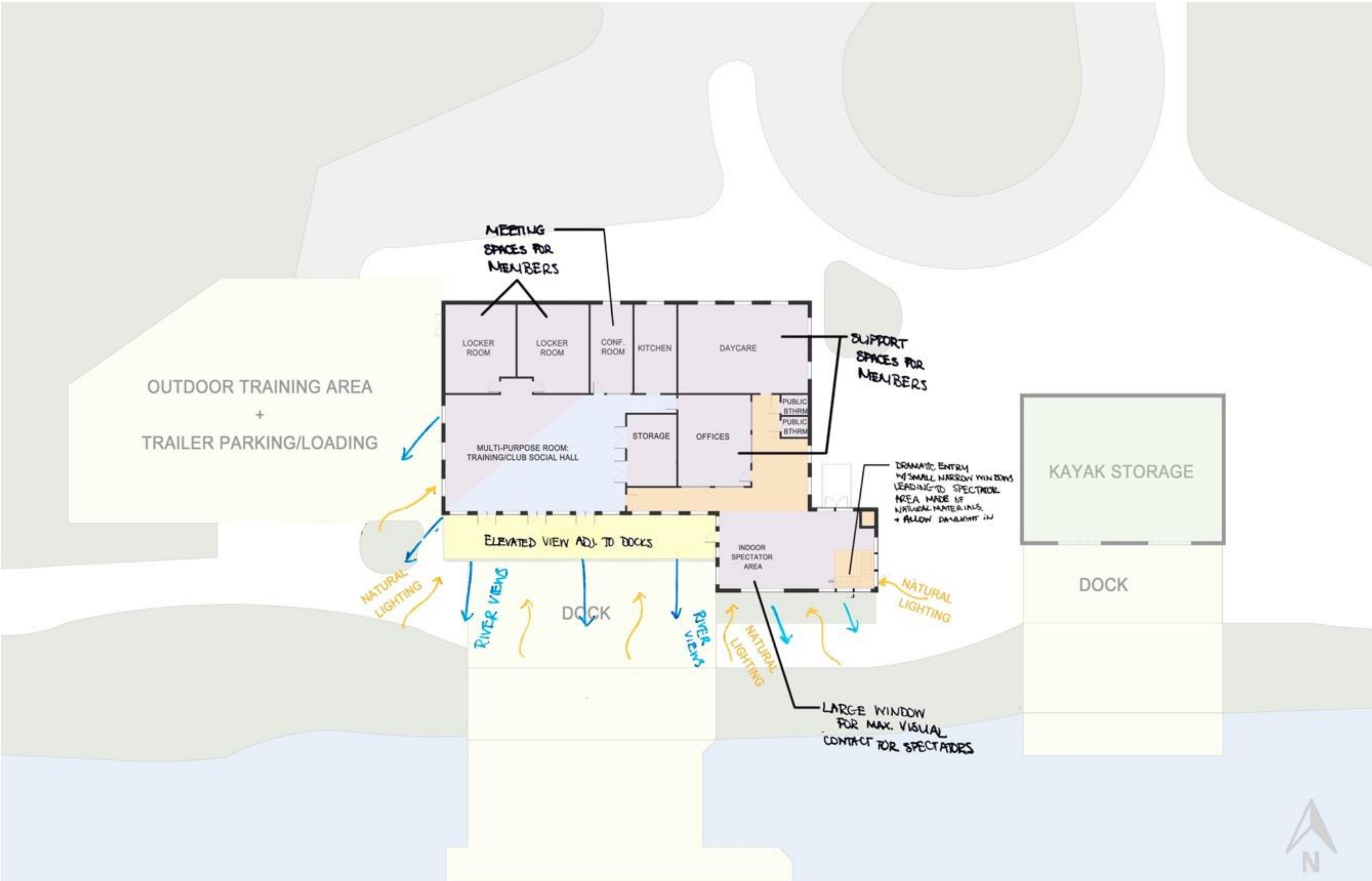

Figure 49: Second Floor Analysis (not to scale), source: author

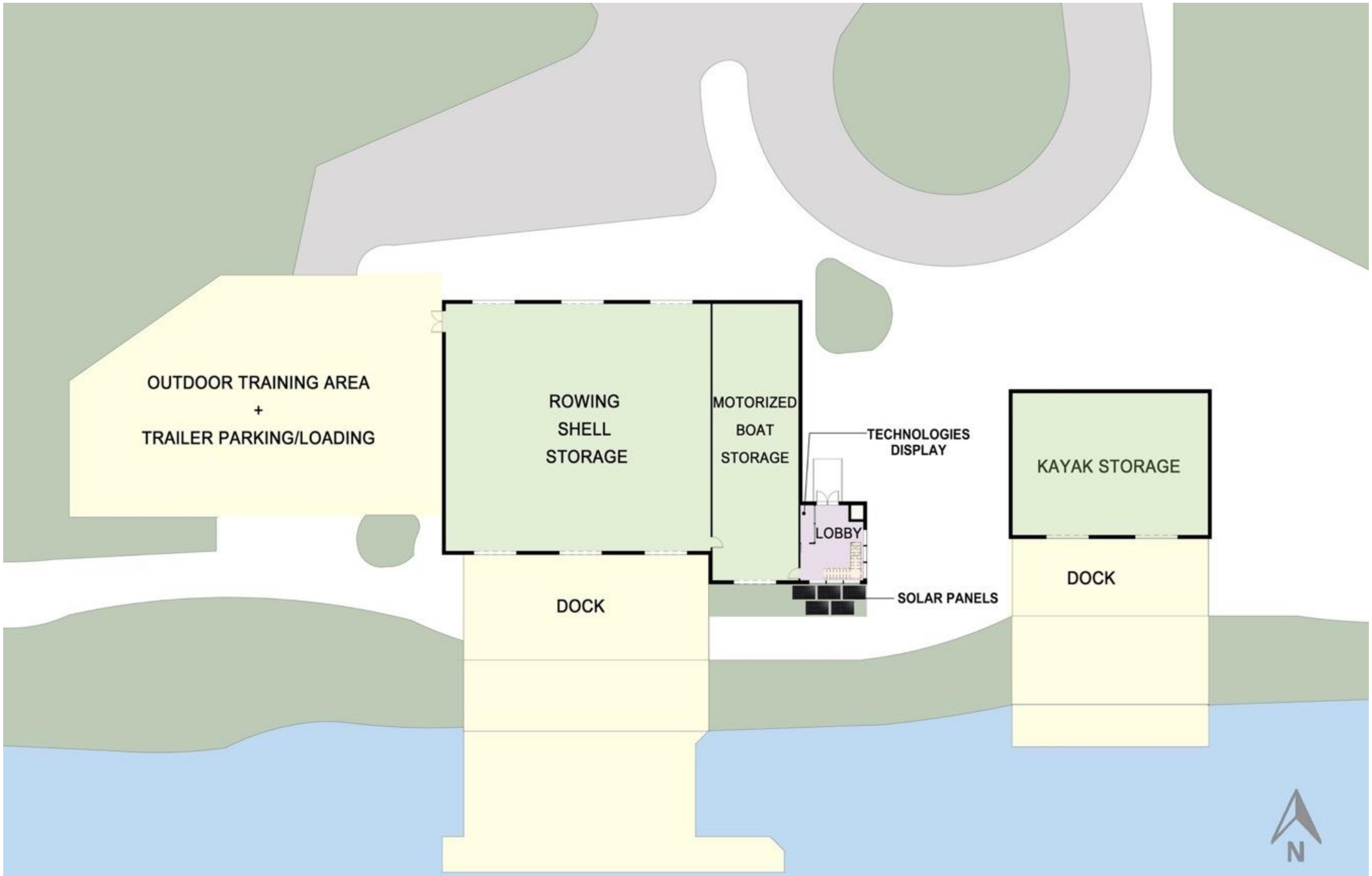

Figure 50: Ground Floor Plan (not to scale), source: author

Figure 51: Second Floor Plan (not to scale), source: author

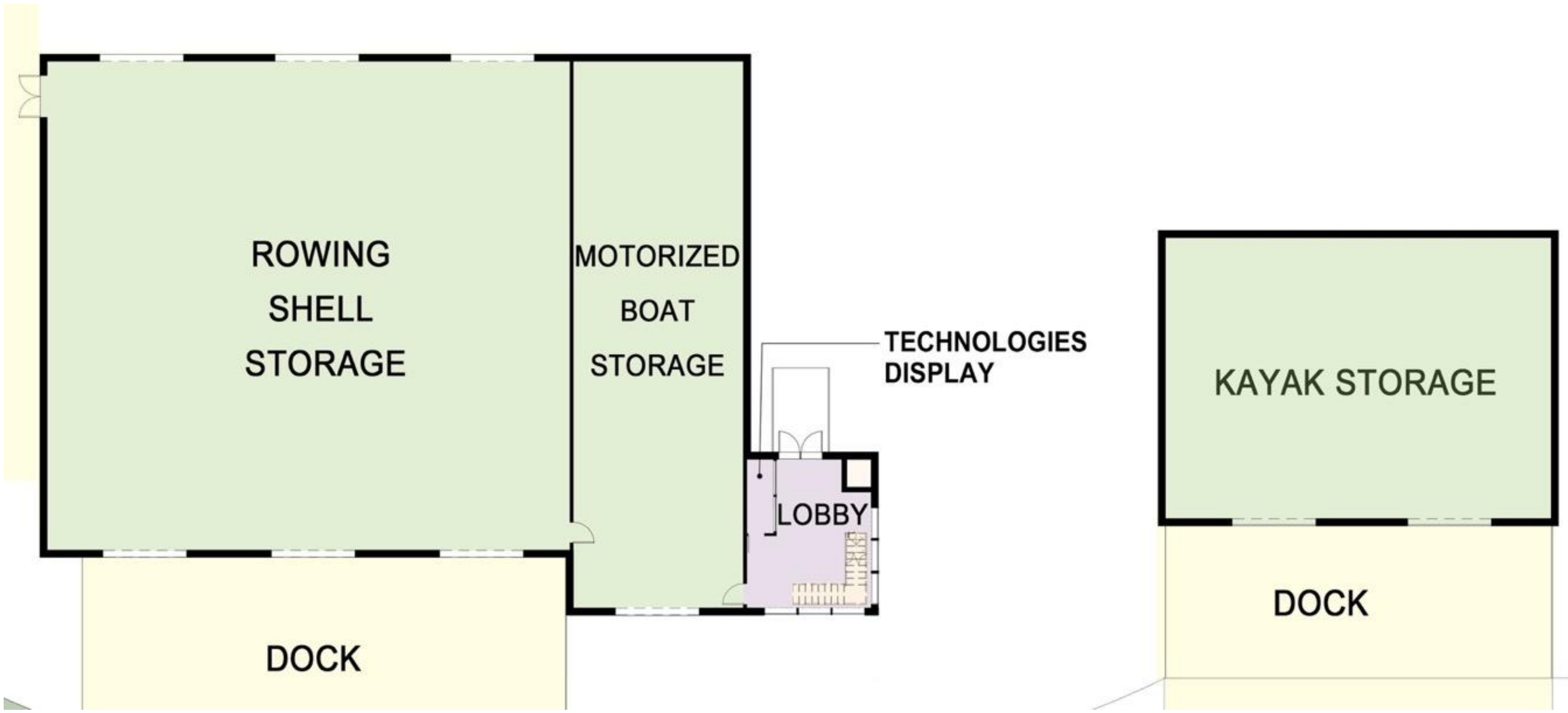

Figure 52: Enlarged Ground Floor Plan (not to scale), source: author

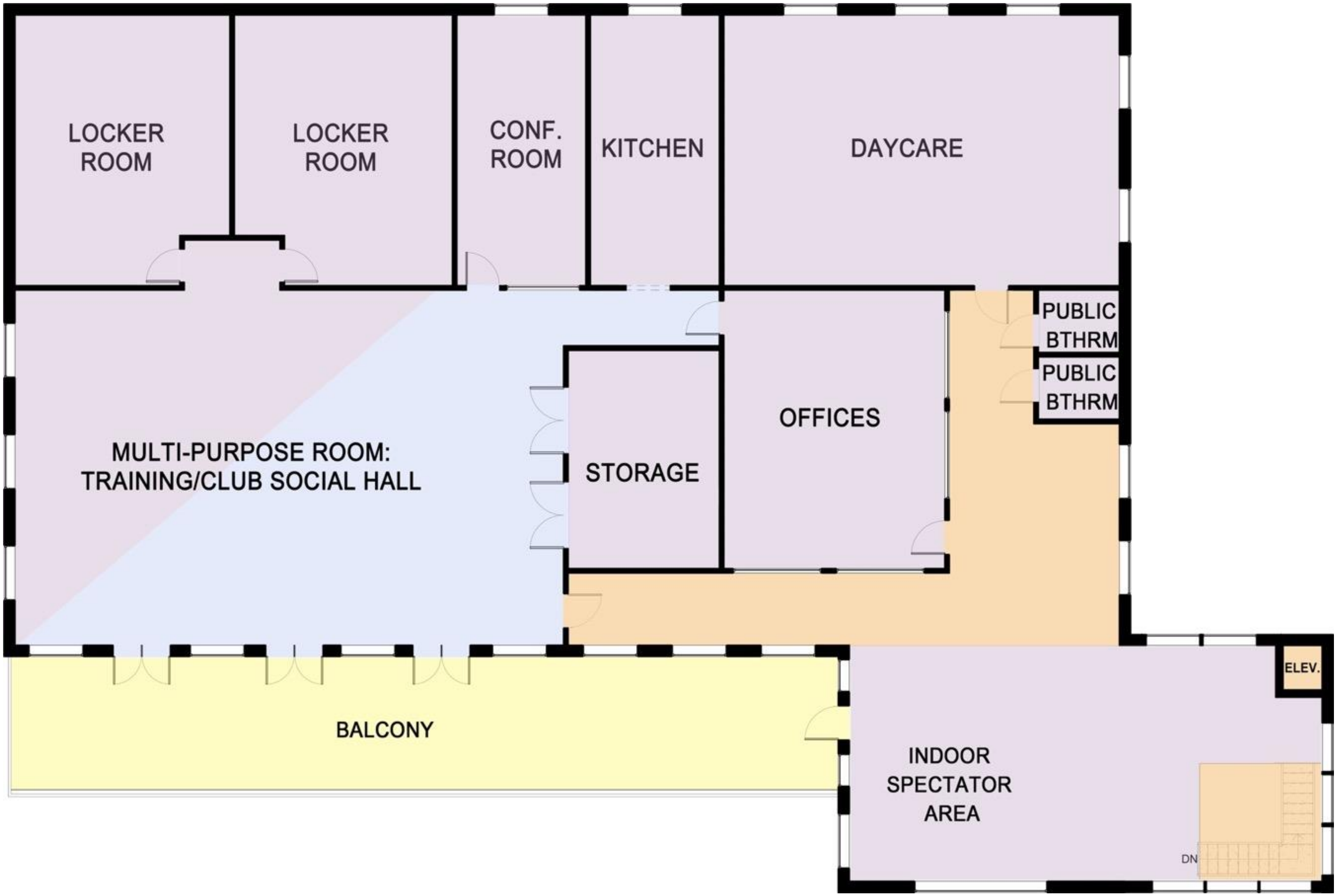

Figure 53: Enlarged Second Floor Plan (not to scale), source: author

Figure 54: Exterior View, source: author


Figure 55: Exterior Rendering, source: author


Figure 56: Exterior Rendering, source: author

Figure 57: Exterior Rendering, source: author

Figure 58: Interior Rendering of Entry, source: author

Figure 59: Interior Rendering of Training Room, source: author

9.2.6 Current GWC vs. Proposed

The proposed boathouse is meant to be a reorganization of the current structure with additions and changes that properly reflect a boathouse. This proposal does not involve replacing the entire existing boathouse with a new structure, but re-designing the structure that organizes the spaces in their appropriate locations. There was an attempt to leave as much of the existing boathouse's structure remaining and Figure *60* below shows the existing structure, hatched in grey, overlaid over the proposed boathouse.

The proposed design shows the existing small storage space has remained in size and in location, but the main building's overall layout has been simplified compared to the existing. The length of the main building has been extended towards the west, replacing what was part of the large exterior trailer parking area to allow more space for both the indoor storage on the ground floor and an accommodating second floor training room and social and support spaces the GWC is in need of. Second, the width of the main building has been reduced to allow more space for members when carrying boats in and out of the boathouse to the river, to the docks when prepping or repairing boats, or to the trailer when loading for races to minimize interference with the public trail and its passing cyclists, runners, or park visitors. The existing offices located in the southeast corner and the public restrooms that make up the northeast corner of the main building have been removed entirely in the re-design. The only other space on the ground floor apart from storage and exterior spaces, is a clear and distinct entry to the proposed main building.

