APPLYING ECOLOGICAL PRINCIPLES OF DESIGN FOR THE RESTORATION OF BROWNFIELDS: A CASE STUDY IN RIVER ROUGE, MI

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ABSTRACT

Failing industrial cities have left behind a legacy of social, economic, and environmental decline, the aftermath includes cities who have experienced departing residents, decaying infrastructure, and urban blight. Although there are many contributing factors to degradation, for cities such as Detroit, MI; much of its infrastructure has become vacant, and due to previous heavy industrial use, some of the lots have turned into brownfields. These sites that contain hazardous substances such as: arsenic, asbestos, lead, petroleum, hydrocarbons, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and Volatile Organic Compounds (EPA). Additionally, there is a lack of understanding in regard to the terms "vacant land" and "brownfield", and within academic literature, there seems to be no definitive definition or difference between the two. Thus, this research adopts a case study approach, where it focuses on safely reconstructing the economic, social, and environmental health of communities by creating an ecological design matrix based on the landscape ecology principles of design; and applying those elements to the 80" Hot Mill company, located in River Rouge, MI, United States. Following the creation of a master plan, the post-design metrics show positive environmental outputs such as the reduction of carbon sequestration, air pollution elements, waste from the site, and an increase in the retention of stormwater. The social impacts measured showed favorable outcomes which included visual quality, safety features, the addition of recreational and gathering spaces, as well as bike lanes and pedestrian walking paths. Economically, improvements have been seen in stormwater maintenance costs and energy savings. The findings from this research aim to help future designers and planners in implementing ecological principles within their designs and optimize restoration processes.

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LIST OF ABBREVIATIONS

AOC: Area of Concern

CERCLE: Comprehensive Environmental Response, Compensation and Liability Act

CPRT: California Planning Round Table

EPA: Environmental Protection Agency

FQI: Floristic Quality Index

HOLC: Home Owner’s Loan Corporation

LAF: Landscape Architecture Foundation

LID: Low Impact Development

LPR: Landscape Performance Research

LPS: Landscape Performance Series

NBS: Nature Based Solutions

NYC: New York City

USPS: United States Post Service

CHAPTER 1. INTRODUCTION

During the late 1950s, industrial cities experienced sudden economic failures due to companies leaving that led to a phenomenon known as shrinkage (Wang et al., 2020). The abrupt exit of businesses had a domino effect, socially through a decrease in population, economically through a weakened workforce and tax base, and environmentally with the rise of vacancies throughout the city. As stated by Newman et al. (2016), urban vacancies are caused by the uneven expansion of the population, since residents tend to move further away from the *core* of the city, leaving behind much of the existing infrastructure. There is a natural social cause for urban vacancies taking place, some due to job losses and economic instability. However, these cities once had booming economies, and historically, most were part of what is known as the 'Rust Belt'. The City of Detroit, Michigan is a prime example of a shrinking city.

There have been past attempts to prevent urban vacancies, however, it has been difficult to maintain such efforts. Any city that is experiencing high rates of vacancy also undergoes financial difficulties; fewer citizens mean there is no excess tax revenue for revitalization of vacant lots. Many of the now vacant cities are fully equipped to handle high population densities—their infrastructure remained intact (Gu et al., 2019). Recently, the idea of sustainable urbanism has been gaining popularity, this is where the existing framework of a city is retrofitted to current standards. One way of promoting sustainable urbanism is through revitalizing vacant lots or brownfields, and through the Environmental Protection Agency (EPA), there is financial support available for the betterment of the community. As mentioned on the EPA website, there are different types of grants available to facilitate the restoration processes of public resources. Ultimately, the goal is to minimize any environmental or ecological damage that could be caused by any new and unnecessary construction of infrastructure.

Generally, brownfields contribute to increasing environmental, social, and economic challenges. The greatest risk factor associated with brownfields is the negative impact they pose to human health (Zhong & Popovich, 2022). Historically, most polluted sites were previously used as dumping grounds or as old factories. The contaminants are deep within the soil particles and have compromised the air quality surrounding the site.

One major consideration for rehabilitating brownfields is applying ecological restoration approaches, which is defined as the reconstruction of a degraded ecosystem (Ghosh et al., 2021). In these processes, attempts are made to restore already decayed soil. Research conducted by Ghosh et al., (2021) has shown that certain plant species, especially ornamental grasses, are able to restore much of the soil nutrition to its original state. The restoration is due to successful soil microbial processes which involve carbon as the main element to maintaining soil health. The different pools that involve soil organic carbon consist of water-soluble C(SWC) and permanganate oxidizable C($KMnO_4$-C) to help identify the early stages of successful eco-restoration. It has been found that when soil enzymes interact with carbon, it is a great assessment to the degree which the restoration will be successful. The ecological restoration process of the soil is extensive, nonetheless, it has a ripple effect by positively impacting plant health and improving air quality. Although there is no official index by the EPA on how to measure the efficiency of eco-restoration strategies such as the ones discussed, there are resources available to support such efforts. Ultimately, restoring an ecosystem takes an unidentifiable amount of time and it is largely a trial-and-error process.

Most previous restoration efforts using ecological planning principles have only been implemented at small scales. In the journal article *Beyond Park Boundaries*; Craig Shafer introduces the concept that parks are ecologically incomplete entities, he states: "parks are too small to contain all the area needed by some migrant herbivores and boundary adjustments could make these parks more complete" (Shafer, 1994); meaning that parks were not planned to serve the needs of the ecological community and are designed based on human needs. One of the influencing factors for the physical boundaries of parks is the political circumstances and legislation that dictate how land is split up, regardless of the natural borders or habitats on the fringes of the land. The solutions offered by Shafer such as providing corridors to prevent isolation, planning at a regional scale, and providing buffer zones serve as the building blocks to the ecological planning principles that many landscape architects and planners are using to guide their designs. Shafer introduces issues including fragmentation (the break-up of habitats), loss of species populations (decrease in numbers), and encroachment (placing infrastructure in natural areas), which are all linked to site boundaries. Subsequently, he suggests that soft edges, buffer zones, and creating corridors/greenways would help to connect species. There is mention of how these environmental issues are multi-dimensional, meaning that some of the issues that species face is due to both social and economic concerns.

The purpose of this research is to create a design guideline for how to revitalize industrial vacant lands or brownfields by applying ecological design principles. After conducting literature reviews and case studies, a comprehensive design and planning guideline regarding ecological principles was created for an abandoned steel factory. A landscape performance assessment was performed to evaluate the benefits of the proposed planning and outcomes regarding environmental, social, and economic aspects. Given the breadth of the site, the scope is to create "universal" guidelines and make broad recommendations. In recognizing that different sites bring on a unique set of challenges, these design propositions will assist by giving recommendations for possible future actions.

Audiences that would benefit from this research include environmental designers, ecologists, urban planners, and landscape architects. At their core, the tasks these individuals face daily is to improve the quality of the environment; whether that would be from a scientific or a design standpoint. With the research conducted by this study, the recommendations made would help to create the safest ecological design given the previous land use.

CHAPTER 2. LITERATURE REVIEW

Cities across the Rust Belt region, an area that has been the manufacturing hub for steel, weapons, and automobiles in the United States, have experienced different degrees of urban vacancies. The severe cases of vacancies have led to brownfields, which pose health risks to both humans and the environment. Previously, research efforts have been made on how to revitalize vacant lands through community engagement and retrofitting infrastructure. However, little is known about the ecological revitalization of brownfields. This chapter will focus on the challenges brought on by brownfields, past efforts, applicable ecological design principles, and landscape performance research.

Common uses for existing vacant lots and brownfields include parking lots, athletic fields, play areas, or junkyards; few become community gardens (Anderson & Minor, 2017). In order for the restoration to be successful, the economic status of the residential areas needs to be considered, since much of the heavy lifting to maintain and restore a brownfield is done by the community, which is why involvement is crucial. In a particular study conducted in the City of Roanoke, VA, researchers aimed to test the ecological benefits of different vegetation in multiple environments. There were five categories defined: post-industrial sites (power plants, landfills, military sites), derelict sites (developed land that is currently vacant), unattended sites with vegetation (conservation areas), natural sites (wetlands, drainage areas, hillsides) and transportation-related sites (highways and railroad tracks) (Kim et al, 2015). The results showed that in each vacancy, the ecological restoration provided by trees proved to be most beneficial for carbon-storage sequestration and air pollution removal. This finding is important to the research community because it showcases that the use of vegetation, in particular trees, is an effective way of restoring air quality on previously contaminated sites.

