Shifting Sediments:
Inhabiting the Land, the Sea and the Space In-Between

by

Natasha C.E. Zubricki

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Dalhousie University is located in Mi’kmaq’i,
the ancestral and unceded territory of the Mi’kmaq.
We are all Treaty people.

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Abstract

The coastline is a dynamic edge between land and sea ruled by natural forces and illustrated through material processes of erosion, accretion, and deposition. As our climate warms, increasing storm conditions and sea levels, these natural forces accelerate. Growth and destruction are inevitable aspects of various actors and habitat formations, situated within the interconnected systems of air, earth, and water. The thesis examines the potential the ruin has for housing new life and supporting new ways of living. Prince Edward Island is explored as a case study of how to shift our perspective, embracing the ocean as an instigator of opportunity. Three locations along the edge are investigated exploring various material and programmatic relationships that can be utilized as a layered strategy - becoming a catalyst for new life. A temporal architecture that is both measure and armature is implemented as an infrastructural approach aimed to adapt to inevitable uncertainty.

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Chapter 1: Introduction

Landscapes are in constant evolution. As time passes, they are formed through human intervention, natural forces, and the inhabitation of non-human life. Every actor in this cycle provides both an element of growth and decay, much like how all life is bound to a cycle governed by a birth, growth, aging, and eventual death. Ruin is an aspect of this cycle which occurs between age and death - a time span that reveals the transformative process and illustrates the workings of nature. Weathering occurs at varying speeds and at different times allowing for a developing dialogue between seemingly permanent and temporal dimensions. The edge condition between land and sea is a dynamic zone where the process of ruin is easily illustrated and understood. The land is subject to erosion, accretion of new life, and deposition of existing sediment. Through time, the edge is not only shaped by the forces of the ocean, but also the human and non-human actors who inhabit this boundary.

Ecology can be a tool for design by embracing the non-human actors and positioning humans as a piece within a greater network. Human-centric design that ignores this greater network can lead to the devastation of habitat and disjointed ecologies severed by development. By fostering habitat and creating strong ecosystems, landscapes can provide a natural method for climate mitigation that can easily adapt to a changing environment. The non-human is a key actor living between land and sea that can help rebuild natural defenses and teach us how to thrive in this transformative yet vulnerable zone. Additionally, natural processes that occur at the shoreline are equally as critical as an instigator of change. The composition of the land and how it transforms over time, as well as the local hydrology all come together to inform how the edge will evolve. The ecological conditions, geological formations, and hydrological forces act on the coastline forming a continual cycle of growth and decay.

In Chapter 5, Prince Edward Island is presented as an edge condition which illustrates this continual transformative process instigated directly by the ocean. The Island, formerly part of Nova Scotia, became subject to rising seas millions of years ago resulting in a divide now known as the Northumberland Strait. A ruin of past existence, the Island can be considered remnants of what once was. Continually shaped and formed by hydrological processes, the Island will continue to reveal the powerful effects of the ocean. As the state of the climate crisis worsens, and sea levels continue to rise, PEI will be divided into three separate fragments of land. This only requires an increase of two degrees in water temperature. Through analysis of the Island's hydrology, geology, and ecology, we can gain a more comprehensive understanding of how to inhabit these dynamic boundaries created by the rising sea. Due to the vulnerability of the geological composition, rising seas and the continual action of wave and tidal cycles, a small inlet on the Island's north shore, Savage Harbor, will become disconnected by sea levels. Habitat destruction and disconnection due to increased erosion and salt intrusion, will have a great impact on humans and other species. This change in landscape will sever transportation links, ground water resources, crop production, as well as alter the habitat's of plants, animals, birds, and aquatic life. This increase in sea levels and the natural processes involved in climate change will eventually create connections between the Northumberland Strait and the Atlantic Ocean, forming even more edges between land and sea. Savage Harbor can serve as a laboratory for exploration for how to adapt to an ever-evolving environment.

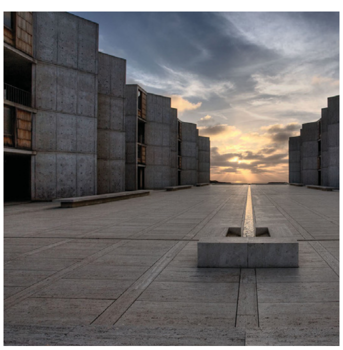
This thesis explores various ways of inhabiting the edge and embracing an evolving and temporal environment. Can humans collaborate with the forces of nature and ecological networks to create an architecture of change? This thesis aims to answer this question creating design that is instigated by the ocean to form new ways of living and allow the act of weathering to be a catalyst for new space.

Three separate experiments are implemented for living within the ever-changing edge condition that adapts to uncertainty. Each method works together to hold existing shorelines, create new boundaries, and provide ways to monitor and measure an ever-evolving landscape. The explorations are all tethered to existing geology that grounds the space in ruin, connecting the past as a foundation for the present to build on for the future.

Chapter 2: The Rise and Fall

Architecture is often viewed as a static object birthed from engineering, made to defy nature and time. Through this idea, ruin is only perceived as an indication of failure - the opposite of bringing into being. As much as we like to believe buildings will stand forever, architecture is not immune to the cycles of life. Like our human bodies, buildings have a time of birth, growth, age, and inevitable decay. Many architects have had a fascination with ruin including John Soane and Louis Kahn. Through Soane's tomb, he played with the relationship between eternity and temporality using ephemeral materials that will stand the test of time far past his inevitable death. Soane explored the ruin through the notion of monument and an architecture of time (Hill 2019,194). Similarly, Kahn constructed buildings with its eventual decay in mind, highlighting the ruin instead of the building itself. With the design of the Salk Institute, the "nature of nature" (Hill 2019, 238) was emphasized through tangible materials and associated regeneration. Thus, both Kahn and Soane embrace this metaphor of the passage of time with the potential for survival or renewal (Hill 2019,194). The ruin can embody a memory of the past while also being engrained in the landscape of the present. The fragments of architectural decay contrasts from bodily decay as it can evoke both life and death in a single moment. Time affects building materials at different paces. These fragments of the earth that form our cities change through time at varying speeds, allowing some materials to last for centuries almost untouched by the demands of nature, while others have much shorter life spans. This dialogue between permanence and temporal dimensions brings potential for renewal or survival.