Lastly, the materials of the existing building that, in this case, would be demolished, would be repurposed in the GWC's re-design and the new exterior walls of the proposed boathouse's first level would match the existing fluted concrete walls that remain. This project proposes to recycle the demolished interior and exterior concrete walls by utilizing the rubble as flooring throughout the entry and storage spaces in the main building.

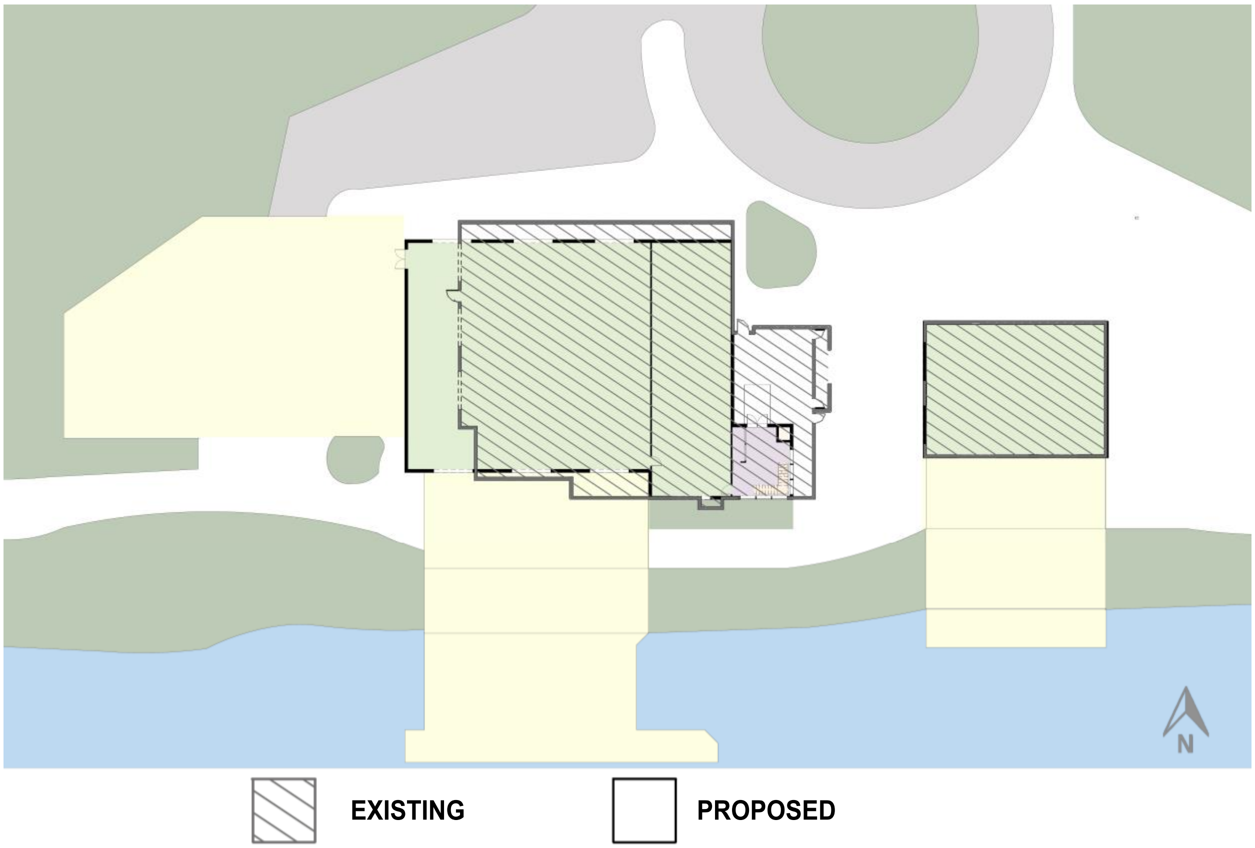

Figure 60: Existing GWC structure overlaid over proposed, source: author

9.3 Phosphorus Filtration Method for GWC Boathouse

9.3.1 Building Integrated System

The vision for this boathouse is not only to act as a community gateway to the river, but also to contribute to maintaining the health of the river. The proposed re-design of the GWC includes a filtration method that is integrated into the boathouse where members are able to participate in the environmental efforts of restoring the Genesee River. Including community members allows them to become educated on the significance of a healthy environment. This proposed solution can demonstrate how humans and nature can be positively connected through the utilization of architecture.

The Genesee River requires an environment where oxygen levels are maintained to prevent excess levels of P so that algae and bacteria will not increase or dominate the river. The last report shows phosphorus levels in the Genesee River at an average of 78.9 ± 14.9 µg P/L, while the NYSDEC's river guideline advises phosphorus levels to be at 20 µg P/L. The goal is to keep P levels maintained, as it "is an important nutrient for every living organism," and is part of the Food Chain.[23] River aeration is a natural solution that allows the stagnant body of water beneath the surface to rise to the surface and become oxygenated. "In most natural waters, the supply of oxygen to water exceeds the amount used in oxygen-consuming processes," whereas the Genesee River's oxygen supply is currently less than the amount used.[35] While the surface of the river moves rapidly and is oxygenated, the bottom of the river has zero flow where disease-causing bacteria and other unwanted species are able to thrive. A key factor required to deliver a

[35] Tucker, Craig. Pond Aeration SRAC Factsheet 3007. srac.tamu.edu

natural solution to excess P is adequate retention time “to allow a consistent environment to be maintained so that nature can establish the productive biome and Food Chain required.”[23]

There are many approaches to filtering phosphorus from water, but not every approach is appropriate for every water type and size. Many of the filtration systems researched in this project were designed for smaller-scale bodies of water and would not be able to handle the capacity of the Genesee River. Several approaches have been considered for this project including a retention pond, a removal structure, a removal treatment plant, and other on-site features. However, they were rejected for this project for the following reasons.

A retention pond could be a possible solution for the Genesee River, but is not ideal for the GWC. A retention pond would require damming the river and diverting it into a retention basin. After aerating the water, it would then be returned back into the river. Creating a retention is too is too large and expensive of a solution, which is beyond the scope for GWC.

The USGS filtration system is an entire treatment plant that would require a large amount of space, taking away already limited space from the GWC. Second, this treatment plant, although an effective primary filtering agent, is only capable of filtering 100,000 gallons per day. The Genesee River’s flow rate is 1,981,140.8 gallons per minute (or 2,852,274,597.7 gpd) meaning this system is too small scale for what the Genesee River needs.

The phosphorus removal structure is a bed filter that was constructed for a very small-scale project. It was meant to intercept agricultural run off before reaching a creek. This structure was effective for only 7-8 months before its materials need replacing and was found to only remove about 25% of P that entered the structure. Additionally, one structure can only handle about 100 gpm, requiring about 20,000 structures along the river that would all need replacing every 8 months and minimal filtration.

A more efficient and appropriate solution for integrating environmental sustainability to the boathouse design would be to introduce a smaller corrective intervention along the river at several points to make a significant impact. This approach corrects the Genesee River's phosphorus issue by balancing P and oxygen to their desired levels for a healthy ecosystem without adding any obstructions that would interfere with boats on the river or harmful chemicals or materials that would create new problems for the river's ecosystem. This thesis looks to use the boathouse as one tool to maintain the health of the river by converting the power generated by the GWC athletes to drive the compressor.

The selected solution for this project involves aeration units at the bottom of the river that circulate the water allowing the entire atmosphere around it to become oxygenated, neutralizing toxic gases at the bottom of the river and improving overall river quality. The aeration unit is made up of a diffuser that is installed at the bottom of the water, and a compressor, located inside the GWC and supplies air to the diffuser.

There are two types of aeration tanks, surface and submersible tanks. Surface and submersible aeration systems are selected based on many different reasons, including water body type, size, temperature, pressure, and characteristics of the wastewater. Surface aeration systems are typically used for shallow waters ranging between depths 8 feet or less. Surface aerators are used when large amounts of oxygen are needed in a small amount of time and break up the water to create more surface area for gas exchange. Submersible or bottom aeration is ideal in waters deeper than 8 feet. Bottom aeration releases bubbles at the bottom of the river and they "rise through the water column, carrying vast amounts of dead, bottom water to the surface where harmful gases can vent into the atmosphere and oxygen can enter the water," as shown in Figure

61.[36] This aerator is directly proportional to how much water the bubbles carry, which is why the deeper the water, the more the water is circulated.