2.1. DEFINING VACANT LANDS AND BROWNFIELDS

The term ‘vacant land’ is broad and can be challenging to thoroughly understand its implications. Researchers find it difficult to agree on terms that should be used to define vacant lands, but many believe that the following definition would accurately describe them: razed land, bare soil, and abandoned buildings/structures (Kim, G., 2018;(Kremer, P., Hamstead, Z., & McPhearson, T. (2013).

When considering legislature, each state has its own criteria for what it considers vacant land; some may use a city’s tax structure to define vacant lands, while others rely on different criteria. An example of this is the definition used by the California Planning Round Table (CPRT) states: “lands or buildings that are not actively used for any purpose” or, as it is defined by the New York City (NYC) Department of Finance: “on which no lawful structure exists and which is not otherwise being used for any purpose for which it may lawfully be used” (Kremer et al., 2013). When considering the City of Detroit 2021 Zoning Code (2021), there is a protocol in place for vacant buildings–any vacant property must be reported to the city; whereas there is no mention of vacant lots. The city ordinance defines vacant buildings as: “a building or structure that is unoccupied for more than 30 days, is unsecured, is secured by other than normal means, as defined in this section, is illegally occupied, or poses an imminent danger to the health and safety of surrounding residents and properties or to the general public by being unsafe as determined by an authorized local official, including, but not limited to, the existence of a fire hazard, a collapsed or dilapidated portion, the loss of a utility, or an unsanitary condition.” (Building Construction and Property Maintenance, 2021). Although parts of these elements can be applied to vacant land; a concrete definition will have to be created in order to assess and categorize those properties in the City of Detroit. However, a definition that has greater familiarity within the discipline is “brownfields”, these are a sub-category of vacant lands and along with being vacant, contain hazardous materials. The EPA administration defines a brownfield as “a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.” (EPA). An additional layer to the definition provided by the EPA, and as discussed by Smollin and Lubitow (2019) suggests that brownfields shall not be confused with superfund sites, as the clean-up processes between the two differ, “it is less severely contaminated, and thus less likely to be cleaned up with federal funds.” (Smollin & Lubitow, 2019). According to the EPA, the term superfund is formally known as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLE), which was passed in 1980 (EPA). The sites that qualify under the CERCLE Act are toxic waste dumps and the parties responsible for the contamination are held liable.

In academia, each researcher has their own unique terms as to what characteristics constitute vacant land. For example, Kremer et al. (2013), defines vacant land as: “typically included in this category are bare soil, agriculture at the edge of an urbanized area or uncultivated land, For recently razed land, derelict land, land with abandoned buildings and structures, brownfields, and greenfield”. Similarly, Kim et al. (2018), defines vacant land as: “under-utilized lands including bare soil, derelict land, abandoned buildings and structures, brownfields, greenfields, uncultivated land or marginal agricultural land and recently razed land.” Being able to correctly account for vacant land is one of the more challenging aspects of ecological research, as land is fluid–the purpose of it is ever-changing. In the article written by Newman et al. (2016), vacant land was defined based on USPS records, which considered addresses that have not collected their mail in 90 days or more. The defining factors currently used for brownfields and vacant lands are similar, but the difference is brownfields are hazardous due to extensive pollution. For the purposes of this research, brownfields are defined as unused parcels of land with a history of contamination.

2.2. CHALLENGES OF URBAN VACANCY AND BROWNFIELDS

The hardships that communities face due to urban vacancy and brownfields are multilateral and tend to have a domino effect—each one impacting the other. From a social perspective, city maintenance lessens, retail stores close, the number of abandoned buildings increases, crime rates are amplified, and the quality of life of current residents decreases. In economic terms, vacancies lead to a decrease in property values and stunt economic growth for the whole city since there is less incoming tax revenue, as mentioned by Newman et al. (2016). Many cities have demolished their vacant buildings and housing units, but that has exposed residents to airborne contaminants at extremely toxic levels (Nassauer et al., 2014). Additionally, the contaminants used in the construction materials, once demolished, are absorbed into the soil and contribute to soil pollution. Nassauer et al. (2014) state that some of the contaminants that are introduced into the soil are: "PAHs [Polycyclic aromatic hydrocarbons] from gasoline and oil, several heavy metals from tires and vehicle part repair, and organochlorines and pesticides from pest control" (Nassauer et al., 2014).

There is no perfect solution that can be applied to all vacant land or brownfields. A few potential solutions to restore and redevelop contaminated or abandoned land have been identified, one of which is to apply nature-based solutions (NBS). A research paper conducted by Song et al. (2019), claims "using nature-based remediation technologies, such as phytoremediation and bioremediation, can offer a great variety of benefits, ranging from less energy usage and higher material efficiency to increased resilience to global environmental change" (Song et al., 2019). Although nature-based solutions are a step in the right direction, there are still issues with the application of these ideas. This new concept is more of an umbrella term and is used to promote greener approaches to design.

An economically focused study was conducted by Mihaescu for the city of Cincinnati, Ohio, with the intent to measure the depreciation of home values that are adjacent to brownfields. As described by Mihaescu and Hofe, "contaminated properties yield little review for local governments. They are unsafe for ecosystems, and human health and impair the neighborhoods that contain them." (Mihaescu & Hofe, 2012). Their research emphasizes the importance of restoring brownfields to offset the negative environmental, social, and economic impacts that result from urban sprawl, as more people move out of the city. The approach used by the City of Cincinnati to estimate the economic impacts is called the Spatial Hedonic Pricing Framework, where the market values of single-family residential properties are evaluated based on locational, structural, housing, and neighborhood characteristics (Mihaescu & Hofe, 2012). Following the collection and analysis of data, results show that on average, brownfield sites decrease the price value of houses by a range of 19.96% – 21.93% (Mihaescu & Hofe, 2012).

Another study focused on the effects of remediated brownfields on adjacent property values, which combined EPA administrative records and housing data. First, there was a conservative approach taken, considering a 2,070-meter buffer zone and within that boundary, the total value of housing units was measured. Only the houses that sold in five years and within the delegated buffer zone were accounted for; findings show that the average housing value increase is $4,077,098/unit (Haninger & Timmins, 2012). Although the methods of quantifying the economic value of brownfields are conservative, the metrics provided by the research still provides benefits to understanding the advantages of investing in remediation processes.

2.3. EFFORTS IN RESTORING URBAN VACANCY/BROWNFIELDS

There are a plethora of alternative uses for vacant land, but the community that the vacant land overlaps tends to govern the use of said land. Therefore, vacancy should be considered in terms of immediate needs, rather than a life-long commitment. When restoring vacant land, research suggests that a long-term design approach is not a good fit because there are many moving parts that include economic, social, and political aspects (Nemeth & Langhorst, 2014). In recent years, the increase in vacant lands is due to a push for developing new infrastructure instead of the rehabilitation of old ones, a shift towards a more fluid work environment, urban sprawl, economic cycles and lack of strong policy (Nemeth & Langhorst, 2014). However, land should be viewed as flexible, and not as a fixed design approach, which will allow for more flexibility and sustainability in the chosen design approach.

A few past efforts have been made regarding alternative practices to existing infrastructure. These concepts have been introduced by Shafer, as seen in Figure 1. Nature Reserve System Design: Simplicity Within Complexity, where Shafer argues that having a complete habitat is better than an incomplete one because a complete habitat would offer more feeding grounds, reserves, migration routes, and watersheds (Shafer, 1994). However, a major limitation in his argument is due to only having considered a park system and not the different types of the built environment. He briefly mentions how humans negatively impact the sustainability of species populations through infrastructure but fails to consider ways in which more sustainable infrastructure could be implemented.

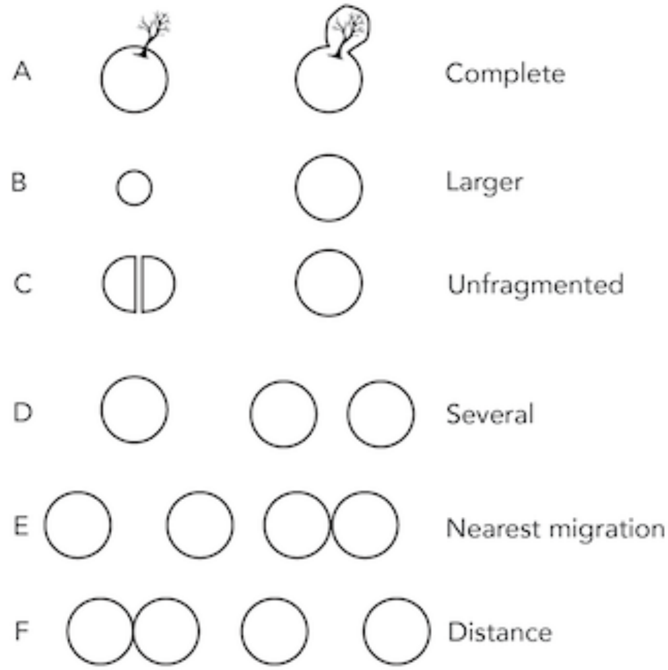

Figure 1. Nature Reserve System Design. Adopted from Beyond Park Boundaries, Shafer, 1994

Another past effort in understanding the complex relationship between species' health and the built environment was made by Jared M. Diamond. The focus of his research was on species behavior following disruptive human activities, which he referred to as the "Island Dilemma". A few similar ecological principles to the ones suggested by Shafer were mentioned such as size, migration, and connectivity, but the focus was shifted more toward prevention than restoration. As illustrated in figure 2, Geometric Principles, one of the main components of healthy habitats is proximity to one another. It is theorized that the closer they are together, the greater the likelihood of surviving. Diamond argues that larger reserves are better than small reserves because species can be at equilibrium, meaning that those species can be sustained in a healthy manner, and will have lower extinction rates (Diamond, 1975). When considering species numbers, equilibrium means that there are not too many of one species.