Soane's Tomb, 1815.
(Sir John Soane's Museum London 2020)



Louis Kahn , Salk Institute 1965 (Lardinois 2016)

Carlo Scarpa, The Brion Cemetery, 1978 (Patt 2021)

Weathering allows us a glimpse into the ongoing transformation time causes on our cities. The failure of materials due to weather leaves behind a visual reminder of the passage of time. Works by Carlo Scarpa use this idea of weathering in a way that not only highlights the materials' gradual degradation, but also designs with it in mind. Scarpa's Brion Cemetery utilizes this notion of life and death through material by designing consciously where the water will travel and slowly affect the walls, thus attempting to design where nature impacts the space over time. He believes that "marking reveals, through weather, (shows) nature's temporality; the beginning of the end of things" (Leatherbarrow 2021, 102). This radical idea of designing for eventual demise has been seen throughout time. Embracing the life cycle and finding opportunity within it. Weathering is simply a part of this life cycle process- a snapshot of a building's life when we can see it slowly becoming ruin.

The weathering on the exterior concrete work of Brion Cemetery (Seier 2018)

Fragments that continue to exist long past human occupation become engulfed in vegetation, naturalizing the ruin. In this phase of time, it is clear of architecture's existence as an "enduring geological formation" (Hill 2019, 62). The earth is formed by natural systems of weather and the slower transformations of geological systems, such as tectonic uplift, erosion, deposition, and accruement. Architecture, made of elements of earth itself, is part of this continuous material evolution. The glass flows, steel will rust, and concrete erodes in synchronous with the terrain. Through time, "structures become overgrown with moss and all sorts of organic matter…(architecture) also trembles, burns, corrodes and erodes" (Trevelo 2022,167). Nature is potentially more prominent in shaping our world then architects themselves. In celebrating natural processes and strategically allowing the decay of materials, new possibilities and futures can grow from a memory of the past. The human and non-human are equally as important actors in the overall existence of structures. When humans no longer occupy buildings, nature takes over. Plants, birds and small animals slowly inhabit these ruins and create new uses for a past structure at the end of its life - Architecture returning to earth. Water, ecology and atmosphere are all actors in this transformation. Wind, rain and salt content in the air from earth systems and hydrological cycles becomes visible on our structures as time progresses. Additionally, our actions can cause changes on natural processes. For example, water can have an impact on pier foundations, causing changes in deposition, erosion around the structures, and create micro climates for certain ecologies. The power of water, geological qualities, erosion, and weather all play a key role in how our architectures will change throughout time.

Climate and weather have always been an influence on how we design. Historically, humans have created spaces that embrace the sun path, shield against wind, or create microclimates of clam air. These natural factors have always played a part not only in the design but also how the structure wears throughout time. Stewart Brand has developed the “Open Building” theory which illustrates the components of a building and their individual temporality (Brand1994). This theory designs with a layered approach embracing life cycle and the elements in which it exists. With the increase in climate awareness and the influx of climate related weather action, this is becoming an even more prominent topic.

Our climate is warming, promoting an increase in severe weather activity, rising sea levels, warming oceans, and the shorelines erosion occurring at an even faster pace. In the face of climate change, whole landscapes can become ruins. This can be lamented as a loss, but there is potential as well. The fear of the future, change and death of what we know can either “induce melancholic lethargy or stimulate creativity in every living moment” (Hill 2019, 195). Embracing all the human, non-human, and atmospheric actors who can become collaborators on built form and inspire a new way to inhabit an ever evolving environment.

Chapter 3: Ecology as a Tool for Design

Ecosystems are defined as a network of interconnected elements and processes forming a community of organisms within a specific environment. Humans and non-humans coexist in this system and each play an equally significant role in the function of life. Ecology is the study of making home - habitat's within an environment. Architecture is often seen as a method of making home for humans while disregarding the non-humans and other natural systems that co-exist within the same environment. Human-centric design is often destructive to habitat and creates divisions and fragments within the natural networks, often leading to an architecture "that can be destructive and parasitic as it can be reciprocal and symbiotic" (Reed and Lister 2014, 54). Creating an architecture of relationships that can embrace our position in the larger ecosystem as well as acknowledge the role of non-human actors to create a more resilient and adaptable future.

The idea of mindful designing with consideration to the relationship between humans and our ecosystems are not new concepts. Ian McHarg's *Design with Nature*, published in 1969, is a prime example of a seminal text which opens the idea of using physical landscape as a tool for design. This shift away from industrialization to a more nature-based strategy emerged due to an increased awareness of the global climate crisis. This environmental decline has shed a light not only on the importance of natural systems, but also the interconnectedness of humans and ecology. An ecological basis for design that reaches far beyond its scientific understanding. James Corner described this method as a pathway to “enable alternative forms of relationships and hybridization between people, place, material and earth” (Corner and Hirsch 2014, 279). A way to engage both temporal and multi-actor species. Ecologically-based design has been seen as a stark divergence from the industrial, consumptive methods to a method that creates synergies and connected cycles that are integrated into all natural systems.

Today, the importance of the ecosystem is understood far beyond its physical properties and place within the landscape mosaic. Ecological design has evolved into a broader understanding of the dynamism and unpredictability that is critical to the longevity of these networks. For example, storm surge destroys habitat while also redistributing sediment. This results in creating robust dune networks and prosperous habitats. It has been understood that “ecological systems that have survived are those that are able to absorb and adapt to traumas” (Reed and Lister 2014, 107). Ecosystems are reliant on these changes for environmental renewal and longevity. Therefore, ecology can be used as a framework to not only understand the present but also predict possible futures. The edge is a zone between two or more systems that forms a distinct boundary. For instance, the conditions between land and sea can be considered an ecological edge (Forman and Moore 1992, 236). The temporal dynamics and spatial qualities evolve and change through time with natural forces. The habitat and ecosystems of the edge are constructed in tandem with the natural processes of accretion, erosion and deposition, resulting in both new life and ruin to take form. Thus, the ruin of one habitat and ecosystem provides fertile ground for new life and an opportunity for renewal.

