Ecologically restoring brownfields in urban coastal zones: a case for South Providence, Rhode Island

by

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A REPORT

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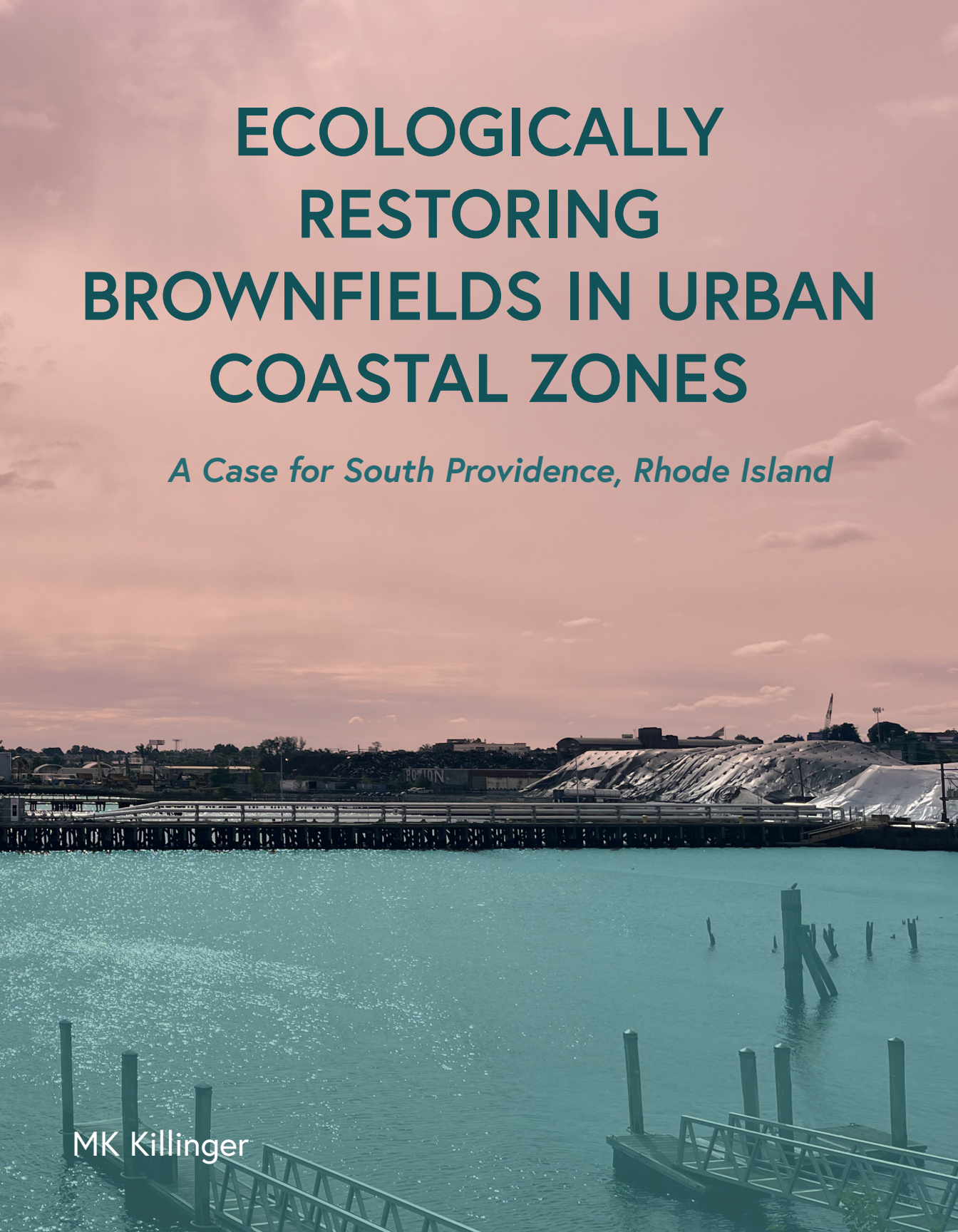
Abstract

Coastal brownfields are a critical issue in coastal areas, especially in port and post-industrial cities. There have been many studies conducted on the redevelopment of brownfields. However, there are limited reports covering both short-term solutions and long-term ecological restoration of sites in coastal brownfields. This study explores the feasibility and potential of restoration strategies for a coastal brownfield in the short and long term. The Port Area of South Providence, RI, is the focus of the study as it is a typical post-industrial city with ecological problems resulting from coastal brownfields. The proposed project consists of two phases: research and design phases. First, the research phase includes coastal brownfield literature analysis, expert surveys, and interviews with local experts in Providence. The research phase aims to create a framework to synthesize coastal brownfield restoration strategies at different site scales and restoration timeframes. Second, the design phase includes site analysis, precedent studies, and projective design. The design phase aims to develop a proposal for a short-term site-scale coastal brownfield restoration and a long-term ecological restoration at an urban scale. The outcomes are a multiphase conceptual master plan with short-term and long-term ecological restoration solutions and design works for brownfield restoration. The study's outcomes contribute to the discussion of the ecological restoration of coastal brownfields and can be utilized as a reference for other landscape architects, urban designers, brownfield experts, and city planners.

ECOLOGICALLY RESTORING BROWNFIELDS IN URBAN COASTAL ZONES

A Case for South Providence, Rhode Island



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Glossary

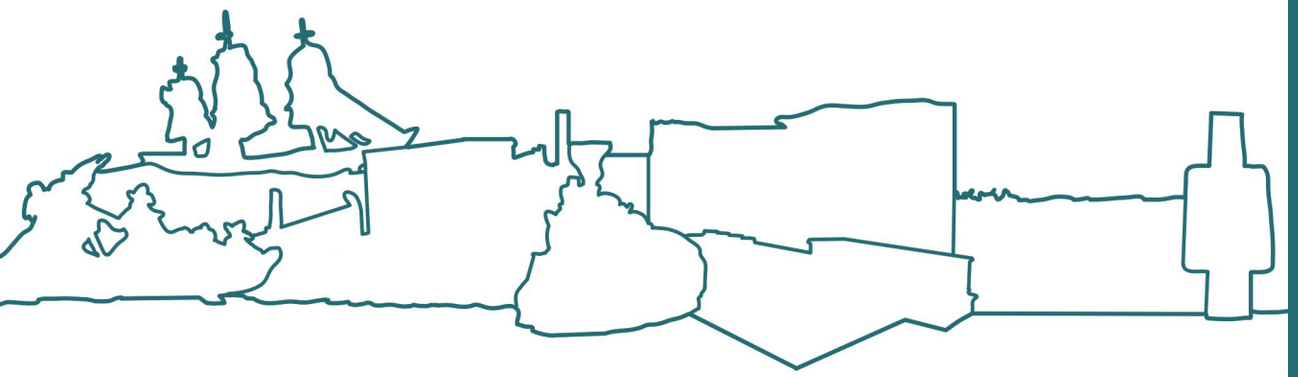
Biodiversity: "refers to biota in terms of taxonomic and genetic diversity, the variety of life forms present and the community structure thereby created, and the ecological roles performed" (SER 2004, 6)

Brownfields: "Brownfields are former industrial and commercial sites that have been abandoned because of contamination or fear of contamination." (Levi and Kocher, 2006, 804)

Ecological functions: "are the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment" (SER 2004, 6)

Environmental-based adaptation: "the use of biodiversity and ecosystem services as part of an overall strategy to help people adapt to the adverse effects of climate change" (UNEP 2016)

Resilience: "the ability of a social or ecological system to maintain basic structural and functional characteristics over time despite external pressures" (UNEP 2016)



Chapter 01
Introduction

Background

The research focuses on the ecological restoration of urban coastal brownfields. Historically, industrial and port cities have developed through international trade and commerce while providing jobs for the surrounding communities. With the cities' growing need for ports and their expansions, the coastline of the United States transformed into impervious industrial structures that have disrupted the natural ecosystems of the coast (Goodwin 1999; Seavitt et al. 2018). As time passed and industries left the port areas, industrial development became coastal brownfields that contaminated the surrounding environment and held scraps, chemicals, hazardous materials, and other waste (see Figure 1.1) (Hollander, Kirkwood, and Gold 2010). The contaminant also impacts the soil, air, and water quality, creating considerable risk for marine life and increasing coastal erosion (Barnett, 2010; Bardos et al. 2020; U.S. Department of Commerce 2003). The industrialization of coastal areas prevents coastlines from performing their ecological functions, causing contamination to spread into adjacent bodies of water, and degrading the natural landscape (Levi and Kocher 2006; NOAA 2015; Powell et al. 2019; Temmerman et al. 2013). This coastal degradation hinders the coast's ability to protect the surrounding areas from ocean-related events (Bayraktarov et al. 2020) and relies on coastal infrastructure to protect the city's edge (see Figure 1.2). Coastal brownfields are also at elevated risk of flooding and climate change events that can further damage the site and spread to the surrounding area water and through the air, harming the surrounding communities (Levi and Kocher, 2006). Brownfield redevelopment has been studied in these post-industrial cities, however there are minimal studies on the effectiveness of short-term to long-term ecological restoration of coastal brownfields in urban port zones.

Figure. 1.1. Industries on the Providence River (By Author 2023)

Figure. 1.2. Boat Ramp at Point Collier Park (By Author 2023)

Figure. 1.3. India Point Park. (By Author 2023).

Providence, Rhode Island

Providence, Rhode Island, is on an estuary of the Narragansett Bay and contains industrial ports and brownfields. Providence is a typical coastal city that has experienced the contamination and degradation of its coastline due to over-industrialization. The city also has a history of gray infrastructure for coastal protection, such as the Fox Point Hurricane Barrier, which protects only 280 acres of the downtown (Rubinoff et al. 2021; Providence Working Waterfront Alliance n.d.). Industrial development, river engineering, and coastal protection infrastructure have changed the shape and function of the Providence coastline (see Figure 1.3) (Binder et al. 2021; Providence Working Waterfront Alliance n.d.; Rubinoff et al. 2021). Industrial port facilities are impacted critically by climate-related events, especially in South Providence (Binder et al. 2021). This area can catalyze coastal ecological restoration and serve as this research's project site.

Research Questions

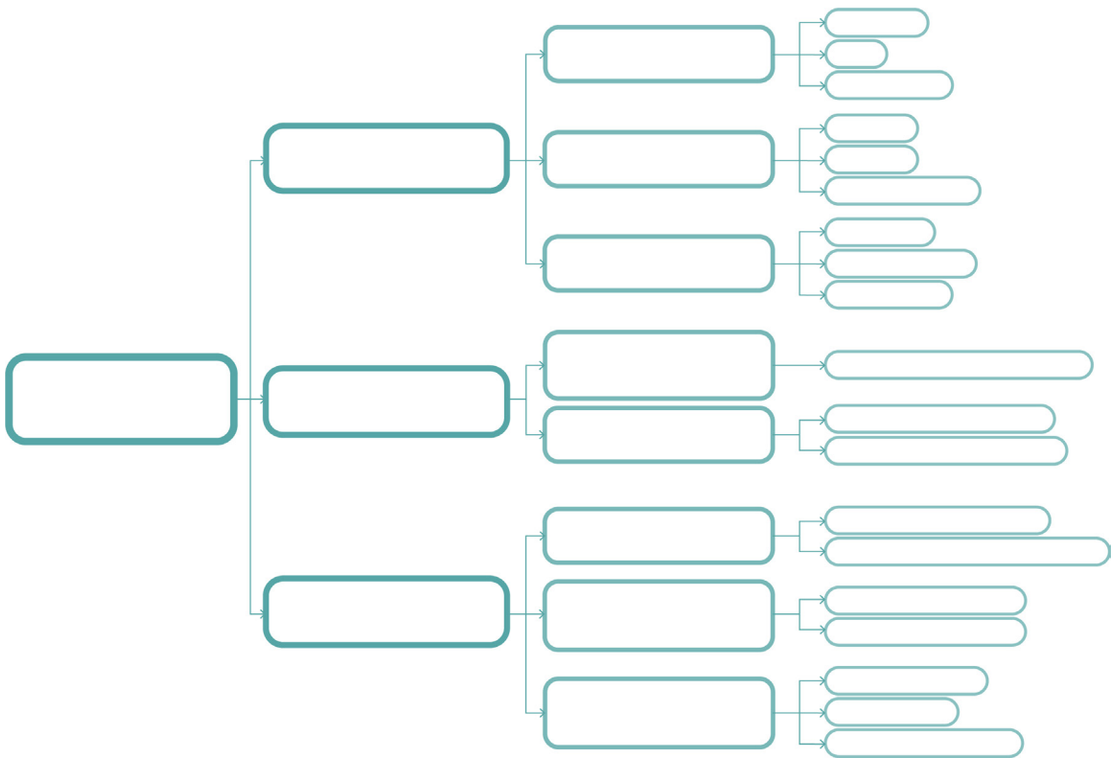
Primary Question: How can urban coastal brownfields be ecologically restored?

- **Sub Question One:** Why should urban coastal brownfields be cleaned up, remediated, and re-established ecologically?
- **Sub Question Two:** How can urban coastal brownfields be ecologically restored in a short-term as well as long-term perspective?
- **Sub Question Three:** What brownfield restoration strategies are plausible in urban coastal zones such as the Providence Port area?

Significance

This research is significant in understanding ecological restoration strategies feasible in urban coastal brownfields. Providence is a typical example of a coastal city facing ecological problems from brownfields along its coastline (see Figure 1.4). By choosing the South Providence Port Area, the research can focus on problems common in cities with comparable contexts. Providence will serve as a case study for other coastal cities to refer to when restoring coastal brownfields.

Figure. 1.4. History of Providence's Coastline. (By Author 2023).



Chapter 02
Literature Review

Chapter Overview

The literature review's purpose is to understand the background of brownfields in urban coastal zones. The three main concepts examined in the literature review are coastal brownfields, coastal infrastructure in industrial port zones, and ecological restoration of coastal brownfields (see Figure 2.1). These concepts were selected to examine the different facets of ecological restoration of coastal brownfields in the short to long term. These concepts define why there is a problem with coastal brownfields, the existing infrastructure, and the solutions to solve this issue. They relate by addressing the quality of the coastal environment after degradation from industrialization. The literature chosen is from reputable sources and was found primarily through Google Scholar and K-State Library Database searches. Terms used in these searches include "coastal brownfields," "coastal restoration," "green infrastructure," "gray infrastructure," "coastal infrastructure," "coastal ecologies," "coastal ecological functions," and "coastal biodiversity." The other sources were found by using references from previous literature.

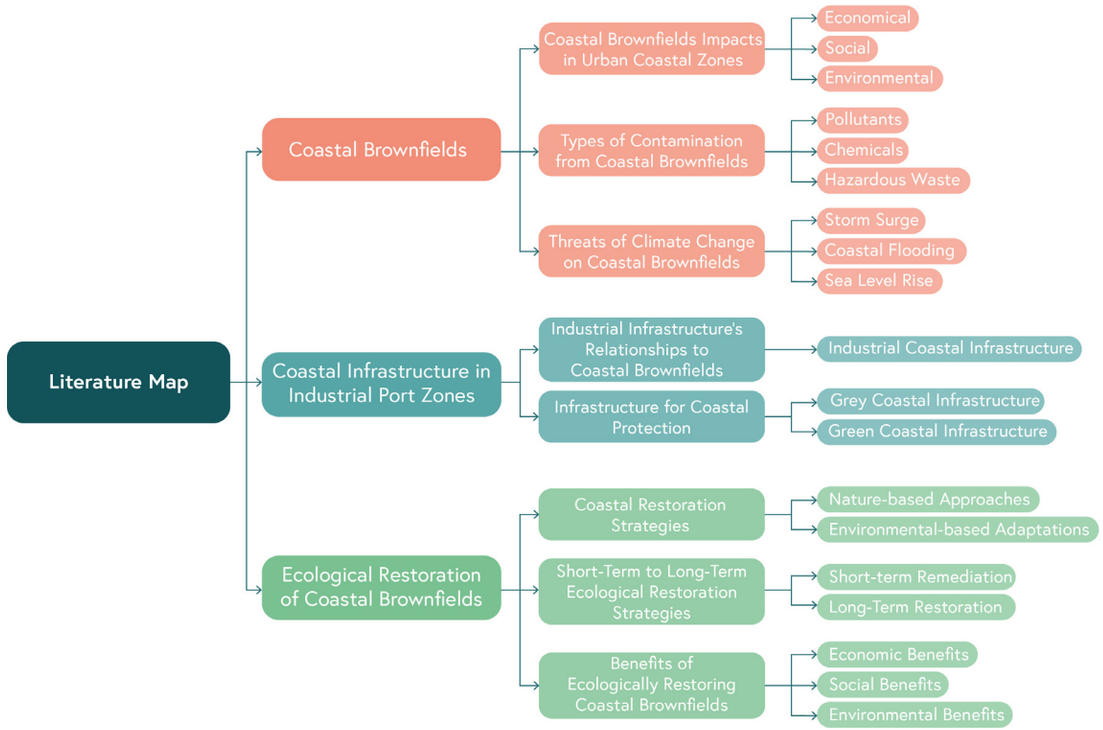


Figure. 2.1. Literature Map. (By Author 2023)

Coastal Brownfields

Coastal brownfields were once industrial or commercial areas that were neglected due to contamination or threat along coastlines (Barnett 2010; Levi and Kocher 2006; Seavitt et al. 2018). Areas with a history of ports and industrialization have an abundance of brownfields along their coasts that impact the environment and well-being of the surrounding neighborhoods (see Figure 2.2). Contamination is a significant factor in brownfields and infiltrates the surrounding environment through the soil, air, and water. Along the coast, the contaminates are picked up by the waves, travel further, and impact adjacent communities (Barnett 2010; Bardos et al. 2020; Levi and Kocher 2006). The environmental impacts from the coastal brownfields are exacerbated by climate change as flooding events become more frequent and sea levels rise (Barnett 2010; Levi and Kocher 2006). The following sections explore the topics of environmental impacts, contamination types, and climate change threats on coastal brownfields.

Coastal Brownfields Impacts in Urban Coastal Zones

Coastal brownfields have direct environmental, economic, and social impacts on the adjacent areas. Coastal brownfields harm the environment, decreasing the quality of the soil, air, and water. Contaminates such as chemicals and hazardous waste are held in the soil, prevent vegetation growth, and cause erosion (Zheng and Kirkwood 2020). Some other pollutants, such as debris, can become airborne and travel into surrounding areas (see Figure 2.3) (Bardos et al. 2020). Often, coastal brownfields are close to large populations and create health risks to vulnerable communities and the environment (Bardos et al. 2020; Barnett 2010). On the coast, brownfields contaminate and pollute the water and disrupt the functions of the shoreline (Levi and Kocher 2006). The economic impacts of coastal brownfields relate to the community's economy and socioeconomic status. The threat of contamination can lower the surrounding areas' property values and economic development (Hollander, Kirkwood, and Gold 2010; Levi and Kocher 2006). The social impact of coastal brownfields is the minimal interaction of

Figure. 2.2. Abandoned Lots in the Study Site. (By Author 2023)

Figure. 2.3. Road Salts Mound in the Study Site. (By Author 2023)

the community within this area due to their dangerous perceptions (Levi and Kocher 2006). Coastal brownfields affect not only the encompassing environment and communities but also a larger-scale urban area due to their coastal locations.

Types of Contamination from Coastal Brownfields

A brownfield is considered "coastal" if it is in a coastal zone within the high tide line. A coastal brownfield is deemed to be at risk for further contamination when located within a 100-year floodplain (Barnett 2010). Industrial port brownfields contain many pollutants and contaminants that have detrimental effects on the coastal environment. The common contaminants found in brownfields are waste (in liquid, solids, gases, or sludge form), manufacturing by-products, combinations of chemicals, and petroleum products (Bardos et al. 2020). Polychlorinated Biphenyl (PCB) is a typical chemical found in coastal brownfields notorious for causing adverse health impacts like cancer (Barnett 2010) Brownfields also cause erosion and hold solid particulates, debris, pathogens, and plastics (Bardos et al. 2020). These contaminants stay even after the initial waste is removed and continue to impact the environment (Bardos et al. 2020; Zheng and Kirkwood 2020). Intense and continuous remediation needs to occur to rid brownfields of all harmful pollutants that are often mixed and presented in multiple layers (Zheng and Kirkwood 2020). By having a web of contaminants from industrial use, coastal brownfield remediation is a complex and multifaceted undertaking.

Threats of Climate Change on Coastal Brownfields

Ecological restoration is becoming increasingly integral to coastal cities as climate change increases the frequency of flooding events, storm surges, and sea level rise (Seavitt et al. 2018; UNEP 2016). Climate change has caused water-based phenomena to become more frequent, such as storm surges, coastal flooding, and sea level rise (Bardos et al. 2020; Bayraktarov et al. 2020; Seavitt et al. 2018). Sea level rise poses a unique threat to coastal brownfields, which are at a greater risk of contamination by hazardous materials released into waterways. These contaminants can travel farther and more rapidly to neighboring communities and environments (Bardos et al. 2020; Barnett 2010; O'Connor et al. 2019). As these water events continue to happen more frequently, the surrounding areas and places downstream are threatened by contamination as water collects and moves pollutants.

Coastal Infrastructure in Industrial Port Zones

Built infrastructure is an essential factor in coastal brownfields' containment of contaminants and coastal protection. Coastal brownfields were once industrial facilities that contained many large machines and infrastructure that were once used for production and now contribute to site pollution (Hollander, Kirkwood, and Gold 2010). To compensate for the ecological function loss in urban industrial zones from brownfields and other contamination, cities use gray infrastructure for coastal protection (see Figure 2.4). Coastal infrastructure is utilized in waterfront cities to protect coastal areas from ocean-related events such as flooding, sea-level rise, and storm surges due to climate change (Powell et al. 2019; Seavitt et al. 2018; Temmerman et al. 2013; UNEP 2016). Gray infrastructure is most common in port cities and includes levees, seawalls, earth-form dikes, storm surge barriers, and bulkheads (NOAA 2015; Powell et al. 2019; Seavitt et al. 2018; Temmerman et al. 2013). The following section delves into the different types of infrastructure found in a coastal brownfield, including industrial, gray, and green structures.

Industrial Infrastructure's Relationship to Coastal Brownfields

Coastal brownfields that were once industrial port areas contain many large industrial equipment and material storage infrastructure. This built infrastructure can hold many hazardous materials and contribute to the continuous contamination of the site. These infrastructures include old warehouses, machinery, oil, gas tanks, and more (Zheng and Kirkwood 2020). Gas tanks, subsurface or below-grade, can emit harmful gases into the air. These industrial coastal brownfields are either abandoned or partially abandoned, padlocked, and gated off. Inside the site, remnants of industrial buildings with poor structural quality are surrounded by asphalt and concrete pieces (Hollander, Kirkwood, and Gold 2010). These abandoned industrial infrastructures contribute to soil degradation by storing and emitting contaminants into the site (Zheng and Kirkwood 2020).

Figure. 2.4. Underneath The Providence River Bridge (By Author 2023)

Soil degradation from industrial infrastructure disrupts the environment's natural functions and vegetation growth (Levi and Kocher 2006; Zheng and Kirkwood 2020). This prevents the coastline from naturally protecting the surrounding area from flood-related events.

Infrastructure for Coastal Protection

Coastal protection infrastructure is implemented to defend industrial zones in port areas. The infrastructure remained as the industrial sites were left to transition into brownfields. As well as industrial infrastructure, coastal brownfields also include coastal protection infrastructure that ranges from the traditional "gray" or hard structures to "green," which uses natural structures to protect the shoreline (Powell et al. 2019; Seavitt et al. 2018; Temmerman et al. 2013; UNEP 2016). Gray infrastructure is closely related to coastal brownfields because it is incorporated into the lands used for coastal protection and to maximize the efficiency of industrial shipping. The abandoned industrial structures and hard infrastructure impact the soil function, preventing it from being used for ecological purposes (Bardos et al. 2020; Zheng and Kirkwood 2020). However, gray infrastructure harms the environment, such as loss of sediment, decrease in beach volume and dimension, intertidal habitat, habitat fragmentation, biodiversity decline (NOAA 2015; Powell et al. 2019), invasive species increase, and reduced habitat migration (Powell et al. 2019). Traditional infrastructure can provide some opportunities for coastal brownfields due to its proximity to gray infrastructure; they can be used to revitalize waterfront areas, improve marine transportation, and protect coastal resources (U.S. Department of Commerce 2003). This combination of restoration strategies and gray infrastructure can be used to rethink brownfields and their future uses.

In contrast to gray infrastructure, green infrastructure can be used as a restoration tool in places of industrial overuse by improving water quality, carbon sequestration, producing fisheries, nature conservation, and creating recreational space (Temmerman et al. 2013). Strategies of green infrastructure that can improve coastal resilience and protect urban coastal areas are environmental-based adaptations. The United Nations Environment Program (UNEP) defines environmental-based adaptations or EbA as "the use of biodiversity and ecosystem services as part of an overall strategy to help people adapt to the adverse effects of climate change" (UNEP 2016). Green infrastructure can restore coastal ecologies, improving the area's biodiversity and ecological functions (Temmerman et al. 2013).

Ecological Restoration of Coastal Brownfields

Restoring coastal brownfields allows for the creation of public space that improves the health and well-being of the people and their environment (Bardos et al. 2020; Barnett 2010; Levi and Kocher 2006). Many different types of coastal restoration strategies include nature-based approaches and green infrastructure. Using these strategies in multiple restoration stages can help improve the site's effectiveness. A restored coastal brownfield creates a multitude of economic, social, and environmental benefits for the project site and the surrounding areas (U.S. Department of Commerce 2003). The preceding sections outline ecological coastal restoration strategies, short-term to long-term strategies, and the benefits of ecological restoration of coastal brownfields.

Coastal Restoration Strategies

There are several nature-based approaches to ecologically restoring coastal brownfields. One method is "soft" reuse, which restored brownfields as a green space, habitat, or place for natural product generation. This method can foster environmental, social, and economic benefits (Bardos et al. 2020). There are also several low-input approaches, including phytoremediation, where coastal plants assimilate high levels of metal, and bioremediation, where microbial activity decreases contaminants within the system. Low input strategies also include redeveloping brownfields into wetlands, parkland, or forests (Bardos et al. 2020; O'Connor et al. 2019; Song et al. 2019). Another solution can be to transform coastal brownfields into nature preserves. Nature preserves can provide green space for low-income communities and places for recreation. Place-based approaches allow for community involvement in the design and decision-making for the future of the contaminated site. This approach creates a place that is well-connected and personal to the community (Levi and Kocher 2006; Song et al. 2019).

Another type of coastal restoration strategy is environmental-based adaptations implemented into brownfields. This type of green infrastructure can improve coastal resilience and protect urban coastal areas with environmental-based adaptations. EbA increases resiliency by conserving, restoring, and managing ecosystems, as well as assisting communities in adjusting to climate change (UNEP 2016). Environmental-based adaptations positively impact the waterfront, including reducing coastal erosion, protecting from coastal flooding, increasing native flora and fauna, increasing biodiversity, and improving ecological functions. EbA is integrated into a coastline to counter the biophysical changes from climate change (UNEP 2016). These strategies include coral reef restoration (UNEP 2016), living breakwaters (NOAA 2022; UNEP 2016), mangrove restoration (UNEP 2016), seagrass restoration (UNEP 2016), and coastal wetland restoration (Temmerman et al. 2013; UNEP 2016)These solutions can benefit coastal brownfields by improving degraded coastlines and protecting the environment from climate change events.

Short-Term to Long-Term Ecological Restoration Strategies

Ecological restoration for coastal brownfields requires multiple phases to be completed. Short-term and small-scale projects are vital to expand into long-term ecological restoration. Brownfields and old industrial areas have stigmas and poor reputations, making people unwilling to visit or even care about these sites. The stigma can be related to high crime rates or the contamination of the area, making it unsafe and unhealthy (Hollander, Kirkwood, and Gold 2010; Levi and Kocher 2006). To start a restoration project, there needs to be public support, and to do that, the community needs to feel welcome and connected to the space. More minor interventions, such as community gardens or gathering spaces, are often used to break the stigma and make the community more familiar to the site (Levi and Kocher 2006). Cleaning up coastal brownfields can be a political, technical, and economic

problem, but there is typically a lot of support due to the fear of contaminated sites (Levi and Kocher 2006). A conservation approach may be considered short-term because it cleans up the site to be used for future use (Hollander et al. 2010; Levi and Kocher 2006). Cleaning up a contaminated site creates a blank slate for long-term restoration projects that can further improve the surrounding environment. More progressive and impactful strategies can be used to increase the environmental functions and restore coastal ecosystems to a system resembling predevelopment or a new effective environment. Long-term restoration is meant to stop further pollution from the site and enhance the quality of the environment. Large-scale restoration projects use a multitude of restoration strategies that stimulate economic, social, and environmental growth.

Benefits of Ecologically Restoring Coastal Brownfields

There are many benefits resulting from coastal brownfield restoration. These include economic, social, and environmental benefits that improve the quality of life for the surrounding communities. Site cleanup can generate new jobs, and ecological remediation could lower restoration costs (Song et al. 2019). There are also some social benefits as it can provide a tourist destination (Levi and Kocher 2006) gathering place and improving people's well-being (Bardos et al. 2020; Song et al. 2019). The environmental benefits include improving the function of land, soils, water quality, ecological management, and creating a higher land use value (Bardos et al. 2020; Hollander, Kirkwood, and Gold 2010; Song et al. 2019). Restored brownfields can also provide an aesthetic value, habitat recreation for plants, mammals, birds, and invertebrates, increased filtration, flood storage capacity, and reduced flood risk (see Figure 2.5). Another environmental benefit of brownfield restoration is the re-establishment of coastal ecosystems.

Coastal ecosystems are essential to the function of the coastline and the improvement of the environment's health (Boström et

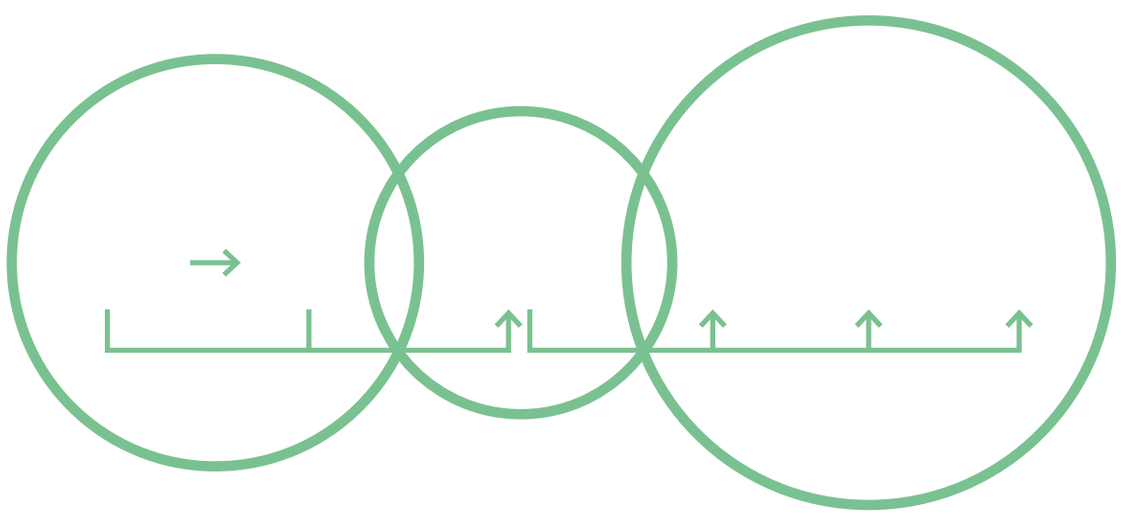
Figure. 2.5. Coast of India Point Park. (By Author 2023)

al. 2011). Climate change and industrialization contribute to the degradation of the ecological functions of a coastline (Bayraktarov et al. 2016). Without coastal ecosystems, coastal areas experience flooding events, water pollution, contamination, habitat fragmentation, and diminished waterfronts. Coastal ecosystems serve the community through services including storm buffering, fisheries production, and enhanced water quality (Barbier et al. 2008; Bayraktarov et al. 2020). Within coastal ecosystems, there are ecological functions and biodiversity. Ecological functions are "the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment" (SER 2004, 6), and biodiversity is "biota in terms of taxonomic and genetic diversity, the variety of life forms present, and the community structure thereby created, and the ecological roles performed" (SER 2004, 6). These two aspects of coastal ecosystems influence the environmental richness and improve the quality of the landscape.