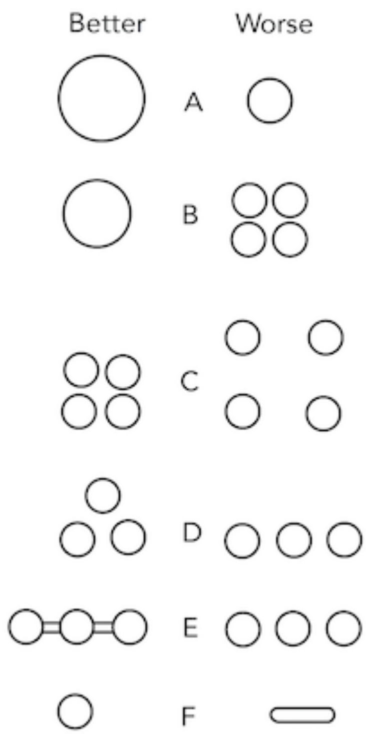

Figure 2. Geometric Principles. Adopted from The island dilemma: lessons of modern biogeographic studies for the design of natural reserves, Diamond, 1975

Although much consideration has been given to smaller scale projects such as parking lots, vacant residency lots, and abandoned lots, the same consideration needs to be given to larger scale abandoned sites. When analyzing the makeup of Detroit, the entire city matrix has deteriorated and fragmented due to human processes and how they have changed the use of the landscape and its natural function. Given the fragmentation, these vacant patches exhibit a degree of isolation for the nearby communities—it does not allow for a seamless connection between communities or for economic development. What makes this issue more challenging is the different shapes and sizes of the fragmented patches. Historically, these patches have been modified to fit new uses; where today they do not serve an ecological purpose.

Cities such as Detroit, MI have experienced a great loss of identity over the past few decades due to the economic depression it has experienced. As more lots became vacant, the City of Detroit started a project in 1989 that is still ongoing, named the Greening of Detroit with the goal of re-envisioning the city and creating more green space. This project operates at 5 scales: 1) derelict sites 2) unattended sites with vegetation 3) transportation-related sites 4) unattended sites with vegetation 5) natural sites (Kim, 2018). The Greening of Detroit project has helped develop other programs to combat vacancies such as the "dollar-lot" program, which provides gardening permits during the growing season for community gardens around Detroit. The Green Corps, another initiative, cares for 20,000 – 30,000 trees annually by watering them. Green Corps also undertakes maintenance needs of pocket parks, recreational areas, and community gardens (Kim, 2018).

A case study conducted in Detroit focused on waterfront revitalization and the clean-up of the Detroit River. This restoration effort started back in 1985 and now has been recognized as one of the most exceptional ecological revitalization stories (Harting, 2018). If similar restoration approaches are continued, much ecological improvement can be made to the health of waterfront cities. Foremost, designers should keep in mind that restoration is a long-term process; plants need extensive periods to establish themselves in a healthy manner. There are periodic disturbances to land such as mowing or weed killers that disturb the land and interrupt natural growing patterns (Anderson & Minor, 2017). Another consideration is the type of plant systems that will be established on the vacant land; the determined restoration approach correlates with the maintenance needed for the site for ecosystems to be able to successfully establish themselves (Wilson et al., 2011). Some studies suggest that certain large seed plantings such as tall perennials are most likely to establish themselves in an urban restoration of vacant land

(Fischer et al., 2013). A study conducted by (Kim et al., 2015) shows the major ecological benefits trees could have on any type of vacancy. Native species should be considered first when selecting a plant pallet for the site. While establishing plant material in vacant land, there are weed restrictions put in place to help keep native species safe and prevent invasive kinds from spreading aggressively. However, even with restrictions placed, one of the greater challenges presented is that the public lacks knowledge and appreciation for native plantings along with native biodiversity (Anderson & Minor, 2017); driving a divide between residents and restoration efforts in their neighborhoods.

An undervalued aspect in the revitalization process of vacant lands is waterfront design; and how that will further impact plant habitat restoration. As defined in the Journal of Great Lakes Research, waterfronts are "an area with current or historical ecological, economic or social connections to the community (neighborhood, city) and the adjacent Great Lake…" (Angradi et al., 2019). The Detroit River has been contaminated due to heavy industrial use and lack of regulations. The revitalization of a waterfront is complex, similar to the complexity of vacant land redesign. Many aspects need to be taken into consideration, such as suitability metrics, design, and benefits to ecology. The Detroit River has been an Area of Concern (AOC) and is considered one of the most contaminated rivers in the United States. Due to the industrial history of Detroit, the river played a massive role in the shipment of cargo which caused oil pollution, phosphorus pollution, and eutrophication. Thus, causing many animal and fish populations to decrease (Haring, 2018). The revitalization changes that were made to the Detroit River have brought back flora, and fauna, and re-created a physical habitat for animals. Given the size of the river, not all its wildlife has been fully revitalized, but steps have been taken toward improvement. As indicated by Angradi (2019), the goal for revitalizing a waterfront should be broken down into four main categories: environmental, social, economic, and governance goals. For the scope of this study, the main focus will be placed on environmental goals and applied to the design. However, social, and economic aspects will be considered in the improvement of the City of River Rouge community. The restoration goals are as follows:

1. Implement stormwater management function to bio filtrate water
2. Create green spaces along the waterfront that will aid in nearshore aquatic habitat restoration
3. Increase the resilience of the waterfront (aquatic habitat, flora, and fauna)
4. Create and enhance waterfront views that will increase the social use of the land

2.4. ECOLOGICAL DESIGN AND PLANNING PRINCIPLES

The concept of landscape ecology is well-established within land use planning; this discipline combines spatial analysis and functional approaches while focusing on the functionality of ecosystems (Ndubisi, 2002). Similarly, ecological planning centers on the desired structure of the landscape. As noted by author Forster Ndubisi, there are connections between ecological planning and landscape ecology. From his perspective, ecological planning deals with more theoretical aspects such as social, economic, and political contexts, not only environmental ones. Rather, ecological planning serves as a model of the interaction between humans and landscape processes and patterns. One of the models introduced in his book is the Patch/Corridor/Matrix model, this is where the horizontal landscape structure is analyzed, and each element serves a specific ecological function (Ndubisi, 2002).

Within this model offered by Ndubisi, there are subcategories such as fragmentation, connectivity, size, and isolation; these concepts have been observed within the context of landscape ecology. In the book, Landscape Ecology Principles in Landscape Architecture and Land-Use Planning by Dramstad et al., (1996) explains that in a matrix, fragmentation occurs within the landscape and is generally the cause of species isolation due to infrastructure development. Some solutions to this issue are the implementation of patches and corridors. Patches are defined as demonstrations of isolation within species; Dramstad et al., (1996) suggest that patches, as a principle, should be analyzed in terms of size, number, and location. Isolation of species is furthered by edges since these are physical boundaries that abstain animals from their natural migratory patterns. One ecological planning principle is the enforcement of corridors as avenues to help species migrate and move through habitat patches.

2.5. LANDSCAPE PERFORMANCE RESEARCH

Landscape Performance Research (LPR) has been a widely accepted tool because of its impact on planning and landscape architecture (Shevela, 2022). Many researchers, as well as practicing professionals, use the tools provided by LPR to design improved public spaces that are also ecologically safe. Essentially, LPR is the quantification of environmental, social, and economic benefits calculated using a metric driven approach which are provided by the built environment through landscape architecture projects Another trusted resource can be found through the Landscape Architecture Foundation (LAF), which established the Landscape Performance Series (LPS) as a way of sharing successful projects with the community and serves as an educational resource for both professionals and students. The projects listed under ‘Case Study Briefs’ are real-world projects designed by firms throughout the United States, and partner with educational institutions that can quantify the design methods used. Generally, every case study has information about the location, size, budget, and overall scope of the project. This section will address some of the studies conducted by LPR and thoroughly analyze each as to how they pertain to the re-design of a brownfield site in River Rouge, Michigan.