The edge condition between land and sea is an example of a space that is in constant movement and fluctuation. Temporal dynamics, evolving ruins, and diverse ecology are all found along the edge. Different depths, topographical forms and material makeup of the ocean hold varying ecosystem networks that depend on different levels of water, light, and food sources. The intertidal zone is characterized as the boundary between land and sea- An ecology that is submerged in water at high tide but exposed to the elements in low tide. This segment of the ocean is in constant fluctuation, making the species who thrive here “masters of adaptation” (Cullis-Suzuki 2020, 13). Ecological edges bordering the ocean vary and create different systems that work together to bridge the zone between land and sea. In addition to the rocky intertidal zone, shallow water shelves, barrier islands, inlets, and sand dunes also form dynamic boundaries characterized by their geological composition of sand and silt. This sandy edge creates a different spatial dynamic and ecological network to that of the rocky shore, being more easily influenced by the wave action of the ocean beyond. The geological makeup, hydrological conditions, and ecological networks all inform the boundary condition and the way it will transform over time. The sand is constantly being pushed and pulled by the waves and creating a dynamic space for any occupants who call the barrier Island’s home. The life and growth of organisms that live in both the intertidal zone and the sandy shore are closely intertwined with their ecology. They adapt to changing space and form new life off fragments of the earth, allowing for new possibilities despite the shifts and decay.

The rocky intertidal zone exposed during low tide.

Mussels growing on rocks in the intertidal zone

Chapter 4: Natural Processes of the Water's Edge

The Land

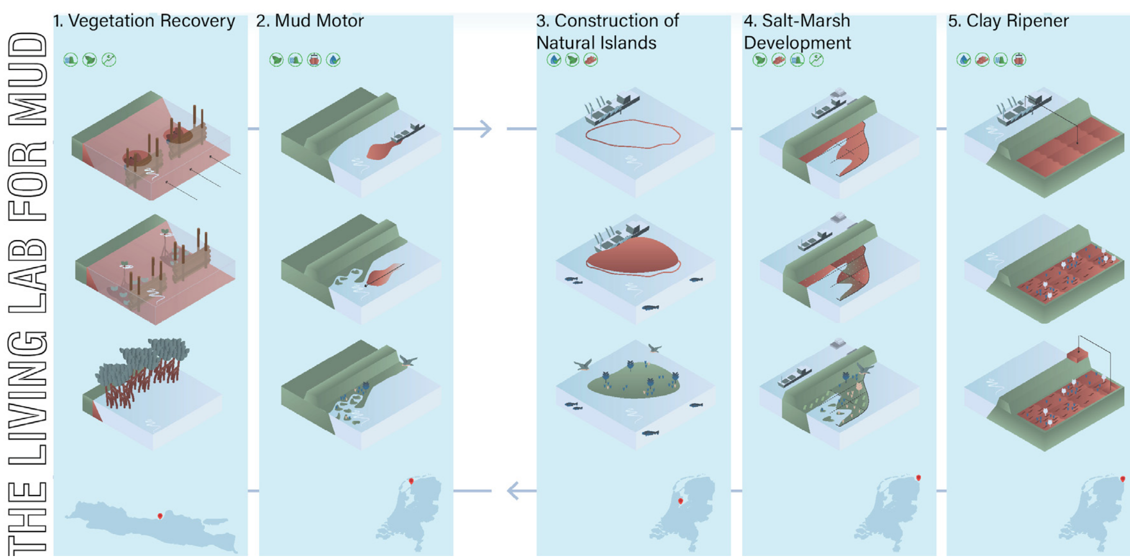
Sand dune ecologies are vulnerable networks positioned at the interface between land and sea. The ecology of sand dunes is an intricate system engrained in movement and temporality. The intensity of wave action that occurs along the shore paired with the light substrate of sand results in a high amount of sediment transport, either through accumulation or dispersing of sand. Therefore, the coastline is constantly in flux and shaped by the waves. The earth is eroding, moving, crumbling, shifting, and accumulating. This continual transformation is intensified and accelerated at the edge between land and sea.

Sediment transport is largely driven by wave action and particle sizes of the ocean bed. When particles are "cohesive", such as clay, the sediment bed has a stickiness that is not as influenced by the force of the waves requiring significant stress to induce motion. In contrast non-cohesive particles, such as sand, move throughout the ocean columns freely. Large waves often generated from storm conditions increase the sediment transport of these non-cohesive particles, lifting them high into the water columns. These non-cohesive particles are carried by waves and are eventually deposited on our shorelines. Therefore, large storms that lift more non-cohesive particles can influence the shape of our coastlines. As the current slows, the sediment has a chance to deposit. The more active and forceful the waves, the slower the rate of sediments deposition is. With an increase in storms brought on by changing climatic conditions, the more sediment is going to be in motion, dramatically changing the shape of our beaches. Understanding how the waves influence the shape of our land can help us to lean on this natural process and build with deposition instead of against it.

The Netherlands is currently battling the pressing issue of advancing shorelines and applied many methods to combat the quickly changing landscape. They implemented new projects that utilize the sediment table as a method of defense, changing the way the country uses their beaches. The Sand Motor is a project which uses dredged material in a beneficial manner, aimed at increasing sand nourishment along the coast and replenishing lost shoreline. The project required a large amount of sediment from offshore to be deposited along the coast to form a hook shape jutting out from the natural coastline. Over time, waves distribute the sand along the shore, re nourishing the eroding beaches. The project has been successful in not only replenishing the shoreline of needed sediment, but also increasing biodiversity and recreational activities along the new sandbars.

The Sand Motor, Rijkswaterstaat, Netherlands (TUDelft 2021)

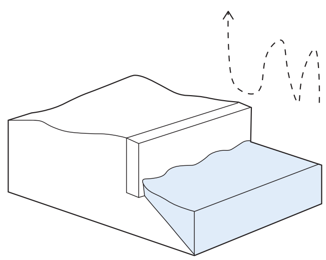
Similarly, the Living Lab for Mud was also created, which utilizes the abundant clay along the Netherlands' coast instead of sand. Since clay isn't easily transported by wave action, the mud motor is used to redistribute the clay and release otherwise impacted areas of the hydrological system. As natural sediment movement is disrupted by human infrastructure, it accumulates in some areas while lacking in others. This uneven distribution often causes riverbeds to have an excess of cohesive sediment, while other areas to have more sediment being removed than deposited. The project is focused on using dredged clay material to help protect shorelines from flooding. The clay is used to form resilient dikes that build up farmland, and create barrier Islands in the water. The newly reinforced areas can restore depleting ecosystems such as salt marshes surrounding the shoreline, and even create building material. The Living Lab for Mud is taking a critical look at dredged material and finding ways to both replenish sediment and remove clogged water systems that increase risks of flooding. Understanding and working with sediment is a key factor in managing water