Summary of Literature Review

Understanding the ecological restoration of a coastal brownfield is a complex process because it comprises different avenues of remediation and strategies. Industrial brownfields have a unique set of problems with contamination compared to infrastructural and landfill brownfields (Zheng and Kirkwood 2020). Coastal brownfields have another layer of difficulties because they face coastal water challenges daily that are increasing in intensity due to climate change (Bardos et al. 2020; Bayraktarov et al. 2020; Seavitt et al. 2018). There is a need for coastal brownfields to be protected from coastal waves to stop the spread of contamination and further contamination of the site. Coastal protection involves traditional gray or nature-based green infrastructure that can be used possibly in tandem with one another (Powell et al. 2019; Seavitt et al. 2018; Temmerman et al. 2013). Long-term restoration of these areas cannot occur until the site's stigma and environment are cleaned up and can serve as a blank state for ecological strategies (Hollander, Kirkwood, and Gold 2010; Levi and Kocher 2006). The research gap is what ecological strategies and processes are best suited in short-term, small-scale sites and transition to long-term urban-scale sites for complete coastal brownfield restoration in urban areas.

Figure. 2.6. Port of Providence Shoreline (By Author 2023)



Chapter 03
Methodology

Chapter Overview

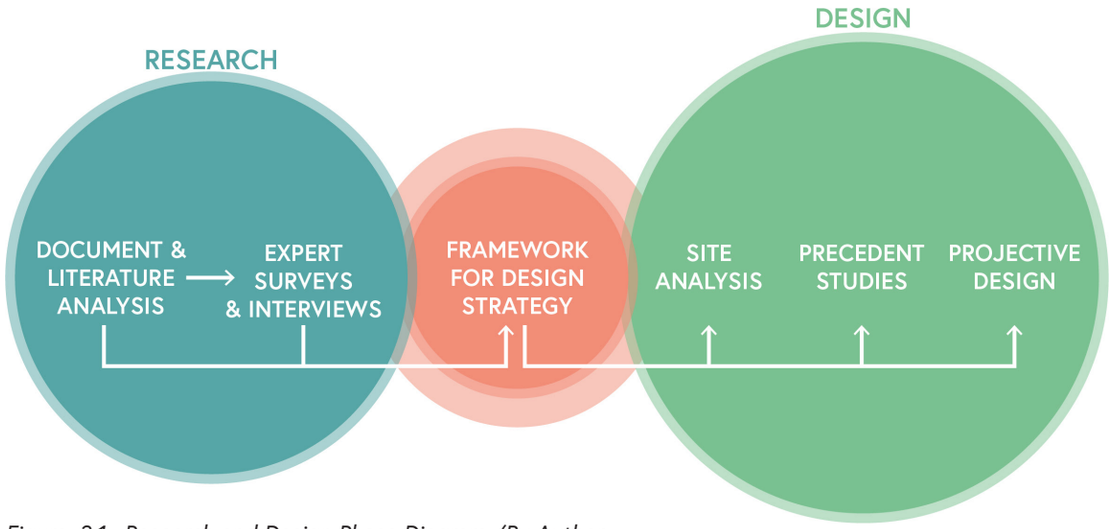


Figure. 3.1. Research and Design Phase Diagram. (By Author

The selected methods determine the suitability and choice of ecological restoration strategies to restore coastal brownfields in the urban coastal project site. The study consists of research and design phases (see Figure 3.1). The research phase methodology includes document and literature analysis, expert surveys, and local expert interviews. The framework of coastal brownfield design strategy is derived from the information gathered in the research phase, which links it to the design phase by informing the design goals and strategies, as shown below. Then, site analysis, precedent studies, and projective design of these two sites in the South Providence Port Area occurred in the design phase.

Study Area and Scope

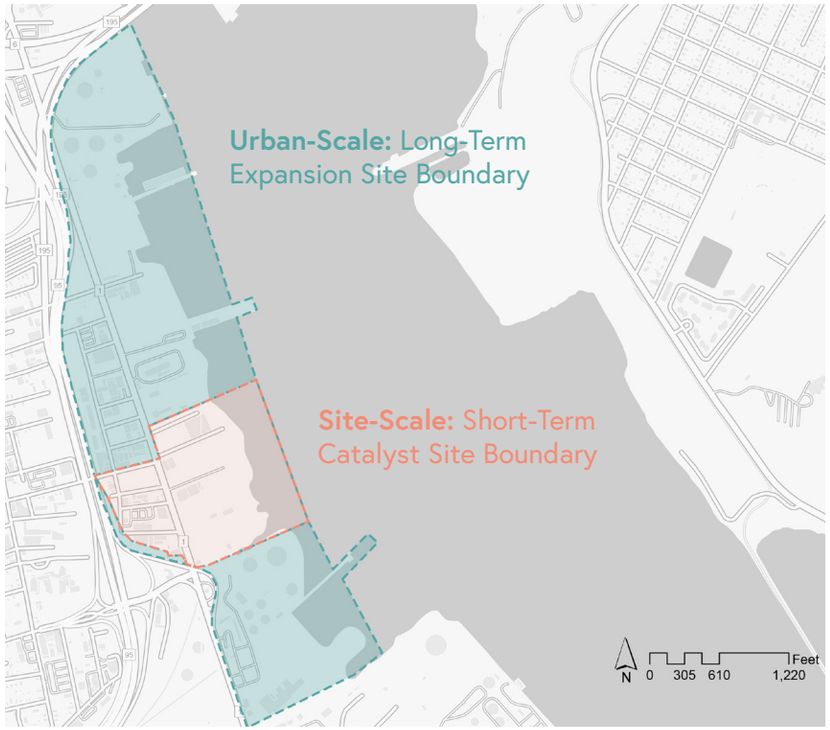


Figure. 3.2. Site Location Map. (By Author 2023)

The research project contains two sites at time scopes of brownfield remediation and restoration (see Figure 3.2). The short-term focus area is a smaller catalyst site on both sides of Allen's Ave, from above the existing Shell Terminal to Sims Metals. The site also includes pedestrian access points from the Lower South Providence neighborhood via Oxford Street. This phase is a short-term solution that catalyzes future restoration plans for the South Providence Port Area. The broader, long-term focus is on an urban scale, including the South Providence Port Area centered on the smaller catalyst site. This phase looks at the long-term ecological restoration of coastal brownfields.

Research Phase

The research phase examined documentation and research on coastal brownfields and expert opinion on coastal restoration and design strategies through surveys and information on South Providence from local experts. Both phases served to answer the sub-questions to the primary research question. The findings and outcomes from the research phase inform the projective design in the design phase of this study (see Figure 3.3).

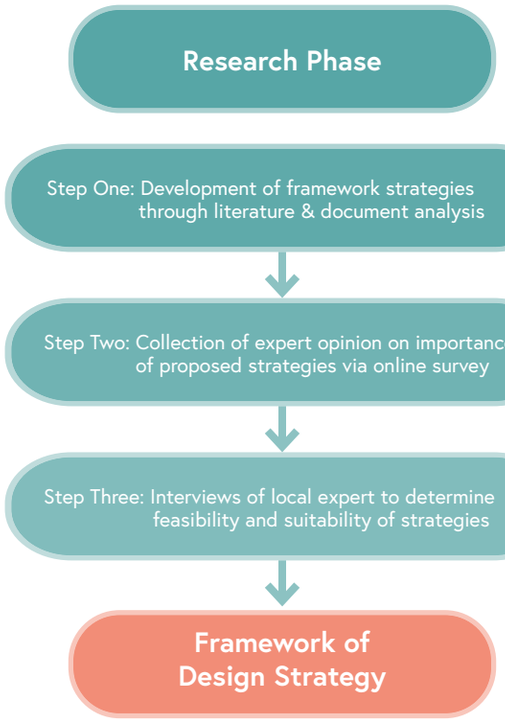


Figure. 3.3. Research Phase Diagram. (By Author 2024)

Literature and Document Analysis

Purpose

Document analysis gathered information on coastal environmental-based green infrastructure strategies, brownfield restoration, and the South Providence Port Area. This method included analyzing relevant primary and secondary sources. It aimed to develop a framework matrix that evaluates ecological restoration strategies for coastal brownfields and answer the **Sub Question One: Why should urban coastal brownfields be cleaned up, remediated, and re-established ecologically?**

Procedure

The first step for literature & document analysis was collecting scholarly sources relevant to coastal restoration, brownfield restoration, and the South Providence Port area. The documents included brownfield restoration strategies, ecological restoration guidelines, and coastal restoration literature. The literature was organized into a table stating its relevance to coastal brownfield restoration, remediation, and redevelopment strategies. The information from the analysis included researching broader knowledge of brownfield and coastal restoration strategies.

Outcomes

The information from the literature & document analysis informed the framework of coastal brownfield restoration strategy that assesses the suitability of design strategies for coastal brownfield restoration. The data and information gathered from this analysis inform readers of the coastal strategies utilized in the projective design.

Coastal Brownfield Expert Surveys

Purpose

The expert surveys conducted determined the relative importance of each coastal brownfield restoration design strategy. The design strategies were synthesized from the document and literature analysis and ranked on importance by coastal brownfield experts. The surveys provided primary data for the master's research and report and informed the design strategies and goals for the projective design. The purpose of the expert surveys was to answer **Sub Question Two: How can urban coastal brownfields be ecologically restored in a short-term as well as long-term perspective?**

Selection Criteria

Survey participants were experts in coastal restoration and brownfield development. The initial participants were chosen through database searches on the Environmental Protection Agency website and the Office of Brownfield and Land Restoration in coastal regions. Snowball sampling was also used to determine the selection of participants, with suggestions from other participants on who would be good to survey.

Survey Procedure and Questions

These surveys were a questionnaire asking the participant to rank the importance of design strategies on a five-point Likert scale on a short-term, long-term, site-scale, and urban scale, respectively (see Appendix A for the survey questions). The participants were also asked about their background and knowledge in the subject area. Since this study involved human subjects, IRB was obtained prior to data collection (see Appendix C for IRB approval letter).

Outcomes

The data collected from the survey determined the design strategies and goals for the projective design. This data was analyzed using Qualtrics software to determine the survey results, which are displayed in charts and graphs that support the findings.

Local Expert Interviews

Purpose

Local expert interviews were conducted to gather information on coastal restoration, brownfield restoration, and the South Providence Port Area. Interviews provided primary data for the master's research and report. The information given by the interviewees determined the feasibility of the proposed design strategies in South Providence.

Selection Criteria

Interviewees were relevant stakeholders and professionals with knowledge of coastal restoration, brownfield restoration, and the South Providence Port Area. Snowball sampling determined the selection of interviewees. Each participant was chosen based on suggestions from other professionals on who would be a good interviewee.

Interview Procedure and Questions

These interviews were held in person during the site visit to Providence. The interviews were approximately 30 minutes long. The interview questions formed the conversation and allowed the interviewee to answer freely. Questions were altered depending on the interviewee's expertise. Since the study involved human subjects, IRB was obtained before the interviews (see Appendix B for interview questions and Appendix C for the IRB approval letter).

Outcomes

The information collected from the interview determined the suitability of restoration strategies and the importance and feasibility of coastal restoration in coastal brownfields. The opinions and feedback from the experts on the coastal restoration criteria and strategies gave local knowledge of the site and the stakeholder's vision of the ecological restoration of that area. Finally, the responses helped to inform the projective design and complete design works for brownfield coastal restoration.

Framework of Design Strategy

Each method in the research phase was a step in developing the framework of design strategy. The coastal restoration benefits and design strategies were derived from the literature. These design strategies were analyzed based on the benefits associated with short-term, long-term, site-scale, and urban-scale restoration projects. A combination of literature analysis, expert surveys, and local expert interviews was synthesized to complete the matrix (see Appendix D for the complete Framework of Design Strategy).

Benefits of Design Strategy

After interpreting the literature, the benefits of coastal brownfield design strategies can be broken down into three categories: economic, social, and environmental restoration (see Figure 3.4). The economic benefits chosen for this matrix include maintenance and operation costs, job creation, increased property value, and real estate development, and tourism and visitor spending. Social benefits of restoring coastal brownfields include recreation, health and well-being, safety, and education. Finally, the benefits of environmental restoration include resilience, coastline protection, environmental quality, coastal ecological functions, biodiversity, flood protection, and climate change. These benefits analyze the suitability of each design strategy and how they perform on a short-term and long-term basis as well as on a site and urban scale.

Coastal Brownfield Restoration Design Strategies

Synthesized from the readings, coastal brownfield restoration strategies have four main categories: remediation strategies, environmental-based adaptations, low-input remediation strategies, and redevelopment strategies (see Figure 3.5). Remediation strategies focus on cleaning the site's environment and perception to improve its ecological functions and possibly allow human access. Environmental-based strategies combine biodiversity and ecosystem services with flood and climate change protection (UNEP 2016). Low-input remediation strategies remediate the soil to remove any toxins and contaminants and then transition into the redevelopment of the site (O'Conner et al. 2019; Song et al. 2019). Redevelopment strategies look at more long-term projects and transform coastal brownfields into productive landscapes for the environment and the surrounding communities.

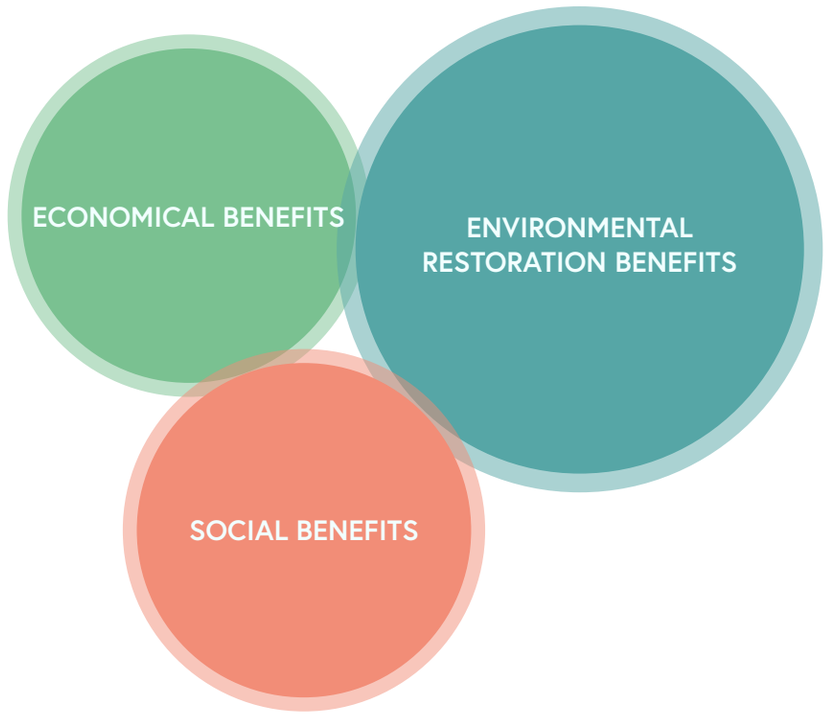


Figure. 3.4. Coastal Brownfield Restoration Benefits Diagram. (By Author 2024).

Remediation

Soil Capping: Topping the soil with a cap layer of uncontaminated soil to prevent contamination from spreading (Lewis 2008). By capping the soil, the contamination is isolated from people, reducing the risk of exposure (Zheng and Kirkwood 2020).

Soil Fill and Removal: Removal of contaminated soil that is replaced with rich topsoil (Lewis 2008).

Site Clean Up: Site clean-up creates opportunities for new development or uses of coastal brownfields. These areas can be transformed into access points and recreational areas to preserve natural habitats. Programs such as the Environmental Protection Agency's Brownfields Economic Redevelopment Initiative provide funding for clean-ups and protection from potential environmental actions in the future (Levi and Kocher 2006).

Pollution Reduction or Elimination: Pollution and contamination can be reduced through remediation processes. However, it is difficult to completely eliminate pollutants with residual materials left after remedial practices. Industrial brownfields have mixed pollution types; disposing of material carriers reduces the pollutants and contaminants present in the brownfield (Zheng and Kirkwood 2020).

Habitat (Re)Development: Habitat redevelopment enhances natural ecosystems for native species, including animals, vegetation, and organisms. It can range from small-scale habitat formation to large-scale ecosystems (Strain et al. 2018). Habitats also provide ecosystems for migrating species (Lewis 2008).

Accessibility & Connectivity: By providing public access to these sites, people can access the coastline and waterways. Providing access to these coastal areas creates a destination for locals and non-locals. People want access to coastal areas that serve as recreational and educational areas (Levi and Kocher 2006).

Aesthetics: Aesthetics are applied to attract people to visit an area and create a destination (Levi and Kocher 2006). Enhancing the aesthetic characteristics and features of the site serves as attention to the landscape architecture of a contaminated site. Aesthetic improvements benefit the adjacent community because they impact the perception of the surrounding area (Song et al. 2019).

Stigma: The stigma around a contaminated site directly impacts the public support of the cleanup and their perception of risk. Stigma can cause a decline in land values and development. People living near coastal brownfields feel at risk of exposure to hazardous materials. By changing their perception of risk to the area, the public is willing to access the site and support its restoration. People see less risk when the site's activity has a potential benefit for them (Levi and Kocher 2006).

Transportation: Transportation is a vital connection between a community and a redeveloped coastal brownfield. Restoring coastal brownfields can improve marine transportation (US Department of Commerce 2003). Public transportation access is important for selecting suitable brownfields to redevelop (Song et al. 2019).

Environmental-based Adaptations

Marshland Restoration: Marshlands can be a barrier between the sea and a city. Marshes allow for excess water containment, which mitigates storm surges and minimizes flood risk. Marshland restoration also provides for native habitat conservation and can be used as a flood defense on a large scale (Temmerman et al. 2013).

Coral Reef Restoration: Coral reef restoration involves establishing protected areas or no-take zones, excluding anthropogenic disturbances. Re-establishment of coral reefs includes rearing, transplanting, and monitoring reef fragments. Coral reefs provide ecosystem services such as coastal protection, adaptation to sea level rise, habitat for native species, spurring biodiversity, support tourism and recreation, and can be cost-effective (UNEP 2016).

Living Breakwater: Living breakwaters consist of offshore structures that separate the land from the sea. The underwater structure is made up of materials that provide habitats or aid the restoration of the coral reef restoration. The structures work to imitate the natural reef's functions. They can be constructed from purpose-built concrete structures or repurposed objects from previous structures. The approach combines built and natural infrastructure (UNEP 2016).

Oyster Reef Restoration: Oyster reefs are a coastal defense strategy typically constructed with oyster shell-filled gabions. Young oysters fix themselves onto the shells, forming a living oyster reef. These reefs provide a habitat for native fish species while reducing waves, currents, and erosion (Temmerman et al. 2013).

Seagrass Restoration: Seagrass restoration reduces environmental threats such as pollution and infrastructural damage. Restoration efforts include harvesting and transplanting seagrass plants, as well as monitoring and management. The benefits of seagrass restoration include coastal protection, adaptation to sea level rise, providing habitat and nursery, and the chance to enhance biodiversity and carbon storage (UNEP 2016).

Low-input Remediation

Phytoremediation: Phytoremediation uses native or non-native plant species to improve and clean contaminated environments. In an urban area, phytoremediation improves water management and can restore bare soil by preventing contaminated soil migration. Phytoremediation produces biomass, a valuable environmental resource that can be harvested and used to extract contaminants from the soil through plant roots (O'Connor et al. 2019; Song et al. 2019).

Bioremediation: Bioremediation removes contaminants from the soil and groundwater using microbial activity. This strategy works by introducing a microbial culture to degrade contaminates to the site or implementing substrates that stimulate the development of native organisms (Song et al. 2019).

Biochar Stabilization: Stabilization using biochar reduces the mobility of contamination, including the wide spread of heavy metals. Reagents obtained from biological waste or biochar are utilized for stabilization. Remediation through biochar is newly developed and has been mostly studied in laboratories and greenhouses (Song et al. 2019).

Nano-remediation: Nanoparticles can degrade contaminants in soil and water. Green nanotechnology creates and improves nanoparticles to be cost-effective, biocompatible, non-toxic, and eco-friendly. Plant extracts are used for contamination reduction and soil capping means (Song et al. 2019).

Redevelopment

Coastal Wetland Restoration: Coastal wetland restoration combines saltwater marshes, estuaries, mangroves, lagoons, and coral reefs. Wetlands are known for providing ecosystem services, reducing incoming wave and tidal energy, erosion, coastal flood risk, and storm surge height, and they can adapt to rising sea levels. (UNEP 2016).

Nature Preserves: The transformation of brownfields into nature preserves allows people to access areas that were once known for contamination and have a dangerous perception. Nature preserves allow for the surrounding communities to have recreational access to the site and access along the coast. Areas with high levels of contamination are restricted for the health and safety of the visitors (Levi and Kocher 2006).

Managed Retreat: Managed coastal retreat is applied to create an area of defense for low-lying areas. Coastal retreat proactively determines and implements coastal setbacks in coastal areas impacted by urban, rural, or agricultural uses. The coastal retreat has two different forms: managed realignment and coastal setback. Managed realignment alters the flood protection practices, allowing for planned flooding. Coastal setback is used in planning to identify a zone to be transitioned into a buffer area. This planning tool predefines the distance from the shoreline or elevations from sea level that exclude infrastructure and create restrictions in actions in coastal hazard risk areas (UNEP 2016).

Green Space: Transitioning brownfields to green space is a way to instate native habitat, ecosystem restoration, stormwater management, and natural filtration systems that improve water quality. Green space can be utilized as recreational space, greenways, natural areas, and other community amenities (Lewis 2008).

Parkland: Converting brownfields into open park spaces allows for flexible programming and environmental regeneration to take its course (Zheng and Kirkwood, 2020). Parklands also allow for low-input practices to remediate the soil. The community can access the parkland and benefit from its enhancement of social qualities. Parklands address climate change, urban revitalization, and the revitalization of contaminated land (Bardos et al. 2020).

Forests: Redeveloping coastal brownfields as forests enhances the resilience to global environmental pressures. Forest plantings can mitigate noise and air pollution while lowering heat island effects. Urban forests are also used for carbon reduction through carbon storage and sequestration. Planting density, type, and spacing strategies depend on the restoration goals. The adjacent communities benefit from the environmental qualities produced by the forest (Bardos et al. 2020).

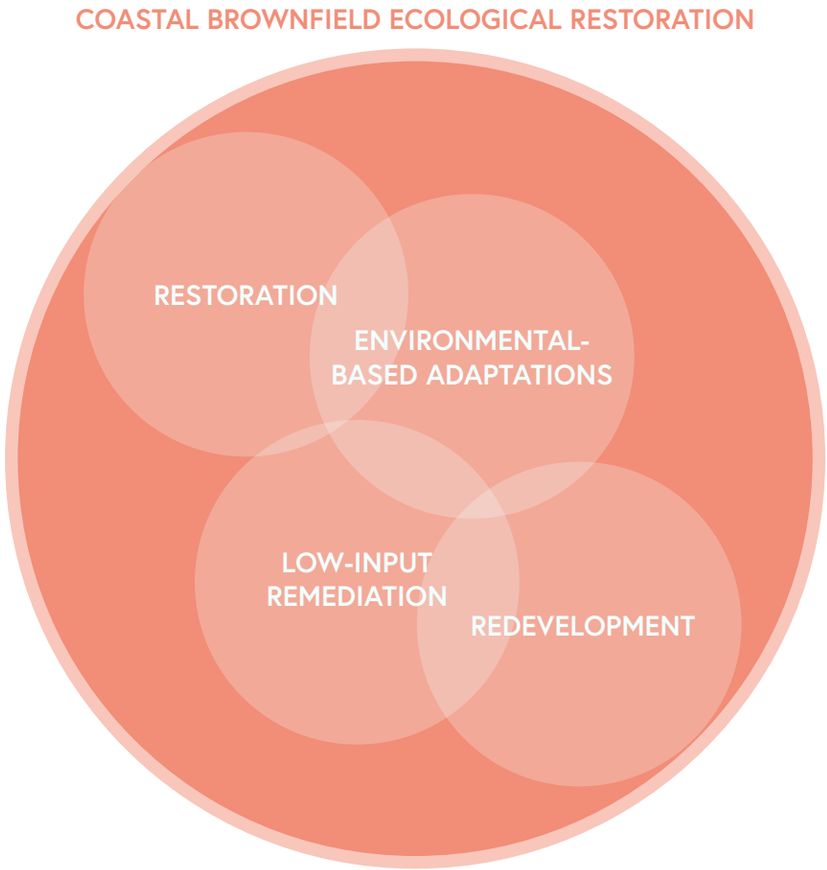


Figure. 3.5. Coastal Brownfield Ecological Restoration Diagram. (By Author 2024)

Design Phase

The design phase utilized the data and information collected from the research phase to create a projective design for the site and a set of design works that serve as an implementation framework. Site analysis of the study area and its surrounding context, relevant precedent studies, and a projective design. The design phase included two stages of coastal restoration as a short-term catalyst site and a long-term urban plan that answers the **Sub Question Three: What brownfield restoration strategies are plausible in urban coastal zones such as the Providence Port area?**

Site Analysis

Purpose

Site analysis helped to understand the site and its existing conditions. It was also used to gather primary data that informed the feasibility of the coastal restoration strategy. The site was evaluated using criteria from the coastal brownfield restoration framework.

Procedure

GIS and online database analysis searches gathered information on the project's context on an urban, regional, and site scale. The information gained from GIS analysis included hydrology (flooding hazard areas and flood plains), neighborhood context (income, community infrastructure, surrounding buildings), soil maps, land use (open green spaces, brownfields, pervious vs. impervious surfaces), and present contamination issues. The information from the database searched involved city codes, zoning, historical use, historical context, and native flora and fauna for the project site. A site visit took place from October 14th to the 16th, 2023, to take site photos and take notes on observations of the project area and its context.

Providence GIS provided data on building footprints, development, capital improvement plans, contour lines, neighborhood boundaries, parks and open space, city boundaries, parcels, roads, and zoning. The Rhode Island GIS (RIGIS) supplied access to soil maps of Providence and Rhode Island impervious surfaces. The Federal Emergency Management Agency (FEMA) Flood Hazard Layer map displayed the flood plain and at-risk areas. The EnviroMapper detailed the different Environmental Protection Agency (EPA) programs and industries, the present chemicals in South Providence, and the quality of surrounding water features. The EPA programs include the facilities involved with air pollution, toxic releases, hazardous waste, and water discharge in the river (See Appendix E for site inventory maps). The 2021 census demographics were used to compare the social environment in the neighborhoods surrounding the site.

Outcomes

The information gathered from the site analysis determined the suitability of each restoration design strategy and redevelopment in the project area. The data informed the projective design and the overall design works. The research from the data analysis was gathered to create maps depicting the opportunities and challenges of coastal restoration and redevelopment for the catalyst and expansion sites (see Figures 5.13 - 5.16).

Precedent Studies

Purpose

The use of precedent studies aimed to research other projects involving brownfield restoration in urban coastal areas. The goals, findings, and recommendations from these projects informed design decisions for this Master's project. This method also helped to understand successful or unsuccessful strategies in different contexts. The selection of the case studies is based on the same criteria as the coastal brownfield restoration matrix.

Procedure

Precedent studies were found through online database searches such as K-State Libraries and Google Scholar. These studies were chosen based on the project goals and site challenges they address. The inclusion criteria for the case studies incorporated projects located in coastal areas, brownfield restoration, existing industrial or infrastructural use, completed or semi-completed, and in an urban area. The exclusion criteria involve non-ecological redevelopment, inland projects, smaller than 10 acres, and larger than 300 acres (see Appendix F for selection criteria). The precedent studies were evaluated using the incorporated restoration strategies and lessons learned from the project.

Outcomes

The information from the previous studies was synthesized into a table organized by the remediation strategies performed and the lessons learned from completing the project. The ideas and findings guided the design decisions and goals for the projective design. The most successful strategies in areas of similar environmental elements and development were integrated into the design.

Projective Design

Purpose

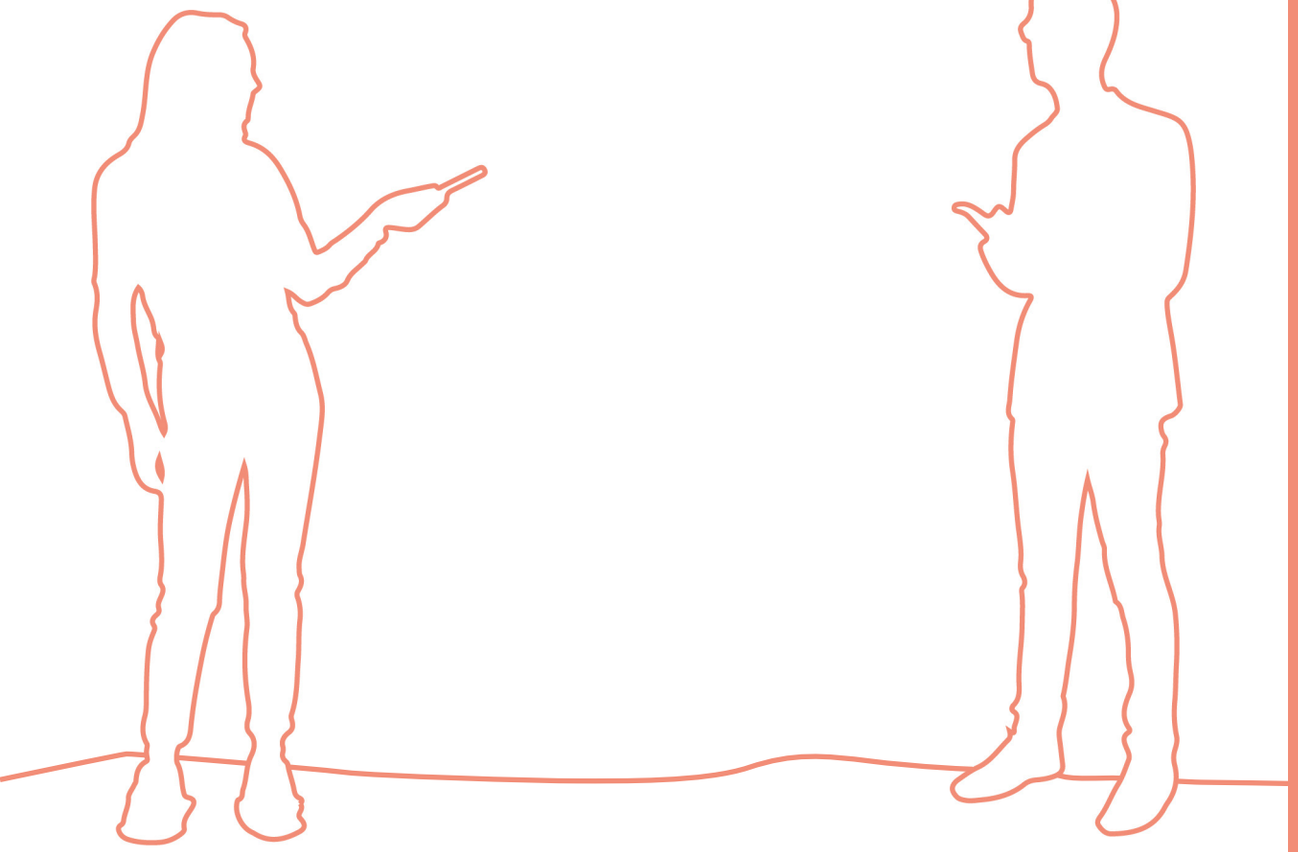
The projective design involved short-term and long-term designs for the coastal restoration of the South Providence port area. The short-term solution of a singular site served to catalyze the restoration of the rest of the port. The long-term design utilized coastal restoration strategies on an urban scale. The site encompassed the short-term site and the surrounding industrial coast area. The coastal brownfield restoration criteria served as the design goals of the project. The strategies chosen for the short-term and long-term designs were selected from the framework of coastal brownfield restoration strategies. The goal of the projective design was to answer the **Primary Question: How can urban coastal brownfields be ecologically restored?**

Design Procedure

The projective design is in the South Providence Port area. The design procedure included the long-term plan of the urban area and how it can transform to adapt to climate change and address brownfields. The comprehensive design was comprised of site sections, perspectives, and diagrams. The catalyst site served as a transitional space for ecological restoration to achieve the long-term design.

Outcomes

The outcomes of the projective design include a set of design works for the expansion site and a closer look at the expansion site. Design works for the long-term site include a comprehensive master plan of the long-term site, sections of the neighborhood-to-coast connection, reasoning diagrams, section-perspectives, and design vignettes (see Figures 5.27 - 5.29). The catalyst design set include design reasoning diagrams, site plans, site programming, streetscape design, and planting palettes for three phases of ecological restoration (see Figures 5.40 - 5.52).



Chapter 04
Research Results

Chapter Overview

This chapter discusses the results found in the research phase. The literature and document analysis produced information on the remediation and restoration strategies used in coastal brownfield restoration. These strategies were then sent via survey to coastal brownfield experts to determine their importance in short-term, long-term, site-scale, and urban-scale restoration. The knowledge gained from the analysis formed the questions for the local expert interviews relevant to the research topic. The information from the research phase was integrated into the development and completion of the framework of the design strategy.