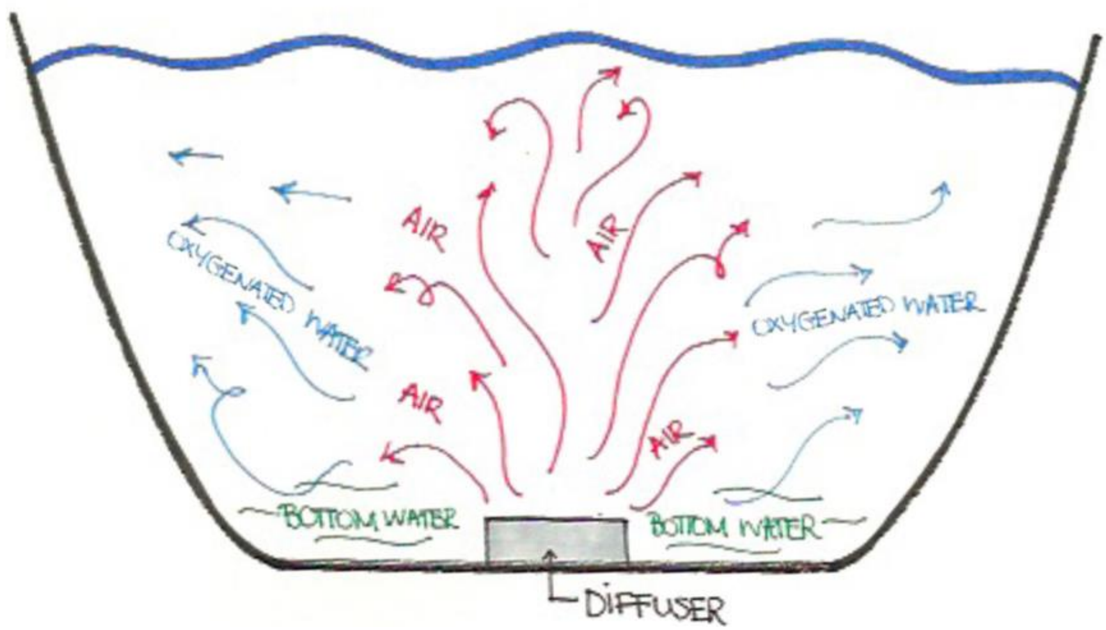

Figure 61: Water circulation of aerator elevation, source: author

An aeration unit is made up of a diffuser and a compressor. The compressor, installed on land near a power source, is a system that supplies the air to the diffuser, which is installed at the bottom of the river. The diffuser has pores that release bubbles to transfer oxygen as bubbles, which rise through the water column. Depending on the amount of oxygen required, diffusers can release fine, medium, or large bubbles. Fine bubble diffusers range between 0-3mm and coarse diffusers range between 3-50mm. Diffusers for large scale aeration are typically discs, plates or tubes constructed of corrosion-resistant materials since they operate in the water and under the influence of atmospheric oxygen. These materials include: stainless steel, cast iron,

[36] Wolf, Megan. "Surface V.s. Bottom Aeration." Kasco Marine. August 28, 2017. https://kascomarine.com/surface-v-s-bottom-aeration/.

glass-bonded silica, ceramic, porous plastic, or flexible perforated membranes. The diffuser is made of a stainless-steel base and a porous material often found in soaker hoses, where oxygen is released, shown more closely in Figure *62*.

Figure 62: Diffuser, source: Kasco Marine, inc.

Figure 63 illustrates each of the aeration system's components and how it works. The aeration system begins from the compressor and ends at the diffuser. The compressor, 24" long x 18" wide x 20" high, is located inside the GWC and pumps air to the diffuser. Before reaching the diffuser, the air is pumped through a PVC pipe that is connected to the compressor inside and makes its way outside to the water's edge. The PVC is connected to sink weighted tubing by a valve. The 3/8" tubing sits underwater, further sending along the pumped oxygen from PVC pipe on land to the diffuser that is permanently located underwater, releasing oxygen at the river's bottom.

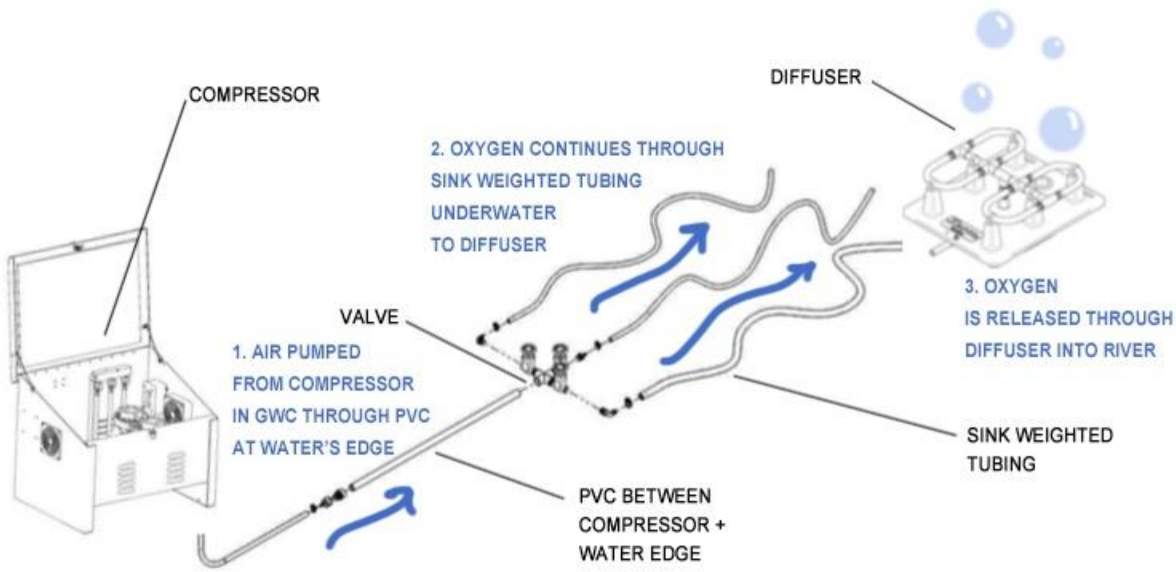

Figure 63: Bottom Aeration System, source: Kasco Marine, inc.

Diffusers are individually arranged in a grid pattern throughout the bottom of the water to work most efficiently and their number is determined by the oxygen transfer rate of the diffuser and the oxygen consumption rate in the water.

The proposed system for this project is a bottom aeration system that releases fine bubbles. A fine bubble diffuser has more of an advantage in that smaller bubbles result in more surface area coverage per unit and there is a greater oxygen transfer rate versus a coarse bubble diffuser, which is better at mixing than aerating. Fine bubble diffuser is more efficient, bubbles ascend more slowly through the water column, has a higher oxygen transfer efficiency, has lower volatile organic compound (VOC) emissions, requires less energy to run, is better used for primary treatment phase, and satisfies high oxygen demands.[37] The disadvantages of a fine bubble diffuser is that it is more prone to clogging due to sludge that may affect the transfer efficiency, requiring more maintenance, as it would need routine cleaning.[38] One diffuser can successfully oxygenate 1.5 surface acres of water and a maximum of 50 feet in depth.

9.3.2 How to Power

GWC borders about 650' of the Genesee River's length and at this location the river is 30' wide. The boathouse stands outside of a total of ½ acre of the river's surface area. The best location for the aeration diffuser would be at the midpoint of the river abutting the boathouse. Since the river is 30' wide, the diffuser would sit at the 15' mark so it aerates the river evenly. One diffuser placed at the GWC alone would make a small contribution to the river water, but could make a more significant impact if more aeration diffusers were placed throughout the Genesee River. The more diffusers there are in one location means more area is aerated. However, that also means more energy is required from the compressor to power multiple diffusers. Additionally, since the diffuser in this project would be placed in a river where there is a constant flow downstream, the P levels may not be impacted in the location of where the diffusers are, but instead downstream from the diffuser. The system is securely installed deep enough at the bottom of the river, it can operate without interfering rowers, kayakers or boating and without obstructing the natural view of the river. On the other hand, the compressor is placed inside the GWC's entry, which acts as the boathouse's display room where athletes and

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[37] "Fine Bubble vs Coarse Bubble Diffusers | Bubble Diffuser Differences." Mooers Products. http://www.mooersproductsinc.com/bubble-diffuser-aeration-differences/.