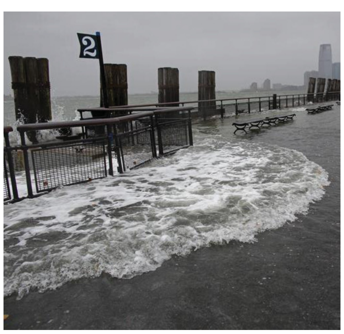
"The Living Lab for Mud", Netherlands. Diagrams illustrating the different ways sediment can be utilized for coastal resiliency. (EcoShape 2018) flows and creating a coastline that absorbs the effects of storm surge and increased wave action. Finding ways to work with natural processes of sediment movement and utilizing human intervention can promote growth in areas that are becoming engulfed by rising seas.

The Sea

The force of the ocean has the power to transform the world around us by pushing the shoreline, eating away at rock, and flooding forced into low lying areas. The power of water is a critical actor in creating temporal dynamics at the edge. The continual warming of the ocean has also led to an increase in sea level, making more sandy coastlines vulnerable to encroaching waves. The increasing number of storms, and the subsequent water levels, has resulted in an accelerated timeline of landscape evolution. The natural forces of the ocean have always been an instigator of change, but as the climate alters the speed in which it operates is dramatically increased. The earth is shifting faster and more violently.

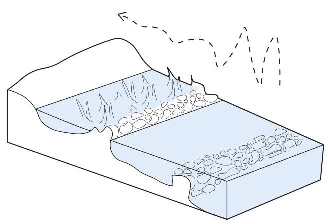


Coastal hardening works against the forces of the ocean, creating a hard surface for the water to crash into. This often leads to erosion and the depletion of beaches due to the force of the waves on the barrier.



Waves wash over the seawall at Battery Park in New York City due to storm surge associated with Hurricane Sandy. (Ruttle 2012)

How we build coastlines has been an ever-evolving subject with varying implications on the land we're trying to protect. Coastal Hardening has been a popular method for creating barriers between land and sea for many years by working against the ocean forces. These methods are often expressed through seawalls, and jetty infrastructure made to keep the sea away from the land. This increasingly popular device for combating rising sea levels is causing habitat degradation, shrinking of intertidal zones and wetlands, and a loss of natural hydrological processes. By creating these hard divisions, the natural sandy beaches are being lost, and in its place are walls of concrete. These walls not only create a hard divide between the ocean and coastal communities, but also form a hostile environment for marine ecology. It is estimated that about 14% of the shoreline in the United States has been developed with hard landscaping (Gittman et al. 2015, 301). New York is a prime example of some of these industrialized coastlines with original pier systems as hard edges. Since hurricane Sandy devastated large areas of the city's shorelines in 2012, engineers and designers have been exploring ways to armor the city. A prominent project was that of a 16' sea wall focused on keeping the water out of Manhattan (Gittman et al. 2015, 301). As the sea levels rise, this wall will have to become higher and higher to properly shield the urban space from the adjacent sea. In contrast, other approaches claim that sea walls are simply "engineering away our natural defenses" (Gittman et al. 2015, 301). Since then, the hard infrastructure has been "softened" with vegetation and space for both water and aquatic life due to the issues further along Manhattan's harder edges.

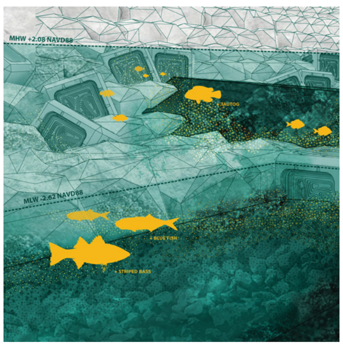


Coastal softening works with the forces of the ocean by mimicking natural edges with breakwalls, secondary pools and underwater topographies.

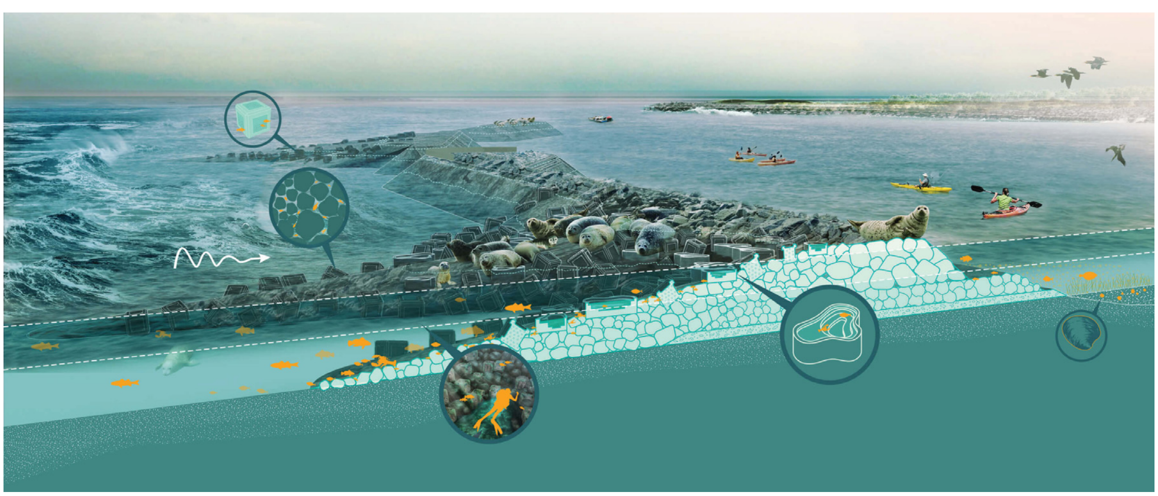
In contrast, coastal softening is an approach which utilizes natural strategies for sea level mitigation and designs to provide space for water instead of struggling to maintain a barrier. Coastal softening is about creating natural barriers between the open sea and the coastline. This strategy mimics the design of wetlands and marshes to absorb wave action before getting to the shoreline, as well as utilizing barrier islands to provide another layer of defense. Instead of creating hard lines that destroy the intertidal zone, growth of wetlands can be promoted through coastal softening to create natural lines of defense between us and the storm. These strategies are often combined with areas of hard and soft edges to develop a language that uses nature and

Oyster-tecture by Scape Architects, New York City (Orff 2009) infrastructure in a way that encourages local ecology and absorbs currents instead of blocking them.