Literature and Document Analysis

The literature used for this analysis included different remediation and redevelopment strategies often used in coastal brownfield restoration and, in general, brownfield and coastal restoration. These strategies were synthesized from the literature to develop the list of design strategies in the framework. The literature also discussed the potential outcomes and benefits of using restoration strategies. Equally as necessary, the authors outlined the strategies' limitations based on the site's location and context. The literature was analyzed (see Table 4.1) by its relevance to the research topic, the remediation strategies in restoration projects, and the long-term redevelopment strategies.

Resources	Relevance	Remediation Strategies	Redevelopment Strategies
(Bayraktarov et al. 2020)	The literature outlines crucial factors of coastal restoration that were used to help determine the criteria that could be applied to coastal brownfield restoration.	Seagrass, salt marshes, oysters, mangroves, and coral reefs	N/A
(Strain et al. 2018)	The literature evaluates interventions that can stimulate biodiversity enhancement in existing urban coastal infrastructure.	Eco-engineering interventions: texture, crevice, pit, intertidal water retaining feature, subtidal holes, small elevations, large elevations, soft structures, and habitat-forming taxa	N/A
(Zheng & Kirkwood 2020)	The literature discusses the role landscape architects must play in the redevelopment of brownfields. The strategies include the remediation of in-land and coastal brownfields.	"Brown Earth-Work" and environmental engineering, isolation (overhead and covering), remediation (in situ and ex-situ), backfilling, and phytoremediation	Urban parks, cultural parks, expo parks, sports and recreational parks, and county parks
(Fanelli et al. 2023)	This literature investigates a long-term remediation project that used passive remediation.	Passive restoration	N/A
(Levi and Kocher 2006)	The paper discusses the potential of brownfields being transformed into nature preserves or recreational areas. They also discuss the perception of a place and how that impacts the uses of the site.	Site clean-up, public perception, tourism, aesthetics, and residential uses.	Nature preserves and recreational areas
(Bardos et al. 2020)	This literature describes how low-impact remediation strategies can be used for coastal brownfield restoration.	Bioremediation and phytoremediation	Brownfield conversion to coastal wetlands, parkland, and forests
(O'Connor et al. 2019)	This research paper discusses how phytoremediation can be applied to redeveloping coastal brownfields. The authors discuss the environmental, social, and economic benefits of a phytoremediation project.	Phytoremediation	N/A
(Song et al. 2019)	This literature reviewes the effectiveness of nature-based solutions for brownfields. The literature referenced both in-land and coastal projects.	Phytoremediation, bioremediation, constructed wetlands, nano remediation, biochar stabilization, revegetation, and integration with landscape architecture	Converting to green spaces, green industrial heritage parks, ground source heating and cooling, and nature preserves
(Lewis 2008)	This paper describes environmental strategies that could transform brownfields into ecologically productive landscapes. It provides the benefits of the different methods and provides case studies that support their claims.	Wetlands, woodlands, grasslands, recreational space, greenways, natural areas, passive open space, public access, soil removal, and soil capping	Green buildings, alternative building approaches, green infrastructure, environmentally conscious landscape design, natural open spaces and parks, water-recycling techniques, and renewable energy systems
(UNEP 2016)	This guide outlines the different ecosystem-based adaptations used to help coastal regions adapt to climate change. The guidebook provides the benefits and limitations of each strategy depending on the location's context. These strategies include short-term and long-term outcomes.	Coral reef restoration and conservation, living breakwaters, mangrove restoration and conservation, seagrass conservation, dune stabilization, and coastal wetland conservation and restoration	Managed realignment/ coastal setbacks and livelihoods diversification and protection of ecosystem-based livelihoods
(Temmerman et al. 2013)	This research paper argues that ecosystem-based flood protection and restoration are more sustainable and cost-efficient than traditional coastal engineering. It discusses the suitability of these projects on a global and large scale.	Marsh restoration, mangrove restoration, beach and dune barriers, and oyster, coral, and shellfish reefs	Large-scale wetland restoration

Table. 4.1. Literature and Document Analysis

Key Takeaways from the Literature and Document Analysis

There were several takeaways from the analysis, including understanding the goals of restoration. Firstly, the goal of ecological restoration takes time and must be done in phases to achieve the most suited outcomes. Similarly, the soil, air, and water take time and need limited disturbance to improve their quality. The remediation strategies are used in tandem with each other to address different restoration areas while benefiting one another. Understanding the site and the type of contamination present is vital to understanding the feasibility of each design strategy.

Coastal Brownfield Expert Surveys

The coastal brownfield expert survey was sent in two rounds to eighty experts who met the selection criteria. The first round was sent on January 10th, 2024, and the second round was sent on January 22nd, 2024. Experts whom other participants suggested were emailed separately. The survey's response rate was 21% with a sample size of 16, and of those responses, nine were viable. The survey collection process ended on February 7th, 2024.

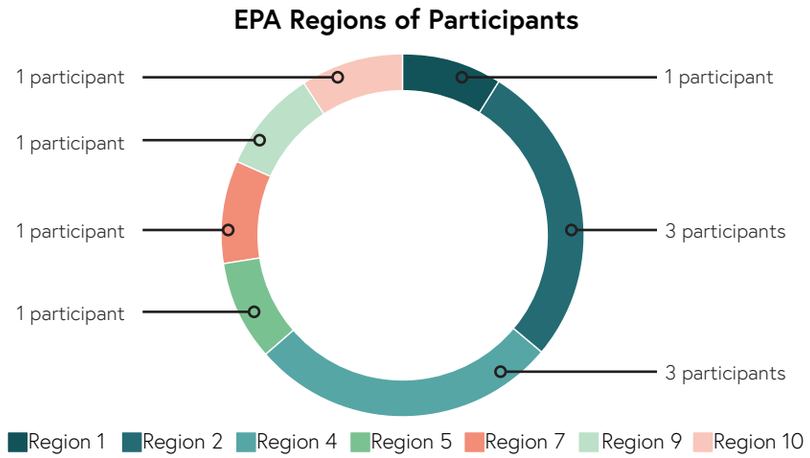
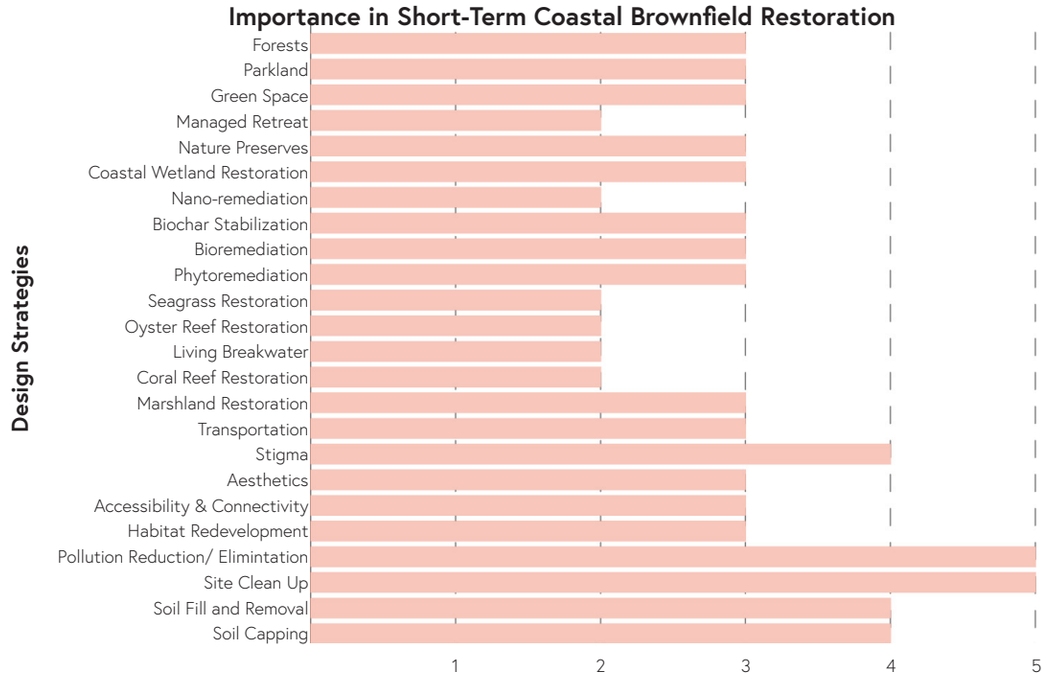


Figure. 4.1. EPA Regions of Coastal Brownfield Expert Participants. (By Author 2024)



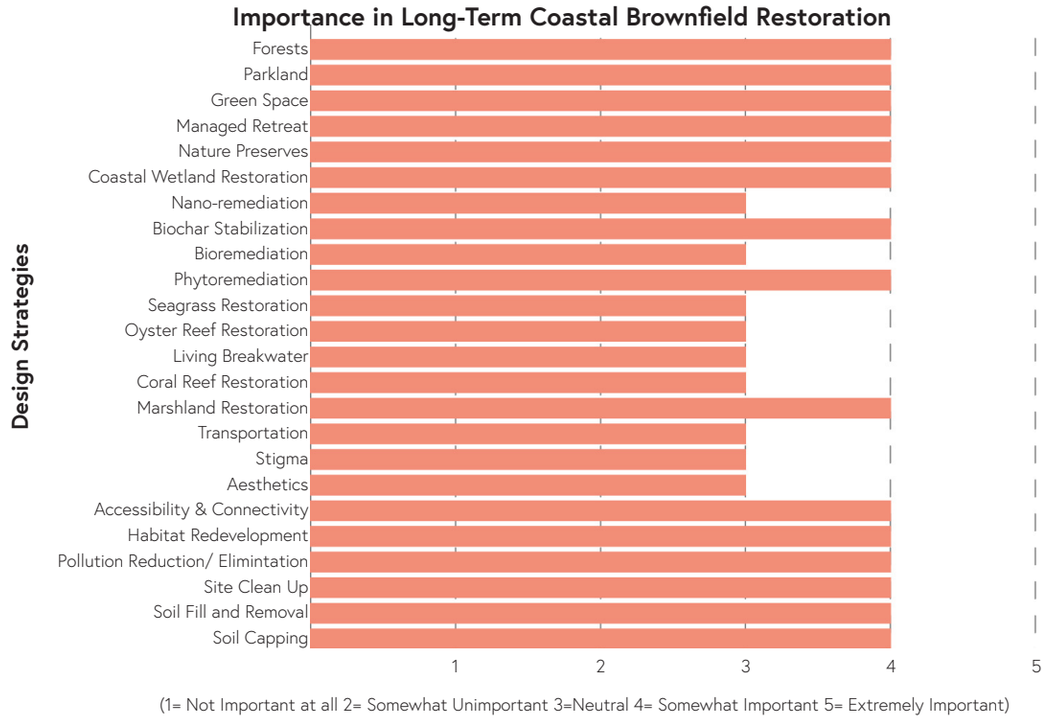
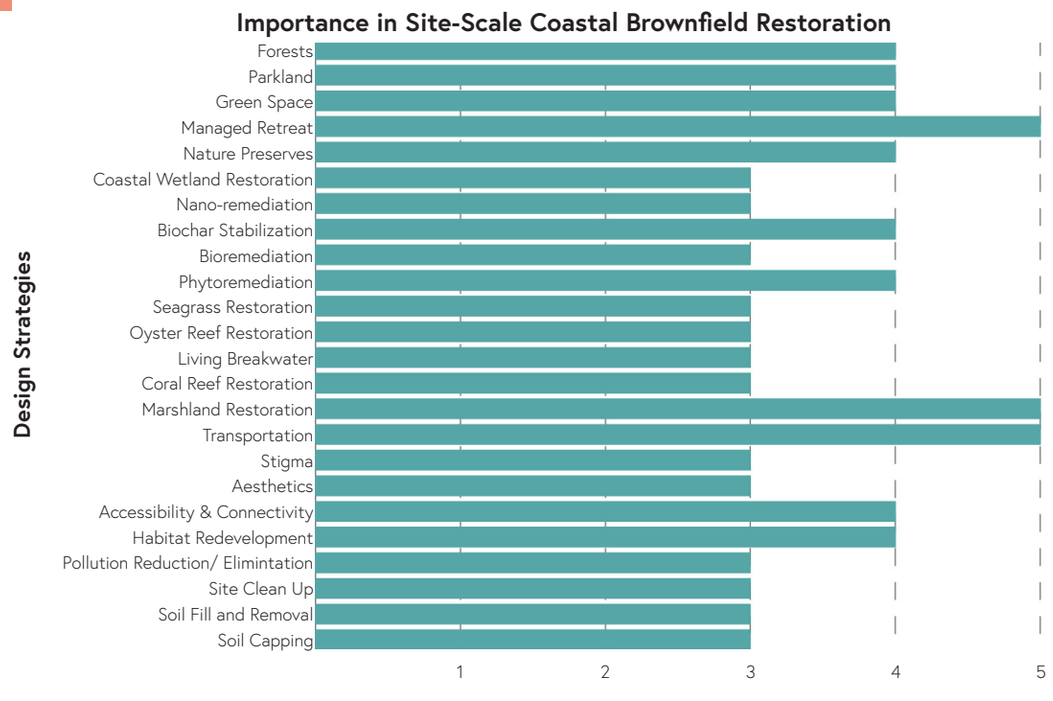
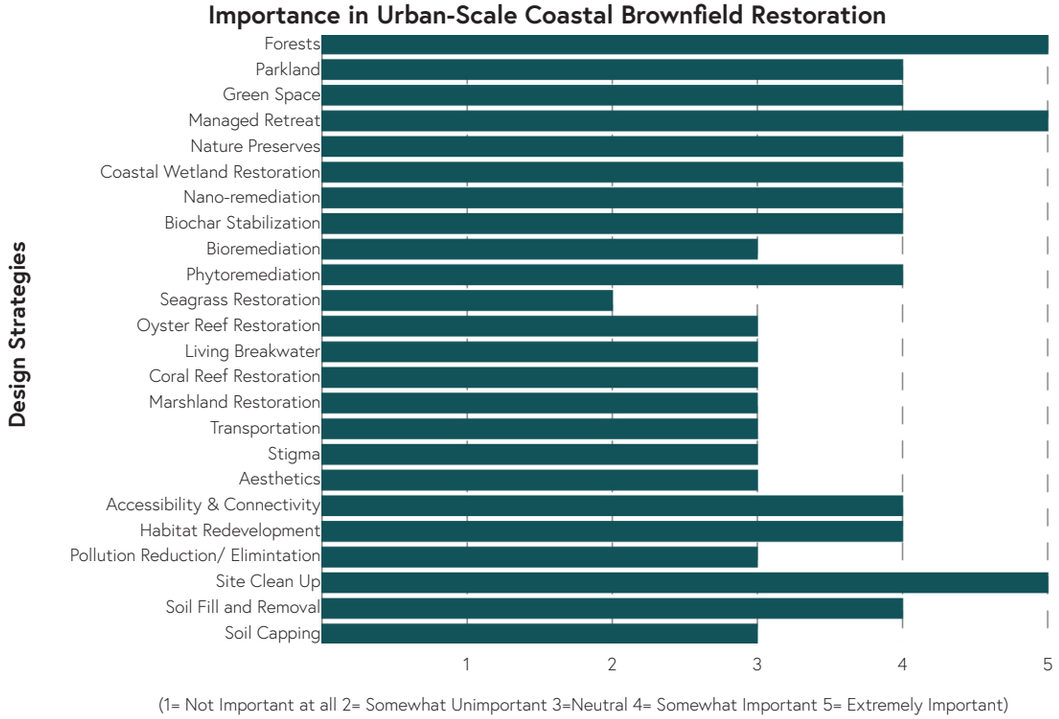


Figure. 4.2. (Top Right) Short-Term Importance. (By Author 2024)
Figure. 4.3. (Bottom Right) Long-Term Importance. (By Author 2024)





Summary of Finding from The Survey

The importance of each design strategy differs according to coastal brownfield experts with each restoration time frame and site scale. The design strategies that are extremely important in short-term coastal restoration are pollution reduction or elimination and site clean-up. These strategies are followed by stigma, soil fill and removal, and soil capping (see Figure 4.2). For long-term restoration, most design strategies are somewhat necessary (see Figure 4.3). Site-scale restoration was determined to have three extremely important strategies, including bioremediation, phytoremediation, and pollution reduction and elimination (see Figure 4.4). The extremely important strategies for urban-scale restoration included green space, pollution reduction, and soil capping (see Figure 4.5). One participant noted in the survey that, "Coastal Remediation engineered controls are becoming more and more important due to sea level rise." These strategies all have their importance in various stages of coastal brownfield restoration. The main takeaway from these survey responses is that multiple strategies are essential at each stage and project scale for ecological restoration to be successful. These responses were incorporated into the completion of the framework of design strategy.

Figure. 4.4. (Top Left)
Site-Scale Importance.
(By Author 2024)
Figure. 4.5. (Bottom Left)
Urban-Scale Importance.
(By Author 2024)

Expert Interviews

Two expert interviews were conducted during the site visit from October 14th to the 16th to the project site in South Providence. The first interview was with a local landscape architect with expertise in the project site and the surrounding area. The second interview was with a local planner specializing in the South Providence port area. The discussions were integral to understanding the site's social, cultural, environmental, and political context. Both participants were asked the same questions about the general knowledge of the site, current and future plans for redevelopment, and the feasibility of coastal restoration. The two interviewees had differing views and opinions on the site's future development (see Figure 4.8).

Local Landscape Architect

The landscape architect believed that the site should be capped to stop any further contamination, and the site should focus on a managed retreat, moving the community away from the coastline. They explained that, realistically, a sea wall would be necessary if the communities were to be protected from flooding and climate change events. A significant limitation that the landscape architect explained was that ecological restoration is not enough to solve the problems of the South Providence Port Area, and the answer is not only within the discipline, "I would treat it as an urban problem. Because again, ecology alone cannot do it all." Another point they made was how small interventions of restoration catalyze to inspire further change. They stated how ecological restoration needed to involve phases and relocation. Relocation would mean creating a defined edge to prevent developers from creating high-end housing along the coast.

Local City Planner

The local site planner had a different idea of what the site could be for the community. They thought this area could serve as a launching point for ecological restoration and inspire the redevelopment of the rest of the port area. They believed there was an opportunity for community access to the waterfront and habitat redevelopment. There have been city projects to restore the area, but none led to any other restoration projects. The site is in type six water that allows for heavy industrial use, however it is located close to type one water that involves conservation. There is a potential to transition water uses to allow for conservation and stop port use in the area. Other topics discussed were the main contaminants being petroleum and heavy metal, the fragmental use of the site, and the city's old infrastructure. Despite this, the site has several potential opportunities, including nearby horseshoe crab and osprey habitats and floating biomasses from industrial structures.

Summary of Expert Interviews

Both interviewees talked about the importance of environmental restoration in phases. This allows the site to transition from one land and water use to another. After gathering the answers and suggestions from the interviews, it was evident there are economic, social, and environmental problems as well as opportunities for the South Providence Port Area. A significant issue was the threats and perception of safety. This includes crime, pedestrian safety, and environmental concerns impacting human health. By creating a connection between the port area and South Providence neighborhoods, the stakeholders can have more input in the future of the site's development. That would also help improve the site's perception and open the potential for public access and use. A small intervention can be cleaning up the abandoned site and creating community access to the waterfront. This intervention can catalyze a long-term ecological restoration of the coastal brownfield.

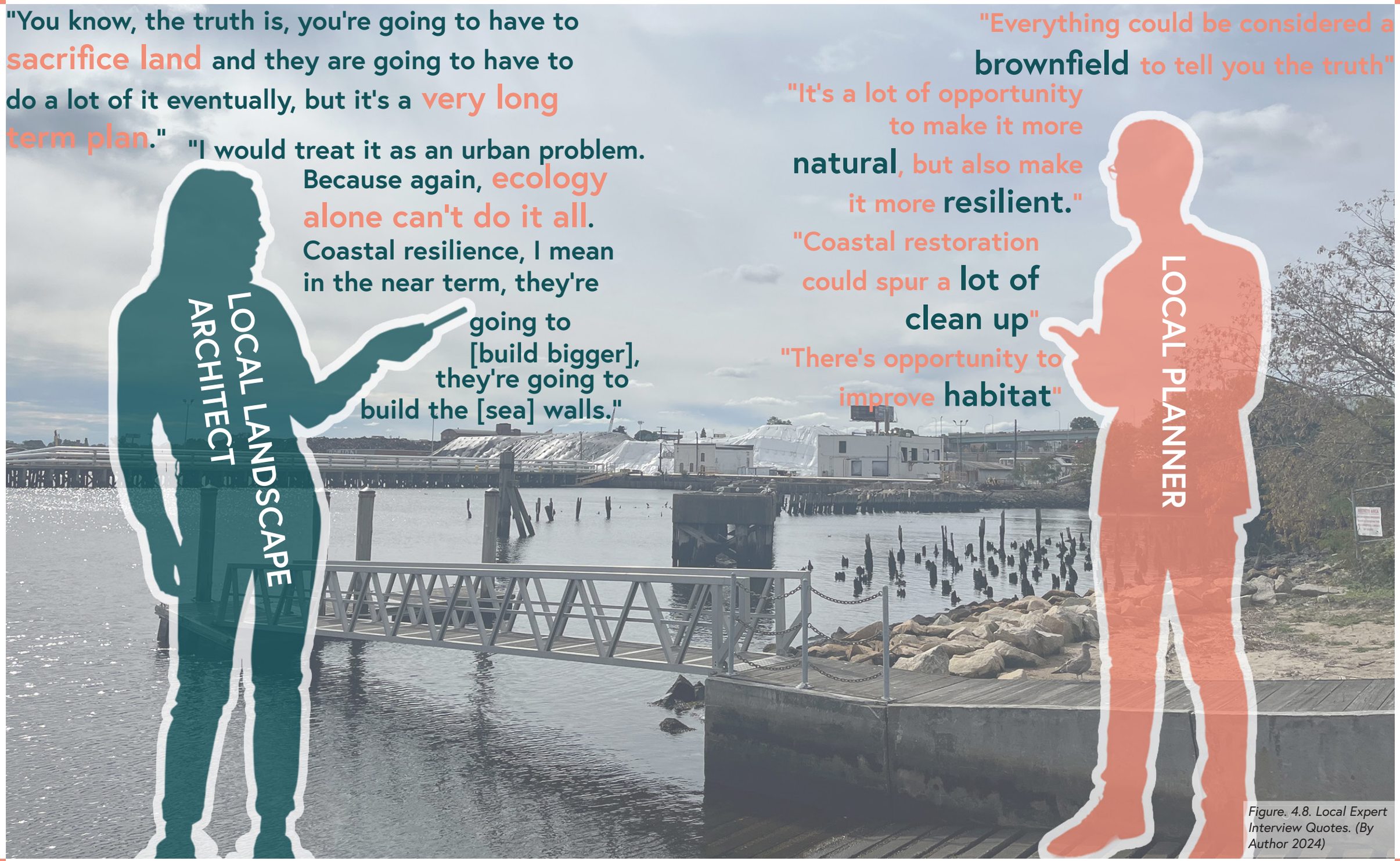


Figure. 4.8. Local Expert Interview Quotes. (By Author 2024)

Synthesis: Framework of Design Strategy

Utilizing the information gathered from the research phase, the Framework of Design Strategy (see Tables 4.2-4.5) was developed. The coastal brownfield design strategies and their economic, social, and environmental restoration benefits were derived from the literature and document analysis. The strategies are divided into four categories: remediation, environmental-based adaptations, low-input remediation, and redevelopment. The literature and document analysis in support of the coastal brownfield expert surveys and local expert interviews were applied to complete the framework. Each strategy is evaluated to determine whether it produces each benefit on a site-scale, urban-scale, short-term, or long-term project. The completion of the framework displays the most feasible strategies that provide the benefits that the community needs. This was used to choose the most suitable and valuable site restoration strategies.

Coastal Brownfield Restoration Strategies		Economical Benefits				Social Benefits				Environmental Restoration							Sources
		Maintenance and Operation Costs	Job Creation	Increased Property Value & Real estate Development	Tourism & Visitor Spending	Recreation	Health & Well-Being	Safety	Education	Resilience	Coastline Protection	Environmental Quality	Coastal Ecological Functions	Biodiversity	Flood Prevention	Climate Change	
Remediation	Soil Capping	○					●	●				●		●			(Lewis 2008; Zheng and Kirkwood 2020)
	Soil and Fill Removal						●	●				●					(Lewis 2008; Zheng and Kirkwood 2020)
	Site Clean Up	○	●	●		●	●	●				●		●			(Levi and Kocher 2006)
	Pollution Reduction or Elimination				●		●					●		●			(Zheng and Kirkwood 2020)
	Habitat (Re)Development			●	●		●					●		●			(Fanelli et al. 2023; Lewis 2008; Strain et al. 2018)
	Accessibility & Connectivity				●	●			●								(Levi and Kocher 2006)
	Aesthetics			●	●				●								(Levi and Kocher 2006; Song et al. 2019)
	Stigma			●	●			●	●								(Levi and Kocher 2006)
	Transportation		●		●	●		●									(Song et al. 2019; U.S. Department of Commerce 2003)

Table. 4.2. Remediation Design Strategies

Key:
○ Site-scale ● Urban-scale ▢ Short-term ■ Long-term

Remediation Design Strategies

The remediation strategies suitable for long-term and urban-scale restoration are soil and fill removal, pollution reduction or elimination, and habitat development, which produce environmental restoration benefits. It also included stigma and accessibility and connectivity which addresses the social benefits.

The strategies most suited for a short-term and site-scale project are soil capping, site clean-up, pollution reduction or elimination, and stigma. These strategies primarily produce environmental restoration benefits (Table 4.2). Addressing the waste above and below the soil was shown to be an essential aspect of remediation.

Coastal Brownfield Restoration Strategies		Economical Benefits				Social Benefits				Environmental Restoration							Sources
		Maintenance and Operation Costs	Job Creation	Increased Property Value & Real estate Development	Tourism & Visitor Spending	Recreation	Health & Well-Being	Safety	Education	Resilience	Coastline Protection	Environmental Quality	Coastal Ecological Functions	Biodiversity	Flood Prevention	Climate Change	
Environmental-based Adaptations	Marshland Restoration	● ● ■							● ● ■		● ● ■	● ● ■	● ● ■	● ● ■	● ● ■	● ● ■	(Temmerman et al. 2013)
	Coral Reef Restoration	● ● ■	● ● ■		● ● ■	● ● ■			● ● ■	● ● ■	● ■		● ● ■	● ● ■	● ■	● ■	(Temmerman et al. 2013; UNEP 2016)
	Living Breakwater	● ● ■	● ● ■		● ■				● ● ■	● ● ■	● ● ■	● ● ■	● ● ■	● ● ■	● ● ■	● ● ■	(Temmerman et al. 2013; UNEP 2016)
	Oyster Reef Restoration	● ■	● ● ■						● ● ■	● ■	● ● ■	● ● ■	● ● ■	● ■	● ● ■	● ■	(NOAA 15; Temmerman et al. 2013)
	Seagrass Restoration		● ● ■	● ● ■					● ● ■	● ■	● ■		● ● ■	● ● ■	● ● ■	● ● ■	(Lewis 2008; NOAA 2015; UNEP 2016)

Table. 4.3. Environmental-based Adaptation Design Strategies

Key:

● Site-scale ● Urban-scale ■ Short-term ■ Long-term

Environmental-based Adaptation Design Strategies

Environmental-based adaptations suitable for the long-term, urban-scale site included marshland restoration and living breakwater. These strategies are sustainable in an urban coastal environment and provide economic and environmental benefits. Seagrass restoration is suitable for site-scale restoration and produces ecological benefits when established over time (Table 4.3). These strategies work together to protect the coast while stabilizing over time.

Coastal Brownfield Restoration Strategies		Economical Benefits				Social Benefits				Environmental Restoration							Sources
		Maintenance and Operation Costs	Job Creation	Increased Property Value & Real estate Development	Tourism & Visitor Spending	Recreation	Health & Well-Being	Safety	Education	Resilience	Coastline Protection	Environmental Quality	Coastal Ecological Functions	Biodiversity	Flood Prevention	Climate Change	
Low-Input Remediation	Phytoremediation	○ ● □ ■					○ ● ■		○ ● □ ■	○ ● ■	○ ● ■	○ ● ■	○ □ ■	○ ● □ ■	● ■	○ ● ■	(O'Connor et al. 2019; Song et al. 2019)
	Bioremediation	● □ ■					○ ● □ ■			○ ● ■		○ ● □ ■	○ ● □ ■			● ■	(Song et al. 2019)
	Biochar Stabilization	○ ● □ ■					○ □					○ □	○ □		○ □		(Song et al. 2019)
	Nano-remediation	○ □ ■					○ □ ■					○ □ ■	○ □ ■				(Song et al. 2019)

Table. 4.4. Low-Input Remediation Design Strategies

Key:

○ Site-scale ● Urban-scale □ Short-term ■ Long-term

Low-Input Remediation Design Strategies

The low input strategies are a more eco-friendly approach to brownfield restoration with lower starting costs. Biochar stabilization and nano-remediation have limited studies on a large-scale and would not be feasible for an urban coastline. Phytoremediation takes time to stabilize and produce benefits, so it should be involved in a short-term project to transition into a long-term restoration (Table 4.4).

Coastal Brownfield Restoration Strategies		Economical Benefits				Social Benefits				Environmental Restoration							Sources
		Maintenance and Operation Costs	Job Creation	Increased Property Value & Real estate Development	Tourism & Visitor Spending	Recreation	Health & Well-Being	Safety	Education	Resilience	Coastline Protection	Environmental Quality	Coastal Ecological Functions	Biodiversity	Flood Prevention	Climate Change	
Redevelopment	Coastal Wetland Restoration	● ■	● ■	● ■			■		● ■	■	● ■	● ■	● ■	● ■	● ■	● ■	(Temmerman et al. 2013; UNEP 2016)
	Nature Preserves			● ■	● ■	● ■	● ■	● ■	● ■				● ■	● ■			(Levi and Kocher 2006; Song et al. 2019)
	Managed Retreat	● ■			● ■	● ■					● ■		● ■				(UNEP 2016)
	Green Space			● ■		● ■	● ■	● ■		● ■	● ■	● ■		● ■	● ■		(Lewis 2008; Song et al. 2019)
	Parkland		● ■	● ■	● ■	● ■	● ■					● ■		● ■	● ■	● ■	(Bardos et al. 2020; Zheng and Kirkwood 2020)
	Forests						● ■	● ■		● ■		● ■		● ■	● ■	● ■	(Bardos et al. 2020)

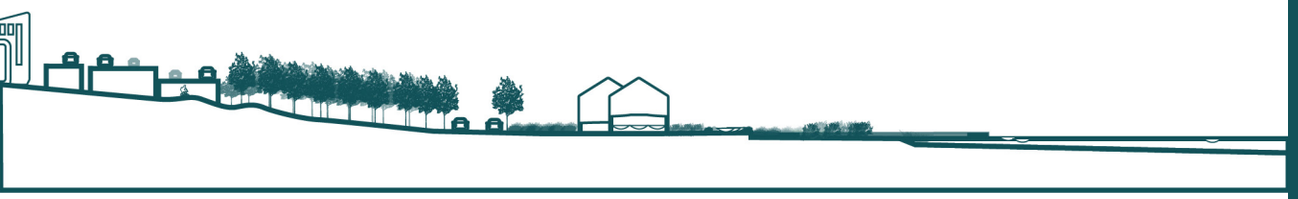
Table. 4.5. Redevelopment Design Strategies

Key:

● Site-scale ● Urban-scale ■ Short-term ■ Long-term

Redevelopment Design Strategies

Redevelopment strategies that are feasible in the long term and urban-scale sites are managed retreat, coastal wetland restoration, and converting to parkland, nature preserves, and green space. These strategies produce economic, social, and environmental restoration benefits (Table 4.5). To begin a long-term expansion of restoration, coastal wetlands, and open green spaces are suitable for a short-term, site-scale project.



Chapter 05
Design Proposal

Chapter Overview

This chapter discusses the outcomes of the design phase and the design work set. The completion of the framework of design strategy was then synthesized in the design phase to develop the design goals and strategies. Site analysis provided a holistic understanding of the South Providence port area and the opportunities and challenges for coastal brownfield restoration and redevelopment. Precedent studies provided real instances of the design strategies used in a coastal brownfield restoration project. These methods then guided the projective design's design goals and strategies for the catalyst and expansion site.

Synthesis from the Framework of Design Strategy

The synthesis of the framework of design strategy produced the project's design goals (see Figure 5.1) and strategies for the project site. The design goals include resilience to climate change, coastal flood protection, ecosystem performance, accessibility and connection, and sustainable redevelopment. Restoration strategies determined suitable for the long-term project include soil removal, habitat redevelopment, and living breakwaters. The redevelopment design strategies suitable for industrial areas include managed retreat, coastal wetland restoration, parkland, nature preserves, and open green space. For the short-term catalyst site, the strategies consist of soil capping, site cleanup, pollution reduction or elimination, addressing stigma, seagrass restoration, phytoremediation, and green space and coastal wetlands redevelopment.