[38] U.S.A. U.S. Environmental Protection Agency. Wastewater Technology Fact Sheet: Fine Bubble Aeration. By Clement Solomon, Peter Casey, Colleen Mackne, and Andrew Lake. Washington, DC: United States Environmental Protection Agency, Office of Water, 1998.

visitors would have the opportunity to learn about the aeration system, where the process begins and ends, and what it looks like. Since the diffuser sits at the bottom of the river, it would not be visible from the boathouse or above the water's surface. However, placing a camera underwater and viewing screen inside the GWC that displays the diffuser releasing oxygen would allow GWC members and visitors to learn about and understand the aeration system's process in its entirety.

Table 4: Aeration System Selection

# Diffusers	Surface Acres	kWh/year	Sure sink weighted 3/8" tubing (ft.)	Max. Depth (ft.)
1	1.5	2628	100	50

Although one diffuser would cover a minimal amount of surface area in the Genesee River, the following analysis pinpoints the area surrounding the Genesee Waterways Center to learn how this boathouse can provide a model for its community. For this reason, this analysis will investigate how much energy is required for only one diffuser. The concept behind this thesis is to use the boathouse and its rowers as a tool to restore the Genesee River by using the energy produced by an indoor rowing machine, a rowing simulator, to help power the aeration system. The aeration system requires a large amount of energy and operates continuously, as explained in Table *4*. It is likely that the system would not be powered by rowing machines alone and will need assistance from other tools as well, such as solar panels that store energy from the sun. This evaluation will estimate how much energy each renewable energy technologies can contribute to operating the aeration system.

The energy conversion using a battery system is a seven-step process, shown in *Figure 64*. An erg is essentially a "pulley-system which converts the chemical energy in your muscles to mechanical energy that drives the flywheel."[39] The alternator is connected to the erg, which then converts mechanical energy into electrical energy.[39] Alternators (AC generators) produce alternating current, whilst a battery only produces direct current (DC). A **rectifier** converts the AC signal to the DC signal before reaching the battery, and the battery is able to store the chemical energy until its use, which is then be converted from DC back into AC through an **inverter**.[39] Due to the loss of energy between the transfer, this system is able to achieve about 45% efficiency.[39]

Based on research conducted by *Bang!* magazine, the efficiency of the circuit components were calculated using the following estimates:[39]

- Alternator: 60%
- Battery (storage): 90%
- Inverter: 85%
- Losses due to friction: negligible

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[39] Juneja, Jai. "How Many Rowers Does it Take to Power a Lightbulb?" Bang!, last modified October 10, 2012, http://www.bangscience.org/2012/10/how-many-rowers-does-take-power-lightbulb/.

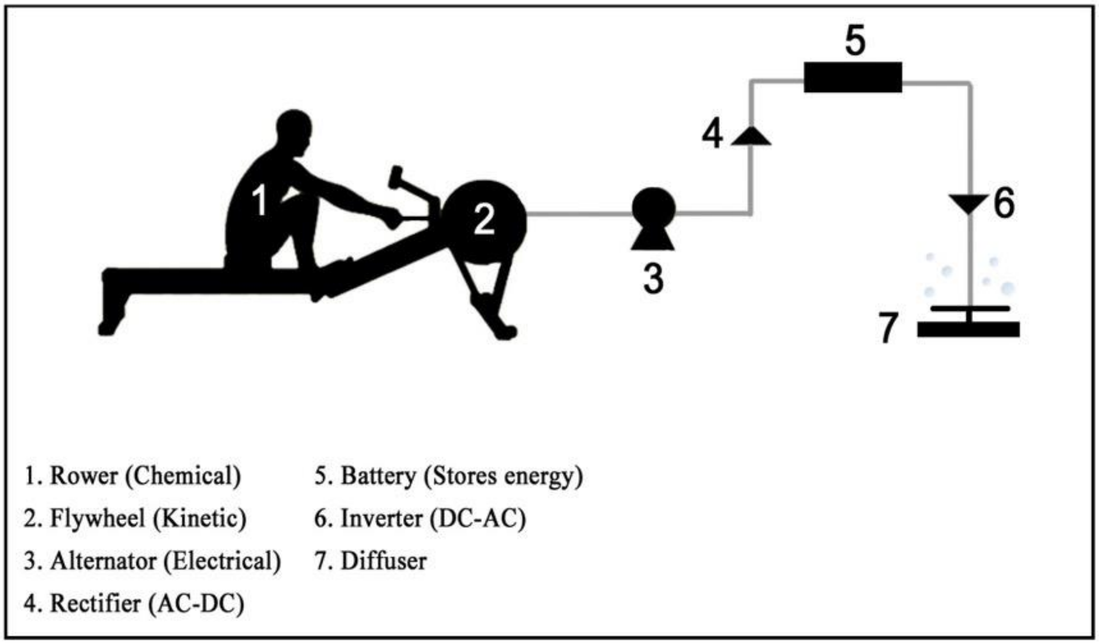

Figure 64: Erg to Aeration Unit, reproduced from *"How Many Rowers Does it Take to Power a Lightbulb?"* by Jai Juneja.

The bottom aeration unit is an automatic system that functions daily, 24 hours a day, to effectively make an impact, even through the winter months. The compressor in the boathouse would continue to pump air to the diffuser at the river's bottom. The diffuser will release bubbles, bringing the warmer bottom water to the river's surface, which would prevent ice buildup and allow the aeration system to continue working. However, the tubing lines require insulation so any condensation that might be in the airlines would not freeze. It is important to note that the aeration system does not restore water quality right away but takes about several months to show signs of improvement. Typically, this chosen aeration unit uses about 2,628 kWh annually. Average wattage is documented assuming each rower holds a steady, moderate pace of 2:12 minutes per 500m (meters) on the rowing machine.

The formula below is used by Concept2 to determine the power generated on an indoor rowing machine, or ergometer, in watts based on a rower's average pace per 500 meters. The indoor rowing machine that rowers would use in this project is an air-resistance ergometer. The erg is made up of a flywheel, handle, damping mechanism, and a return mechanism. The flywheel simulates the boat momentum, storing energy between strokes.[40] The handle, which is attached to the flywheel with a chain and sprocket, acting as a pulley system, simulates the oar.[40] The damping mechanism on the flywheel imitates water friction on the hull and the return mechanism simulates the motion of the boat.[40] The damping is controlled by sliding vents, which restricts the amount of air that is 'pumped' by the fan.[40] The vent setting is controlled by a sliding lever with positions ranging between 1-10, (1=lightest and 10=heaviest) that when changed, alters the friction and "the relationship between power and flywheel speed."[40] The formula shows pace is time (seconds) over distance (meters).[41] This formula is derived from $P = k\,\omega^3$. The dissipated power (P) on an ergometer is related to the cube of the rotation velocity (ω), which is similar to another cube law relationship for dissipated power and boat velocity (u).[40]

P = power supplied to the flywheel (watts)
k = drag factor (a constant)
c = a dependent on the position of the sliding lever, (2.8, a 'realistic' boat speed)
ω = angular velocity (flywheel speed)
u = linear velocity (boat speed)

$$P = k\,\omega^3 = c\,u^3$$

Naturally, the fan's rotational velocity (ω) of the erg, though different, is related to the linear velocity of a boat moving forward (u).[40] This allows the speed rowed on an erg, a spinning flywheel, to be comparable to the speed of a moving rowing shell.