For example, the larger area around New York City has been used as an urban laboratory for understanding ways of mitigating sea level rise and related storm surge effects. While many are campaigning for the common sea wall infrastructure, other landscape architects and designers are working to illustrate the power of habitat reconstruction and using soft methods to armor the shores of New York City. Kate Orff of Scape Studio is developing many projects of this nature, with one currently in construction in the New York Harbor. 'Living Shorelines' utilizes a hybrid of green building methods and engineered structure to facilitate aquatic growth. Concrete blocks of varying sizes and complexity are used to build up an artificial "reef" barrier that provide space for aquatic life to attach. This living breakwater consist of oyster reefs and other coral-like structures which mitigate waves from the open ocean. Breakwaters create a barrier which soften the waves before it gets to the shoreline, therefore slowing the process of erosion and maintaining existing beaches. The filtering and cleaning of water by the



Complexity of blocks in Living Breakwaters, Scape Architects. (Orff 2014)



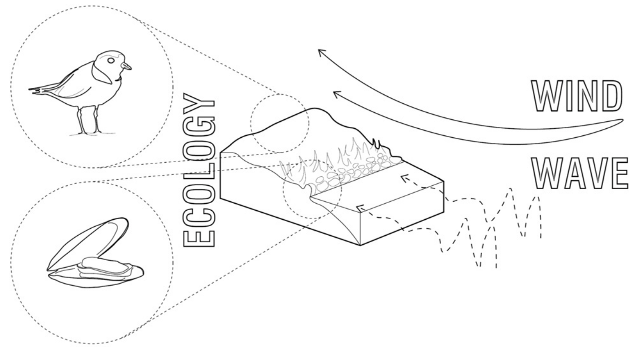
Living Breakwaters, Scape Architects, 2014. (Orff 2014) oysters will have an additional benefit to the harbour as they grow along the shores.

The notion of using habitat and nature to protect our shoreline in a more ecologically centered manner is slowly making its way to the forefront in urban development. Instead of using boulders and groins that slowly destroy habitat and valuable stretches of beach, coastal softening is a method that could work alongside the force of the water, but also re-establish biodiversity along the shoreline.

Strategies for living in this boundary between land and sea can be created using the natural hydrological processes and opportunities the ocean provides. Mindful spaces can be created that work with nature opposed to against it, embracing the temporal dynamics of the edge condition and all life in which it inhabits. From the forces at play, the shifting land masses, and the adaptable organisms who call this boundary home the coast is in constant movement and transformation.

The Air

When considering the dynamic space between land and sea, the atmospheric actors also influence the land beyond. The hydrological cycles dictate the air movements above, which are equally as important forces in shaping our environment. The temperature of the air over the land is different than that of the air above the water causing atmospheric shifts in weather systems and a constant circulation of air in this boundary zone (The Open University 1999, 25). Strong coastal weather patterns alter the shape of the adjacent land and earth beyond. The forces of our environment collaborate with humans and organisms to change existing spaces and evolve faces of the earth through cycles of weather and time. Designing with nature takes into consideration not only organisms, but also the natural conditions of the landscape itself. By embracing the cycles of the land and sea, we can



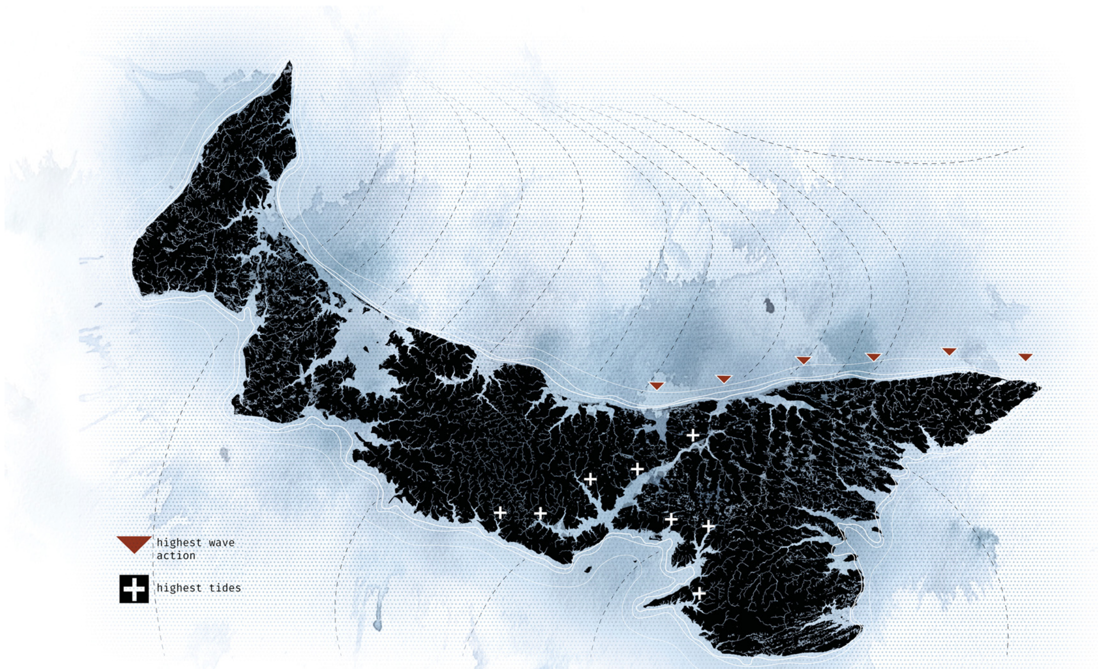
The zone between land and sea is shaped by wind, waves, and ecological habitat.