One inspiring example of a brownfield revitalization is the William G. Milliken State Park in Detroit, MI. The 6.1-acre site, which was re-developed in 2010, had contaminated soil and abandoned infrastructure laying on Detroit's Riverfront. Geographically, it connects the old Tricentennial State Harbor to River Plaza and the Riverwalk. The design was implemented by SmithGroup, and through the conduction of site inventory, analysis, and public engagement, the following recreational activities were implemented: fishing, biking, wildlife viewing and observing waters, pedestrian access, and event venues. When designing the site, the main goal was to create an accessible environment while also optimizing the collection of stormwater runoff. According to the post-construction metrics, the runoff was reduced by almost 50% of the original pre-construction numbers; 1,043,625 compared to 604,395 cubic feet (Deming & Littleton, 2013).

Ecoland Planning and Design Corp., and Tunghsu Azure Renewable Energy Co., Ltd. developed a 373-acre site in 2016. The site used to be a heavily polluted brownfield with a lack of open space, contaminated soils, and polluted water. This new design is a prototype for a large-scale master plan. The City of Linfen, China, used to be a coal-dominated city with a lack of zoning, rules, and pollution legislation. Historically, most of the pollution was directly discharged into the river, but the new design redirected the water into the sewer treatment plant. The landscape architect on the team reintroduced native plants, and revitalized aquatic habitats, and the microclimate. By taking these actions the river's soft edge is able to treat water before it is discharged anywhere else. Ultimately, the goal was to treat human, and wildlife needs as equal users of the park. The implemented landscape design includes wildlife habitats, a flower field stream, riverfront overlooks, an amphitheater for large-scale event space, a boardwalk, Lao-Ju River Oasis greenway for active routes, and the ‘Flowering Streams’ which is both a perennial and sensory garden. Historically, the river was gentrified, but given extensive restoration efforts, it has been restored to a riverfront park. The positive effects are seen by migratory birds coming back, as well as the return of local bird species and river habitats in large numbers. The connected walking paths and footbridges are able to reunite people in green space, while also creating the least amount of disturbance to wildlife. Ultimately, the river, wetlands, and biodiversity were restored (Ye et al., n.d).

CHAPTER 3. METHODS

3.1. STUDY AREA

Before selecting a brownfield site, it is crucial to understand the extent of the contamination. This will be crucial to understanding the needs of the site and how to redesign it for optimal revitalization. The City of River Rouge, MI was selected as the city case study location; it is a small industrial extension of Detroit's history since it has Zug Island. Throughout its 200-year history, River Rouge served as an integral part of Metro-Detroit's automotive industry since it focused on manufacturing iron and steel that were used for car construction. The peak population experienced by the city was in the 1950s when the steel and iron industries were prosperous (Wayne County Economic Development Corporation). However, once those factories were shut down, more than half of the population who was able to afford to move did so, leaving the city fragmented. In the case of River Rouge, it is a classic example of a prosperous city that quickly turned sour and makes for a great case study. The qualifications for the case study location are as follows: bordering a waterfront, proximity to a city, flooding associated with water quality issues, under-utilized industrial facility, and presence of invasive plant species. The 80" Hot Mill Steel Company fits all of the above criteria. As shown in Figure 3. Site Context, the steel company lays on the Detroit River with proximity to residential areas of the City of River Rouge and residential parks.

Figure 3. Site Context

3.2. 80" HOT MILL STEEL COMPANY

The site selected for this research is the 80" Hot Mill Steel Company located in River Rouge, MI. The first steel company that was established in the River Rouge neighborhood was Zug Island, which was initially designed to be an industrial dumping site. However, it became a steel manufacturing plant and experienced immense growth leading to the establishment of the Great Lakes Steel Company and the 80" Hot Mill. These three companies, being connected by railroad, operated together for over 100 years since their opening in 1902, but during that century, they faced few issues. Starting in 1931, the three sister companies switched ownership to National Steel and until the 1940s, they employed 20,000 people serving much of the economic area. With the deindustrialization of the automobile, between 1940-2003, many employees were laid off.

The selected site for this study holds a special design challenge; besides the rich history, socio-economic measures are rather unique. The mill is nestled between the City of Ecorse and the City of Detroit with a population of 7,224 according to data from the United States Census Bureau (United States Census Bureau, 2020). Additionally, the population has a lower percentage of high school graduates compared to surrounding cities with an average of 80% for River Rouge and 82% for Detroit. When comparing educational data for college graduates, the statistics are even lower with 9% of residents of River Rouge having a college degree in comparison to 16% in Detroit and 11% in Ecorse. The demographic data also depicts that the residents of River Rouge are predominantly African American (49%) and White (42%). Economically, River Rouge has the lowest median income of $23,000 when compared to Ecorse or Detroit, which both have an average of $33,000 (United States Census Bureau, 2020).

The 80" Hot Mill Steel Company is about 260 acres, with warehouse buildings that take up 1,216,319 square feet and average 150 feet in height (Figure 3). While the structural integrity of the buildings is undetermined, it is safe to assume that with degradation they are not structurally intact. The accessibility of the site is challenging as there are little to no paved accessible paths for pedestrians or entryways for automobiles. Great Lakes Ave is paved using concrete, but the road connecting to the site has deteriorated. Given the vast coverage of concrete and the flatness of the site, there are severe flooding issues. There are train tracks that connect

Great Lakes Steel and Zug Island, which were previously used for transportation purposes. Since the plants have been inactive, the structural components and sturdiness are unknown.