[40] "Basic Physics of Rowing." The Physics of Ergometers. February 19, 2008. http://eodg.atm.ox.ac.uk/user/dudhia/rowing/physics/ergometer.html.
[41] "Watts Calculator." Concept2. July 13, 2018. https://www.concept2.com/indoor-rowers/training/calculators/watts-calculator.

$$u = (k / c)^{1/3} \omega$$

The constant (*c*) 2.80 in the formula, though somewhat arbitrary has been selected to indicate a 'realistic' boat speed for a given output power."[40] Therefore, the formula used to determine the power output comprised by Concept2 and calculated by the ergometer's computer:

$$\text{watts} = 2.80/\text{pace}^3$$

pace: 2:12/500m = 132 seconds/500 meters

$$2.80/(132/500)^3 = 152 \text{ watts}$$

At this pace, this means that one rower is capable of generating power equivalent to 152 watts. However, due to the 45% efficiency of the system, only 68.4 watts of electrical power are output. To understand how much energy is used in a certain amount of time, the following formula helps us understand how many kilowatts (1 kW = 1000 W) of energy are used per hour.

$$\text{kWh} = \text{W x hr} / 1000$$

The Genesee Waterways Center is composed of 60 competitive collegiate and masters rowers and beginner and intermediate recreational rowers. This analysis assumes all 60 participants row annually, one hour per day, six days of the week. This means that all 60 rowers cumulatively spend a total of 18,720 hours rowing on a rowing machine throughout one year. If each of the 60 GWC rowers follows the training schedule outlined above and holds a moderate pace, they can collectively generate a total of 1,280 kWh per year.

$$68.4 \text{ W x } 18{,}720 \text{ hours} / 1000 = 1{,}280 \text{ kWh}$$

This aeration unit would require about 2,628 kWh a year, meaning the rowers would annually contribute 49% of energy required.

In this case, another source of renewable energy is required to assist in powering the aeration unit, possibly from solar or water. The benefit of the water wheel is that it can produce energy 24 hours per day as it works from flowing water, but during the winter months, the water will freeze, leaving the water wheel to sit still and not generate any electricity for several months. The best option is to use solar panels, which do not work 24 hours a day, but can work year round for several hours a day.

There are seven types of solar panels and they are categorized into three generations.[42] The first generation, monocrystalline and polycrystalline, are the traditional types and are most commonly used. The second generation solar panels, Thin-Film and Amorphous Silicon, are made of thin film solar cells and typically "used for photovoltaic (PV) power stations, integrated in buildings, or smaller power systems."[42] The third generation, Biohybrid, Cadmium Telluride, and Concentrated PV, are all still in the process of being researched or developed[42]

The Monocrystalline panel (Mono-SI) is the most pure, containing very small quantities of elements other than silicon monocrystals. Due to its pure silicon, the Mono-SI has one of the highest efficiency rates, typically ranging between 15-20% efficiency, but recently reaching just over 20%.[43] The Mono-SI is made up of monocrystalline silicon and is well known for its uniform dark look, as shown in *Figure 65*.[42]

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[42] Bagher, Askari Mohammad, Mirzaei Mahmoud Abadi Vahid, and Mirhabibi Mohsen. *Types of Solar Cells and Application.* American Journal of Optics and Photonics. Vol. 3, No. 5, 2015, pp. 94-113. doi: 10.11648/j.ajop.20150305.17.

[43] Maehlum, Mathias Aarre. "Which Solar Panel Type Is Best? Mono-, Polycrystalline or Thin Film?" Energy Informative. May 2018. http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/.

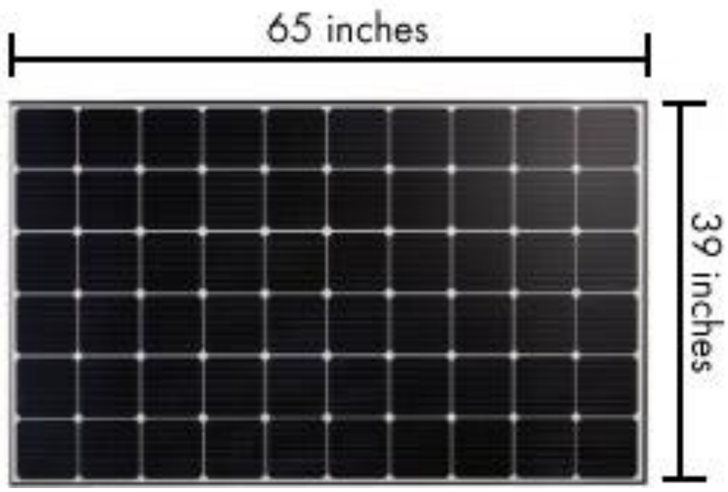

Figure 65: Typical size of solar panel, source: Solar Power Rocks

Mono-SI solar panels, along with every other type of solar panel, comes in a wide range of power output ratings and there is not one typical or average wattage output. However, several examples researched use a DC output rating of 250 W per panel and will also be used in this thesis. While the amount of sunlight solar panels receive is important, a more accurate description of energy the panels can produce are based on "peak sun-hours" rather than total hours of daylight. "Peak sun-hours refers to the solar insolation [sic] which a particular location would receive if the sun were shining at its maximum value for a certain number of hours."[44] As shown in *Figure 66*, Rochester's average daily values for insolation are 3-4 kWH/m^2/day, or 3-4 sun hours.

[44] "Average Solar Radiation." Average Solar Radiation | PVEducation. https://www.pveducation.org/pvcdrom/average-solar-radiation.

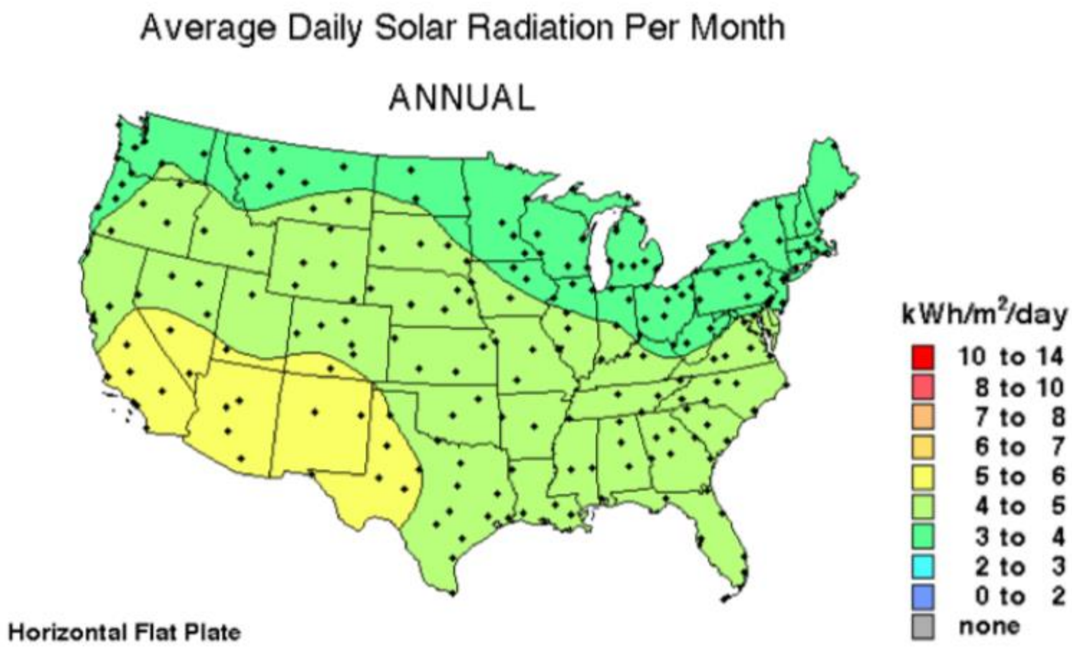

Figure 66: Annual solar radiation as measured by a flat plate collector on a horizontal surface, source:http://wnypeace.org/new/Images/Sunshine Report.pdf

1 panel output= 250 W

Average sun hours per year= (3.5 hours per day x 365 days)= 1277.5 sun hours

$$250 \text{ W} \times 1277.5 \text{ hours} = 319 \text{ kWh}$$

Therefore, 5 solar panels (319 kWh x 5 panels= 1,595 kWh) are required to help power the aeration system. However, if there is excess electricity generated, as determined above, it is stored in the battery and could potentially be used at a later time if the solar panels do not produce enough energy needed. *Figure 67* below illustrates the process of how sunlight is converted to energy that can be utilized to power the aeration system.