Chapter 5: Prince Edward Island

Prince Edward Island's indigenous name, Abegweit, means cradled on the waves, illustrating the importance of the Island's connection to its shoreline. The smallest province in Canada off the shore of Nova Scotia and New Brunswick, Prince Edward Island's history is one that is entangled with its relationship to the ocean. As sea levels rose thousands of years ago, a piece of Nova Scotia's shore became separated by what is now the Northumberland Strait. Prince Edward Island came to be due to the increase in sea levels, and is still currently in conflict with this same condition. The Island can be considered a remnant of what once was, a ruin of a past existence. Prince Edward Island is encircled by dynamic edges bordering land and sea, resulting in transformative and temporal landscapes. Every piece of the Island is close to the shoreline, making rising sea levels and accelerated erosion a pertinent issue. Through analyzing the Island's hydrology, geology, and ecology, we can form a comprehensive understanding of how to design between land and sea.

Hydrology of the Island

Water exists in abundance on Prince Edward Island, beyond the body of salt water that surrounds it. Freshwater creeks, marshes, and inlets are also major players in the way that water influences the land. Due to the Island's lack of large bodies of fresh water, PEI is reliant on its groundwater sources for human activity, from drinking water to the irrigation of agriculture. Groundwater is characterized as water that flows underground in the small spaces between rock and soil before finding its way into creeks and streams. Prince Edward Island is formed on a bed of sandstone, which



The hydrology of Prince Edward Island is mainly directed by ocean currents. Along the north shore, some of the highest wave action coming from the Atlantic are seen, while along the south shore some of the highest tides are expected. This combination of high tides and forceful waves creates a vulnerable location susceptible to flooding.

consists of many fractures and pores, allowing the water to easily accumulate below the surface. As a province that greatly rely financially on agriculture, groundwater is just as important to PEI's longevity as the ocean which cradles it.

As the freshwater travels through streams, it will eventually find itself in an estuary or saltwater wetland, where it becomes brackish. Saltwater wetlands are generally positioned behind barrier islands as a mitigation point between ocean and land. These pockets of shallow water are breeding grounds for diverse life forms, ranging from plants, fish, birds to mammals. The plants that thrive in this between space are often used as nesting material and sources of food for the native bird species. Additionally, the fish and shellfish who make home in this wetland also feed the birds and other mammals that wade through shallow

Wetlands behind barrier Islands at Savage Harbour, PEI.

The slip for boats to travel between the open ocean and the bay beyond.

The existing groin infrastructure along the dredged waterway.

waters. This saltwater barrier between land and sea is a dynamic space that is quickly disappearing due to human-centric development on Prince Edward Island.

On PEI, the ocean is the ultimate destination for freshwater. From the estuaries or wetlands, the water is transported out through currents and carried into the sea. As the water evaporates and becomes precipitation, the salt water once again transitions into a source of freshwater released back into the earth. In turn, as climate change threatens the land, it also threatens the water's natural cycles. The Island's groundwater is increasingly at risk due to saltwater intrusion as the rising seawater slowly encroaches onto the land. This injection of salt water alters the number of freshwater resources the communities can rely on. Additionally, with the rising of the sea levels comes the flooding of existing mudflat and wetland spaces. Without a consistent depositing of sediment, the wetlands will flood and simply be an extension of the ocean itself. As the earth warms, the ice coverage along the coast is also decreasing, resulting in a more vulnerable coastline. Due to winter being the stormiest season, the ice coverage along the shore has been an important tool in mitigating waves and preventing erosion in the winter months. There has been a drop in about 50% of total ice concentration, therefore extending open water season and reducing the protection of the shore (Manson 2016, 3). As the water warms and strips away the natural tools that mitigated erosion for thousands of years, we need to find new ways to break wave action and re-establish the space between land and sea.

Geology of the Island

The rolling farmlands of Prince Edward Island

Another defining aspect of the island is its iconic red land. Today, PEI's major industry is shared between both agriculture and aquaculture. Most of the Island is composed of man-made parcels of agricultural land, critical to the livelihood of many families in the province. The low-lying rolling hills of crops clearly define the landscape of PEI. The major crop being produced are potatoes, which thrives in the iron-rich soils of PEI that retain an ideal amount of moisture during the growing season (Davies 2011, 6). This relationship between both land and water is critical to the Island's identity. As sea levels rise, the agricultural land is at risk of flooding, as well as feeling the effects of saltwater intrusion. If too much salt water enters the soils, the potato industry will ultimately struggle to maintain their crop. The threat of sea level rise on the coast of PEI is becoming increasingly more problematic for the livelihood of those who inhabit and farm close to the shore.

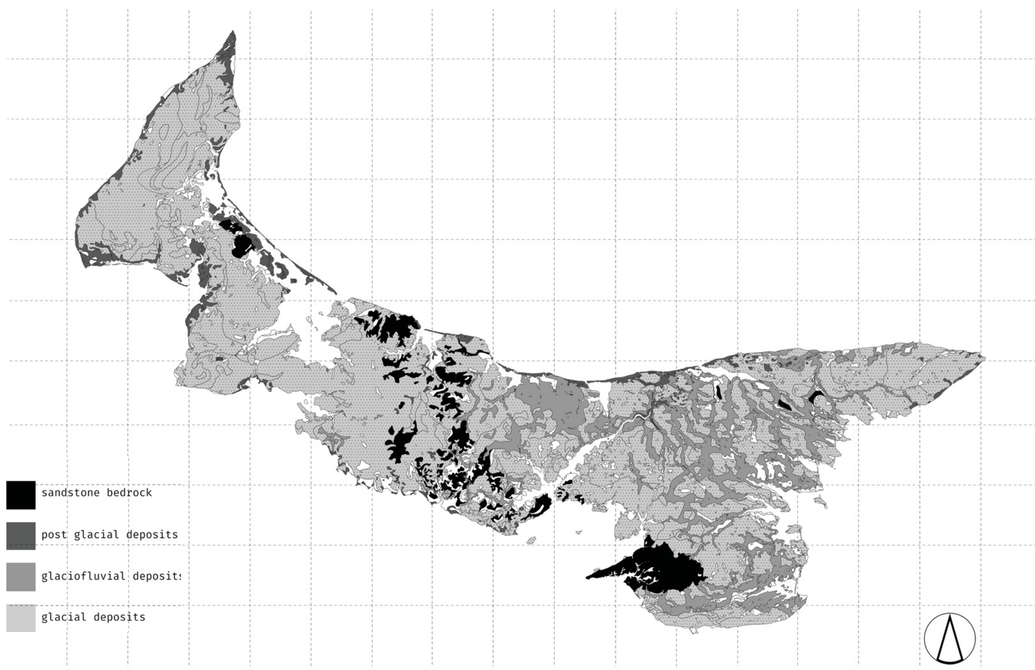
The salt water marsh located directly behind the sand dunes at the mouth of the harbour.