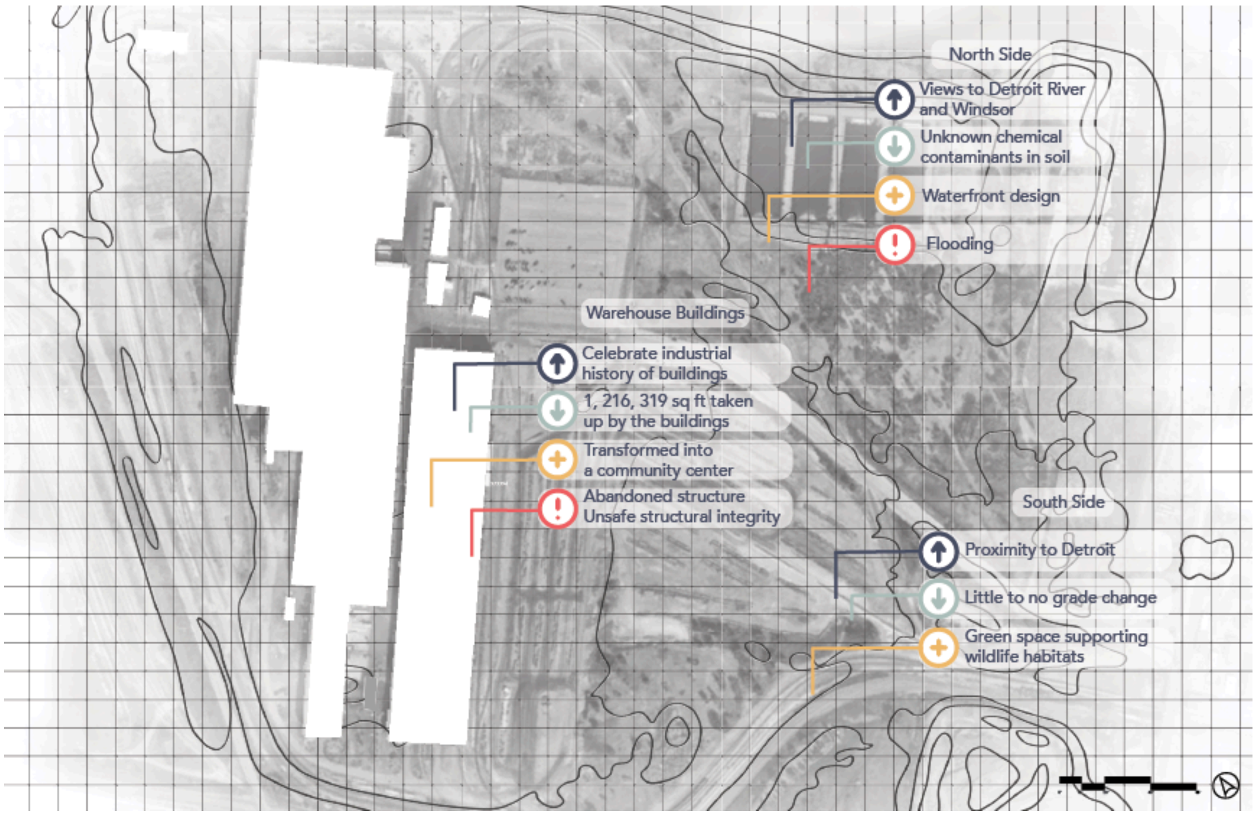

Figure 4. Site Analysis

3.3. SITE ANALYSIS

Further site analysis was conducted where elements such as greenspace, contaminated soils, and circulation patterns were considered (Figure 5). Most of the site is made up of contaminated soils from the previous steel company. The leftover space is vegetation; however, it was mostly comprised of invasive species and other plants in unhealthy condition. The circulation pattern is limited, with one 24’ foot road leading to the warehouse buildings and a parking lot. There are train tracks on site that were historically used to connect the 80” Hot Mill to Zug Island. The abiotic elements considered were topography, flood zones, and soil types. The topography of the site was rather flat, along with the clay based soils lead to the conclusion that the site would experience flood events and the proposed design would have to consider low-impact development (LID) elements. The soil data obtained from the United States Department of Agriculture Natural Resources and Conservation Science shows that the largest part, 26.9% (59.7 acres), of the site is made up of relict lake beds. The other soils are a type of sandy loam. Lastly, the flood zone was considered, whose basin takes up 1/3 of the site. The following infographic, Figure 5. Biotic and Abiotic Conditions shows the information described above. Assessing the findings discussed, the use of the site is limited and the contamination along with flooding concerns poses a great risk to human health.

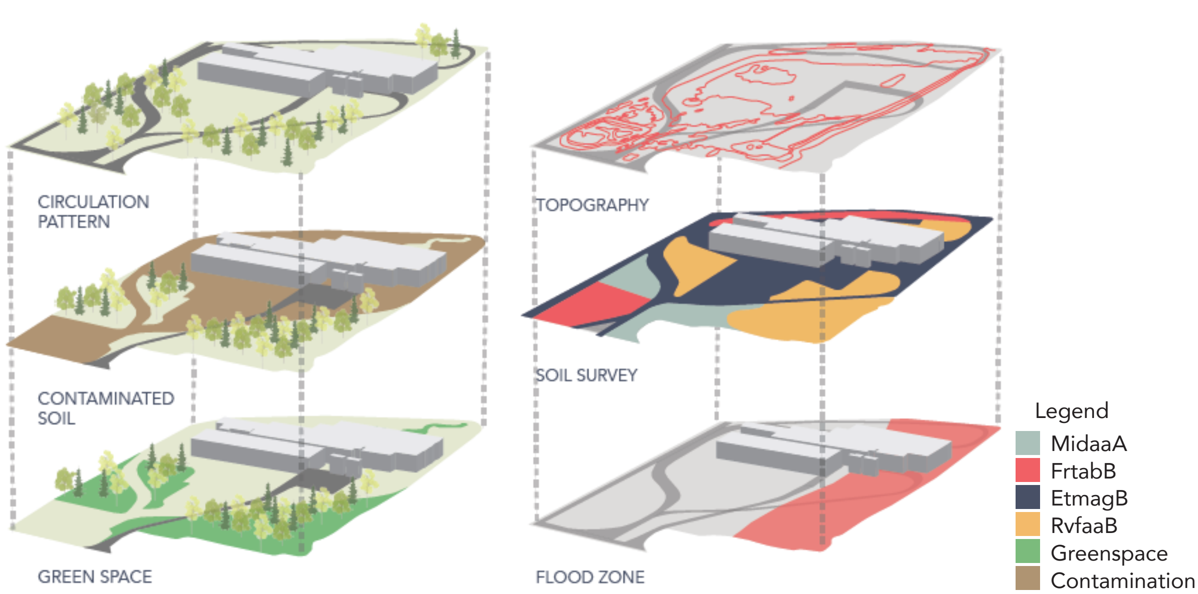

Figure 5. Biotic and Abiotic Conditions

3.4. ECOLOGICAL DESIGN MATRIX

As part of the recommendation for the site, a design matrix has been developed after reviewing landscape ecology principles (see Table 1) (Dramstad et al., 1996). The type of design matrix has been selected based on the literature review and the findings from site analysis. The design matrix for this study has been divided into two main categories: Design Principles and Design Goals. The design principles have established design goals and elements to be applied to the final master plan.

Table 1. Ecological Design Matrix

	Design Principles	Design Goals	
Types	Definition	Design Considerations	Design Elements
Patches “Fragmentation” 	Fragmented patches are occurred by human development which have led destruction of habitats, leaving behind smaller unconnected areas, and decreasing habitat quality.	Connecting species habitats through vegetation or improving the quality of the existing habitat will increase species diversity.	Open space, vegetation, floating islands, proximity of wetlands
Patches “Size” 	Human development has led to changes in habitat size, interrupting the natural ways in which species interact with one another.	Varying the width and length of a patch improves species diversity and quality	Open space, vegetation, varying plant species given their root systems

Table 1 (cont'd)

Isolation "Edges" 	Physical boundaries between different types of patches.	Varying the size and length of edges can lead to richer "edge" animal species.	Soft and undulating edges using vegetation.
Connectivity "Corridors" 	The structure in which species can interact with or migrate across other paths or habitats.	Providing avenues where species can travel improves species quality.	Proximity of greenspaces and floating islands to one another using native species for vegetation.

Reference: Dramstad, W. E., Olson, J. D., & Forman, R. T. (1996)

The aforementioned goals were established with the use of landscape ecology principles of design and created with the consideration of the site analysis conducted. The site offers opportunities for stormwater management, providing social benefits for the community, waterfront design, as well as creating wildlife habitats, and implementing other sustainable practices. The design goals are broken into three categories, with each having a sub-goal, as depicted in figure 6. Within the category of mobility, there are protected bike lanes, ADA-accessible walks, boardwalks, and opportunities for people to connect with nature. Second, the design goal of connectivity is meant to provide a bridge connecting the gaps between people and the environment in a sustainable and safe manner. Similarly, the goal of sustainability is to create avenues for habitats to regenerate themselves, whether that is through species connectivity, harvesting/recycling stormwater, or promoting native species on site.

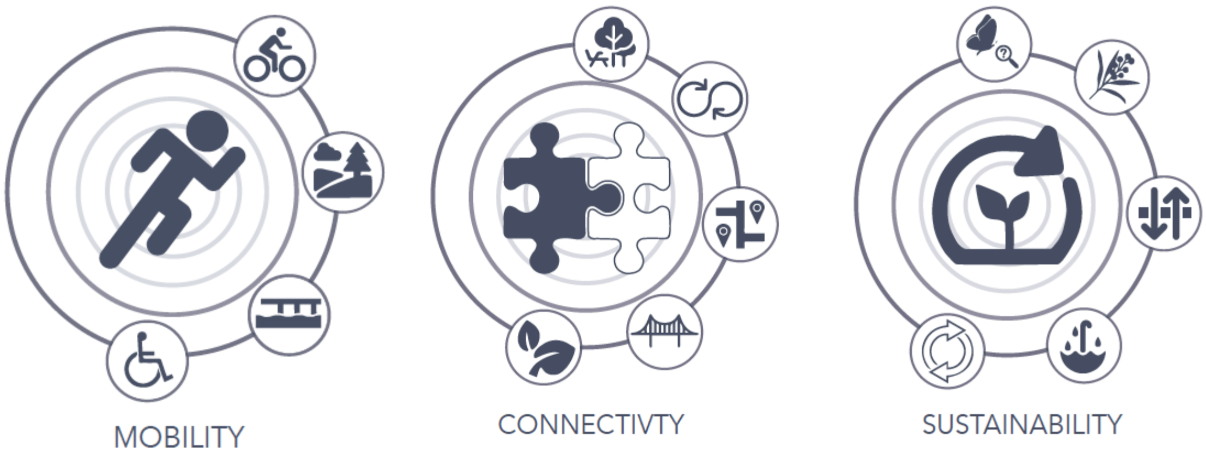

Figure 6. Design Goals

The principles of ecological design were used to create the site-based goals. By implementing program elements such as an elevated boardwalk, the species habitat is not fragmented, and their health is preserved while still providing mobility for site visitors. The implementation of floating islands would help alleviate problems of species isolation and the patch size by designing various sizes of floating wetlands along with utilizing different plant species to provide a soft and undulating surface where species habitats can flourish. By designing a corridor where the Detroit River connects to the site, species are able to migrate across multiple habitats and the quality would be improved.

3.5. LANDSCAPE PERFORMANCE VARIABLES AND DATA COLLECTION

Along with the conduction of this study, a series of metrics was suggested in order to measure the success of the proposed design. Using the tools provided by Landscape Performance Research (LPR), metrics were created in the following three categories: environmental, social, and economic (Table 2).