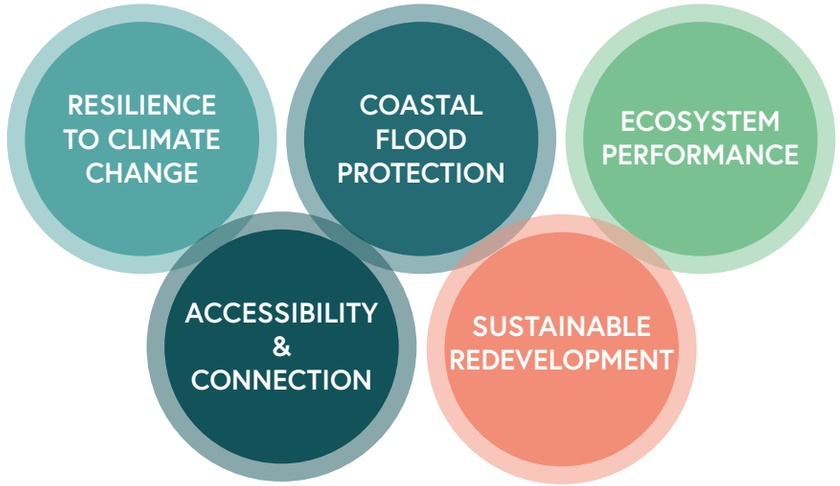


Figure. 5.1. Design Goals. (By Author 2024)

Site Analysis Themes

Coastal Restoration Opportunities and Challenges

- **Hydrology and floodplain:** the location of the 100-year and 500-year floodplain, the direction of stormwater runoff, Providence River High Tide, three- and five-foot sea level rise, and the locations of the water discharging facilities.
- **Environmental Quality:** where the soil has been filled, the location of air pollution and toxic release facilities, water quality and impaired sources, contaminants and hazardous materials, the number of gas tanks, and infrastructure in the Providence River.
- **Coastal Biology and Ecology:** location of wildlife habitats, ecosystems, impervious surfaces, and shoreline conditions.

Brownfield Redevelopment Opportunities and Challenges

- **Transportation and Accessibility:** what streets have sidewalks, crosswalks, bike lanes, and bus stops; what are the major roads and highway systems on the site; what streets provide access to the South Providence Neighborhoods?
- **Land Use and Waterfront Use:** what are the building uses, are the ports active, and what are the locations of vacant lots and boat launches?
- **Developments in South Providence:** locations of the environmental development projects, park improvements, public green space, other brownfields, Providence precedent studies, and road improvement projects.
- **Social Environment:** the demographics of the adjacent neighborhoods and downtown areas: median home value, average household income, population below the poverty line, and average age.

Coastal Restoration | Hydrology and Floodplain

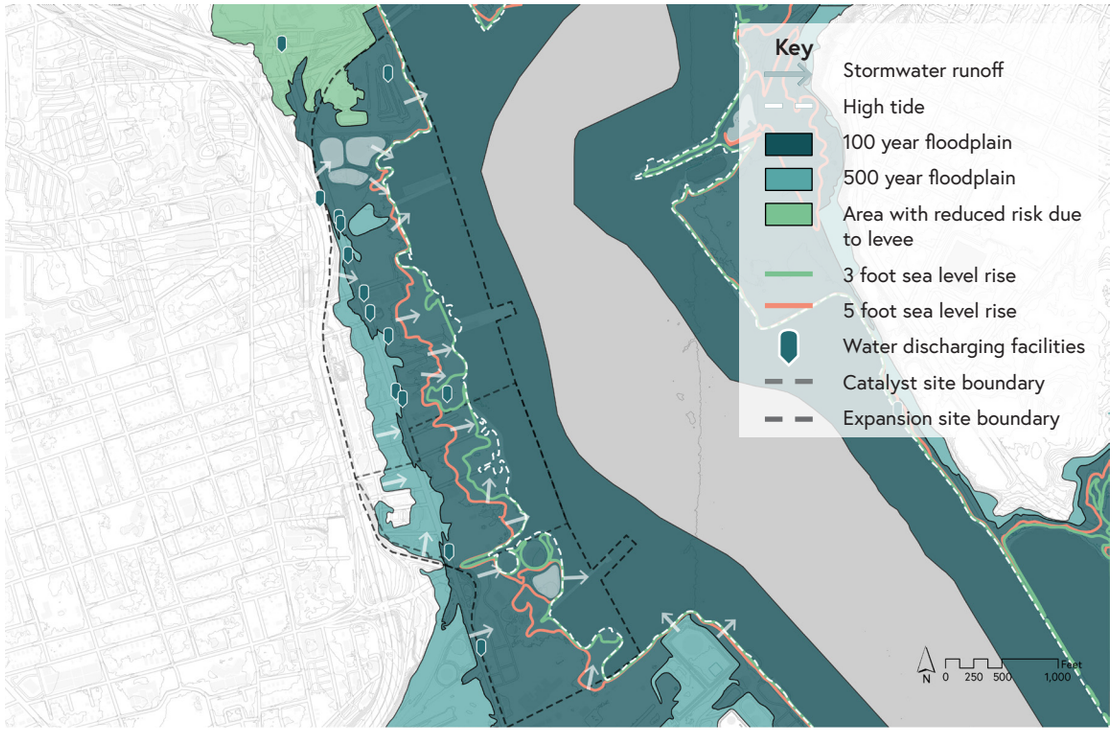


Figure. 5.2. Hydrology and Floodplain Map. Data sourced from EnviroMapper, FEMA's National Flood Hazard Layer, & NOAA Sea Level Rise Viewer. Map sourced from ArcGIS. (By Author 2024)

The majority of the site is located within the 100-year floodplain and a smaller portion in the 500-year floodplain. This leaves the development vulnerable to flood events and risks the spread of contamination located within the site. Future development within Providence must be built with three to five feet of sea level rise, which currently cuts through most of the industrial areas. The site collects the stormwater runoff from I-95, causing more flooding events. Approximately 12 facilities within the study area are permitted to discharge wastewater into the Providence River. Due to combined sewer overflow, dissolved oxygen issues, fecal coliform, and excess nitrogen, the river is considered an impaired water source (see Figure 5.2).

Coastal Restoration | Environmental Quality

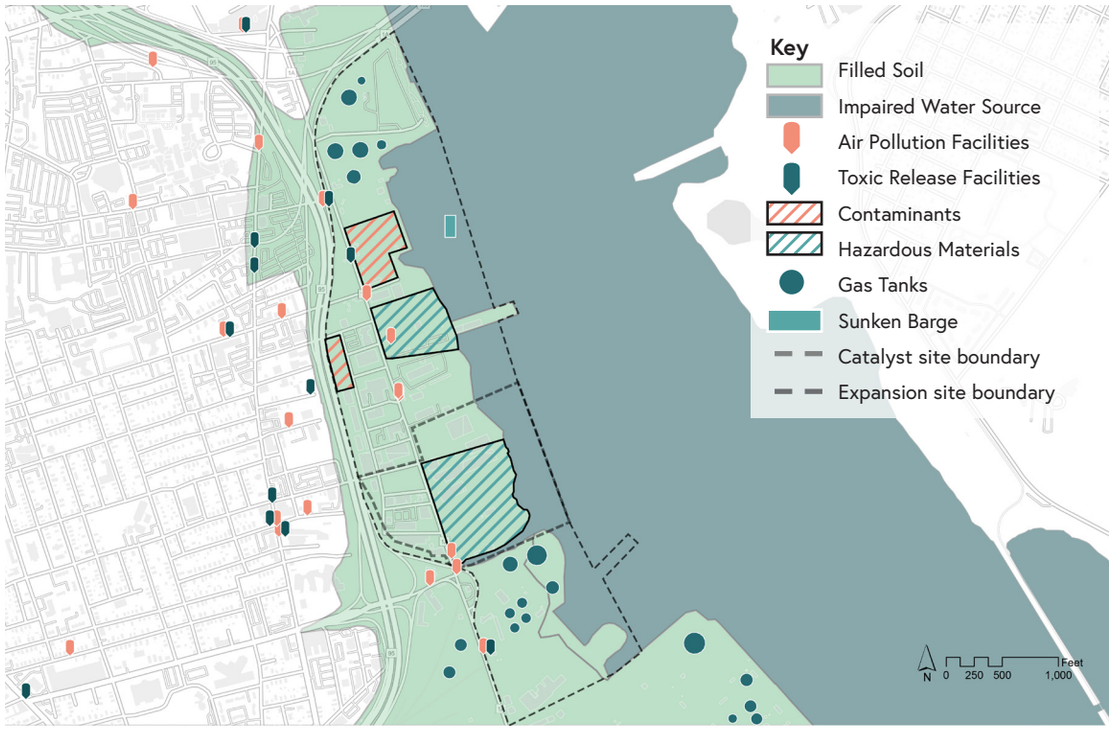


Figure. 5.3. Environmental Quality Map. Data Sourced from EnviroMapper and RIGIS. Map sourced from ArcGIS. (By Author 2024)

According to EnviroMapper from the EPA, seven facilities produce air pollution within the site, as well as 29 facilities handling hazardous waste, and three are permitted to release toxic waste (reference Appendix E for inventory maps). The entirety of the land in the project area is filled with soil and contains large areas of hazardous materials and contaminants. Infrastructure contaminants include 14 petroleum tanks and a sunken barge in the Providence River (see Figure 5.3). The Providence River is considered to be an impaired water source with issues of dissolved oxygen, nitrogen, and fecal coliform (State of Rhode Island 2021).

Coastal Restoration | Coastal Biodiversity and Ecology

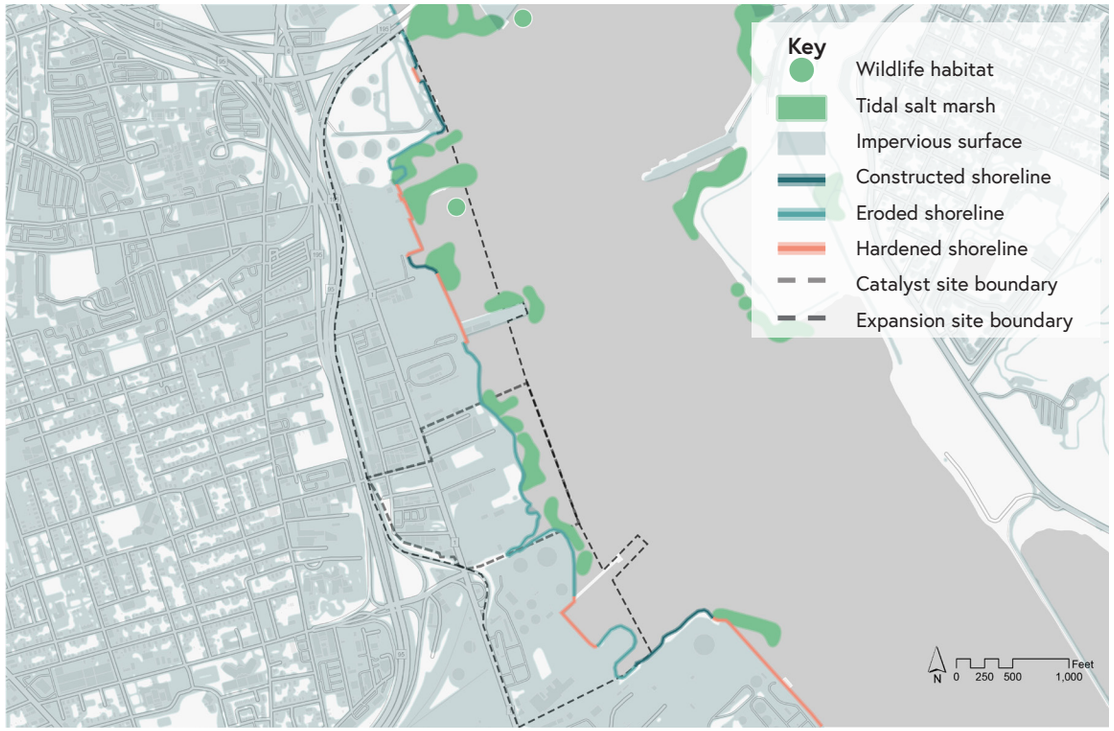


Figure. 5.4. Coastal Biodiversity and Ecology Map. Data sourced from RIGIS & The Nature Conservancy. Map sourced from ArcGIS. (By Author 2024)

The project area's shoreline has three conditions: hardened, constructed, and eroded. The hardened shorelines are sea walls along the industrial sites that have ports. The constructed shorelines are present along previous restoration project sites, and the rest of the coastline has been eroded due to the heavy industrial use of the coast. Data shows that tidal salt marsh ecosystems in this area have the opportunity to be conserved or restored based on their ecosystem performance. There is also evidence of wildlife habitat in a nearby park and an osprey habitat on the sunken barge (see Figure 5.4).

Site Photos

Figure. 5.5. (Top left) Abandoned Waste and Scraps from RI Recycled Metals. (By Author 2023).
Figure. 5.6. (Top Right) Scrap Metals at Sims Metals. (By Author 2023).
Figure. 5.7. (Bottom Left) Domestic Waste and Abandoned Building on Allens Ave. (By Author 2023).
Figure. 5.8. (Bottom Right) Crane on Top of Sunken Barge. (By Author 2023).

Brownfield Redevelopment | Transportation and Accessibility

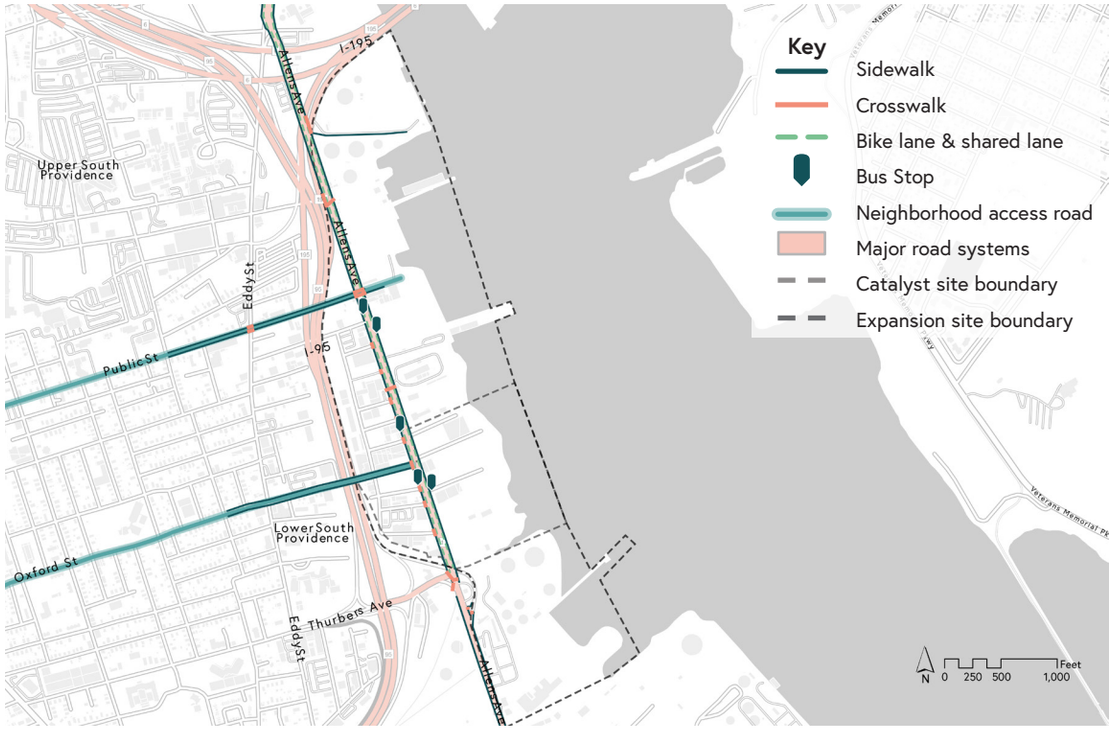


Figure. 5.9. Transportation and Accessibility Map. Data sourced from Providence GIS. Map sourced from ArcGIS. (By Author 2024)

The main streets running through and adjacent to the site are Allens Ave and I-95. I-95 serves as a defined edge of the project area. Allens Ave is lined with a sidewalk with bike and shared lanes leading into the downtown. There are limited crosswalks, and the area is primarily car-focused, making it dangerous for pedestrians. Oxford St. and Public St. are the only two streets that connect the project area to the South Providence neighborhoods by going under I-95. These streets provide the opportunity to serve as entry points for the restored area (see Figure 5.9).

Brownfield Redevelopment | Land Use and Waterfront Use

Figure. 5.10. Land Use and Waterfront Use Map. Data sourced from Providence GIS. Map sourced from ArcGIS. (By Author 2024)

Most building uses are industrial, with various infrastructural and adult clubs. The medical center in the catalyst site draws the community into the existing site. The active ports challenge the conservation use of the shoreline. The vacant lots are all located within the catalyst site, which allows open programming for the short-term design (see Figure 5.10).

Brownfield Redevelopment | Developments in South Providence

Figure. 5.11. Developments in South Providence Map. Data sourced from EnviroMapper & Providence GIS. Map sourced from ArcGIS. (By Author 2024)

Several developments have been completed or underway in South Providence. The environmental developments include a shoreline access project on Public Street that was halted due to the neighboring businesses. ProvPort developed wind farms to harness wind energy for the surrounding area. The urban trail system has the potential to connect the site to the rest of Providence and the public green spaces. India Point Park and Save the Bay Center both serve as precedent studies with design strategies that could be implemented in the project site (see Figure 5.11).

Brownfield Redevelopment | Social Environment

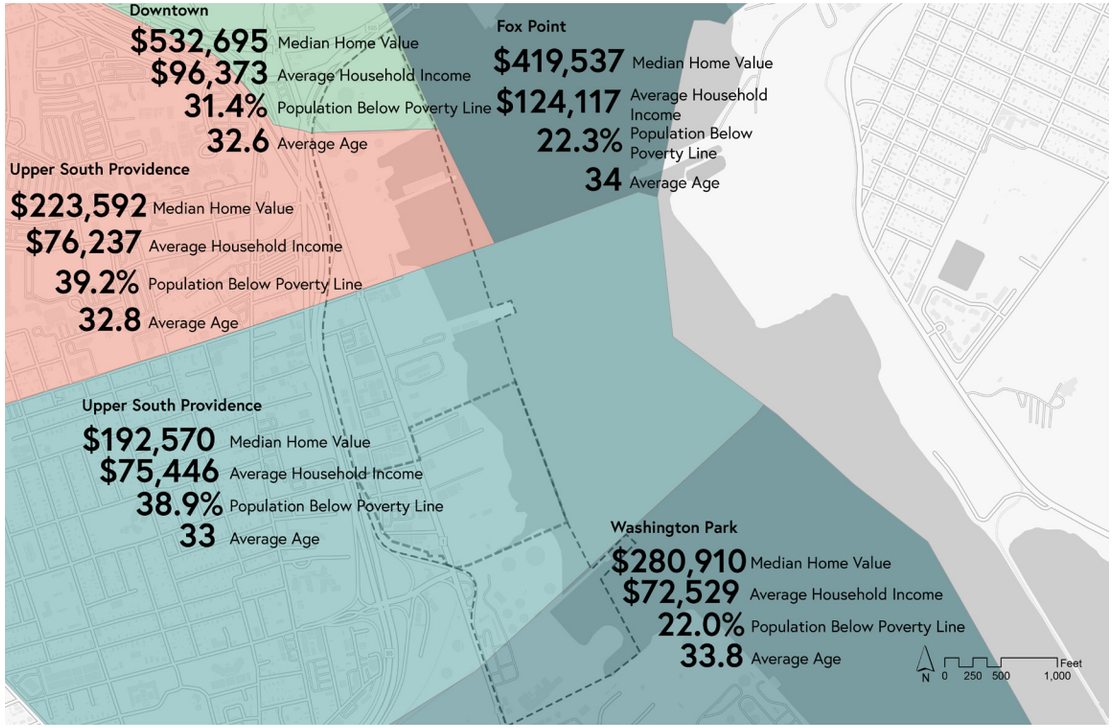


Figure. 5.12. Social Environment Map. Information sourced from City-Data, Niche & Point2. Data sourced from Providence GIS. Map sourced from ArcGIS. (By Author 2024)

The neighborhoods encompassing the project site are Upper and Lower South Providence. Both neighborhoods have almost 40% of their population below the poverty line, with an average income of approximately $75,000. These demographics contrast with the adjacent neighborhoods of Downtown Providence and Fox Point. Washington Park makes up the most southern portion of the site, with a lower average household income. The neighborhoods within the project site are economically vulnerable (see Figure 5.12).

Coastal Restoration Constraints

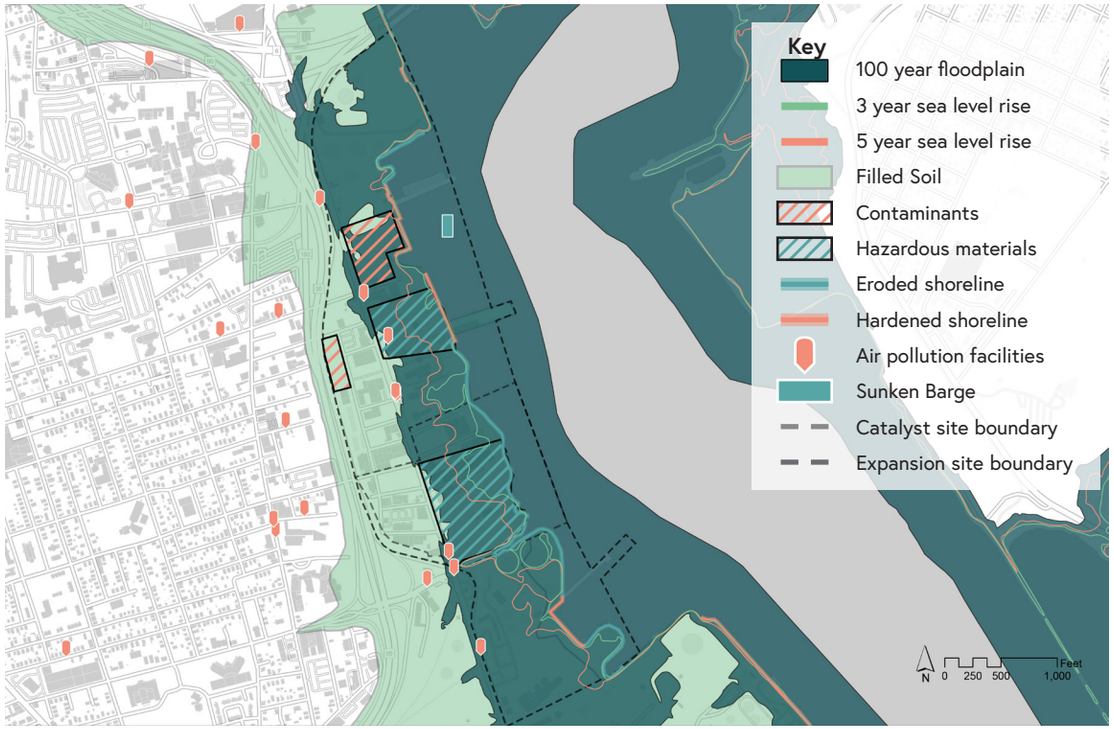


Figure. 5.13. Coastal Restoration Constraints Map. Data sourced from EnviroMapper, FEMA's National Flood Hazard Layer, NOAA Sea Level Rise Viewer, & RIGIS. Map sourced from ArcGIS. (By Author 2024)

The main constraints for coastal restoration are the site's location within the 100-year floodplain and the 5-foot sea level rise through most of it. Hazardous material and contaminants must be removed to fully restore the site, posing a health risk to the community and environment. Other environmental health risks include the sunken barge off the coast in the river and the multiple air pollution facilitators in and around the project site. Finally, precautions must be taken when dealing with the soil since the entire project area is filled (see Figure 5.13).

Brownfield Redevelopment Constraints

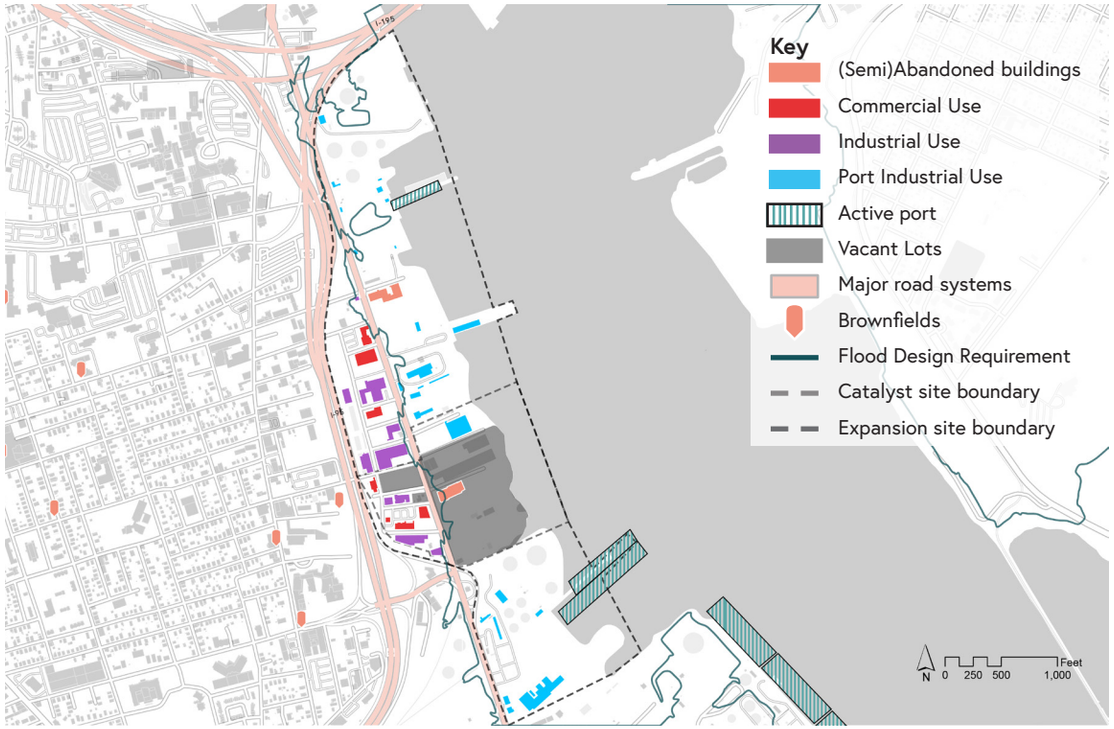


Figure. 5.14. Brownfield Redevelopment Constraints. Data sourced from EnviroMapper & Providence GIS. Map sourced from ArcGIS. (By Author 2024)

There are constraints on the building uses for redevelopment as most of them are either industrial and/or within the zone of flood design requirement. All buildings within the flood design requirement line and the shoreline must be adapted to minimize flood damage, and any new development requires permits. Many of the buildings within this zone are abandoned or contain hazardous materials. I-95 poses a threat due to stormwater runoff from the highway flooding the site. Several brownfields surround the site and contribute to the community's health risks (see Figure 5.14).

Coastal Restoration and Brownfield Redevelopment Opportunities

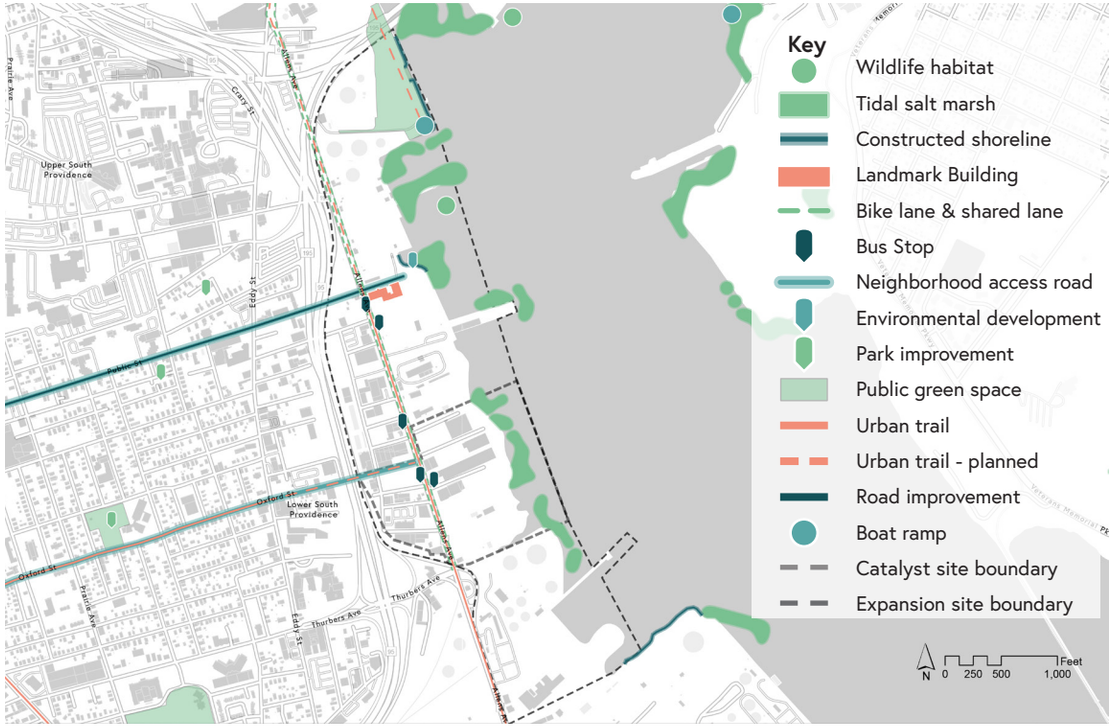


Figure. 5.15. Coastal Restoration and Redevelopment Opportunities Map. Data sourced from Providence GIS & RIGIS. Map sourced from ArcGIS. (By Author 2024)

The opportunities for coastal restoration include the nearby wildlife habitats and existing tidal salt marsh ecosystems that can be restored. Some areas along the shoreline are constructed of large rocks that help mitigate the flooding. Several redevelopment opportunities include existing bike and shared lanes, the urban trail system and the planned routes that cut through the site, and road improvement plans. There are also nearby park improvement plans and environmental developments. Public Street and Oxford Street connect Upper and Lower South Providence neighborhoods to the project site. The green space and boat ramp from Point Collier Park drive people to the area, which can be built upon (see Figure 5.15).

Catalyst Site Analysis

Figure. 5.16. Catalyst Site Analysis Map. Data sourced from NOAA Sea Level Rise Viewer, Providence GIS & RIGIS. Map sourced from ArcGIS. (By Author 2024)

Most of the site is on impervious soil with small pockets of permeable soil. The shoreline is eroded due to the harsh chemicals from previous industrial use. Other challenges for the site include the large concrete lots and industrial buildings. The abandoned structures were once industrial and are located on lots with contaminated soil and temporary soil. Another issue is the potential for a rise of 5 feet in sea level, threatening to spread the contamination further. Some opportunities for the site include four bus stops within the site and a community medical center, which brings the public to the existing site (see Figure 5.16).

Community Needs Analysis

The typical users of the site now and who are directly impacted by restoration efforts are those living in the Upper and Lower South Providence neighborhoods. People living in these neighborhoods are vulnerable due to their economic status as well as proximity to industrial sites and brownfields containing petroleum and other pollutants. Methane was found in the soil of a nearby contaminated site on the port. Therefore, it is assumed to be present in the proposed project site (EPA 2017). The neighborhoods are stated to have some of the highest asthma rates due to the Port of Providence and Interstate 95. The port is also known to contain polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, benzene, formaldehyde, cyanide, asbestos, lead, ammonia, arsenic, and polychlorinated biphenyl. (Carini 2019). According to the USDA, South Providence is considered a food desert according to the low-income and low food access standards of a half mile within an urban area. There are a minimal number of large food markets, grocery stores, or food stores in South Providence that are located within a half mile of residence (see Figure 5.17). Another issue the South Providence neighborhood faces is the high percentage of low vehicle access that hinders residents' access to clean food and supermarkets (USDA 2023) (see Figure 5.18).