Prince Edward Island is not only known for its rolling hills of farmland, but also its long stretches of coastline. The edge between sea and land is a critical point in the nature of the Island itself. The coastline can be categorized into 3 zones: the nearshore, foreshore, and backshore (Davies 2011, 8). Prince Edward Island's nearshore generally is composed of sandstone bedrock overlaid with sand, which meets a similarly composed foreshore, except with sandstone rocks often along the edges. PEI's backshores vary depending on location, but it consists of either sandstone cliffs or sand dunes with low coastal plains. The rest of the island is mostly composed of low rolling topography of clay and fruitful soils for agriculture. The red sands and cliffs are key characteristics of the Island's landscape; a result of

Sand Dunes facing the Atlantic Ocean at the mouth of Savage Harbour, PEI.

the abundance of iron found in the soil and surrounding sandstone (Davies 2011, 56). These red cliffs are mainly found along the west and south ends of the Island, while the north shore is primarily composed of sand dunes driven by marine deposition, resulting in a vulnerable edge condition.

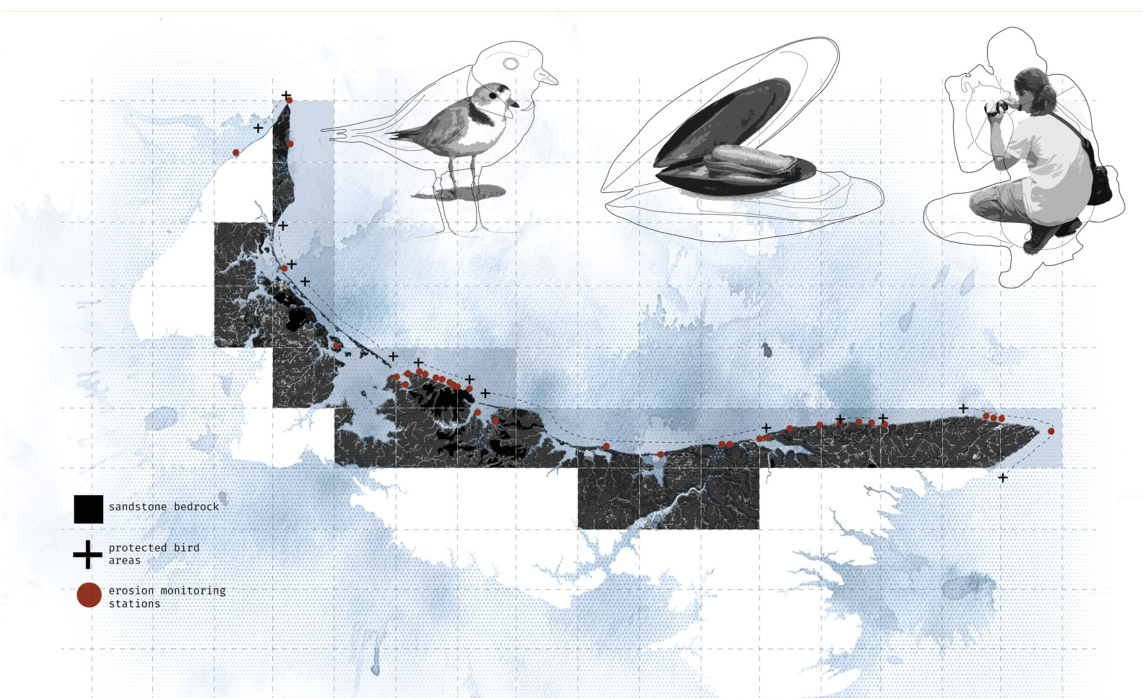
Marine processes have been slowly carving Prince Edward Island since the beginning of time, giving the coastline and its inhabitants a unique relationship with its surrounding ocean. It has been discovered that water levels around the Island have been rising for more than 8,000 years, resulting in every piece of coastline to be classified as erosional or transgressive (Davies 2011, 51). This categorizes PEI as a secondary coastline, meaning the land is primarily shaped through natural processes driven by the ocean opposed to plate tectonics. PEI, like most other Islands, has been and continues to be slowly molded, and transformed by the movements of the ocean. The north shore of PEI



The geology of Prince Edward Island is mainly characterized through sandy shorelines, rocky cliffs found along the north edge and red cliffs that follow the south shoreline. As seen in black, only small patches of the geology are made from solid bedrock. (Dept. A&F 1973) illustrates this temporality of the coast perfectly through the constant evolution of the sandy shores. The shore consists of interlocking sand dunes and barrier islands that have always been evolving and changing shape. The high wave action paired with the light substrate of sand, has resulted in a high amount of sediment transport in the area. Therefore, the coastline is constantly in motion and shaped by the waves themselves.

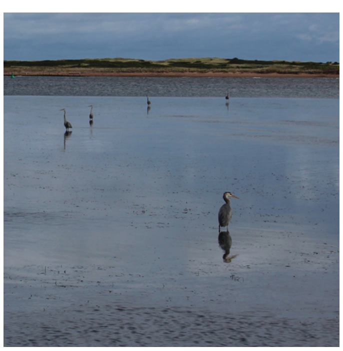
Ecology of the Island

The coastline of Prince Edward Island consists of a network of ecological systems that are influenced by the varying conditions at the connection between land and sea. The rocky intertidal zone and the sand dunes create various ecosystems that inform this boundary. Many shorebirds make their home in this sandy landscape including two