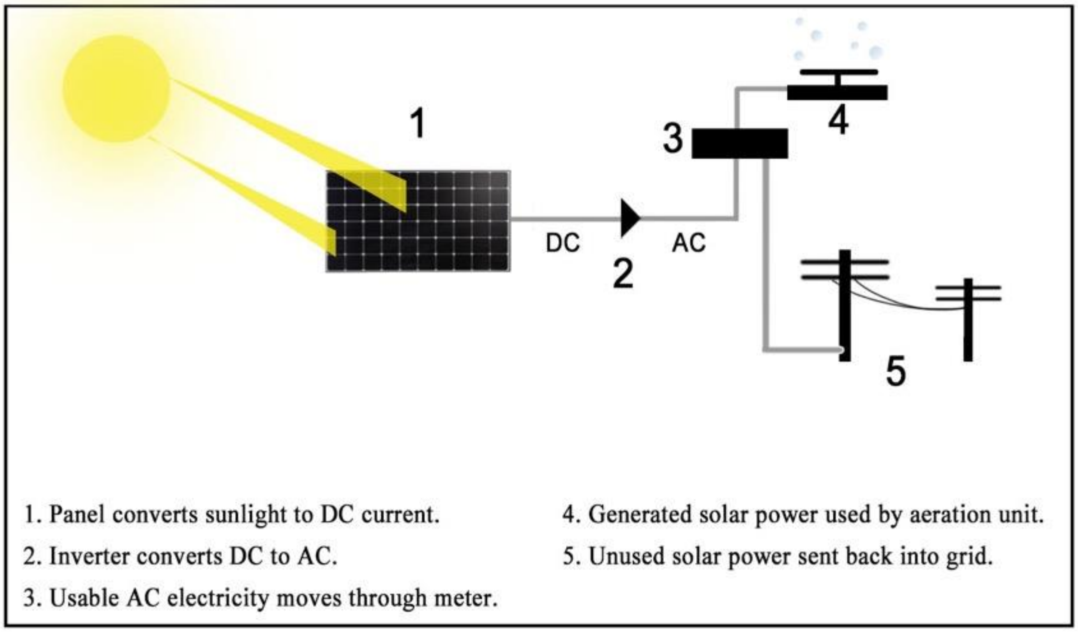

Figure 67: Solar Power to Aeration System, source: author

The aeration system operates 24 hours per day but the solar panels and rowing machines do not constantly generate the electricity that powers it 24 hours per day, consuming 7.2 kWh throughout one day. It is likely the rowers would complete their one hour of rowing at different times throughout the day depending on their team schedule, but as long as each of the 60 rowers completes their one hour of rowing at a minimum pace of 2:12 minutes/500 meters, as outlined above, each day, the amount of required energy generated would be about 3.51 kWh per day. The solar panels only collect sunlight for about 3.5 hours per day during peak sun-hours, generating about 4.37 kWh per day. As both rowers and solar panels produce energy, it is converted, stored in the battery, and the electricity is delivered to power the aeration system at a later time as needed. *Figure 68* below shows how much energy (kWh) is produced per day by both the solar panels and rowers and how much energy is consumed daily by the aeration system.

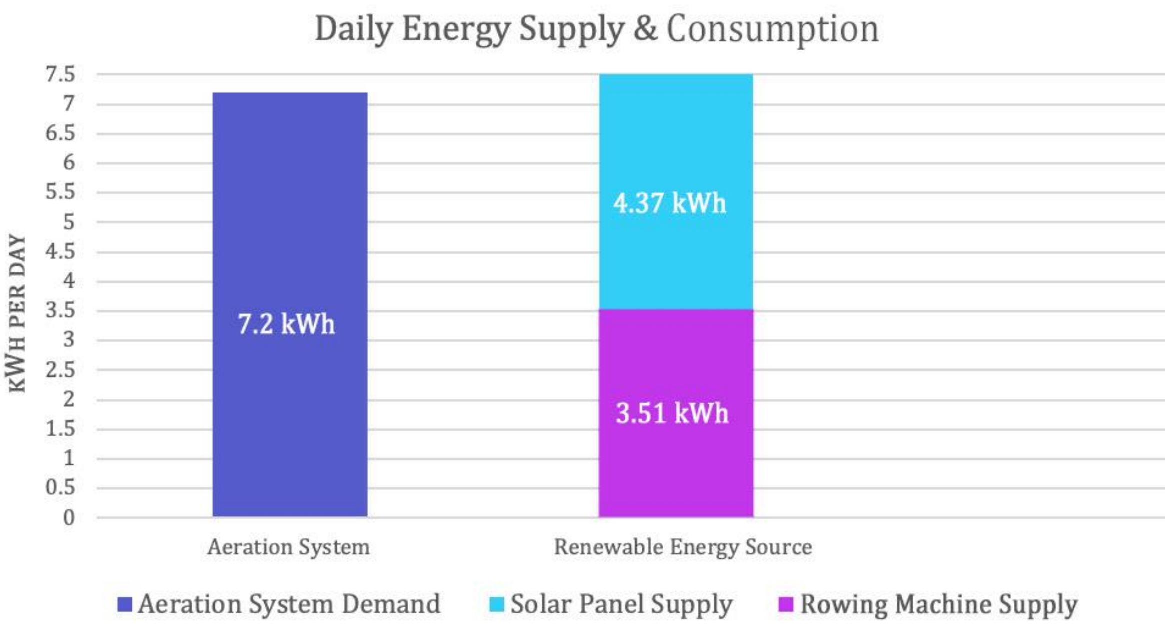

Figure 68: Daily Energy Supply & Consumption, source: author

The solar panels and rowers combined are able to generate a total of 7.88 kWh per day, while the aeration system uses 7.2 kWh per day, leaving .68 kWh of generated energy unused and stored in the battery. The GWC owns about 25 rowing machines, which means 25 of the 60 rowers can row at the same time and if all 60 rowers completed their one hour of rowing within the same time frame, they could generate their required energy within 3 hours. The solar panels generate energy for about 3.5 hours per day. The aeration system runs 24 hours per day, which means that 0.3 kWh are used per hour. If the rowers and solar panels generate energy at the same time, the aeration system would use about 1.05 kWh in those 3.5 hours. Finally, the aeration system uses about 6.15 kWh during the 20.5 hours that energy is not being generated throughout the rest of the day.

Energy generated per day	(4.37 kWh + 3.51kWh)	= **7.88 kWh / day**
Energy used per hour	(7.2 kWh / 24 hours)	= **0.3 kWh / hour**

Energy used during same time as energy generated (3.5 hours x 0.3 kWh) = **1.05 kWh / hour**

Energy generated that is not used & stored (7.88 kWh – 7.2 kWh) = **0.68 kWh / day**

Energy needed when electricity is not being generated (20.5 hours x 0.3 kWh)= **6.15 kWh /day**

If the required amount of energy is not met by the rowers or solar panels, the potentially stored energy of 0.68 kWh per day would not meet the demand of the aeration system, which needs 7.2 kWh per day to run. The solar panels and rowers combined produce just over the amount of energy required to power the aeration system, leaving a miniscule amount of energy unused and stored. The battery required for energy storage would need to be able to store about 6.83 kWh per day, distributing 6.15 kWh throughout the day during the 20.5 hours that electricity is not being generated in addition to the remaining 0.68 kWh that is not used. The battery size best suited for this system is one comparable to a Toyota Prius battery, a Li-ion battery, that has a capacity of 8.8 kWh.

As the seasons change through the year, the rowing workouts change as well. While indoor rowing is practiced throughout the year, practices are mostly held on the river during summer and spring. Time spent on the erg increases during autumn and is exclusive in the winter season. Though this project uses one moderate workout on the rowing machines year-round to learn the minimum amount of energy that can be produced by rowers, it is important to note that the workouts and time spent on the erg change throughout the year. The typical rowing workouts of every season would show an increase in the amount of energy produced during fall and winter with longer and more intense erg workouts and a likely decrease during summer and spring with less time spent on the erg.