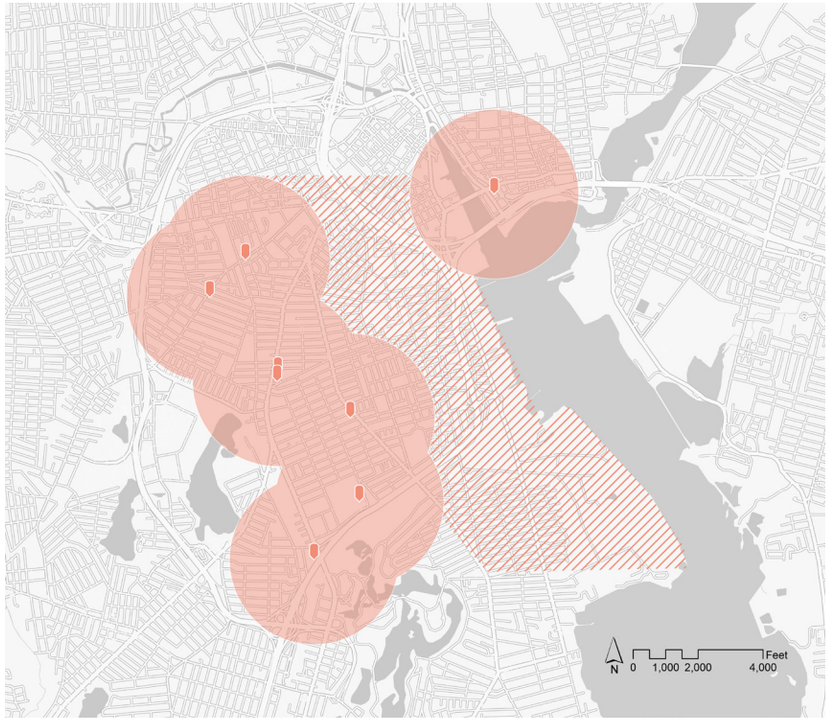


Figure. 5.17. Food Insecurity Map of South Providence Neighborhoods. Map sourced from ArcGIS. (By Author 2024)

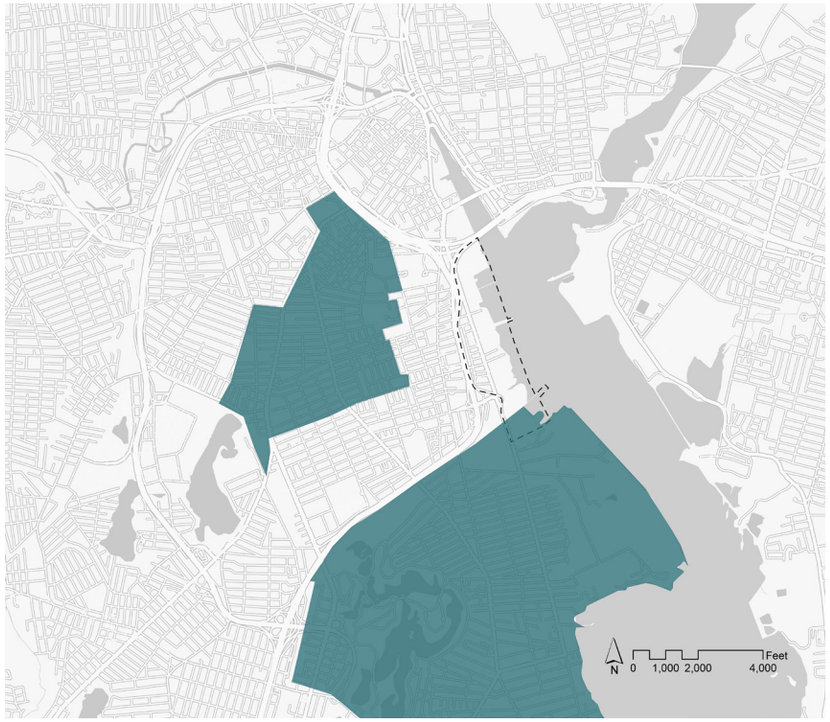


Figure. 5.18. Vehicle Accessibility. Data sourced from USDA. Map sourced from ArcGIS. (By Author 2024)

Precedent Studies

Overview

The precedent studies chosen are all brownfield restoration projects located in coastal areas with previous industrial or infrastructural use. Each study was examined using the remediation strategies and lessons learned throughout the project. These remediation strategies were implemented based on their success in the project. They were also chosen based on how similar their situation and problems were to the project site (see Appendix F for selection criteria).

Precedent Study Analysis

Resources	Precedent Study Overview	Remediation Strategies Used	Lessons Learned
(Bishop 2023; Department of Ecology 2023; Way 2013)	Seattle Gasworks Park: An urban park that was environmentally restored from a gas company with a history of contamination.	Original Restoration: on-site and in situ strategies, bioremediation, and soil capping Phase 1: Removal and capping of soil, dredging and capping of sediment, and administrative site use controls. Ongoing Phase: Public volunteering	Original bioremediation efforts successfully preserved soil and water and became biologically productive. Contaminants are still present after decades of site clean-up.
(Betancourt 2002; Friends of India Point Park n.d.)	India Point Park: History of a Scrap Yard Redeveloped into a Public Park on the Providence River.	Phase 1: debris removal, public access (walking, sitting, and picnicking opportunities), trees, and open space. Phase 2: open green space, shade-providing trees, native wildflowers, views to waterfront, walkways, and public parking.	Ongoing organized clean-ups for park maintenance. Native plants used to provide habitats for shorebirds and fish species.

Table. 5.1. Precedent Study Analysis (By Author 2024)

Figure. 5.19. India Point Park Precedent. (Burling 2013)

Figure. 5.20. Gas Works Park Precedent (Wildcat Dunny 2019)

Figure. 5.21. Seoul Haneul Park Precedent (Travel Oriented 2013)

(Song 2017)	Seoul Haneul & Nanji-Han River Park: A large landfill transitioned into an Eco-Park.	Stabilization practices: leachate treatment, soil capping, gas treatment, and slope stability. Landscape forms made from waste: bearing, blocking, drainage, vegetation, and top later. Yearly Monitoring: increase in plants, wild birds, and terrestrial insects. Methane: gas extraction wells providing heating.	Economic effects: gas collection and increase in property value. Sociocultural effects: large number of visitors and range of programming. Problems with the people living in the surrounding community are solved through job creation and housing rights.
(Elphick 2006; EPA 2017)	Save the Bay Center: Restoration project along the Providence River addressing soil contamination and sea level rise.	Soil capping: contaminated soil layer, geotextile marker layer, 6" clean dredge spoils, 6" topsoil, and vegetated surface layer. Methane gas: venting system, a rubber liner, and a methane detection system. Stormwater management: pervious surfaces and bioretention swales and basins Public access: educational programs, organized tours, or public use (fishing or picnicking). Coastal Protection: salt marsh and coastal buffer (protective stone structure).	Smart growth principles are important in the development and policies of coastal communities. The Rhode Island Coastal Management Program water-typing scheme helps develop the coast, and the Coastal Zone Management Act helps with planning, zoning, and growth management.
(EPA 2016)	Woodbridge Waterfront Park: A manufacturing plant that contaminated the site's groundwater transformed into an energy center and waterfront park.	Remediation and redevelopment outcomes: job creation, clean energy, green space, and waterfront public access. 1st Steps: site clean-up, restoring wetland areas, and creating public recreation areas. Restoration: hydraulic barrier wall, excavation and disposal of contaminated soils, soil capping, and filling and capping of a contaminated pond.	Permits and regulatory permits are essential due to the size of the project and remediation site. The site's cleanup encourages redevelopment, increased property values, and the interest of new businesses.

Design Goals

The design goals synthesized from the framework were defined based on the findings of the site analysis and precedent studies (see Figure 5.22). These design goals are implemented into the approaches of the long-term expansion site and the short-term catalyst site.

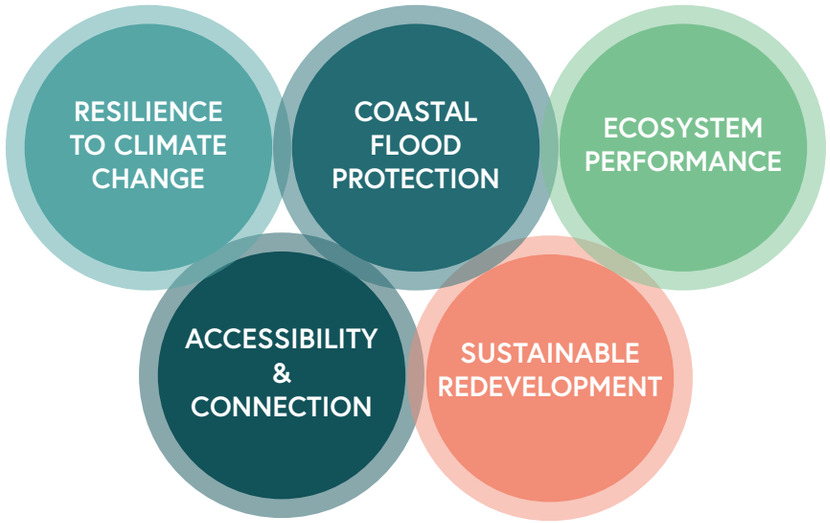


Figure. 5.22. Design Goals. (By Author 2024)

Resilience to Climate Change
The restoration project must be resilient when facing climate change factors. This includes a sea level rise of three to five feet, as is standard in Providence, which impacts the immediate area adjacent to the coast. The design also addressed urban heat island impacts and the rising temperature they cause by decreasing the high number of impervious surfaces. Finally, the design combats storm surges and increases storm events through coastal protection strategies.

Coastal Flood Protection
The project's next goal is to protect the surrounding area from coastal flooding. The majority of the site is within the 100-year floodplain and at risk of flooding and spreading the present contaminants to surrounding areas. Coastal protection involves flood protection infrastructure as well as flood mitigation strategies.

Ecosystem Performance
Improving the area's ecosystem performance is a critical project design goal. The site must provide habitat for wildlife and filtrate contaminated water to protect the shoreline and surrounding environment. It is located near healthy marine ecosystems that could expand into the project area.

Accessibility & Connection
Accessibility and connection are social design goals that enhance the relationship between the community and the project site. This includes the physical connection and access to the site as well as the community ties to the area. Neighborhood streets provide direct access from the neighborhoods to the waterfront.

Sustainable Redevelopment
The last goal is to redevelop the area so that it boosts the local economy of the South Providence neighborhood by providing markets for local farmers to sell goods and creating jobs for current industrial workers. The buildings are constructed using sustainable development practices and include energy-renewing technologies, such as adaptive reuse and solar energy.

Key Users

Figure. 5.23. South Providence Neighborhoods Connection. (By Author 2024)

Local Families

Families in Upper and Lower South Providence have limited access to green space and vegetation. Due to I-95 and the industrial strip, locals are disconnected from their shoreline and the river. Providing site accessibility allows the community to foster a physical and emotional tie to the riverfront. Large gathering spaces further connect local families and enhance the already strong sense of community (see Figure 5.23).

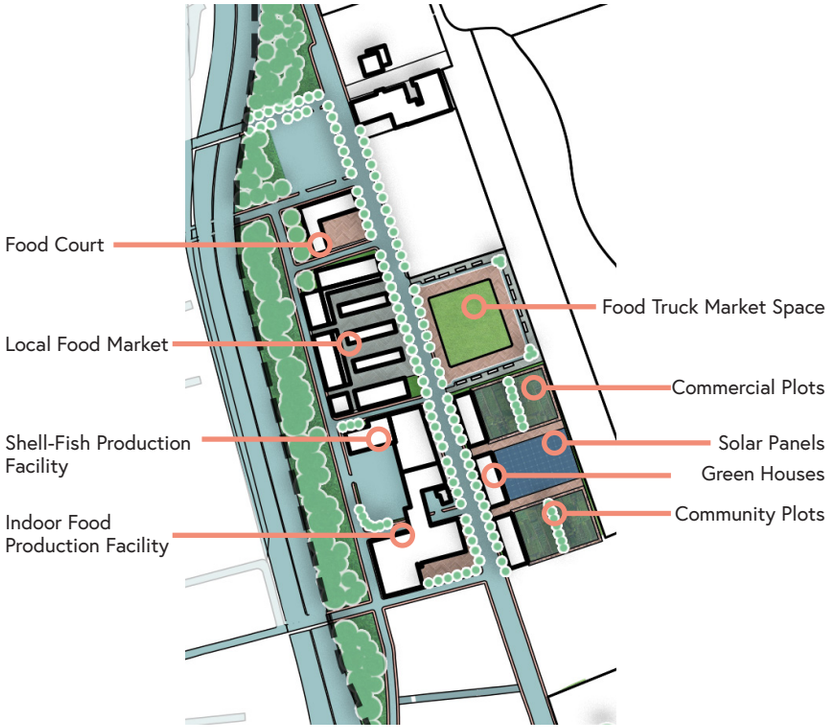


Figure. 5.24. South Providence Urban Farm Production. (By Author 2024)

Urban Farmers

South Providence is located in a food desert with limited supermarkets, superstores, and large grocery stores. Many residents have limited access to fresh food and vehicular access, creating a social problem. Systems for community gardens and urban farms are already in place within South Providence but focus more on the eastern side. Providing a Food Hub allows local urban farmers to sell their crops and goods from different cultures. The integration of shellfish farming creates opportunities for job growth for urban farmers (see Figure 5.24).

Key Users

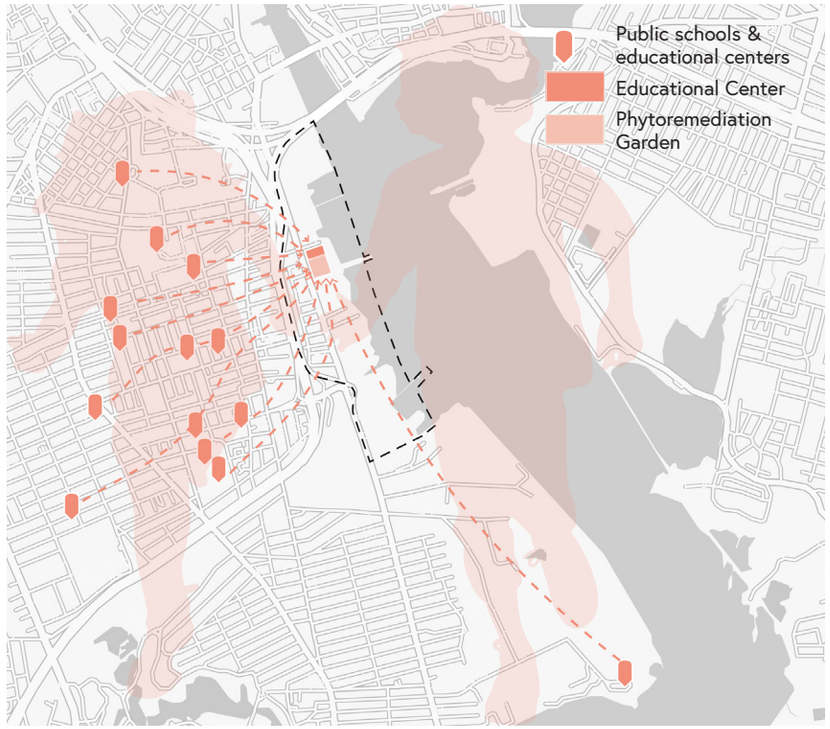


Figure. 5.25. South Providence Public Education System. (By Author 2024)

School Children

Several public schools are located within Upper and Lower South Providence. By providing after-school programs, children can learn more about the history of their shoreline and the process of land and river remediation. Education integration is important in this neighborhood, and due to the high percentage of non-English speakers, lessons and signage are taught in Spanish and English (see Figure 5.25).

Figure. 5.26. Job Creation on South Providence Waterfront. (By Author 2024)

Current Industrial Workers

According to the Statistical Atlas, approximately 11% of South Providence residents work in facilities, and approximately 11% work in production (Statistical Atlas 2020). With the design removing these industries, local residents are provided with new job opportunities. Those working in the existing industrial port area are offered new jobs at the proposed site. These jobs include urban farming, restoration maintenance, and educational tour guides of the industrial site. Urban agriculture includes the Food Hub and shellfish farming. Maintenance for soil and water remediation is essential for the success of ecological restoration. Those working in this area have a unique understanding of the site, may know the history of industrial use, and can work in the educational center to teach visitors (see Figure 5.26).

Expansion Site Design Set

Coastal Brownfield Design Strategies

Pollution elimination is proposed by removing and addressing the chemicals, waste, human trash, and other contaminants from the project site to promote the health of the nearby communities and the coastal environment. Using native plantings and restored ecosystems boosts the habitat redevelopment of native Rhode Island species. An important aspect of this project was to create a connection between the neighborhood and the Providence River coastlines; this was done by proposing green streets and safer sidewalks so that residents could have better access to the site. It also included integrating community activities and spaces to give them a reason to visit this area, which helps to improve stigma. To address the contaminated soil, the polluted soil was removed for smaller areas and phytoremediation was used to remediate the soil for heavily polluted industrial sites. The combination of living breakwaters, marshlands, and coastal wetlands was implemented for their environmental restoration benefits and eco-friendly nature. The redevelopment strategies of parkland, nature preserves, and open green spaces were integrated into the overall programming of the site to provide locals access and connectivity to nature. Managed retreat was applied to push back development as sea level rises and storm events became more frequent (see Figure 5.35).

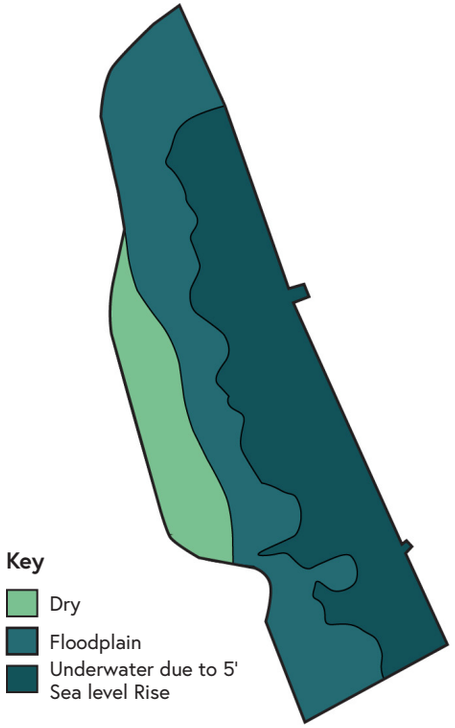


Figure. 5.27. Flooding Diagram. (By Author 2024)

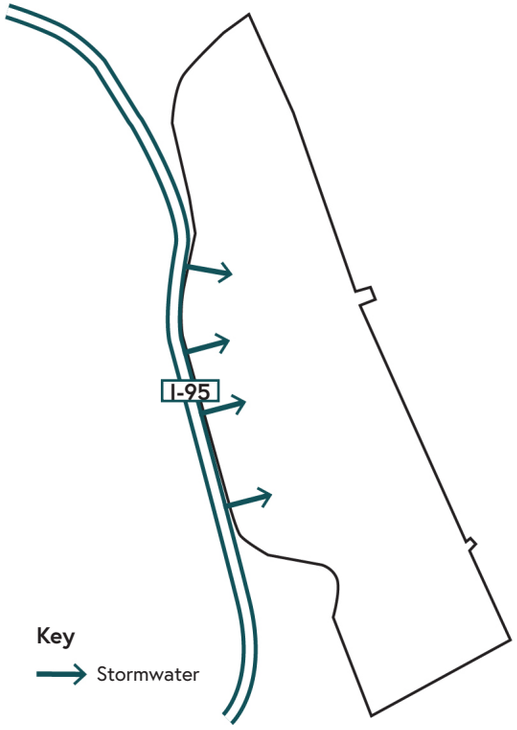


Figure. 5.28. I-95 Interaction Diagram. (By Author 2024)

Regarding flooding, the site can be broken into three zones: dry, within the 100-year floodplain, and underwater due to a five-foot rise in sea level. The dry areas are upland and allow for redevelopment without flood design constraints. The areas within the floodplain require specific building requirements, and no topography modifications to lower the landscape can be made. Finally, the areas below the five-foot sea-level rise must be prepared to flood and potentially be underwater in the future (see Figure 5.27). I-95 also produces flooding issues within the site from stormwater runoff that could spread pollutants from the highway into the project area (see Figure 5.28).

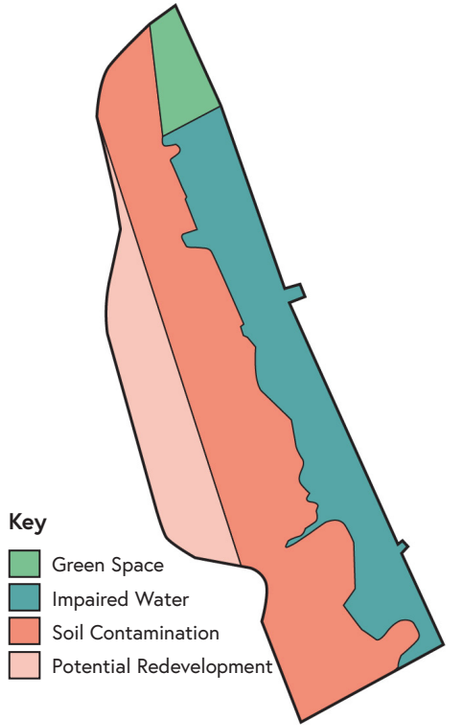


Figure. 5.29. Site Clean Up Diagram. (By Author 2024)

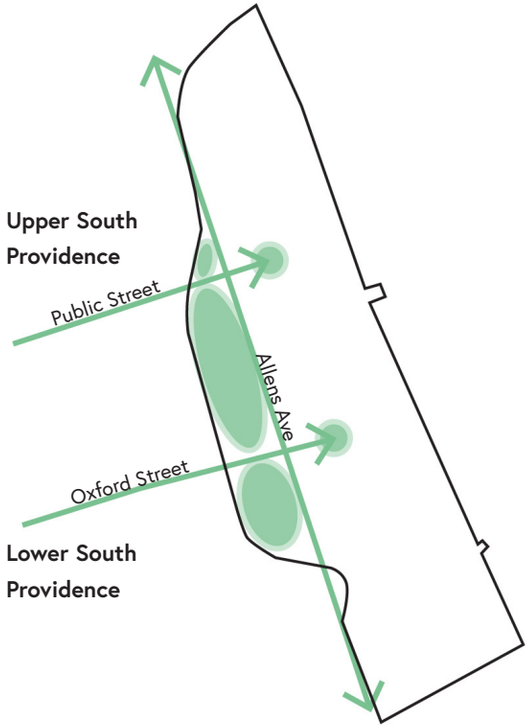


Figure. 5.30. Entry into Site Diagram. (By Author 2024)

Another area of concern that must be addressed is the impaired water and soil within and around the site. These areas must be addressed and remediated for successful ecological restoration (see Figure 5.29). The last reason looked at was using the connections from the surrounding context to create different nodes within the design. The streets coming from the neighborhoods lead to the river and create a vocal viewpoint. The two streets intersection with Allens Ave, which leads into the downtown area, forms three separate areas (see Figure 5.30).

Site Programming

The programming of the long-term design provides areas of ecological restoration, public education, and clean food accessibility for all in the South Providence neighborhood (see Figure 5.31). The design adapts to the altering landscape resulting from climate change using living breakwaters, reconstructed coastal wetlands, and marshes. These strategies also provide coastal protection and restore the coastal natural ecological functions. Soil and water remediation were addressed by isolating contamination from the public and native vegetation. These areas offer educational opportunities for the South Providence residents on the importance of their coast and its natural functions. Due to the flood plain and rising sea levels, the development is pushed back and focuses primarily on the access to fresh food needs of South Providence. Due to the site's programming, residents of South Providence have direct access to the river that extends past the shoreline.

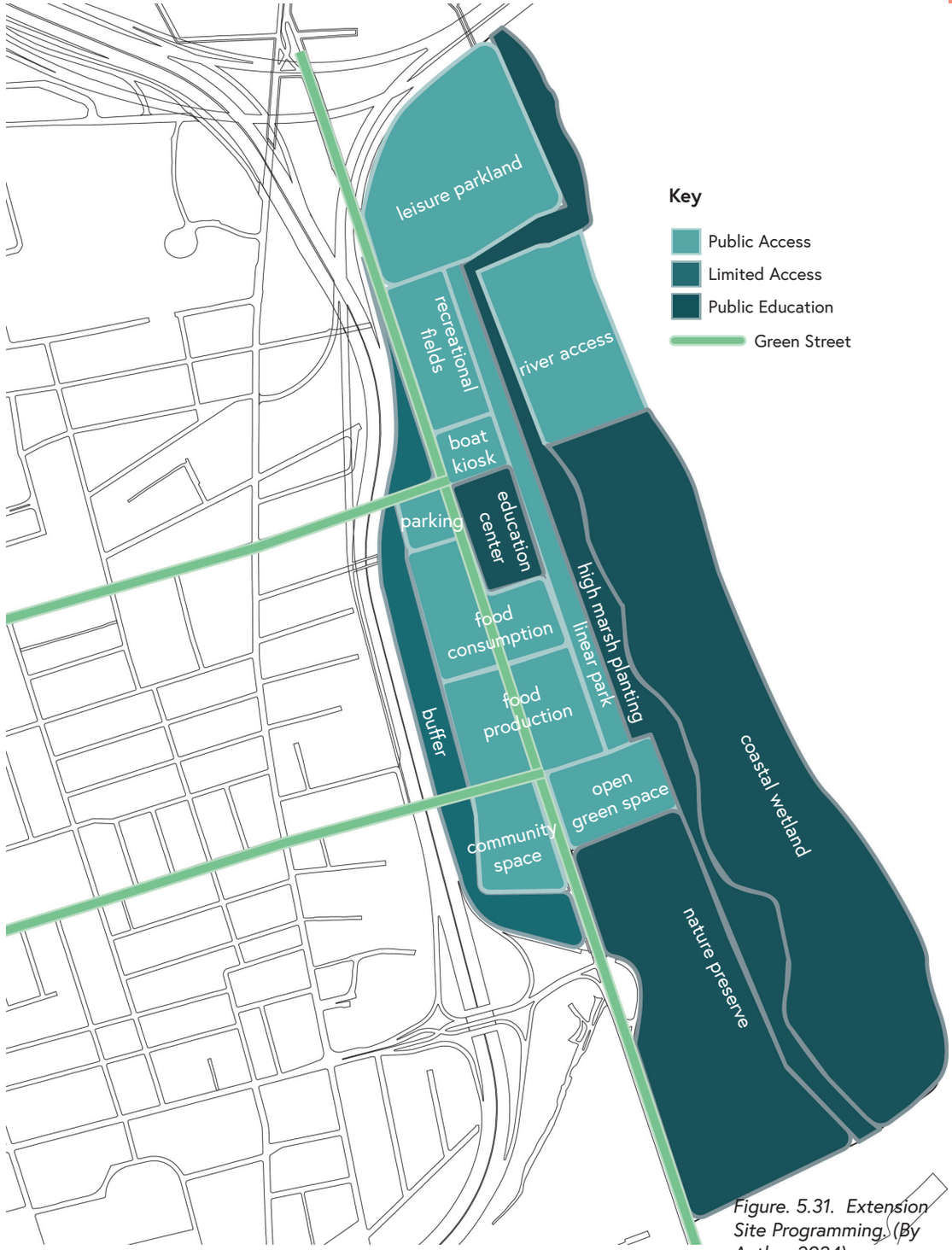


Figure. 5.31. Extension Site Programming. (By Author 2024)

Key Locations

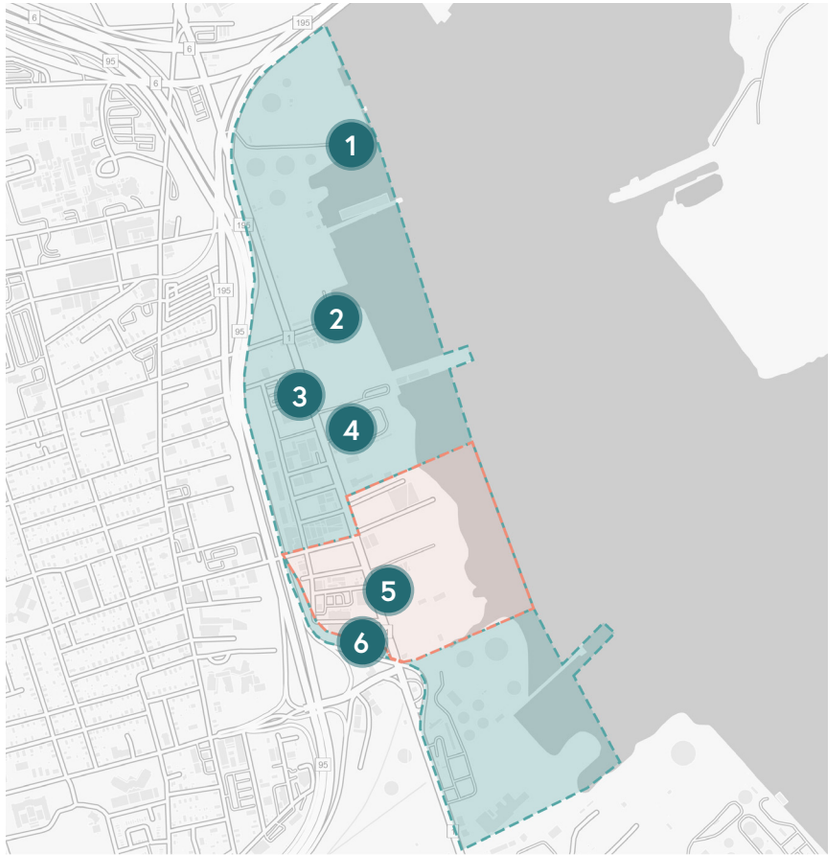


Figure. 5.32. Map of Key Locations. (By Author 2024)

Highlighted are some key locations of heavy pollution and potential for ecological redevelopment along Allens Ave, which splits the project area (see Figure 5.32). The first location is Point Collier Park, one of the few public parks in South Providence that contain large gas tanks and work with a natural gas company. Public Street provides shore access to the public; however, the adjacent industries utilize the shared road as a service road. Large gas tanks and industrial buildings line Allens Ave, creating an uncomfortable and uneasy user experience. Scrap metal recycling is a prevalent business on the port as large piles of scraps block views of the coastline. Allens Ave is home to several vacant lots that collect trash and graffiti art, which are blocked by rows of metal gates restricting access to the public. Finally, several industries on Allens Ave contributed to the contamination of the Port of Providence (see Figure 5.33). These areas are all impacted by the brownfields and industries present on Allens Ave and have the potential to become key points for the South Providence community (see Figure 5.34).