Table 2. Landscape Performance Metrics and Methods Employed

Metric	Variable	Description	Methods
Environmental			
Carbon sequestration	Overall condition	The reduced amount of carbon dioxide estimated from materials, paved surfaces, and trees	Pathfinder: Landscape Carbon Calculator
	Total material emissions	Embodied carbon through materials	Pathfinder: Landscape Carbon Calculator
	Total plant sequestration	Embodied carbon through plants	Pathfinder: Landscape Carbon Calculator
Stormwater retention	Runoff reduced	The retained amount of average annual runoff volume	National Stormwater Calculator
	Infiltration	The increased amount of average annual infiltration volume	National Stormwater Calculator
	Evaporation	The increased amount of average annual evaporation volume	National Stormwater Calculator
Removal of air pollution	Total air pollution removed	The amount of pollution removed by trees planted	iTree Planting
Removal of contaminated soil and waste recycling	Total waste removed	Measuring the amount of waste that is removed from the site	Waste Management Calculator
	Recycled steel from train tracks	Measuring the amount of steel recycled from the site	Waste Management Calculator
	Recycled concrete from pavement	Measuring the amount of concrete that is recycled from the site	Waste Management Calculator
Social			

Table 2 (cont'd)

Visual quality	Floristic Quality Index (FQI)	A measurement of the overall quality of the plant species	Universal Floristic Quality Assessment Calculator
Safety	Lighting features	Number of lighting features added	Site design
	Sidewalks	Square feet of sidewalks added	Site design
	Crosswalks	Number of crosswalks added	Site design
Recreational space	Total open/green space created through design	The amount of additional open/green space added	Site design
Gathering space	Total allocated space	The visitor capacity allowed	E How Calculator
	Outdoor amphitheater	The visitor capacity allowed	E How Calculator
	Community center with plaza space	The visitor capacity allowed	E How Calculator
Bikeability	Bike lanes	The length of new bike lanes added	Site design
Economic			
Stormwater retention costs	Annual maintenance cost saved	The money saved with best management practices	Center for Neighborhood Technology Green Values Stormwater Management Calculator
	Life cycle cost saved	The money saved with best management practices	Center for Neighborhood Technology Green Values Stormwater Management Calculator
Pollution savings	Annual savings	The annual savings from pollution removal by trees	iTree Planting

References: Landscape Performance Series (iTree Planting, Pathfinder, Universal Floristic Quality Assessment, Waste Reduction Model, EPA National Stormwater Calculator, E How

Calculator, Center for Neighborhood Technology Green Values Stormwater Management Calculator)

3.5.1 ENVIRONMENTAL METHODS

In this research, the environmental benefit metrics of (1) carbon sequestration, (2) stormwater retention, (3) removal of air pollution, and (4) removal of contaminated soil were measured. These variables were further categorized into sub-categories of each metric as shown in table 3 below. The proposed design predicts great positive change in each category which is greatly due to the use of mitigation strategies. The Pathfinder carbon sequestration model, developed by Conrad, was adopted to predict the number of years until the site would be carbon positive, meaning that the emissions from the site are equal to 0, or within 353 years (Pathfinder: Landscape Carbon Calculator, 2019). After inputting square footage of wetlands, green infrastructure, asphalt, and perennials proposed, the pre-existing conditions data shows that it would take the site 11 years to become carbon positive; compared to 353 years with the existing conditions inputs. The EPA Stormwater Calculator (EPA National Stormwater Calculator, 2015) was used to calculate retention and detention metrics. Similarly, a calculation of acres of land coverage was inputted into the software as well as the LID strategies. Through using the iTree planting calculator, developed in partnership with the United States Department of Agriculture and Forest Service, (iTree Planting Calculator, 2016), the estimated air pollution was measured in tons/per year. With the intent of long-term sustainability and ecological safety, only native trees to Michigan were planted. The Waste Management Calculator (Waste Reduction Model, 2016) was used to measure how many tons of waste was removed from the brownfield, this was obtained by converting square feet to cubic feet, where an average depth of 4” was assumed for both baseline and design scenarios and inputting those values into the calculator. Once the total areas were measured for both the steel train tracks and the concrete to be recycled, the values were inputted into the Waste Management Calculator, where the estimated steel and concrete tons were calculated, and the results shows the emissions created.

3.5.2 SOCIAL METHODS

When redesigning a brownfield, social considerations need to be given, especially economic and environmental factors. For the purposes of this research, the following variables were measured: (1) visual quality, (2) safety, (3) recreational space, (4) gathering space, and (5) bikeability. During the design process, the focus was placed on providing a space where the community could gather and host a variety of event types. When measuring the spaces, outdoor recreational areas were separated from indoor spaces as both provide a different social benefit. The three types of safety features were: lighting, sidewalks, and crosswalks since they proved to have the most weight when enhancing safety. Adding protected bike lanes proves to bring both safety and recreational value to its users. Visual quality was measured using the Floristic Quality Index (FQI), developed by OpenLands (Universal Floristic Quality Assessment Calculator, 2015) an assessment tool that is based on vegetation quality. The results indicate the biological integrity of the planting plan (Minnesota Pollution Control Agency, n.d.). The standards for the tool are as follows: 1-19 (low quality), 20-35 (high quality), and above 35 (exceptional). Given the previous use of the site, there were limitations to the plants that could survive and restore the soil, however, the post-design quality would still be superior.

3.5.3 ECONOMIC METHODS

Economic measures are intended to be an extension of the environmental benefits by showing the monetary savings of an ecological design. The following variables were measured in this research (1) stormwater retention costs and (2) energy savings. A calculator tool provided by Center for Neighborhood Technology Green values (Center for Neighborhood Technology Green Values Calculator, 2020) was used to estimate the annual savings in maintenance costs for the site. The values were obtained by inputting information about the site cover and the LID controls. Using the iTree planting model, developed in partnership with United Stated Department of Agriculture Forest Service (iTree Planting Calculator, 2016), the tree species proposed were placed on the site and the calculator was able to model the pollution savings.

CHAPTER 4. RESULTS

4.1. DESIGN PROPOSAL

Ecological planning and design principles were applied in the creation of the master plan. As the four intents were put into practice, varying elements of floating wetlands, vegetation, soft and undulating plant edges were implemented at different scales in order to improve species equality and diversity.

The proposed plan features three main elements, mobility, connectivity, and sustainability (Figure 7). As visitors enter from Great Lakes Ave, they are welcomed by a visitor center with interpretive displays, programs, services, and information to enhance their experience. The road connecting visitors to and from the site is intended to be one way, to enhance the safety of visitors to the site. Bioswales are a LID control feature, one that serves as a stormwater mitigation strategy and a safety buffer for pedestrians and bikers. Connected to the visitor center and across the entry road there is designated flexible space, meant for versatile use of outdoor activities such as futsal, picnics, or hammocking. One of the ecological planning components of the design is the flower field. The field's purpose is to improve soil health, promote species diversity and bring social benefits to guests. Additionally, this helps reduce the fragmentation that animal species experience with extensive infrastructure development. The large patch size allows for increase in habitat health, species connectivity and mobility. The community park serves a multi-use purpose, as both an open space for flexible use and an outdoor amphitheater to host events. A wetland wraps around the community park and features floating islands for species diversity and health which is done by using ecological planning principles such as soft undulating vegetative edges. These edges decrease the extent of species isolation by providing a buffer zone where species are able to transition smoothly between one habitat to another. Similarly, the Detroit River was invited into the site through a channel; this design implementation provides a corridor for species to move through different environments. The elevated boardwalk suggested as a design element prevents fragmentation of the site by allowing spices habitat to remain intact and sustaining human use. As part of the social improvements, the existing warehouse is to be repurposed into a community center which would hold gathering spaces and educational classes for that community to learn about ecological planning. Lastly, an elevated boardwalk is proposed which allows pedestrians to walk over the wetlands and floating islands and gives them a more intimate experience of the site.