The battery in this seven-step process has the role of storing the energy produced by the rowers and solar panels and converting it into electricity. Electrochemical batteries are the best solution when it comes to renewable energy storage for a number of reasons including performance and compact size.[45] The electrochemical battery proposed for this energy storage system is a lithium-ion battery. A typical lithium-ion battery consists of three elements: an anode, a cathode, and an electrolyte. The anode and cathode are two different terminals and the Li-ions migrate across them producing a flow current, illustrated in *Figure 69* below.[45]

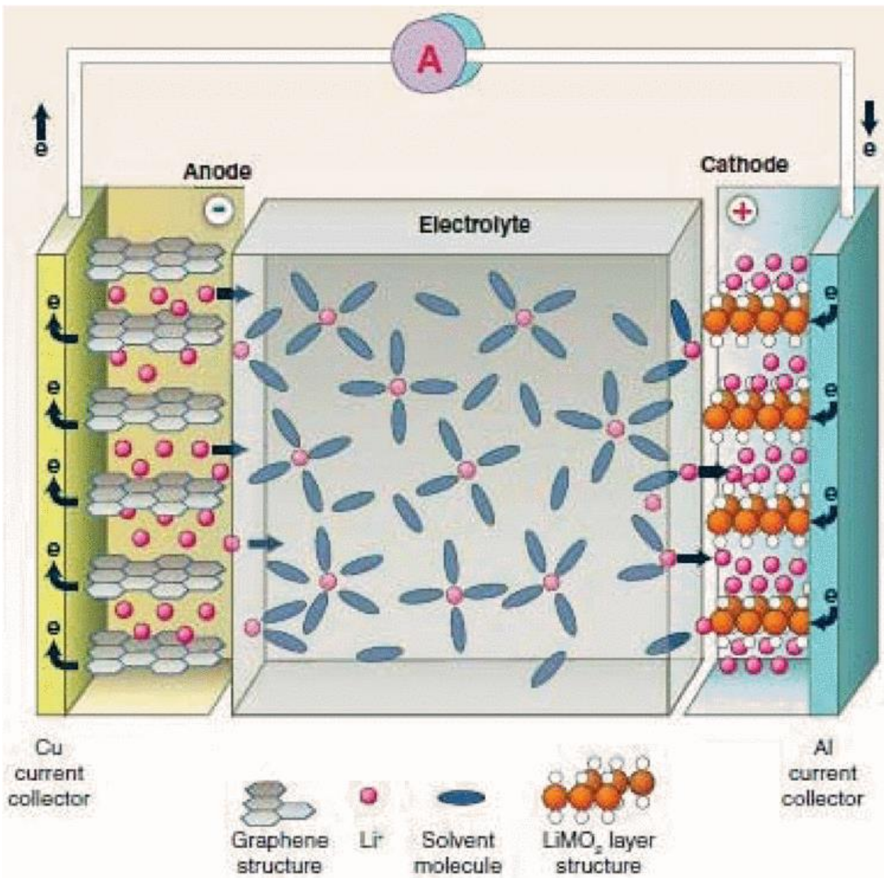

Figure 69: Structure of a li-ion battery, source: Dunn, B., H. Kamath, and J.-M. Tarascon. "Electrical Energy Storage for the Grid: A Battery of Choices." Science 334, no. 6058 (2011): 928-35. doi:10.1126/science.1212741.

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[45] Stan, Ana-Irina, Maciej Swierczynski, Daniel-Ioan Stroe, Remus Teodorescu, and Soren Juhl Andreasen. "Lithium Ion Battery Chemistries from Renewable Energy Storage to Automotive and Back-up Power Applications — An Overview." 2014 International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), 2014. doi:10.1109/optim.2014.6850936.

Compared to other batteries, the lithium-ion is the most applicable solution for renewable energy storage, and specifically for this project, as it has a number of dominant advantages. The Li-ion battery is the most commonly used because it is durable, has a high specific energy, long life-span, no maintenance, and fast charge and discharge performance.[45] Specific energy refers to a battery's capability of storing small or large amounts of energy for its weight or volume of fuel. "Li-ion batteries achieve energy storage efficiencies of close to 100% and have the highest energy density."[46] Additionally, Li-ion batteries can "provide a high energy and power output per unit of battery mass, allowing them to be lighter and smaller than other battery energy storage technologies."[45] "Li-ion batteries have been deployed in a wide range of energy-storage applications, ranging from energy-type batteries of a few kilowatt-hours in residential systems with rooftop photovoltaic arrays to multi-megawatt containerized batteries for the provision of grid ancillary services."[47] The two biggest downsides of a Li-ion battery is safety and high cost. If this battery is overcharged it can overheat and catch fire. Though the cost of Li-ion batters are high, cost reductions are expected in the near-future. However, for the purpose of this project, environmental health and an educational initiative have been prioritized over economic costs.

In summary, the rowing machines and solar powers combined are able to generate enough energy to power the aeration system throughout the year. The aeration system would require an annual total of 2,628 kWh. If the GWC rowers used the schedule outlined above, the

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[46] Garimella, Niraj, and Nirmal-Kumar C. Nair. "Assessment of Battery Energy Storage Systems for Small-scale Renewable Energy Integration." TENCON 2009 - 2009 IEEE Region 10 Conference, 2009. doi:10.1109/tencon.2009.5395831.

[47] "Lithium Ion (LI-ION) Batteries." Energy Storage Association. 2018. http://energystorage.org/energy-storage/technologies/lithium-ion-li-ion-batteries.

rowing machines would be able to generate a total of 1,280 kWh per year and the five solar panels would generate 1,595 kWh. Though it is a small amount, the solar panels would generate an excess amount of electricity, which can be sent to the grid and used in the future if the aeration system is not receiving the appropriate amount of energy required from the rowing machines. Therefore, of the 2,628 kWh needed, the rowing machines would produce 49% of energy and the energy provided by the solar panels would contribute the remaining 51%.

10. Summary & Conclusion

The main goal of this project was to re-design the current Genesee Waterways Center facility to make a socially and environmentally sustainable contribution to its community of Rochester, NY. The re-design includes a reorganization of and addition to the boathouse's spaces inside and outside the facility to provide a more accommodating facility that can support all the GWC's programs and members, properly store all the necessary equipment, and have a clearer connection to its surrounding environment. A proper athletic facility is important for any sport, as it promotes activity and team pride and sets a standard for the teams.

The concept of boathouses originated as a storage space for boats and all equipment. Overtime, the sport of rowing changed from a means of travel to a competitive sport, and the purpose of the boathouse transitioned with it. What was once primarily a storage unit, the boathouse's purpose has more depth to it and is now a stage to prepare and receive boats, a social space, and training space. Both the interior and exterior of boathouses have been designed in a traditional way, including their spaces, materials, and design elements. Although the general style of boathouses has evolved, the key elements, such as waterfront views, two levels, a specifically organized layout, themes of rhythm and movement, have largely remained the same to maintain a strong, healthy relationship between land and water. The research found shows that interior and exterior spaces are divided up into four categories, storage, training, support, and exterior, which has been expressed in the re-design of the GWC. The proposed re-design also includes key architectural features such as, a distinct roofline that represents the rhythm of the water, mixed materials of masonry and wood cladding to hold onto the industrial style that currently exists in both the GWC and in Rochester.

The reorientation of the boathouse's layout encourages wider community interaction with the river. One distinct entry point into the GWC defines a clear pathway for visitors, leading them upstairs to indoor and exterior spectator areas with clear views of the river and boat staging area below. This reorientation enhances the physical and visual connections to the Genesee River, allowing more daylight to pour into the space and a clear focus for the athletes with the view of the river as a reminder of their athletic goals and of their contribution to an environmentally healthier river.

The second issue with the GWC's health, is the Genesee River that it sits adjacent to and frequently interacts with. The Genesee River is highly contaminated with an excess amount of phosphorus. While low levels of phosphorus are necessary for plant growth, too much can cause the increase in the eutrophication process, which is a delicate cycle and can be difficult for a water's ecosystem to escape. As previously discussed, eutrophication is the excessive growth of algae, which limits oxygen levels. The number of issues that are caused by increased eutrophication include unpleasant odors, color changes in the water, reduced water depths, etc. After researching a number of possible phosphorus filtration methods such as the phosphorus removal structure, the sand filter, wastewater treatment plants, and site integrated systems, this study has found that the best solution for the GWC and the Genesee River is an aeration system. The aeration system is the ideal solution for the GWC because it is small-scale enough for the GWC to handle in terms of size, maintenance, and operation.

To reiterate, the purpose of this project is to solve the GWC's social and environmental health in a way that improves the relationship between humans and water, using the boathouse as its tool. This study found that the rowers can produce 49% of the energy required over the course of a year to power the aeration unit and use solar panels for assistance in generating the remaining 51%, whilst still having excess energy that can be stored and used at a later time if less energy has been generated than required. Though just one unit will add a small contribution to solving the Genesee River's P pollution, it will not clean it in its entirety. While the scope of this project only focuses on the Genesee Waterways Center, it is an initial step and provides a model for other riverside community structures that can be replicated and scaled up.

11. List of Figures

12. List of Tables

13. Bibliography

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