1 Point Collier Park

2 Public Street Shore Access

3 Allens Ave

4 Scrap Metal Recycler

5 Vacant Lot

6 Industrial Building

Figure. 5.33. (Right) Images of Key Locations. (By Author 2024)

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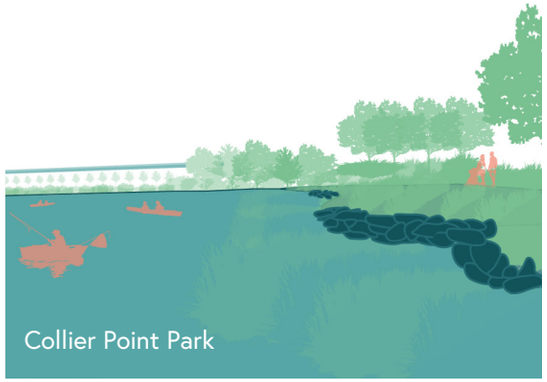

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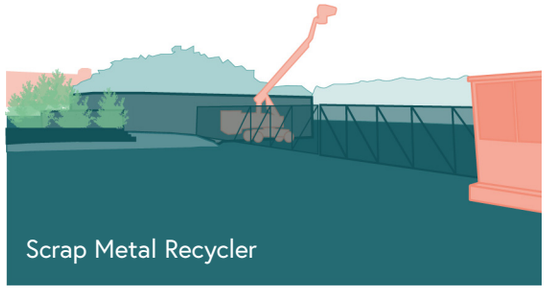

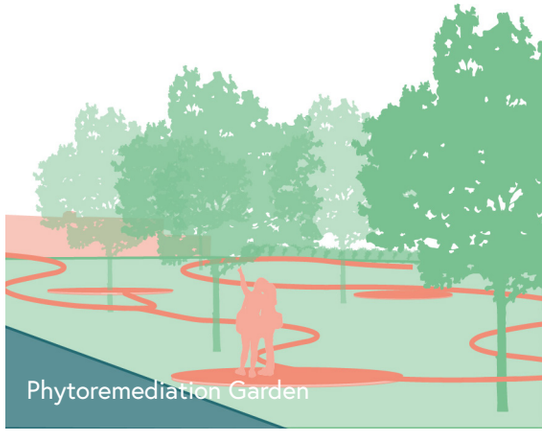

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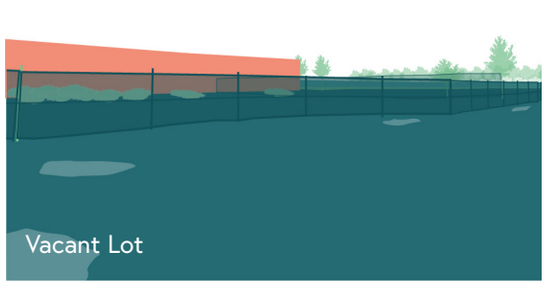

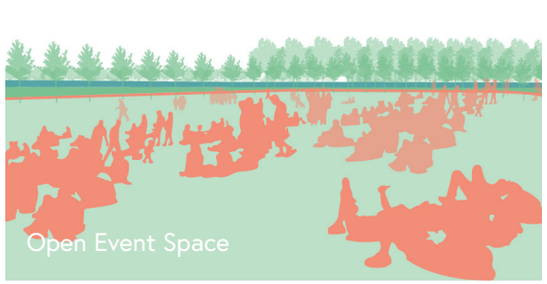

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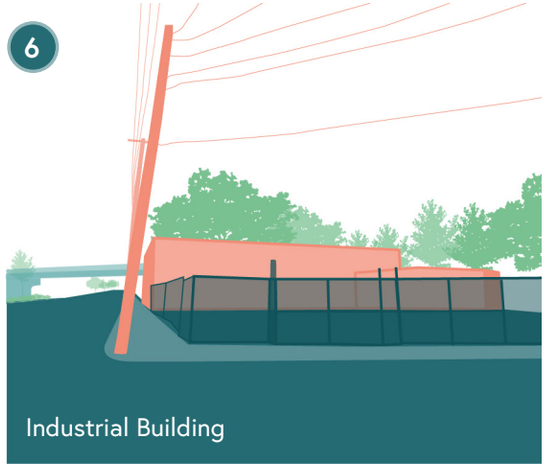

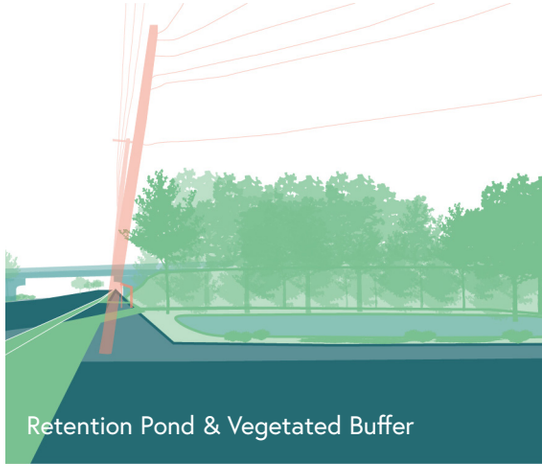

Figure. 5.34. Before & After Vignettes of Key Locations. (By Author 2024)

Long-Term Comprehensive Master Plan

Collier Point Park

Providence River Boat House

Educational Center

Phytoremediation Garden

Upper South Providence

Food Hub

Urban Farming

Food Production

Vegetation Buffer
& Retention Pond

South Providence
Entry Plaza

Lower South Providence

River Access

Living Breakwater

Coastal Wetland

Linear Park

Promenade

High Marsh Planting

Nature Preserve

Providence River

Key

1. Recreation Fields
2. Kayak Launch Point
3. Food Court
4. Food Truck Market Space
5. Open Event Space
6. Playground

site boundaries

N 0' 375' 750' 1,500'

Figure. 5.35. Long-Term Comprehensive Master Plan. (By Author 2024)

ACCESSIBILITY & CONNECTION

SUSTAINABLE REDEVELOPMENT

Site Sections

Oxford and Public Street serve as connection points from the South Providence neighborhoods to the project site. Within the proposed design, they provide direct access to the Providence River through a series of green streets and promenades that extend over the coastal wetlands (see Figure 5.38). Oxford Street starts in the Lower South Providence neighborhood and cuts through the interior food production for residents and a community garden for individual and community plots. Oxford Street also provides shore access to the coastal wetlands and the Linear Park along the coastline (see Figure 5.36). Public Street also provides shore access from Upper South Providence and opportunities for more active marine recreation, such as kayaking and fishing (see Figure 5.37).

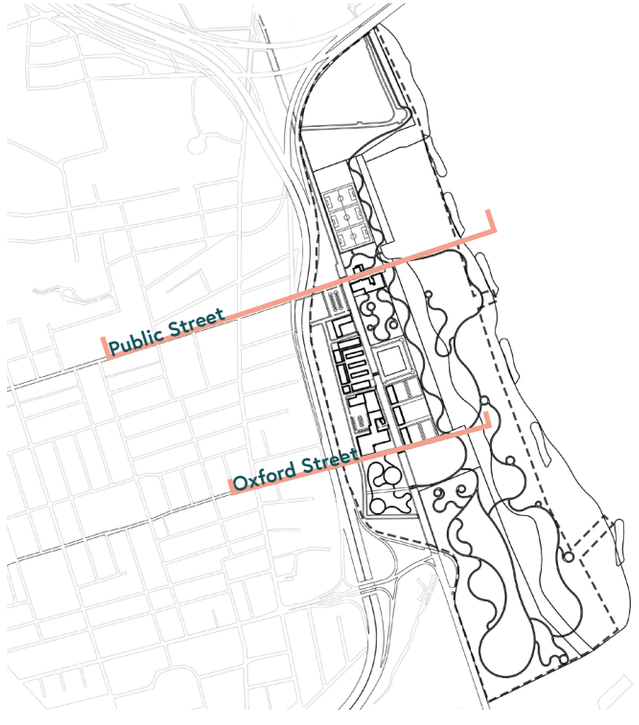

Figure. 5.38. Long-Term Sections Key Map. (By Author 2024)

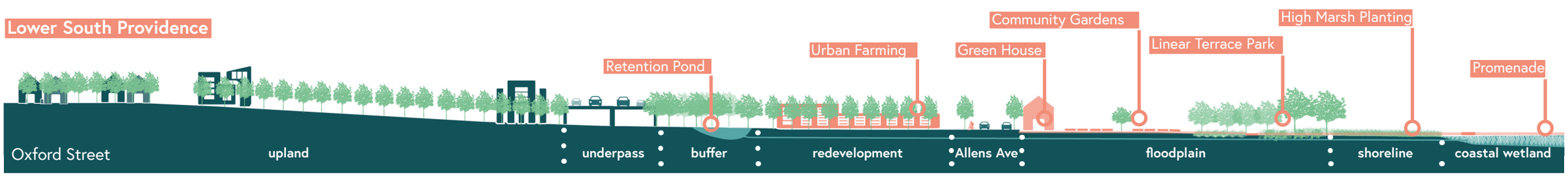

Figure. 5.36. Oxford Street Connection. (By Author

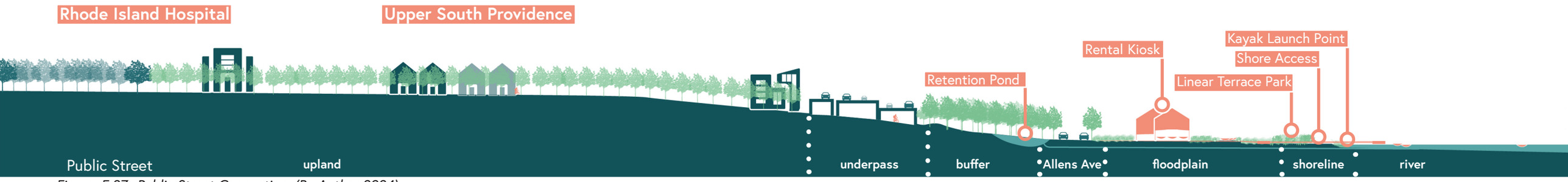

Figure. 5.37. Public Street Connection. (By Author 2024)

Coastal Flood Protection & Filtration

The coastal strategies work in tandem to achieve climate change resiliency, coastal flood protection, and ecosystem services (see Figure 5.39). The coastline is resilient to climate change as it grows along with rising sea levels. The living breakwater incorporates an oyster reef made from old shells that young larvae attach to and build upon one another to create a growing breakwater. The vegetation in the marsh and wetlands collects sediments from the water, and as it builds up, the shore and vegetation grow with it. These design strategies create different levels of barriers for flood protection, with the living breakwater being the first line of defense, followed by the coastal wetland and high marsh areas. This coastal area is designed to withstand high and extreme flooding events through stormwater mitigation by native planting and acting as a giant sponge. Finally, the coastline improves the ecosystem performance by providing habitat in intertidal pools, oyster reefs, and within native wetland planting. It also improved the coast's natural function to filtrate water by collecting sediments and holding water as the tide moves in and out of the shore.

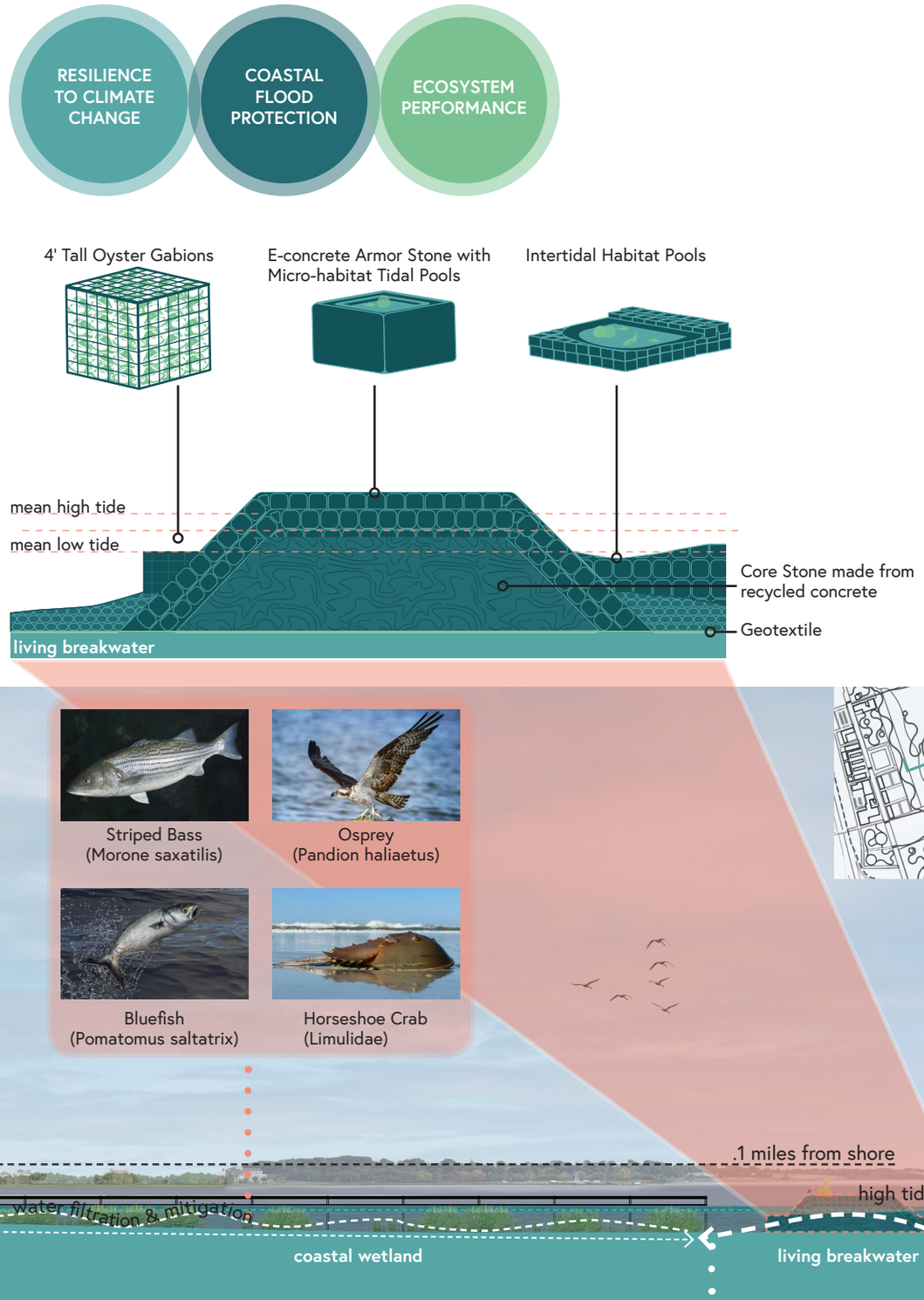

Figure. 5.39. South Providence Shoreline Section. (By Author 2024)

Catalyst Site Design Set

The catalyst site is broken down into three stages of development using different combinations of coastal brownfield design strategies. The first phase focuses on cleaning up the site and its public perception by creating a connection between Lower South Providence and the riverfront. The strategies used in this phase include pollution elimination, site clean-up, stigma, and the beginning stages of phytoremediation. Coastal wetlands and open green space are used to begin the stages of redevelopment. The second phase focuses on creating a community space for events and environmental remediation. The strategies build upon the phase by introducing high marsh planting and more native plants to continue the phytoremediation process. The third phase aims to be an ecologically restored site that provides the community with established restoration design strategies. The design and strategies in these phases spread into the surrounding area, spurring a larger long-term ecological restoration redevelopment.

Coastal Brownfield Design Strategies

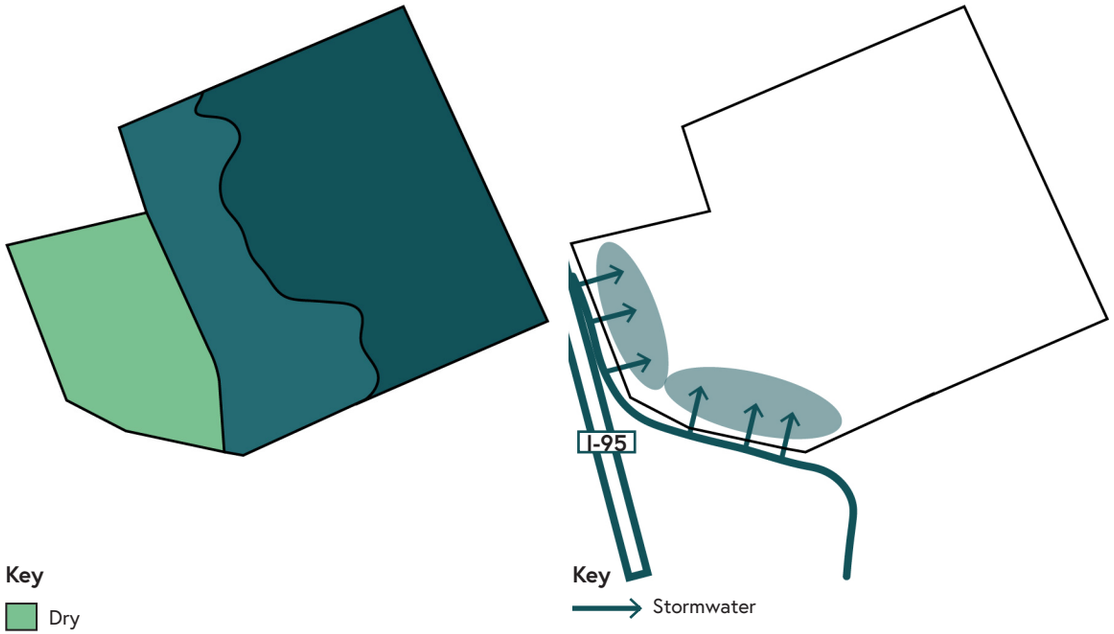

Figure. 5.40. Flooding Diagram. (By Author 2024)

Figure. 5.41. I-95 Interaction Diagram. (By Author 2024)

Like the expansion site, the catalyst site contains relatively dry areas, areas within the floodplain, and areas that will be underwater due to sea level rise. The hardscape development will focus on the dry areas, while the wet zone will consist of water-loving native plantings and floodable programming (see Figure 5.40). The project site is vulnerable to stormwater runoff from I-95 and its onramp from Allens Ave, creating areas for water to collect. The flooding is addressed, and those areas are used as a barrier between the site and the highway (see Figure 5.41).

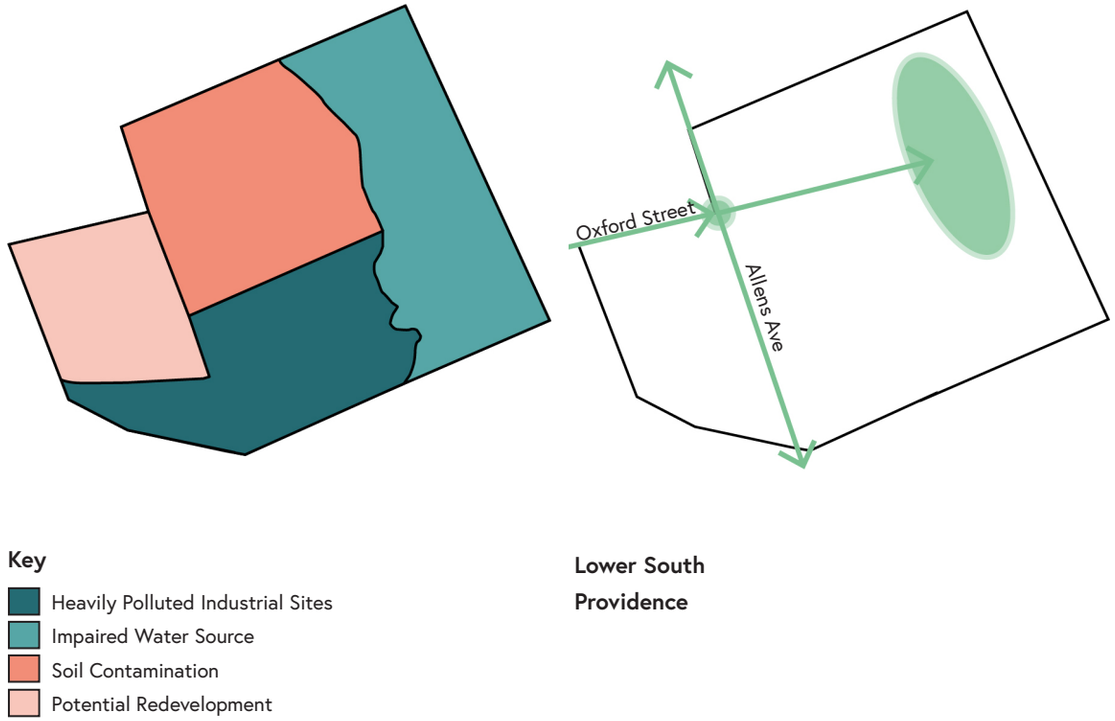

Figure. 5.42. Soil Clean Up Diagram. (By Author 2024)

Figure. 5.43. Entry into Site Diagram. (By Author 2024)

The site's contamination is looked at in more depth in this area. The catalyst design will address impaired water, contaminated soil, and highly contaminated land due to heavy industrial use (see Figure 5.42). Finally, the connection from the surrounding context serves as a way to incentivize residents to visit and use the site. For example, Oxford Street leads straight to the Providence River and creates the connection between Lower South Providence and the riverfront (see Figure 5.43).

Short-Term Site Plan Phase One

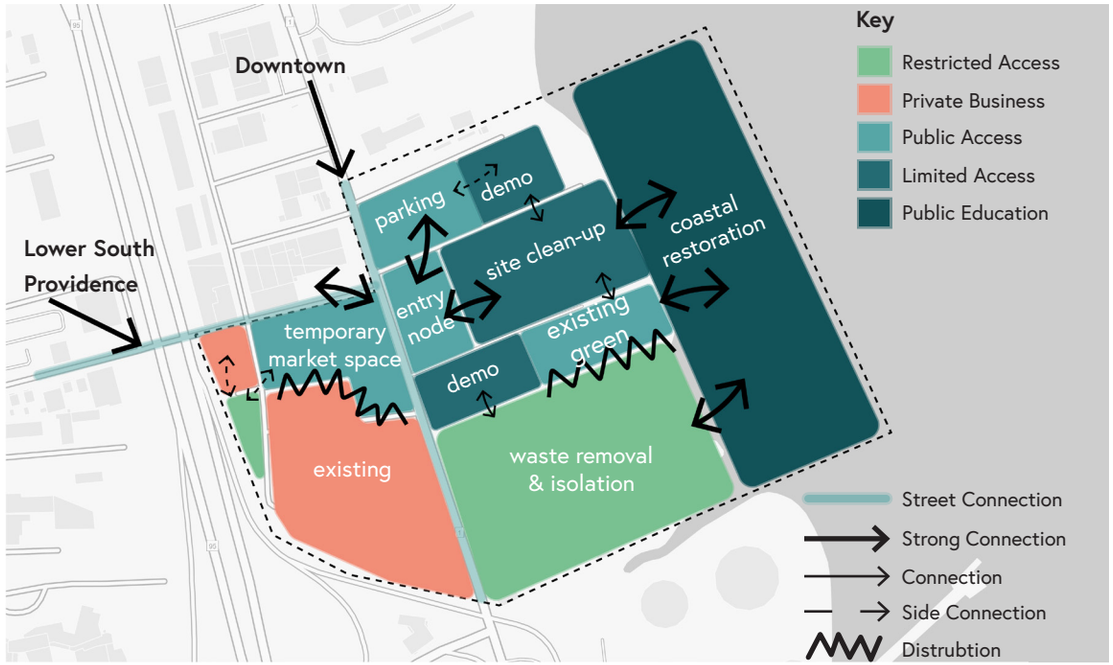

Figure. 5.44. Phase one Programming. (By Author 2024)

The beginning phase focuses on cleaning up the trash, waste, pollutants, scraps, and abandoned structures and buildings that industries have abandoned. Areas with heavy industrial contamination and heavily vegetated areas are isolated from the public to allow for the safe removal of pollutants and hazardous waste. The plan provides for the coexistence with the existing businesses by creating a buffer between them and redevelopment. Areas accessible to the public are parking and open green space along the riverfront. Some temporary programs that entice the community to visit the space include an open-air market space and a rental kiosk for boating and fishing gear. The demolition and site clean-up have limited access to the public for their health and safety. The community is involved with the initial coastal wetland planting as an educational program (see Figures 5.44 & 5.45).

Figure. 5.45. Phase one Site Plan. (By Author 2024)

Short-Term Site Plan Phase Two

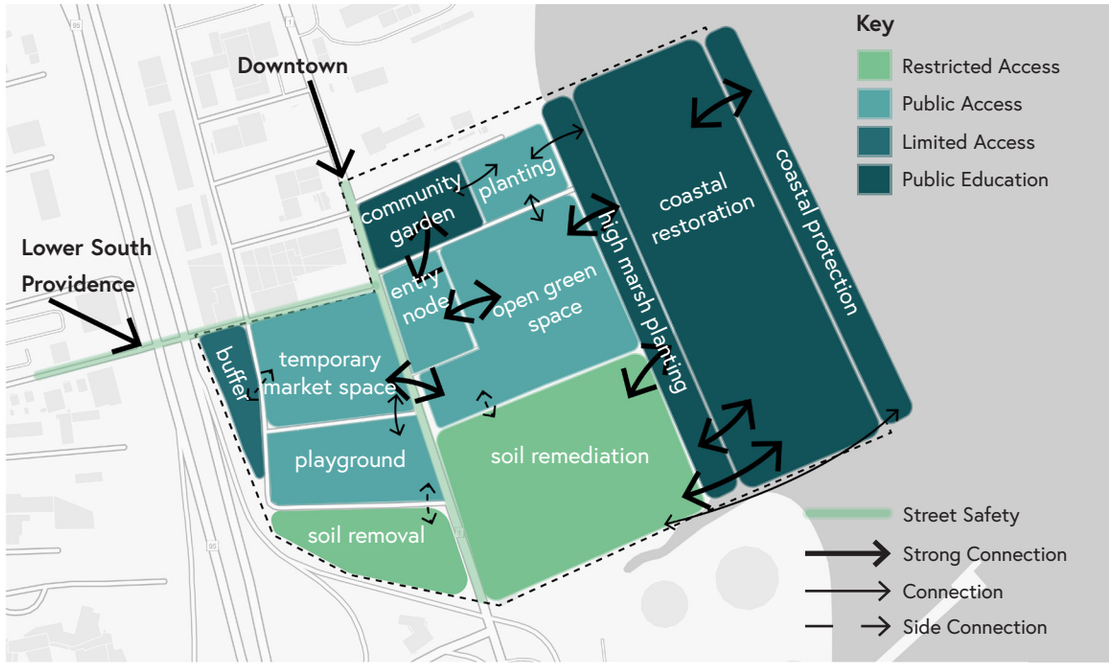

Figure. 5.46. Phase Two Programming. (By Author 2024)

In phase two, the design strategies implemented on the site are becoming more established and producing restoration benefits. This phase is a transition between the existing infrastructure and ecological restoration. More native planting is introduced in the phytoremediation process to continue soil remediation of the heavily polluted site. The contaminated soil from the existing southernmost industrial building is removed. There is an increase in community spaces accessible to the public, including nature play, increased open green space for large gatherings, and native plantings. Community gardens are introduced to teach and provide opportunities for the community to grow their food. High marsh plantings and the integration of living breakwaters are implemented to educate the public on coastal food protection and other natural functions. A large, vegetated buffer creates a noise and stormwater protection barrier from I-95 (see Figures 5.46 & 5.47).

Figure. 5.47. Phase Two Site Plan. (By Author 2024)

Short-Term Site Plan Phase Three

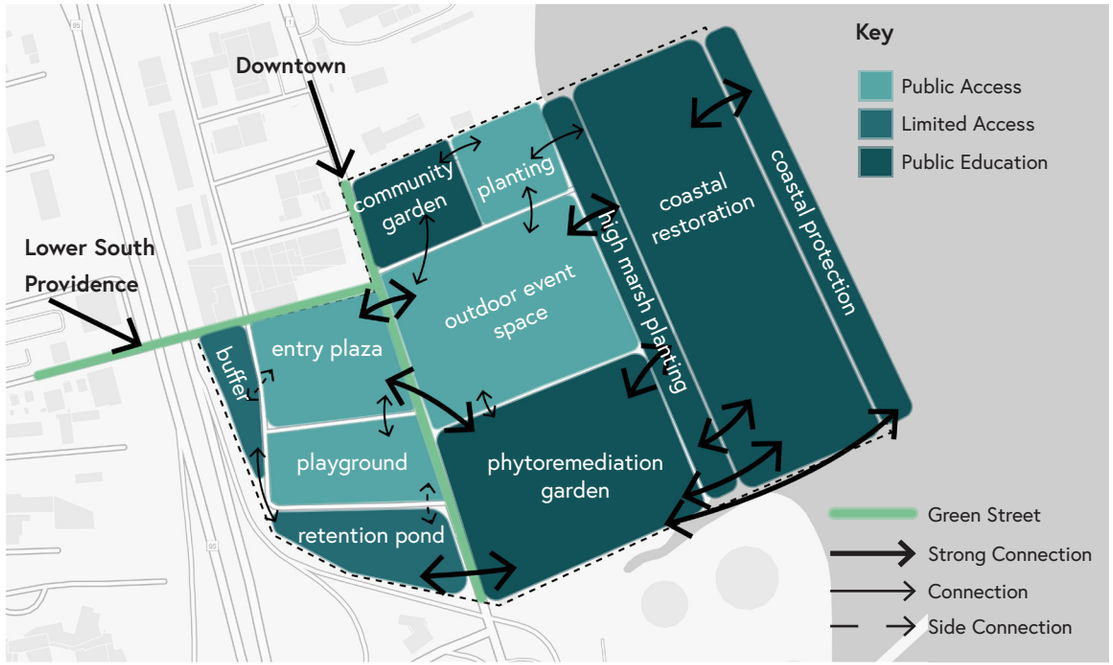

Figure. 5.48. Phase Three Programming. (By Author 2024)

The final phase includes fully established coastal brownfield restoration strategies, directly benefiting Lower South Providence residents and surrounding neighborhoods. The public can access the phytoremediation via a raised promenade that weaves through the garden and continues into a nature preserve. The playground extended into a larger entry plaza for the South Providence community to gather for events. The native plantings are more accessible to visitors as they transition into a linear park that extends north along the coastline. The community garden includes solar panels to provide energy for the development of the surrounding area. The raised promenade connects the community to the reconstructed coastline as well as the other programming of the site. Finally, a series of retention ponds are included in the vegetated buffer to filter stormwater from I-95 (see Figures 5.48 & 5.49).

Figure. 5.49. Phase Three Site Plan. (By Author 2024)

ACCESSIBILITY & CONNECTION

SUSTAINABLE REDEVELOPMENT

Allens Ave Phases

Figure. 5.50. Oxford Street Perspective. (By Author 2024)

With each phase, pedestrian safety is increased on Allens Ave for enhanced community access. The first phase focuses on creating a connection to Lower South Providence by improving the sidewalks, adding a street tree buffer that continues on Oxford Street (see Figure 5.50), and painting the bike lane green on Allens Ave for a more defined separation between motor vehicles. Oxford Street serves as the connection from the Lower South Providence neighborhood to the site. The streetscape and underpass design are replicated for the other connecting streets. In the second phase, pedestrian safety increases from car-slowing infrastructure, including raised crosswalks and buffer plantings. In the final phase, planting beds extend into the road to create a buffer for bicyclists and pedestrians from motorists. The buffer limits the street into two lanes and encourages motorists to drive at a reduced speed. There are also designated bus lanes in front of bus stops, and bike lanes travel behind them for increased safety (see Figure 5.51).

Figure. 5.51. (Right) Allens Ave Perspectives. (By Author 2024)

RESILIENCE TO CLIMATE CHANGE

COASTAL FLOOD PROTECTION

ECOSYSTEM PERFORMANCE

Plant Palette

The plants selected are all native to Rhode Island and are beneficial in coastal brownfield remediation (see figure 5.52). Phase one aims to include plants that are effective in the beginning stages of phytoremediation for uplands and wetlands. Red fescue helps prevent metals from reaching the surface and being exposed (Kennen & Kirkwood 2015, 140). Perennial rye and Indian mustard absorb toxic metals by their roots during the phytoextraction phase in phytoremediation. Common rush is used in the phytovolatilization process and takes ammonium and methane from the soil, transforms them into less hazardous chemicals, and releases them into the atmosphere (Kafle et al. 2022). Salt marsh cordgrass cycles nutrients and pollutants while holding in shoreline soil to reduce erosion (Czakó et al. 2006).

Phase two introduces sunflowers, willows, and marsh mallow that are used in the phytostabilization phase of phytoremediation which, limits the mobility and bioavailability of the contaminated through root stabilization and lowers the hazardous impacts (Kafle et al. 2022). Marsh elder is used as a transitional planting in the high marsh between the uplands and the wetlands, providing erosion control and habitat (Miller et al. 2002). Pickerel weed is used in wetlands to absorb pollutants and excess nutrients in the soil and water (WTrautmannKSCBio 2016).

The final phase includes honeysuckle, which extracts salt from the soil during phytodesalination, and poplar trees to continue the phytovolatilization phase for upland phytoremediation (Kafle et al. 2022). Finally, sea lavender adds more visual interest with its colorful foliage and ability to absorb any heavy metals still in the soil (Angelova 2015).