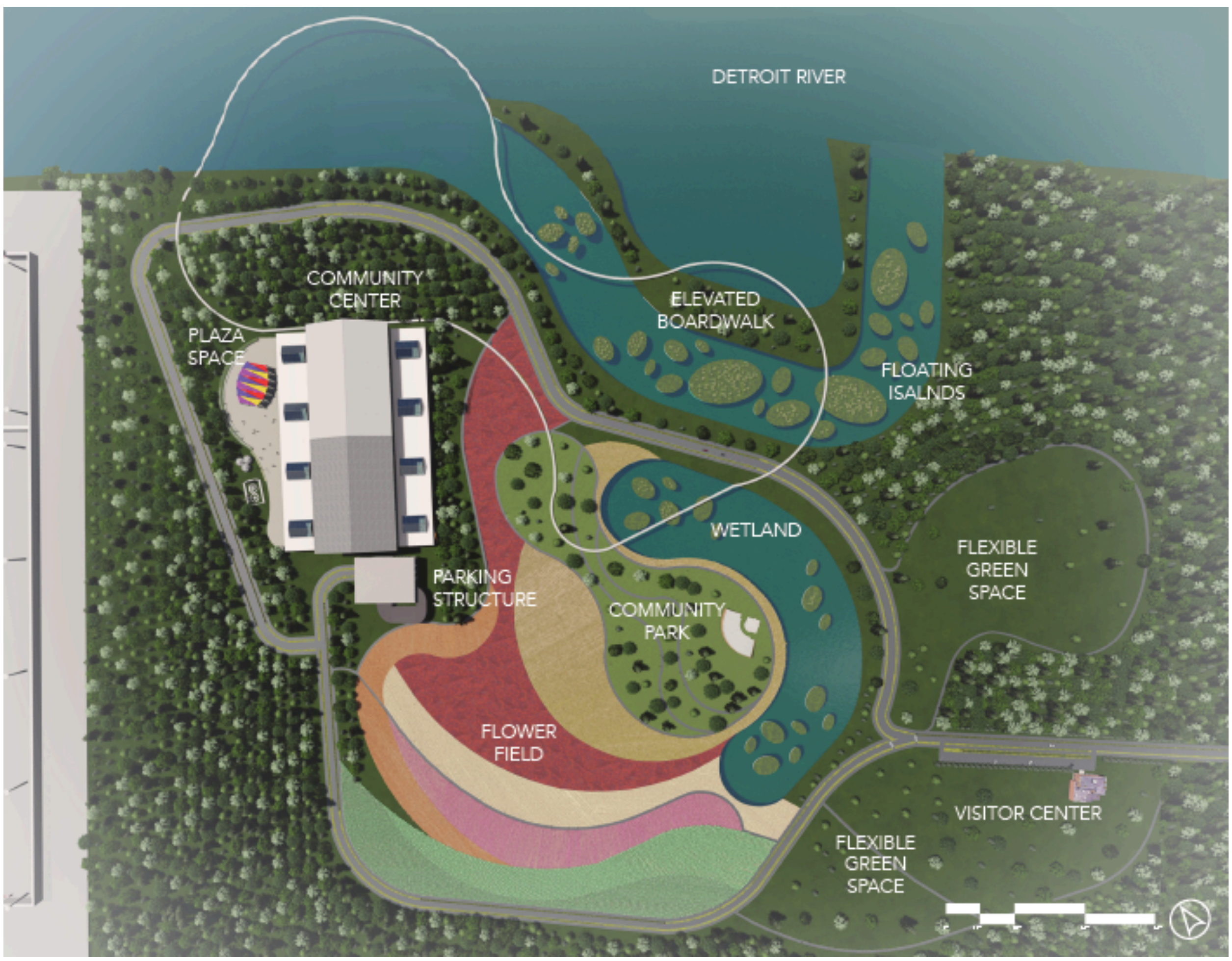

Figure 7. Master Plan

The history of the site was honored by reinforcing the warehouse building structure and repurposing it into a community center that will serve as a space where events could be held. Additionally, the proposed plaza space adjacent to the new community center features "gear/mechanical" shaped sculptures. Additionally, there are raised planters with seating surrounding the plaza with a shade structure and outdoor furniture (figure 8).

Figure 8. Great Lakes Plaza

Another implementation of ecological design is the floating wetlands (Figure 9); with the intent to help with species restoration and habitat creation. The book referenced was by Dramstad, Olson, and Foreman (1996), which discussed the best route in which habitat restoration methods were implemented for the proposed design. The floating wetlands were designed in close proximity to one another to promote migration between species. The soft edges of each wetland are meant to help promote species diversity and richness.

Figure 9. River Promenade

4.2. LANDSCAPE PERFORMANCE ASSESSMENT

Following the proposed design, metrics were extracted and LAF toolkits were used to calculate the provided benefits. Most importantly, the existing environmental conditions of the site were measured and used as a baseline in comparison to the proposed solution. The first three columns of the Environmental, Social, and Economic Benefits Calculations Tables 3, 4, and 5 describe the metric, variable (a sub-metric), and the unit used to calculate. The second half shows the results and the difference (existing-proposed) for each variable.

4.2.1 ENVIRONMENTAL BENEFITS

The advantages of the proposed plan can be seen through the percentage of positive change for each category, as seen in Table 3. Carbon sequestration and stormwater measures experienced great change, with the total plant sequestration post-design improving by 203.40%. Seeing as the materials suggested are eco-friendly, the total emissions only increased by 6.61%. Much of the counterbalance of sequestration and carbon emissions were offset by the 189,201.1 sq ft of wetland, 1,125,646.9 sq ft of perennials, and an additional 18,400 sf of stormwater plantings. The bioswale plant material also counts as a LID treatment for flooding and it is able to infiltrate an additional 28.25 inches of rainwater per year than the existing infrastructure can. The proposed LID treatments are able to infiltrate the average annual rainfall, which according to the EPA is 34.45 in/year. The proposed plan calls for 500 Michigan native trees to be planted. Using iTree planting (2016), a software that is used to estimate the environmental and economic benefits of trees, it was estimated that 22.08 tons of air pollution would be removed per year. Due to a lack of data availability, the baseline scenario for this metric was imputed as zero and therefore the percent change is undetermined. Similarly, the Waste Management Calculator (2016) was able to calculate the proposed design metrics, but there is no data that would help determine the baseline scenario; hence it is set at zero. The square feet of steel from existing train tracks and concrete were calculated and converted into tons. After inputting data into the calculator, the estimated amount of removed contaminated soil is 67,737 tons given the proposed plan.

Table 3. Environmental Benefits Calculations

Metric	Variable	Unit	Ex.	Prop.	Diff.	Change
Environmental						
Carbon sequestration	Overall condition	Metric tons/50 years	50,174	63,148	12,975	25.86%
	Total material emissions	kg CO_2-eqCO2-eq	58,452,112	62,315,914	3,863,802	6.61%
	Total plant sequestration	kg CO_2-eqCO2-eq	8,277,696	251,166,828	16,839,132	203.40%
Stormwater retention	Runoff	Inches/year	22.75	27.73	4.98	21.90%
	Infiltration	Inches/year	6.89	35.14	28.25	410%
	Evaporation	Inches/year	4.82	6.2	1.378	28.60%
Removal of air pollution	Total air pollution removed	Tons/year	0	22.08	22.08	N/A
Removal of contaminated soil	Total waste removed	Tons	0	67,736.94	67,736.94	N/A
	Steel from train tracks	Tons	0	251.94	251.94	N/A
	Concrete from pavement	Tons	0	67,485	67,485	N/A

4.2.2 SOCIAL BENEFITS

The calculations made regarding the new social and recreational opportunities, as well as the safety attributes, are based on the suggested renovations. Since the previous use of the site was industrial, these physical and social activities did not exist. The baseline scenario has been set to zero and the percentage change under this category is not applicable. As seen in Table 4, the visual quality, which was measured by the FQI at 25.8 post-design, in terms of ecological integrity, is high quality. The new safety features added are 100 lighting features, 147,200 sq ft of sidewalks, and 8 crosswalks. An additional safety feature is the buffer zone between the roadway and pedestrian pathways as shown in Figure 10. Stormwater Infiltration System.