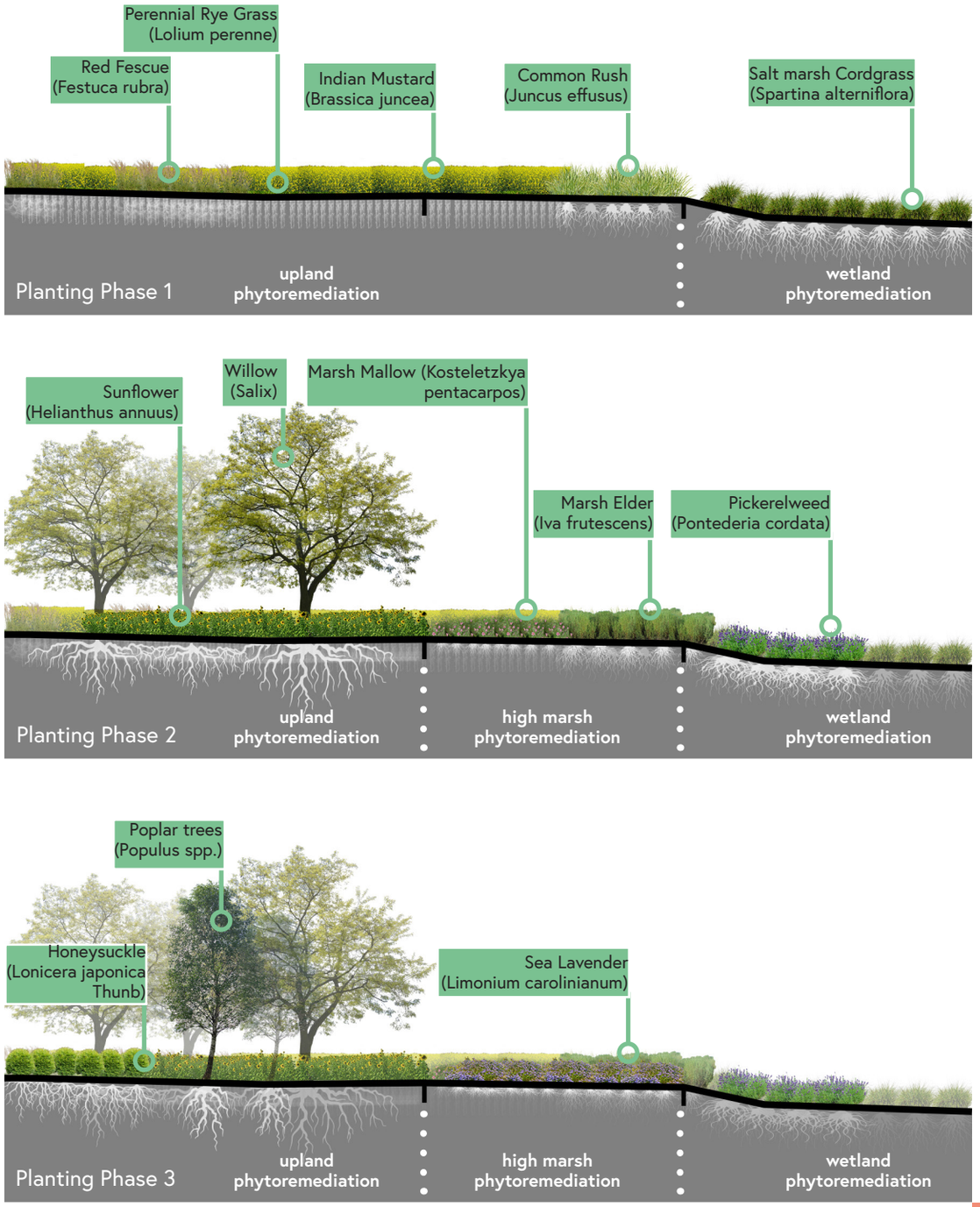

Figure. 5.52. (Right) Planting Plan Phases. (By Author 2024)

Chapter 06
Conclusion

Summary of Results

This research aimed to answer the question of how urban coastal brownfields can be ecologically restored. Projects such as this one require combinations of strategies to achieve a productive coastal landscape for the surrounding environment and communities. The strategies implemented within the design work together to achieve resiliency to climate change, coastal flood protection, enhanced ecosystem performance, accessibility & connectivity, and sustainable redevelopment. Using South Providence as the case for this study allowed the center to be on issues typical to coastal brownfields in post-industrial cities. The literature review identified common problems created by abandoned brownfields as well as nature-based and infrastructural solutions. Using the found information typical of coastal brownfields, the methodology was developed to identify the significant problems caused by the coastal brownfields in the port of South Providence. It also determined which ecological restoration design strategies were suitable for the specific project site.

During the research phase, literature and document analysis were used to answer Sub Question One: Why should urban coastal brownfields be cleaned up, remediated, and re-established ecologically? The literature outlined a coastal brownfield's detrimental impacts on a community and its natural environment. Alongside the effects, the literature included examples of remediation and redevelopment strategies that create economic, social, and environmental benefits. By cleaning, remediating, and re-establishing coastal brownfields ecologically, the coastal areas and communities become resilient to climate change, coastal flooding, and other natural phenomena while being protected from industrial contamination and hazardous waste.

The results from the coastal brownfield expert surveys answered Sub Question Two: How can urban coastal brownfields be ecologically restored in a short-term as well as long-term perspective? Different strategies are necessary for short-term restoration versus long-term restoration. These strategies can transition from one phase to the next. The beginning phases of a site-scale project are more intensive, with soil and water remediation strategies necessary to begin ecological restoration. The long-term phases in an urban-scale project require combinations of ecological strategies that are established and stable due to implementation in earlier stages. Using engineering strategies as well as ecological strategies is essential in any coastal restoration project with sea level rise and increased storm events. The local expert interviews provided knowledge of what strategies would be realistic in South Providence, both short-term and long-term coastal restoration.

The results from the first two sub-questions aided in developing the Framework of Design Strategy. This framework was used to inform the design decisions made within the design phase. With the support from the framework, the design phase answered Sub Question Three: What brownfield restoration strategies are plausible in urban coastal zones such as the Providence Port area? Site analysis summarized the coastal restoration and brownfield redevelopment opportunities and constraints. Mapping the opportunities and constraints established the issues that need to be addressed and the restoration strategies suitable for the catalyst and expansion sites. The precedent studies consisted of projects with contexts similar to those of the South Providence port area that focused on ecological restoration. The strategies used in these projects determine which would suit the project based on their success and the type of benefits produced.

Finally, the projective design answers the overarching question of how urban coastal brownfields can be ecologically restored through a series of design works. The design goals and strategies for the projective design were established based on the outcomes from the previous methods. The design identifies and addresses the major dilemmas within the site through ecological design strategies for coastal brownfields. The long-term site includes several redevelopment strategies used in tandem to create an ecologically productive and cohesive riverfront for the community. The short-term site focuses on the different phases of an ecological restoration on a site-scale and how those strategies extend into the surrounding area. This included the various stages of planting, remediation strategies, and street connectivity. The design works show that urban coastal brownfields can be ecologically restored, but they require the support of long-term urban design practices and coastal protection infrastructure.

Discussion & Limitations

The project aims to create a multi-phase comprehensive design with short-term and long-term ecological restoration solutions, complete design work for coastal brownfield restoration, and a published Master's Project Report. The main takeaway from the research is that restoring coastal brownfields into an ecologically healthy landscape is complex and intensive. The responsibility of coastal remediation does not fall onto one discipline but needs the constant collaboration and discussion of others. Another conclusion is that other coastal protection measures must be combined with ecological restoration as sea levels rise and storm events become more frequent. There is not one overall solution to coastal brownfield restoration, and ecological design strategies must be used parallel to support and enhance their effectiveness.

The most significant limitation of the research was the timeframe given to complete the report. The research and design phase had to be completed within less than two semesters. The number of issues on the site leads to another limitation of what the design could feasibly address. Brownfields, especially in coastal areas, cause many problems that delve into areas beyond the scope of landscape architecture, such as traffic engineering, highway design, contaminate removal, and even environmental engineering. While insight from experts in those fields would be helpful, these areas were mentioned within the design but could not be discussed in depth. Another limitation of the report was the sample sizes for the coastal brownfield expert survey and local expert surveys. Both methods had selection criteria that limited the population number. For the surveys, links would only be sent to United States professionals specializing in coastal brownfield restoration and redevelopment. The interviews were only conducted with local design professionals with a personal understanding and knowledge of the site. The site is in an area with a low feeling of safety and is unwelcome to visitors due to the nature of the businesses. The site encompasses private businesses or areas fenced off from the public. With limited site access, programs such as Google Earth Pro and the Rhode Island and Providence GIS database were used to compensate for the lack of on-site knowledge.

Contribution to Future Research

The Master's Project Report contributes to the conversations of coastal brownfield restoration, coastal protection, and climate change impacts on urban coastlines. While serving as a potential ecological restoration solution for the port of South Providence, the research and design phase findings can serve as a precedent for similar coastal brownfield projects. The Master's Project Report can be used to further future research and real-life applications in urban coastal brownfield projects.

Future Research

This research can contribute to the discussion of the ecological restoration of coastal brownfields and be utilized as a reference for other designers and planners. Restoring brownfields in urban coastal zones is a growing topic, and more cities are involved in city-wide restoration projects that can catalyze continued coastal restoration projects. The Framework of Design Strategy is a comprehensive matrix of coastal brownfield strategies informed by relevant literature. The framework can be used for future research on approaching restoration in multiple phases and site scales. For example, the framework can be applied to future research topics focusing on short to long-term restoration projects on small to large-scale sites. It can also address different areas that require different restoration benefits for their particular community.

Application

The report will be shared with the community based on connections to professionals in relevant fields in Providence. Landscape architects, city planners, and urban designers can apply the research paper's findings to their projects with similar contexts. The research and design phase findings are typical of coastal brownfields in urban port zones. The methodology used throughout the research project can be applied to other coastal brownfield projects to identify the key issues harming the environment and the surrounding communities. The conceptual nature of the projective design allows for the ecological restoration strategies to be adaptable and respond to the unique problems of contaminated industrial waterfronts.

References

Angelova, Violina. 2015. "Potential of Lavender (Lavandula Vera L.) for Phytoremediation of Soils Contaminated with Heavy Metals." *Int J Biol Biomol Agric Food Biotechnol Eng* 9 (January).

Barbier, Edward B., Evamaria W. Koch, Brian R. Silliman, Sally D. Hacker, Eric Wolanski, Jurgenne Primavera, Elise F. Granek, et al. 2008. "Coastal Ecosystem-Based Management with Nonlinear Ecological Functions and Values." *Science* 319 (5861): 321–23.

Bardos, Paul, Kate L. Spencer, Raymond D. Ward, Barbara H. Maco, and Andrew B. Cundy. 2020. "Integrated and Sustainable Management of Post-Industrial Coasts." *Frontiers in Environmental Science 8*. https://www.frontiersin.org/articles/10.3389/fenvs.2020.00086.

Barnett, Aaron A. 2010. "Coastal Brownfields and Adaptation To Climate Change: Discussions On Potential Hazards From Contaminated Groundwater Displacement Due To Saltwater Incursion."

Bayraktarov, Elisa, Shantala Brisbane, Valerie Hagger, Carter S. Smith, Kerrie A. Wilson, Catherine E. Lovelock, Chris Gillies, Andrew D. L. Steven, and Megan I. Saunders. 2020. "Priorities and Motivations of Marine Coastal Restoration Research." *Frontiers in Marine Science 7*. https://www.frontiersin.org/articles/10.3389/fmars.2020.00484.

Bayraktarov, Elisa, Megan I. Saunders, Sabah Abdullah, Morena Mills, Jutta Beher, Hugh P. Possingham, Peter J. Mumby, and Catherine E. Lovelock. 2016. "The Cost and Feasibility of Marine Coastal Restoration." *Ecological Applications* 26 (4): 1055–74. https://doi.org/10.1890/15-1077.

Betancourt, Frances. 2002. "The Creation of India Point Park."

Binder, Andrew E., Selim Suner, H. Curtis Spandling, and Erich Osterberg. 2021. "Providence's Vulnerability to Floods: Impacts of Sea Level Rise, Stronger Storms, and Heavier Rainfall." *Rhode Island Medical Journal* 104 (9): 60–62.

Bishop, Cheryl Ann. 2023. "Cleaning up: Cleanup of Shoreline and Sediment Moving Forward for Seattle's Gas Works Park." 2023. https://ecology.wa.gov/blog/june-2023/cleaning-up-cleanup-of-shoreline-and-sediment-moving-forward-for-seattle-s-gas-works-park.

Boström, Christoffer, Simon J. Pittman, Charles Simenstad, and Ronald T. Kneib. 2011. "Seascape Ecology of Coastal Biogenic Habitats: Advances, Gaps, and Challenges." *Marine Ecology Progress Series* 427 (April): 191–217. https://doi.org/10.3354/meps09051.

Carini, Frank. 2019. "Providence's Toxic Avenue Leads to Neighborhood Problems." *ecoRI News* (blog). April 22, 2019. https://ecori.org/2019-4-22-toxic-avenue-leads-to-ignored-neighborhood-problems/.

Czakó, Mihály, Xianzhong Feng, Yuke He, Dali Liang, and László Márton. 2006. "Transgenic Spartina Alterniflora for Phytoremediation." *Environmental Geochemistry and Health* 28 (1–2): 103–10. https://doi.org/10.1007/s10653-005-9019-8.

Department of Ecology. 2023. "Gas Works Park - (2876)." 2023. https://apps.ecology.wa.gov/cleanupsearch/site/2876.

Elphick, Omay. 2006. "From Landfill to Landmark: Save the Bay Center." 2006. https://19january2017snapshot.epa.gov/sites/production/files/2014-03/documents/savethebayfull1.pdf.

EPA. 2016. "Bringing Clean Energy to an Abandoned Waterfront."

———. 2017. "The Building of The Save The Bay Center." 2017. https://19january2017snapshot.epa.gov/sites/production/files/2014-03/documents/savethebayhistory1.pdf.

Fanelli, Emanuela, Antonio Dell'Anno, Ettore Nepote, Marco Lo Martire, Luigi Musco, Silvia Bianchelli, Cristina Gambi, et al. 2023. "Positive Effects of Two Decades of Passive Ecological Restoration in a Historically Polluted Marine Site." *Frontiers in Marine Science*, July. https://doi.org/10.3389/fmars.2023.1199654.

Friends Of India Point Park. n.d. "Friends Of India Point Park – Promote, Protect, and Improve the Park as an Informal, Natural Open Space." Accessed February 2, 2024. http://www.friendsofindiapointpark.org/.

Goodwin, Robert F. 1999. "Redeveloping Deteriorated Urban Waterfronts: The Effectiveness of U.S. Coastal Management Programs." *Coastal Management* 27 (2–3): 239–69. https://doi.org/10.1080/089207599263857.

Hollander, Justin, Niall Kirkwood, and Julia Gold. 2010. *Principles of Brownfield Regeneration: Cleanup, Design, and Reuse of Derelict Land*. Washington, D. C., UNITED STATES: Island Press. http://ebookcentral.proquest.com/lib/ksu/detail.action?docID=3317506.

Kafle, Arjun, Anil Timilsina, Asmita Gautam, Kaushik Adhikari, Anukul Bhattarai, and Niroj Aryal. 2022. "Phytoremediation: Mechanisms, Plant Selection and Enhancement by Natural and Synthetic Agents." *Environmental Advances* 8 (July): 100203. https://doi.org/10.1016/j.envadv.2022.100203.

Kennen, Kate, and Niall Kirkwood. 2015. *Phyto: Principles and Resources for Site Remediation and Landscape Design*. Routledge.

Levi, Daniel, and Sara Kocher. 2006. "The Use of Coastal Brownfields as Nature Preserves." *Environment and Behavior* 38 (6): 802–19. https://doi.org/10.1177/0013916505285217.

Lewis, Greg. n.d. "Brown to Green: Sustainable Redevelopment of America's Brownfield Sites."

Miller, Christopher, PMS-Southern Ne, and William Skaradek. 2002. "Marsh Elder."

NOAA. 2015. "Guidance for Considering the Use of Living Shorelines." https://cdn.coastalscience.noaa.gov/projects-attachments/311/noaa_guidance_for_considering_the_use_of_living_shorelines_2015.pdf.

———. 2022. "Understanding Living Shorelines | NOAA Fisheries." NOAA. National. October 12, 2022. https://www.fisheries.noaa.gov/insight/understanding-living-shorelines.

O'Connor, David, Xiaodi Zheng, Deyi Hou, Zhengtao Shen, Guanghe Li, Guofang Miao, Shannon O'Connell, and Miao Guo. 2019. "Phytoremediation: Climate Change Resilience and Sustainability Assessment at a Coastal Brownfield Redevelopment." *Environment International* 130 (September): 104945. https://doi.org/10.1016/j.envint.2019.104945.

Powell, Emily J., Megan C. Tyrrell, Andrew Milliken, John M. Tirpak, and Michelle D. Staudinger. 2019. "A Review of Coastal Management Approaches to Support the Integration of Ecological and Human Community Planning for Climate Change." *Journal of Coastal Conservation* 23 (1): 1–18. https://doi.org/10.1007/s11852-018-0632-y.

Providence Working Waterfront Alliance. n.d. "History - Providence Working Waterfront Alliance." Accessed September 17, 2023. https://providenceworkingwaterfront.org/index.php/providences-working-waterfront/history/.

Rubinoff, Pam, Megan Elwell, Sue Kennedy, and Noah Hallisey. 2021. "Towards a Resilient Providence." 2021. https://providenceresilience.org/wp-content/uploads/2022/05/Towards-a-Resilient-Providence_PRP_March2021-1.pdf.

Seavitt Nordenson, Catherine., Guy. Nordenson, and Julia. Chapman. 2018. "Designing for Coastal Resiliency." *In Structures of Coastal Resilience*, 1st ed. 2018., 1–10. Washington, DC: Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-859-6.

SER. 2004. "The SER International Primer on Ecological Restoration." https://cdn.ymaws.com/www.ser.org/resource/resmgr/custompages/publications/ser_publications/ser_primer.pdf.

Song, Jae Min. 2015. "Landfill Recovery Project : Transformation of Landfill to Ecological Park." Seoul Solution. June 20, 2015. https://seoulsolution.kr/en/content/landfill-recovery-project-transformation-landfill-ecological-park.

Song, Yinan, Niall Kirkwood, Čedo Maksimović, Xiaodi Zheng, David O'Connor, Yuanliang Jin, and Deyi Hou. 2019. "Nature Based Solutions for Contaminated Land Remediation and Brownfield Redevelopment in Cities: A Review." *Science of The Total Environment* 663 (May): 568–79. https://doi.org/10.1016/j.scitotenv.2019.01.347.

State of Rhode Island. 2021. "2022 Impaired Waters Report." 2021. https://dem.ri.gov/sites/g/files/xkgbur861/files/2022-08/iwr22.pdf.

Statistical Atlas. 2020. "The Demographic Statistical Atlas of the United States - Statistical Atlas." 2020. https://statisticalatlas.com/neighborhood/Rhode-Island/Providence/Lower-South-Providence/Overview.

Strain, Elisabeth M. A., Celia Olabarria, Mariana Mayer-Pinto, Vivian Cumbo, Rebecca L. Morris, Ana B. Bugnot, Katherine A. Dafforn, et al. 2018. "Eco-Engineering Urban Infrastructure for Marine and Coastal Biodiversity: Which Interventions Have the Greatest Ecological Benefit?" *Journal of Applied Ecology* 55 (1): 426–41. https://doi.org/10.1111/1365-2664.12961.

Temmerman, Stijn, Patrick Meire, Tjeerd J. Bouma, Peter M. J. Herman, Tom Ysebaert, and Huib J. De Vriend. 2013. "Ecosystem-Based Coastal Defence in the Face of Global Change." *Nature* 504 (7478): 79–83. https://doi.org/10.1038/nature12859.

UNEP. 2016. "Options for Ecosystem-Based Adaptation in Coastal Environments." https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/options_for_ecosystem_based_adaptation_in_coastal_environments_low-res.pdf.

U.S. Department of Commerce. 2003. "Portfields: Revitalizing Port Communities."

USDA. 2023. "USDA ERS - Go to the Atlas." 2023. https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas/.

Way, Thaïsa. 2013. "Landscapes of Industrial Excess: A Thick Sections Approach to Gas Works Park." *Journal of Landscape Architecture* 8 (1): 28–39. https://doi.org/10.1080/18626033.2013.798920.

WTrautmannKSCBio. 2016. "Pickerelweed, Pontederia Cordata." *William Trautmann E-Port* (blog). December 15, 2016. https://wtrautmannkscbio.wordpress.com/2016/12/14/pickerelweed-pontederia-cordata/.

Zheng, Xiaodi, and Niall G. Kirkwood. 2020. "Chapter 12 - Landscape Architecture and Sustainable Remediation." In *Sustainable Remediation of Contaminated Soil and Groundwater*, edited by Deyi Hou, 301–24. Butterworth-Heinemann. https://doi.org/10.1016/B978-0-12-817982-6.00012-4.

Image Sources

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- Buttersworth, James. *A Ship's Portrait Near Sandy Hook*. 1817-1894. Oil on canvas. Accessed September 17, 2023. 51308-James E Buttersworth-A Ship's Portrait near Sandy Hook.jpg
- Colonial Rhode Island: *Landing at Providence, Rhode Island*. Print. N.d. Accessed September 17, 2023. http://ushistoryimages.com/colonial-rhode-island.shtm.
- Killinger, Mary Katheryn. *Port of Providence*. Photograph. 2023.
- Killinger, Mary Katheryn. *Port of Providence Sign*. Photograph. 2023.
- *Rumford Chemical Works*. Print. 1886. Accessed September 17, 2023. http://resourcesforhistoryteachers.pbworks.com/w/page/125440676/Consequences%20of%20the%20Industrial%20Revolution
- *Untitled photograph of Boston and Providence Railroad*. Photograph. 1913. Accessed September 17, 2023. https://sites.google.com/site/rrstationsofprovidence/home
- U.S. Army Corps of Engineers. *The Completed Fox Point Hurricane Barrier in March 1966*. Photograph. 1966. Accessed September 17, 2023. https://www.researchgate.net/figure/The-completed-Fox-Point-Hurricane-Barrier-in-March-1966-Providence-RI-Photo-taken-by_fig1_348027152.
- *View of Providence Harbor 1898*. Photograph. 1898. Accessed September 17, 2023. http://www.usgwarchives.net/ri/providence.html

Chapter 2

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- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

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- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- EnviroMapper. *Water Dischargers*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- FEMA. *National Flood Hazard Layer*. Map Image Layer. Last updated on March 30, 2022. https://hazards.fema.gov/gis/nfhl/rest/services/FIRMette/NFHLREST_FIRMette/MapServer
- NOAA. *Sea Level Rise Viewer*. Shapefile. Last modified March 12, 2024. https://coast.noaa.gov/slr/#/layer/sce/2/-7948146.88075264/5132110.655983848/16/satellite/62/0.8/2050/high/midAccretion

Figure. 5.3. Killinger, Mary Katheryn. *Environmental Quality Map*. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- EnviroMapper. *Air Pollution*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- EnviroMapper. *Toxic Releases*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- Rhode Island Geographic Information System. *Soils*. Shapefile. Accessed September 28, 2023. https://www.rigis.org/datasets/78907d1430944b80a10fccb8093b2dc6_0/explore?location=41.806202%2C-71.388056%2C15.36v

Figure. 5.4. Killinger, Mary Katheryn. *Coastal Biodiversity and Ecology* Map. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- Rhode Island Geographic Information System. *Impervious Surface* (April 2020). Raster. Last updated January 30, 2024. https://risegis.ri.gov/imgserver/services/RIDEM/IMG_Impervious/ImageServer
- The National Conservancy. *Terrestrial Habitat U.S. and Canada*. Raster. Last updated on March 31, 2016. https://www.maps.tnc.org/nehabitatmap/

Figure. 5.5. Killinger, Mary Katheryn. *Abandoned Waste and Scraps from RI Recycled Metals*. Photograph. 2023.

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- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about

Figure. 5.10. Killinger, Mary Katheryn. *Land Use and Waterfront Use Map*. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about

Figure. 5.11. Killinger, Mary Katheryn. *Developments in South Providence Map*. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- EnviroMapper. *Brownfield*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- Providence Geographic Information System. *Providence Capital Improvement Plan Viewer*. Shapefile. https://pvdgis.maps.arcgis.com/apps/webappviewer/index.html?id=406291db606c45d995554786e2d4fe59
- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about

Figure. 5.12. Killinger, Mary Katheryn. *Social Environment Map*. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about

Figure. 5.13. Killinger, Mary Katheryn. *Coastal Restoration Constraints Map*. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- EnviroMapper. *Air Pollution*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- EnviroMapper. *Water Dischargers*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- FEMA. *National Flood Hazard Layer*. Map Image Layer. Last updated on March 30, 2022. https://hazards.fema.gov/gis/nfhl/rest/services/FIRMette/NFHLREST_FIRMette/MapServer
- NOAA. *Sea Level Rise Viewer*. Shapefile. Last modified March 12, 2024. https://coast.noaa.gov/slr/#/layer/sce/2/-7948146.88075264/5132110.655983848/16/satellite/62/0.8/2050/high/midAccretion
- Rhode Island Geographic Information System. *Soils*. Shapefile. Accessed September 28, 2023. https://www.rigis.org/datasets/78907d1430944b80a10fccb8093b2dc6_0/explore?location=41.806202%2C-71.388056%2C15.36v

Figure. 5.14. Killinger, Mary Katheryn. *Brownfield Redevelopment Constraints*. Map. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- EnviroMapper. *Brownfield*. Shapefile. Last updated on October 24, 2023. https://geopub.epa.gov/myem/efmap/index.html?ve=11,41.823834,-71.411980&pText=Providence,%20Rhode%20Island
- Providence Geographic Information System. *Providence Capital Improvement Plan Viewer*. Shapefile. https://pvdgis.maps.arcgis.com/apps/webappviewer/index.html?id=406291db606c45d995554786e2d4fe59

- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about

Figure. 5.15. Killinger, Mary Katheryn. *Coastal Restoration and Redevelopment Opportunities* Map. Map. 2024.

- Basemap: Esri Inc. ArcGIS Pro (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- Providence Geographic Information System. *Providence Capital Improvement Plan Viewer*. Shapefile. https://pvdgis.maps.arcgis.com/apps/webappviewer/index.html?id=406291db606c45d995554786e2d4fe59
- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about
- The National Conservancy. *Terrestrial Habitat U.S. and Canada*. Raster. Last updated on March 31, 2016. https://www.maps.tnc.org/nehabitatmap/

Figure. 5.16. Killinger, Mary Katheryn. *Catalyst Site Analysis Map*. Map. 2024.

- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- NOAA. *Sea Level Rise Viewer*. Shapefile. Last modified March 12, 2024. https://coast.noaa.gov/slr/#/layer/sce/2/-7948146.88075264/5132110.655983848/16/satellite/62/0.8/2050/high/midAccretion
- Providence Geographic Information System. *Providence GIS base data package*. Shapefile. Last updated on September 19, 2023. https://providence-gis-hub-pvdgis.hub.arcgis.com/datasets/b4486defc00f4001ab64a897ffce0438/about
- Rhode Island Geographic Information System. *Impervious Surface* (April 2020). Raster. Last updated January 30, 2024. https://risegis.ri.gov/imgserver/services/RIDEM/IMG_Impervious/ImageServer

Figure. 5.17. Killinger, Mary Katheryn. *Food Insecurity Map of South Providence Neighborhoods*. Map. 2024.

- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

Figure. 5.18. Killinger, Mary Katheryn. *Vehicle Accessibility*. Map. 2024.

- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.
- U.S. Department of Agriculture. *Low Vehicle Access*. Shapefile. Last updated on July 6, 2023. https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas/

Figure. 5.19. Burling, Timothy. *India Point Park*. Photograph. 2013. Accessed February 18, 2024. https://www.flickr.com/photos/tburling/9398434333/. CC BY 2.0 DEED.

Figure. 5.20. Wildcat Dunny. *Lake Union from Gas Works Park*. 2019. Accessed February 18, 2024. https://www.flickr.com/photos/wildcat_dunny/3581444939/. CC BY 2.0 DEED.

Figure. 5.21. Travel Oriented. *Seoul Eulalia Festival*. Photograph. 2013. Accessed February 18, 2024. https://www.flickr.com/photos/traveloriented/10362562235/. CC BY-SA 2.0 DEED.

Figure. 5.22. Killinger, Mary Katheryn. *Design Goals*. Diagram. 2024.

Figure. 5.23. Killinger, Mary Katheryn. *South Providence Neighborhoods Connection*. Map. 2024.

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- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

Figure. 5.26. Killinger, Mary Katheryn. Job Creation on South Providence Waterfront. Map. 2024.

- Basemap: Google Earth Pro. (2023). *South Providence, Rhode Island. 41°48'16.61"N, 71°24'11.38"W, elevation 0FT*. (Online). https://earth.google.com/web/@41.8056264,-71.39966625,-53940.00987289a,56871.04391115d,35y,0.0102h,0t,0r/data=OgMKATA. Accessed March 7, 2024.

Figure. 5.27. Killinger, Mary Katheryn. *Flooding Diagram. Diagram*. 2024.

Figure. 5.28. Killinger, Mary Katheryn. *I-95 Interaction Diagram*. Diagram. 2024.

Figure. 5.29. Killinger, Mary Katheryn. *Site Clean Up Diagram*. Diagram. 2024.

Figure. 5.30. Killinger, Mary Katheryn. *Entry into Site Diagram*. Diagram. 2024.

Figure. 5.31. Killinger, Mary Katheryn. *Extension Site Programming*. Diagram. 2024.

Figure. 5.32. Killinger, Mary Katheryn. *Map of Key Locations*. Map. 2024.

- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

Figure. 5.33. Killinger, Mary Katheryn. *Images of Key Locations*. Photographs. 2023.

Figure. 5.34. Killinger, Mary Katheryn. *Before & After Vignettes of Key Locations*. Digital Rendering. 2024.

Figure. 5.35. Killinger, Mary Katheryn. *Long-Term Comprehensive Master Plan*. Digital Rendering. 2024.

- Basemap: Google Earth Pro. (2023). *South Providence, Rhode Island. 41°48'16.61"N, 71°24'11.38"W, elevation 0FT*. (Online). https://earth.google.com/web/@41.8056264,-71.39966625,-53940.00987289a,56871.04391115d,35y,0.0102h,0t,0r/data=OgMKATA. Accessed March 7, 2024.

Figure. 5.36. Killinger, Mary Katheryn. *Oxford Street Connection*. Diagram. 2024

Figure. 5.37. Killinger, Mary Katheryn. *Public Street Connection*. Diagram. 2024.

Figure. 5.38. Killinger, Mary Katheryn. *Long-Term Sections Key Map*. Map. 2024.

Figure. 5.39. Killinger, Mary Katheryn. *South Providence Shoreline Section*. Digital Rendering. 2024.

- Base Image: Google Earth Pro. (2023). *Providence River Port Area. 41°48'20.00" N 71°23'54.17" W, elevation 0FT*. 3D Buildings data layer. (Desktop). https://earth.google.com/web/@41.83707202,-71.41596315,19.30518163a,3838.701448

24d,35y,-22.61437469h,90.03452199t,0r/data=OgMKATA . Accessed March 15, 2024.
- Adobe Stock. *Bluefish Jumps out of Water*. 3D Render. 2019. Accessed https://riverheadlocal.com/2019/12/15/where-have-all-the-bluefish-gone/. Accessed March 15, 2024.
- Allain, Larry. Kosteletzkya Pentacarpos. Photograph. n.d. Accessed March 15, 2024. https://warcapps.usgs.gov/PlantID/Species/Details/1083.
- Barette, Simon P. *Pontederia Cordata*. Photograph. n.d. Accessed March 15, 2024. https://plants.ces.ncsu.edu/plants/pontederia-cordata/.
- Buchsbaum, Robert. *Spartina Cynosuroides*. Photo. 2024. https://gobotany.nativeplanttrust.org/species/spartina/cynosuroides/.
- Chesapeake Bay Program. *Striped Bass*. Photograph. n.d. Accessed March 15, 2024. https://www.chesapeakebay.net/discover/field-guide/entry/striped-bass.
- Jauron, Vicki. *Untitled Photograph of an Osprey*. Photograph. n.d. Accessed March 15, 2024. https://www.treehugger.com/fascinating-facts-about-the-odd-but-awesome-osprey-4864541.
- National Park Service. *Plant in Bloom*. Photograph. n.d. Accessed March 15, 2024. https://plants.ces.ncsu.edu/plants/limonium-carolinianum/.
- National Science Teaching Association. *Untitled photograph of horseshoe crab*. Photograph. n.d. Accessed March 15, 2024. https://www.wdel.com/news/female-horseshoe-crab-gets-a-reprieve/article_e68056c0-6d0b-11ee-afae-a31498b97e07.html
- Romfh, Peggy. *Iva Frutescens (Jesuit's Bark) | NPIN*. Photograph. 2014. https://www.wildflower.org/gallery/result.php?id_image=42447.

Figure. 5.40. Killinger, Mary Katheryn. *Flooding Diagram*. Diagram. 2024.
Figure. 5.41. Killinger, Mary Katheryn. *I-95 Interaction Diagram*. Diagram. 2024.
Figure. 5.42. Killinger, Mary Katheryn. *Soil Clean Up Diagram*. Diagram. 2024.
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Figure. 5.44. Killinger, Mary Katheryn. *Phase one Programming*. Diagram. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

Figure. 5.45. Killinger, Mary Katheryn. *Phase one Site Plan*. Digital Rendering. 2024.
- Basemap: Google Earth Pro. (2023). *South Providence, Rhode Island. 41°48'16.61"N, 71°24'11.38"W, elevation 0FT.* (Online). https://earth.google.com/web/@41.8056264,-71.39966625,-53940.00987289a,56871.04391115d,35y,0.0102h,0t,0r/data=OgMKATA. Accessed March 7, 2024.

Figure. 5.46. Killinger, Mary Katheryn. *Phase Two Programming*. Diagram. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

Figure. 5.47. Killinger, Mary Katheryn. *Phase Two Site Plan*. Digital Rendering. 2024.
- Basemap: Google Earth Pro. (2023). *South Providence, Rhode Island. 41°48'16.61"N, 71°24'11.38"W, elevation 0FT.* (Online). https://earth.google.com/web/@41.8056264,-71.39966625,-53940.00987289a,56871.04391115d,35y,0.0102h,0t,0r/data=OgMKATA. Accessed March 7, 2024.

Figure. 5.48. Killinger, Mary Katheryn. *Phase Three Programming*. Diagram. 2024.
- Basemap: Esri Inc. *ArcGIS Pro* (version 3.1.3). Software. Redlands, CA: Esri Inc, 2023.

Figure. 5.49. Killinger, Mary Katheryn. *Phase Three Site Plan*. Digital Rendering. 2024.
- Basemap: Google Earth Pro. (2023). *South Providence, Rhode Island. 41°48'16.61"N, 71°24'11.38"W, elevation 0FT.* (Online). https://earth.google.com/web/@41.8056264,-71.39966625,-53940.00987289a,56871.04391115d,35y,0.0102h,0t,0r/data=OgMKATA. Accessed March 7, 2024.

Figure. 5.50. Killinger, Mary Katheryn. *Oxford Ave Perspective*. Digital Rendering. 2024.
Figure. 5.51. Killinger, Mary Katheryn. *Allens Ave Perspectives*. Digital Rendering. 2024.
- Base image: Google Earth Pro. (2022). *329 Allens Ave Providence, Rhode Island. 41°48'15.48" N 71°24'06.76" W, elevation 0FT.* (Online). https://earth.google.com/web/@41.80369492,-71.40172285,5.51691103a,0d,60y,-10.8737h,87.9155t,0r/data=IhoKFmVGaG5OV1RKbkdia21uc0NmVVR4SGcQAjoDCgEw. Accessed March 16, 2024.
- Google Earth Pro. (2022). *252 Allens Ave Providence, Rhode Island. 41°48'21.27" N 71°24'09.54" W, elevation 0FT.* (Online). https://earth.google.com/web/@41.80570174,-71.40260818,5.46887732a,0d,60y,347.49983278h,90.95381791t,0r/data=IhoKFkJ6M284LXJ6QzI5LWF6WWE3eHdZaGcQAjoDCgEw. Accessed March 16, 2024.

Figure. 5.52. Killinger, Mary Katheryn. *Planting Plan Phases*. Digital Rendering. 2024.

Appendix A| Coastal Brownfield Expert Survey

KANSAS STATE UNIVERSITY

Question Tour Block 1

Ecologically Restoring Brownfields in Urban Coastal Zones:

A Case for South Providence, Rhode Island

My name is Mary Kate Killinger, and I am a graduate student in the Landscape Architecture program at Kansas State University. Thank you for participating in this survey for my Master's Report research study, Ecologically Restoring Brownfields in Urban Coastal Zones: A Case for South Providence, Rhode Island. This research focuses on the ecological restoration of the urban coastal brownfields to improve the quality of life and health of the environment and the surrounding communities.

This survey contains a series of questions about your expertise and opinion on design strategies for coastal brownfield restoration on a short-term, long-term, site-scale, and urban-scale project. The questions are in matrix form and simple fill-in-the-blank. The survey should take approximately 15 minutes to complete.

No personal or identifying information will be used in the report, only your responses will be included in the publication. Participation in the survey is completely voluntary, there are no anticipated risks associated with your involvement in this study. All personal information will be kept confidential. Your information will not be used or distributed for future research studies. You may exit the survey at any time. By continuing with the survey, you will give consent to participate in this study.

Contact Information
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Faculty Advisor: Hyung Jin Kim hyungjin@ksu.edu | 785.532.5047
K-State IRB, Chair: Lisa Rubin | (785) 532-3224

Block 4

Participant's Background:

What field do you work in?	
How many years have you worked in that field?	
In what region do you work?	

Question Tour Block 2

Rate the importance of these design strategies in short-term coastal brownfield restoration

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Soil Capping	○	○	○	○	○
Soil Fill and Removal	○	○	○	○	○
Site Clean Up	○	○	○	○	○
Pollution Reduction or Elimination	○	○	○	○	○
Habitat (Re)Development	○	○	○	○	○
Accessibility & Connectivity	○	○	○	○	○
Aesthetics	○	○	○	○	○
Stigma	○	○	○	○	○
Transportation	○	○	○	○	○
Marshland Restoration	○	○	○	○	○

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Coral Reef Restoration	○	○	○	○	○
Living Breakwater	○	○	○	○	○
Oyster Reef Restoration	○	○	○	○	○
Seagrass Restoration	○	○	○	○	○
Phytoremediation	○	○	○	○	○
Bioremediation	○	○	○	○	○
Biochar Stabilization	○	○	○	○	○
Nano-remediation	○	○	○	○	○
Coastal Wetland Restoration	○	○	○	○	○
Nature Preserves	○	○	○	○	○
Managed Retreat	○	○	○	○	○
Green Space	○	○	○	○	○
Parkland	○	○	○	○	○
Forests	○	○	○	○	○

(Optional) Include any suggestions or comments on short-term coastal brownfield restoration:

Long-term Matrix Questions

Rate the importance of these design strategies in long-term coastal brownfield

restoration

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Soil Capping	○	○	○	○	○
Soil Fill and Removal	○	○	○	○	○
Site Clean Up	○	○	○	○	○
Pollution Reduction or Elimination	○	○	○	○	○
Habitat (Re)Development	○	○	○	○	○
Accessibility & Connectivity	○	○	○	○	○
Aesthetics	○	○	○	○	○
Stigma	○	○	○	○	○
Transportation	○	○	○	○	○
Marshland Restoration	○	○	○	○	○
Coral Reef Restoration	○	○	○	○	○
Living Breakwater	○	○	○	○	○
Oyster Reef Restoration	○	○	○	○	○
Seagrass Restoration	○	○	○	○	○
Phytoremediation	○	○	○	○	○
Bioremediation	○	○	○	○	○
Biochar Stabilization	○	○	○	○	○
Nano-remediation	○	○	○	○	○
Coastal Wetland Restoration	○	○	○	○	○

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Nature Preserves	○	○	○	○	○
Managed Retreat	○	○	○	○	○
Green Space	○	○	○	○	○
Parkland	○	○	○	○	○
Forests	○	○	○	○	○

(Optional) Include any suggestions or comments on long-term coastal brownfield restoration:

site-scale

Rate the importance of these design strategies in site-scale coastal brownfield restoration

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Soil Capping	○	○	○	○	○
Soil Fill and Removal	○	○	○	○	○
Site Clean Up	○	○	○	○	○
Pollution Reduction or Elimination	○	○	○	○	○
Habitat (Re)Development	○	○	○	○	○
Accessibility & Connectivity	○	○	○	○	○
Aesthetics	○	○	○	○	○

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Stigma	○	○	○	○	○
Transportation	○	○	○	○	○
Marshland Restoration	○	○	○	○	○
Coral Reef Restoration	○	○	○	○	○
Living Breakwater	○	○	○	○	○
Oyster Reef Restoration	○	○	○	○	○
Seagrass Restoration	○	○	○	○	○
Phytoremediation	○	○	○	○	○
Bioremediation	○	○	○	○	○
Biochar Stabilization	○	○	○	○	○
Nano-remediation	○	○	○	○	○
Coastal Wetland Restoration	○	○	○	○	○
Nature Preserves	○	○	○	○	○
Managed Retreat	○	○	○	○	○
Green Space	○	○	○	○	○
Parkland	○	○	○	○	○
Forests	○	○	○	○	○

(Optional) Include any suggestions or comments on site-scale coastal brownfield restoration:

urban-scale

Rate the importance of these design strategies in urban-scale coastal brownfield restoration

	Not important at all	Somewhat Unimportant	Neutral	Somewhat Important	Extremely Important
Soil Capping	○	○	○	○	○
Soil Fill and Removal	○	○	○	○	○
Site Clean Up	○	○	○	○	○
Pollution Reduction or Elimination	○	○	○	○	○
Habitat (Re)Development	○	○	○	○	○
Accessibility & Connectivity	○	○	○	○	○
Aesthetics	○	○	○	○	○
Stigma	○	○	○	○	○
Transportation	○	○	○	○	○
Marshland Restoration	○	○	○	○	○
Coral Reef Restoration	○	○	○	○	○
Living Breakwater	○	○	○	○	○
Oyster Reef Restoration	○	○	○	○	○
Seagrass Restoration	○	○	○	○	○
Phytoremediation	○	○	○	○	○
Bioremediation	○	○	○	○	○
Biochar Stabilization	○	○	○	○	○
Nano-remediation	○	○	○	○	○
Coastal Wetland Restoration	○	○	○	○	○
Nature Preserves	○	○	○	○	○
Managed Retreat	○	○	○	○	○
Green Space	○	○	○	○	○
Parkland	○	○	○	○	○
Forests	○	○	○	○	○

(Optional) Include any suggestions or comments on urban-scale coastal brownfield restoration:

Question Tour Block 4

Thank you for participating in this survey, your responses will contribute to the development of my research project. If you are interested in receiving my Master's Report that will be completed in May 2024 and/ or participating in follow up expert interviews please contact me at mkkillin@ksu.edu.

Would you recommend this survey to a colleague? If so, please provide their email address.

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Appendix B | Interview Questions

1. Questions for Local Experts/Community Leaders in Providence, RI

General knowledge about the study site

- What historical significance does the South Providence port have?
- Who are the key stakeholders, and the main (surrounding) communities, of the South Providence port area?
- What types of public access are available from the Upper and Lower South Providence neighborhoods to the port area? And how accessible?
- What are the environmental qualities of the port? What contaminants are present? How serious of the contamination?
- How was the site used before industrial development?

Plans for Future Development

- Are there any plans or visions for the future development of this port area? Any plans for ecological improvement or restoration?
- What opportunities are there to increase coastal restoration in the Port Area?
    - Are there any existing or visions for coastal restoration projects?
- What type of local policies or jurisdiction will need to be considered for a coastal restoration project to be implemented?

Coastal Restoration

- What kind of environmental or ecological opportunities are present?
- What is the significance of coastal restoration in urban brownfields?
- Are coastal restoration strategies feasible in the proposed site in Providence, RI?
    - What role does an ecological park have in restoring the coastal ecosystems?
    - How would an ecological park be beneficial for the surrounding communities?
- Which proposed environmental-based strategy would be the most stable and durable in urban coastal brownfields?
- Do you have any additional insights or recommendations for the site or this research project?

2. Questions for Experts of Coastal Restoration

Background and Experience

- What is your background in coastal restoration design projects?
    - What is your specific area of expertise?
- How long have you been working in your area?
- Do you know the South Providence port area? If so, have you visited there? What's your general impression of the site?

Coastal Brownfield

- What is the significance of coastal restoration and coastal ecosystems in urban brownfields in port cities, such as Providence?
- To what extent is coastal restoration feasible in the proposed site in Providence, RI?
    - What role does a park have in restoring the coastal ecosystems?
- Which proposed strategy would be the most stable and durable in urban coastal brownfields?

Coastal Restoration Design

- What is the significance of coastal ecology and coastal restoration? And why?
- How should we deal with the existing gray infrastructure (warehouses and impervious surfaces) and waste for coastal restoration for brownfields?
- What type of vegetation do you use in urban coastal restoration for brownfields? Should vegetation be chosen based on its native environment, how durable it is in harsh conditions or another approach?
- What are the driving goals when achieving coastal restoration of an overdeveloped or degraded area?
- Is coastal restoration design important for disaster resilience? If so, how?
- How are coastal ecology and restoration important in the Providence region?

Appendix C | IRB Approval Letters

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Hyung Kim
Landscape Archit & Comm Plan
Manhattan, KS 66506

Proposal Number: IRB-11855

FROM: Lisa Rubin, Chair
Committee on Research Involving Human Subjects

DATE: 10/02/2023

RE: Proposal Entitled, "Restoring Urban Coastlines In Port Brownfields:
A Case of South Providence Port Area."

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §104(d), category:Exempt Category 2 Subsection ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

Electronically signed by Lisa Rubin on 10/02/2023 12:08 PM ET

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Hyung Kim
Landscape Archit & Comm Plan
Manhattan, KS 66506

FROM: Lisa Rubin, Chair
Committee on Research Involving Human Subjects

DATE: 01/03/2024

RE: Proposal #IRB-11855, entitled "Restoring Urban Coastlines In Port Brownfields:
A Case of South Providence Port Area."

MODIFICATION OF IRB PROTOCOL #IRB-11855, ENTITLED, "Restoring Urban Coastlines In Port Brownfields:
A Case of South Providence Port Area"

EXPIRATION DATE: Exempt

The Committee on Research Involving Human Subjects (IRB) has reviewed and approved the request identified above as a modification of a previously approved protocol. **Please note that the original expiration remains the same.**

All approved IRB protocols are subject to continuing review at least annually, which may include the examination of records connected with the project. Announced in-progress reviews may also be performed during the course of this approval period by a member of the University Research Compliance Office staff. Unanticipated adverse events involving risk to subjects or to others must be reported immediately to the Chair of the IRB, and / or the URCO

It is important that your human subjects activity is consistent with submissions to funding / contract entities. It is your responsibility to initiate notification procedures to any funding / contract entity of any changes in your activity that affects the use of human subjects.

Electronically signed by Lisa Rubin on 01/03/2024 10:58 AM ET

Appendix D | Framework of Design Strategy

Coastal Brownfield Restoration Strategies		Economical Benefits				Social Benefits		Social Benefits		Environmental Restoration						Sources
		Maintenance and Operation Costs	Job Creation	Increased Property Value & Real estate Development	Tourism & Visitor Spending	Recreation	Health & Well-Being	Safety	Education	Resilience	Coastline Protection	Environmental Quality	Coastal Ecological Functions	Biodiversity	Flood Prevention	Climate Change	
Remediation	Soil Capping	○					○ ●	○ ●				○ ●		○ ●			(Lewis 2008; Zheng and Kirkwood 2020)
	Soil and Fill Removal						○ ●	○ ●				○ ●					(Lewis 2008; Zheng and Kirkwood 2020)
	Site Clean Up	○	○ ●	●		○ ●	○ ●	○ ●				○ ●		○ ●			(Levi and Kocher 2006)
	Pollution Reduction or Elimination				●		●					●		○ ●			(Zheng and Kirkwood 2020)
	Habitat (Re)Development			○ ●	○ ●		○ ●					○ ●		○ ●			(Fanelli et al. 2023; Lewis 2008; Strain et al. 2018)
	Accessibility & Connectivity				○ ●	○ ●			○ ●								(Levi and Kocher 2006)
	Aesthetics			○ ●	○ ●				○ ●								(Levi and Kocher 2006; Song et al. 2019)
	Stigma			○ ●	○ ●			○ ●	○ ●								(Levi and Kocher 2006)
	Transportation		○ ●		○ ●	○ ●		○ ●									(Song et al. 2019; U.S. Department of Commerce 2003)

Table: Framework of Design Strategy

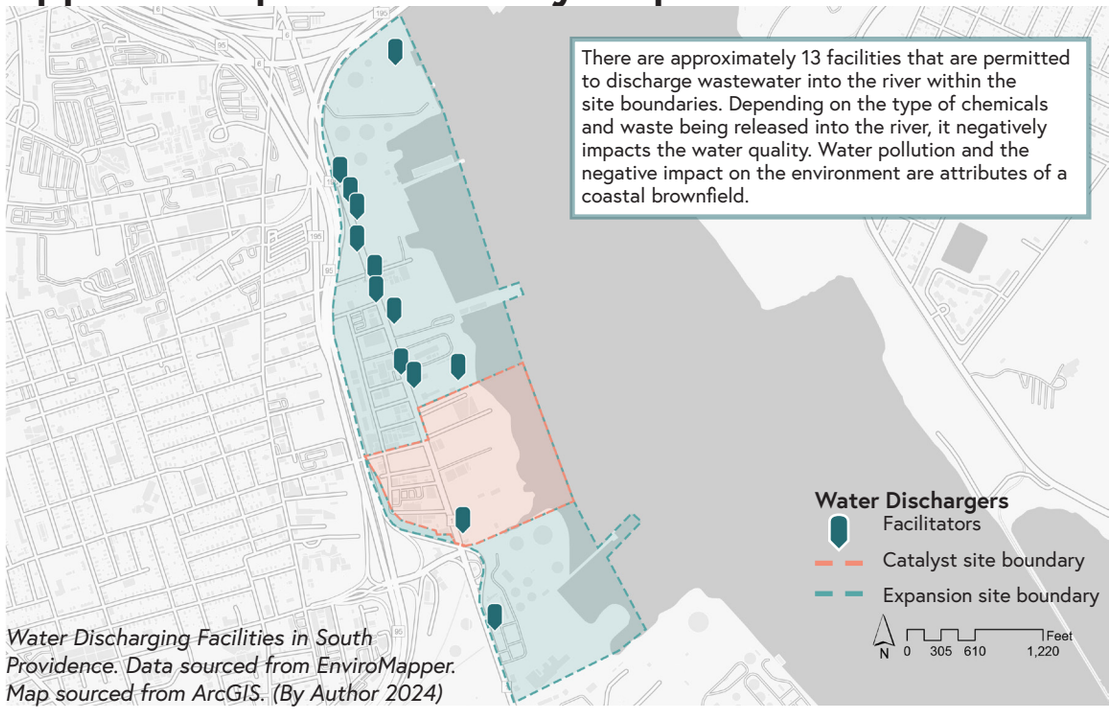
Environmental-based Adaptations	Marshland Restoration														(Temmerman et al. 2013)
	Coral Reef Restoration														(Temmerman et al. 2013; UNEP 2016)
	Living Breakwater														(Temmerman et al. 2013; UNEP 2016)
	Oyster Reef Restoration														(NOAA 15; Temmerman et al. 2013)
	Seagrass Restoration														(Lewis 2008; NOAA 2015; UNEP 2016)
Low Input Remediation	Phytoremediation														(O'Connor et al. 2019; Song et al. 2019)
	Bioremediation														(Song et al. 2019)
	Biochar Stabilization														(Song et al. 2019)
	Nano-remediation														(Song et al. 2019)
Redevelopment	Coastal Wetland Restoration														(Temmerman et al. 2013; UNEP 2016)
	Nature Preserves														(Levi and Kocher 2006; Song et al. 2019)
	Managed Retreat														(UNEP 2016)
	Green Space														(Lewis 2008; Song et al. 2019)
	Parkland														(Bardos et al. 2020; Zheng and Kirkwood 2020)
	Forests														(Bardos et al. 2020)

Table: Framework of Design Strategy (cont.)

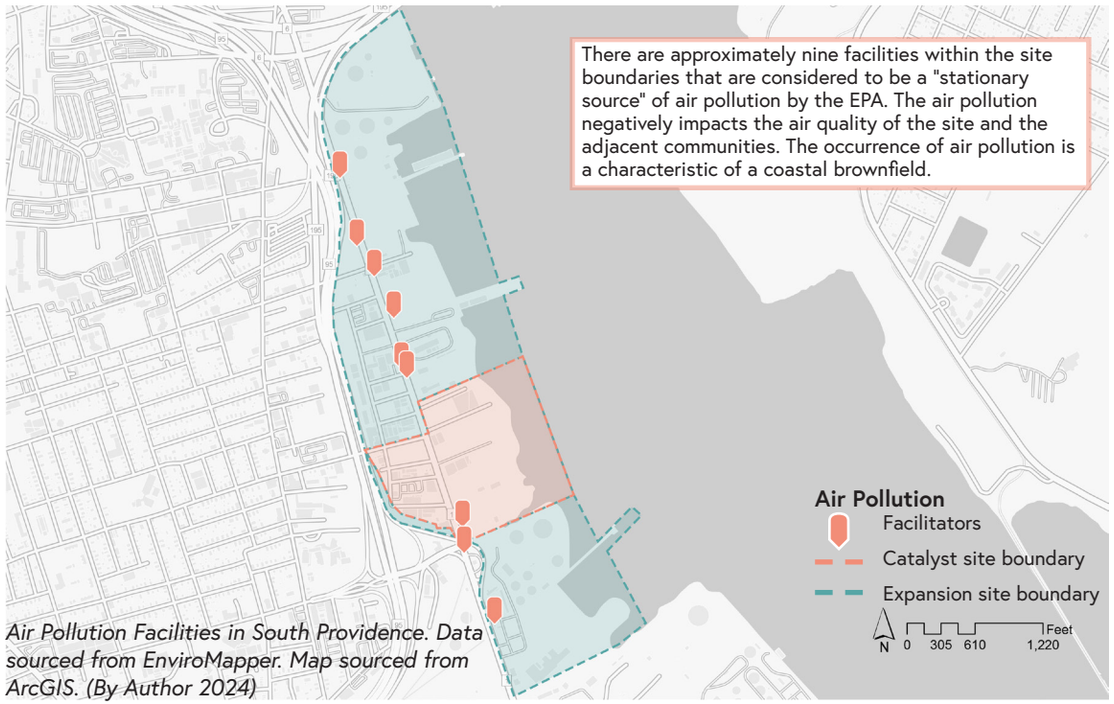
Key:

Site-scale · Urban-scale · Short-term · Long-term

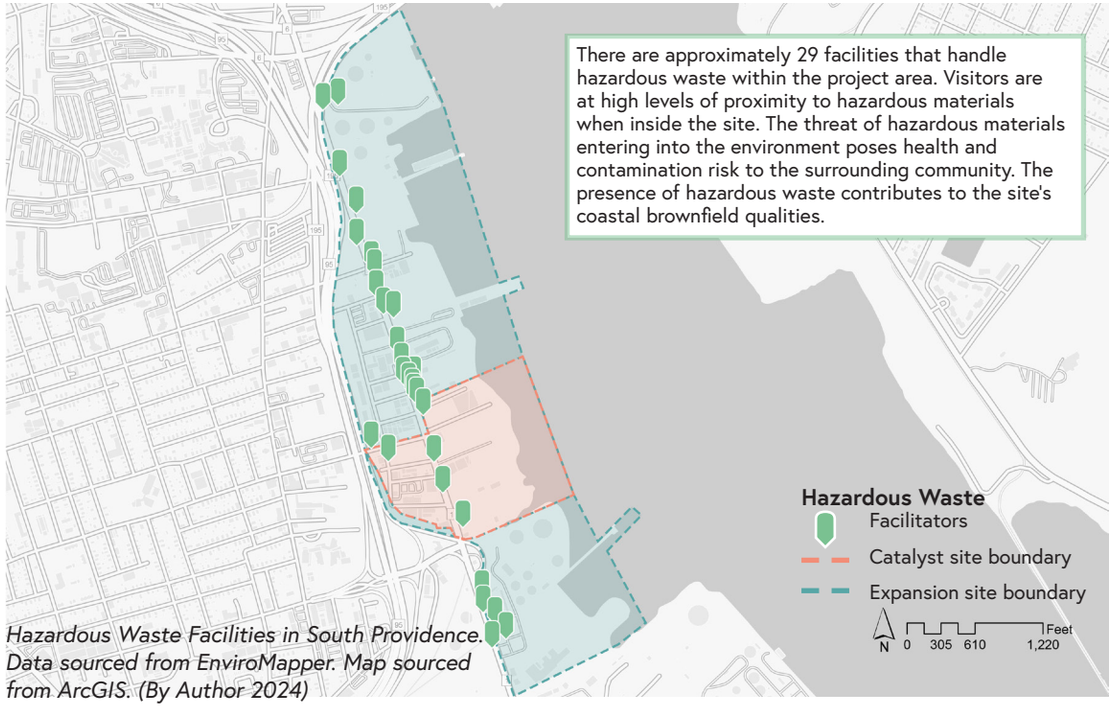
Appendix E | Site Inventory Maps



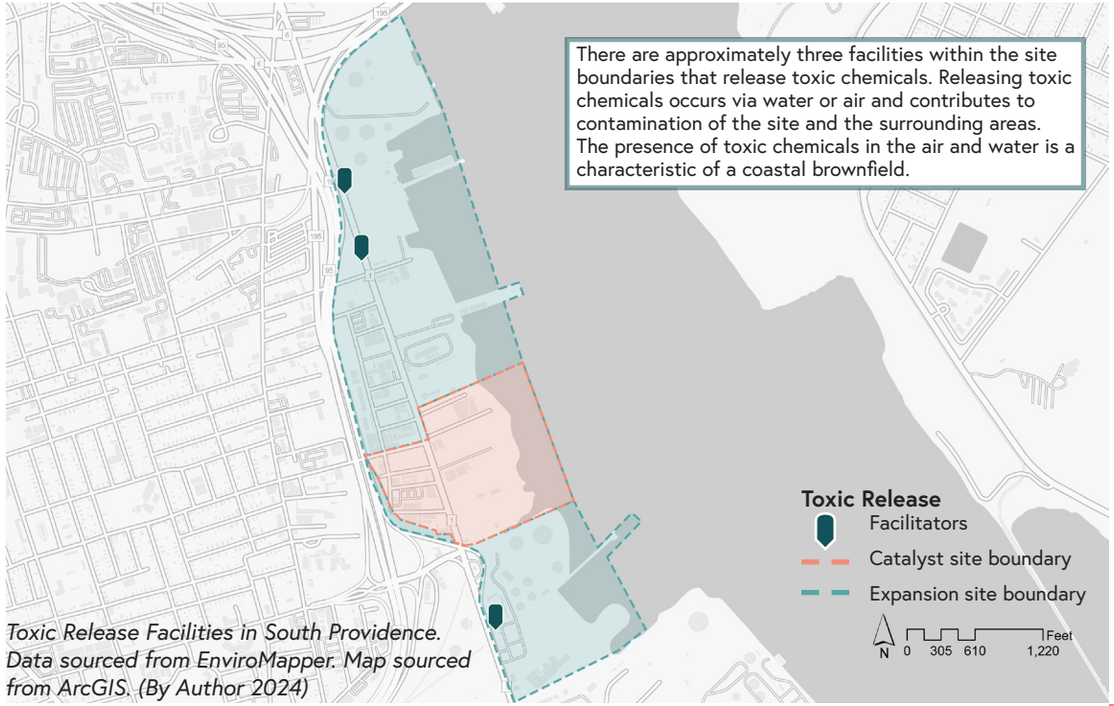
Water Discharging Facilities in South Providence. Data sourced from EnviroMapper. Map sourced from ArcGIS. (By Author 2024)



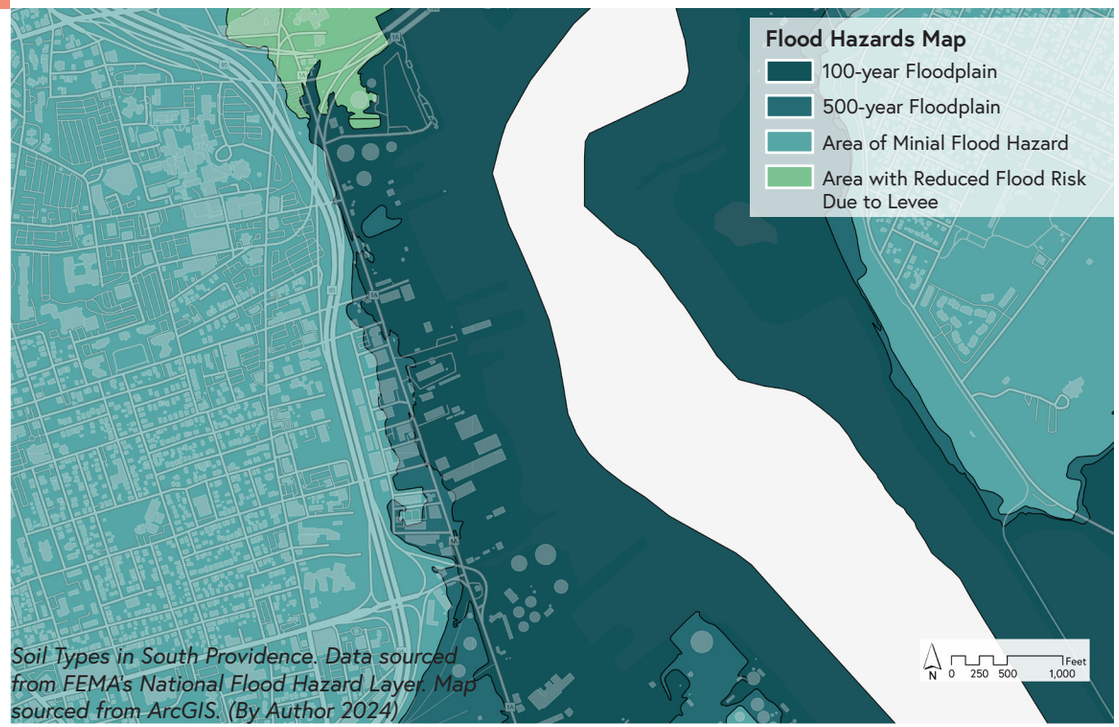
Air Pollution Facilities in South Providence. Data sourced from EnviroMapper. Map sourced from ArcGIS. (By Author 2024)



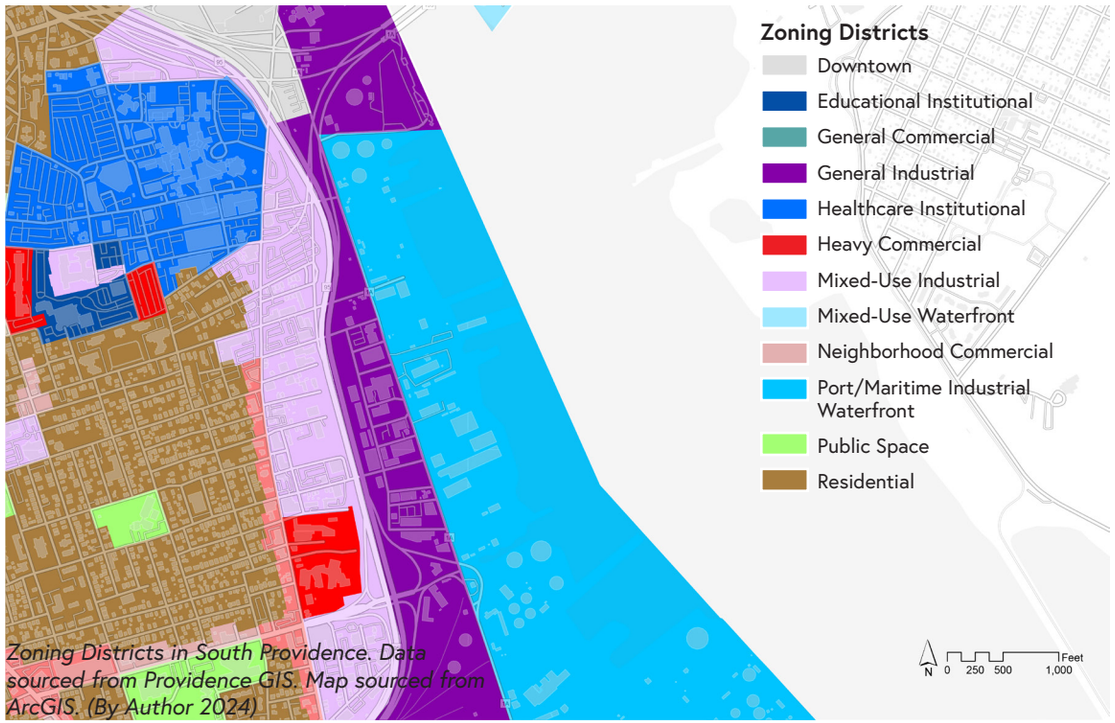
Hazardous Waste Facilities in South Providence. Data sourced from EnviroMapper. Map sourced from ArcGIS. (By Author 2024)



Toxic Release Facilities in South Providence. Data sourced from EnviroMapper. Map sourced from ArcGIS. (By Author 2024)



Soil Types in South Providence. Data sourced from FEMA's National Flood Hazard Layer. Map sourced from ArcGIS. (By Author 2024)



Zoning Districts in South Providence. Data sourced from Providence GIS. Map sourced from ArcGIS. (By Author 2024)

Soil Types in South Providence. Data sourced from RIGIS. Map sourced from ArcGIS. (By Author 2024)

Appendix F | Precedent Study Criteria

Precedent Study	Inclusion					Exclusion			
	Coastal Areas	Brownfield Restoration	Existing Industrial/ Infrastructural Use	Completed or Semi-Completed	Urban Area	Non-Ecological Redevelopment	Inland Projects	Smaller than 10 Acres	Larger Than 300 Acres
Seattle Gasworks Park	✕	✕	✕	✕	✕				
India Point Park	✕	✕	✕	✕	✕				
Fresh Kills Park	✕	✕	✕	✕	✕				✕
Borneo Sprorenburg	✕	✕	✕	✕	✕	✕			
HafenCity	✕	✕	✕	✕	✕				✕
Troutdale Reynolds Industrial Park	✕	✕	✕	✕	✕				✕
Seoul Haneul Park	✕	✕	✕	✕	✕				
Hennepin County Medical Center Whittier Clinic		✕	✕	✕	✕	✕	✕	✕	
The Water City Project, Almada (Portugal)	✕		✕	✕	✕	✕			✕
Save the Bay Center	✕	✕	✕	✕	✕				
Belle Isle Salt Marsh, Boston, Mass	✕	✕	✕	✕	✕				✕
Lead Remediation at Brownfields Sites, New England	✕	✕	✕						✕
Verso Paper Mill, Bucksport, Maine	✕	✕	✕	✕		✕			
Woodbridge Waterfront Park	✕	✕	✕	✕	✕				

Table: *Selection Criteria for Precedent Studies*