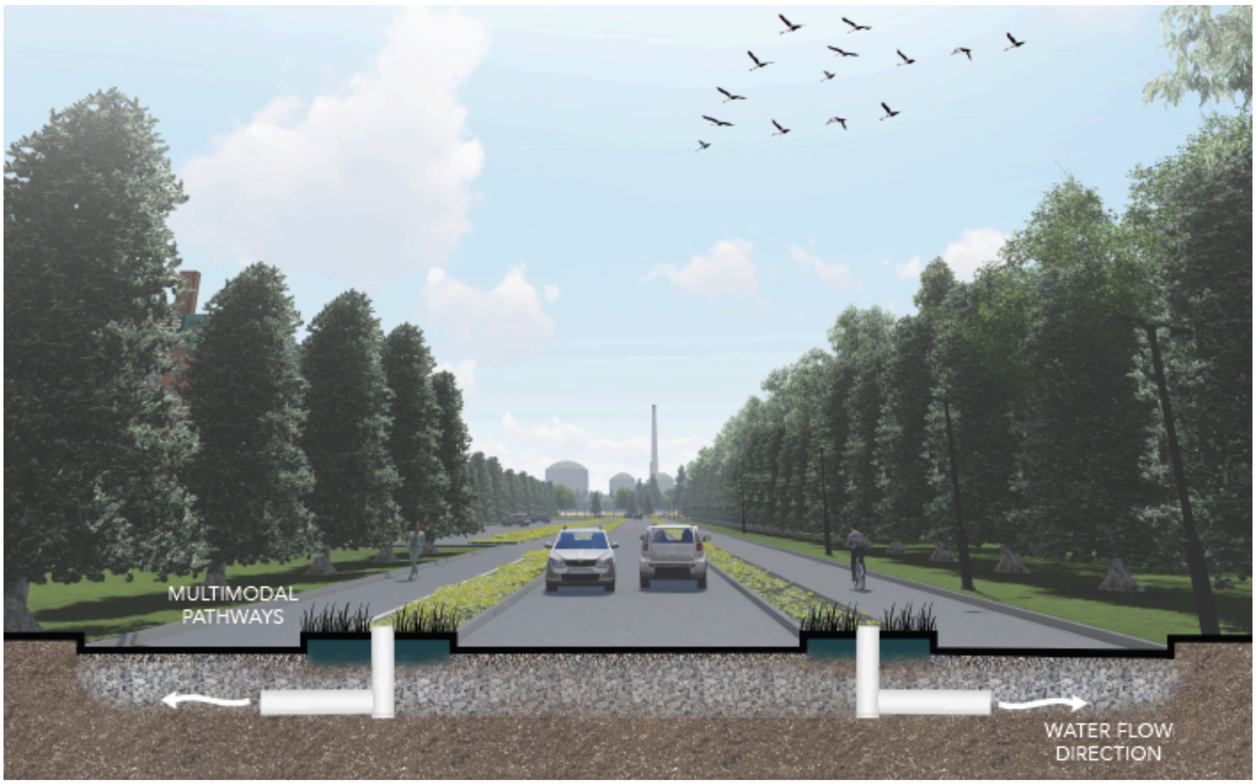

Figure 10. Stormwater Infiltration System

Recreational and gathering spaces were added between the community center and outdoor amphitheater, this allocated space totaled 51,465 square feet. Lastly, bike lanes were added for an additional 18,400 linear feet.

Table 4. Social Benefits Calculations

Metric	Variable	Unit	Ex.	Prop.	Diff.	Change
Social						
Visual quality	Floristic Quality Index (FQI)	Each	0	25.8	25.8	N/A

Table 4 (cont'd)

Safety	Lighting features	Each	0	100	100	N/A
	Sidewalks	Sq ft	0	147,200	147,200	N/A
	Crosswalks	Each	0	8	8	N/A
Recreational space	Total open/green space created through design	Sq ft	0	2,519,660	2,519,660	N/A
Gathering space	Total allocated space	People based on sq ft	0	51,465	51,465	N/A
	Outdoor Amphitheat re	People based on sq ft	0	669	669	N/A
	Community center with plaza space	People based on sq ft	0	50,796	50,796	N/A
Bikeability		Linear ft	0	18,400	18,400	N/A

4.2.3 ECONOMIC BENEFITS

The economic analysis focused on gathering data on cost savings for stormwater retention costs and pollution. The threshold for stormwater was based on the existing vegetation and annual costs without low impact development methods (LID). The data shows that including LID, the overall annual cost would be lowered by 18.18% and the life-cycle cost would decrease by 18%. These annual savings for pollution were estimated using iTree, but there is no value for the base state of the site. With the suggested improvements, $149,298.40 would be saved per year.

Table 5. Economic Benefits Calculations

Metric	**Variable**	**Unit**	**Ex.**	**Prop.**	**Diff.**	**Change**
Economic						
Stormwater retention costs	Annual maintenance cost	$/year	242,626	183,243	59,383	24%
	Life cycle cost	$/year	25,635	10,051	15,584	58%
Air pollution savings	Annual savings	$/year	0	14,298.4	14,298.4	N/A

CHAPTER 5. DISCUSSION AND CONCLUSIONS

The intent of this research was to help determine the ecological process of restoring brownfields. Secondly, it aims to be a tool for professionals to further facilitate learning by using a quantitative research method approach. The blended use of sustainability analysis, case study, and landscape performance assessment offered an honest perspective of what revitalization efforts could entail. Through planning, revitalization and research design considerations will be tailored to further reinforce and support the economic development, social aspects, and environmental benefits that extend beyond the use of the site.

Urban spaces are designed with user intent in mind, meaning the community utilization of space is given much more weight compared to the biodiversity that is being affected in the process of re-design. The success of a design is based on the extent of site-related factors that were considered. Restoring vacant lands is critical to the future of the sustainability of the land, and the health of communities (Nassauer, J., & Raskin, J., 2014). It is a delicate matter to design, especially when this number of considerations must be taken. With the proposed redevelopment of the 80" Hot Mill Company, new amenities for residents were added that will positively impact community health and wellness. The activities implemented are meant to encourage people to be active and participate in engaging their bodies in various physical activities (Kim et al., 2020). Economically, the new amenities will generate revenue for the city of River Rouge, MI, enticing more residents to move to the area and bring life back to what used to be an industrial city. The environmental restoration benefits can be seen through animal species coming back and reclaiming their home, and plants becoming established and growing throughout the site leading to pollution and carbon sequestration being offset by a successful plant palette.

A design guideline that was not widely discussed throughout this study is the importance of policy review and community participation processes. Cities across the United States have established an Office of Sustainability, which is a part of their governing office. The role of this office is to protect the community, preserve and restore ecosystems and protect the safety of the environment, therefore the office creates a city-wide sustainability plan and updates the plan every few years. An example of this plan is when the Washington District of Columbia (Resilient DC, 2016) created a 160-page plan that focused on resilience methods and how to improve the safety and health of its citizens. When creating documents as such, there are community-scale meetings, including the involvement of stakeholders and city officials. A possibility for future research is to combine ecological and community-based planning that would be applied at the city level. The Office of Sustainability could facilitate ways to educate the community on ecological issues and future planning could take an ecological approach.

One of the most critical aspects of a project is follow-up and monitoring to ensure the success of plantings and to reach the design intent. Many revitalization projects have failed due to the lack of post-care which in the end deterred the project away from its original goal (Anderson & Minor, 2017). There has been research conducted on how community engagement in a project leads to its long-term success; this is labeled as civic ecology (Krasny et al., 2014). Individuals and the environment they live in are intertwined in more ways than one—one's own surroundings impact the way he/she feels, thinks, and acts. However, the well-being of an individual refers to social unity. Most often, civic ecology is enacted upon in a time of hardship, such as hurricanes or war, where community-driven efforts are at the core of alleviating the situation. However, what if the same efforts were put forth for resilient design? Designs that would help with the ecological restoration of vacant land. Socially strong communities will be able to contribute to the urban restoration of their own cities. The scale at which they would be acted upon would be a perfect fit for contributing to green infrastructure and ecosystem services (Krasny et al., 2014). Although there are many possible avenues to be taken to monitor the restoration of a community, there is a strong need for realistic goals when revitalizing an urban land since these goals contribute to the function, aesthetics, and sustainability of the project.

When conducting this study, there were a few limitations such as data availability and on-site safety concerns. First, the selected study site did not allow for physical access due to many safety concerns, because of this much of the site analysis was conducted based on secondary data sets such as Google Earth imagery. Other limitation was correlated to data availability. The site is located in a city with scarce resources. In the process of compiling data, there was no data availability for some of the existing condition categories under the social measures/benefits, which led to only measuring the post-design metrics. In addition, for measuring economic benefits, there was little accessible data for property values and therefore it was not included. Although the research took a case study approach, there was no community involvement in the process of creating the social benefits. Ideally, a city-wide meeting would be held where stakeholders are involved in the decision-making process.

The fall of industrial cities has left many communities in disorganized chaos. With the loss of residents and tax revenue, it has become a challenge to sustain lively communities. The potential of vacant lands, specifically brownfields, is unrecognized in the community planning process (Kim et al., 2015). In academic literature, there is no set definition of vacant lands or brownfields as they pertain to vacancies across cities (Anderson & Minor, 2017). Therefore, this study created a definition of vacant land concerning brownfields and aimed to provide ecologically safe solutions. This research explored the avenues that could be taken in order for a site to be revitalized to its fullest and healthiest potential. As in all research, there were limitations concerning data availability and safety concerns due to the accessibility of the site. The proposed design was evaluated using landscape performance metrics, and the percentage change for each metric was calculated to show a positive correlation between design intent and outcome. Further research could be made stronger by focusing on community involvement in the design process as well as creating an extensive site inventory for better design decision-making.

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