Ecology of the North Shore of Prince Edward Island can be identified through the intertidal zone, the sand dune system and the adjacent farmlands. The beings who inhabit these zones are primarily birds, oysters and people. (Dept. A&F 1973) families of birds. Both species thrive at the border between land and sea, feeding between marshy mud flats and grassy plains. The sand dunes act as a nesting habitat for a nationally endangered species of shorebird, the piping plover. In 2011, it was documented that this stretch of beach on PEI supported 4.4% of the total Atlantic Canadian population of piping plovers (Dietz and Chiasson 2000, 6). The birds travel to Atlantic Canada from southern parts of North America between late March and early May and only spend a few months before migrating further south at the end of the summer (Dietz and Chiasson 2000, 14). These birds' nest in the sand dunes are created using foraged sticks, grasses and shells from nearby wetlands and grassy plains. Plovers consume both aquatic and terrestrial species, such as insects and crustaceans, which are abundant in the intersection of land and water (Dietz and Chiasson 2000, 14). Piping Plovers are a key piece of the ecological system of PEI's sand dune landscapes. A major threat to the livelihood of these birds are disturbances brought forth by human development and activity. Beach goers and dog walkers in the summer months often pose a major threat to the nesting practices of the plovers by unknowingly destroying their nests. Another threat is shoreline development that causes sand loss. Human activity is only one aspect that needs addressing to protect the plover habitats, since many terrestrial predators, such as foxes roam the beaches and threaten these endangered species. Maintaining beaches reaches far beyond human interest by protecting non-human species who also make home within this ecology.

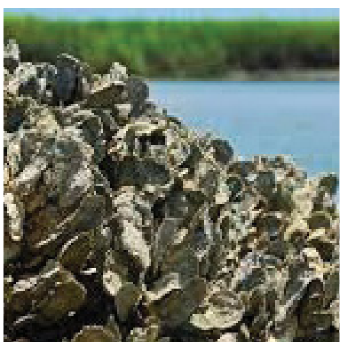
Piping Plovers (Milicia 2014)



Herons scattered around the wetland zone behind the dunes of Savage Harbour

The ecological landscape of sand dunes is one in constant transformation with its environment. The sand is always slowly being pushed and shaped by natural processes of

Oyster reef structures underwater. The bivalves can open allowing time to freely feed on the bacteria and plankton in the water column. (Rhode Island DEM 2021)



Oyster reef structures above water. Oysters are forced to hold water in their shells for survival. (Maxwell and Wilker 2017)

Byssal threads attaching itself to a rock (Qin 2013)

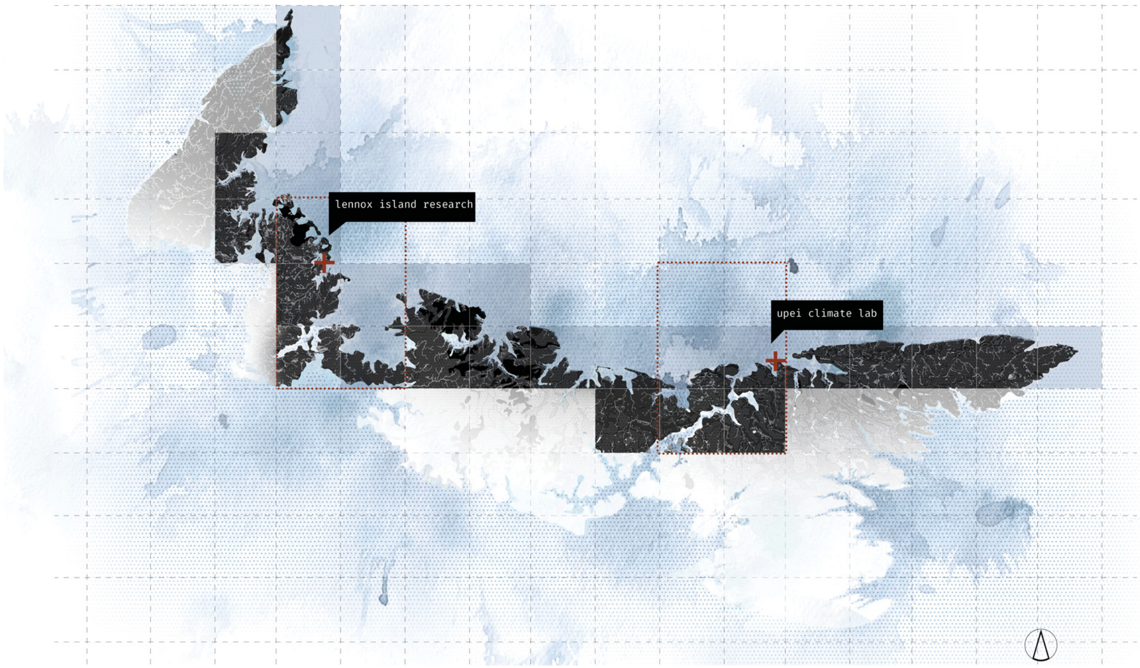
wind and the movement of ocean currents. This dynamic environment is inhabitable only for only adaptable and temporal creatures. Storm surges and the increase of climate induced conditions have resulted in many beaches along the shoreline, to be broken up and flooded in areas. This formation of barrier islands due to storm has the potential to be beneficial for the existing coastline it protects and help revive the ecology. Piping plovers thrive in this disjointed space due to the lack of human and predator disturbance. Their naturally nomadic and light-footed presence makes them easily adaptable to shifting landscapes and prosper in collapsing beach systems. The species who thrive in this ecology are not only adaptable, but also live between dry land and ocean fluctuations with ease. Birds are key players in this in-between space and are vital actors in the functioning of our coastlines through insect control and providing nutrients for the native mammals.

Additionally, the intertidal zone is another major ecosystem at play in the boundary between land and sea of PEI. Bivalves flourish in this dynamic space and can be found in abundance in the intertidal zones surrounding Prince Edward Island. Mussels and oysters are the most common bivalve species that make home along this interface between land and sea (Cullis-Suzuki 2020, 13). They have adapted to be able to hold water in their shells, allowing them to survive for long periods of time away from the ocean. Bivalves attach themselves to substrate using byssal threads or a chalky protein which that can withstand the daily crashing of tidal waves, and push and pull of a storm surge. Bivalves are unique in the way they fuse to one another and create reef structures (Cullis-Suzuki 2020, 13). The forms are first created usually over dense beds of mud or silt where the bivalves attach to dead shells left on the ocean floor. The shellfish hunt for the familiarity of calcium carbonate to attach themselves to, resulting in bivalves clumping onto one another eventually forming reef-like structures in the shallow waters of the ocean. These natural reef structures go through cycles, increasing in size and breaking down in areas because of major storms. This cycle of falling apart to come back together is critical for the resilience in this intertidal zone ecosystem.

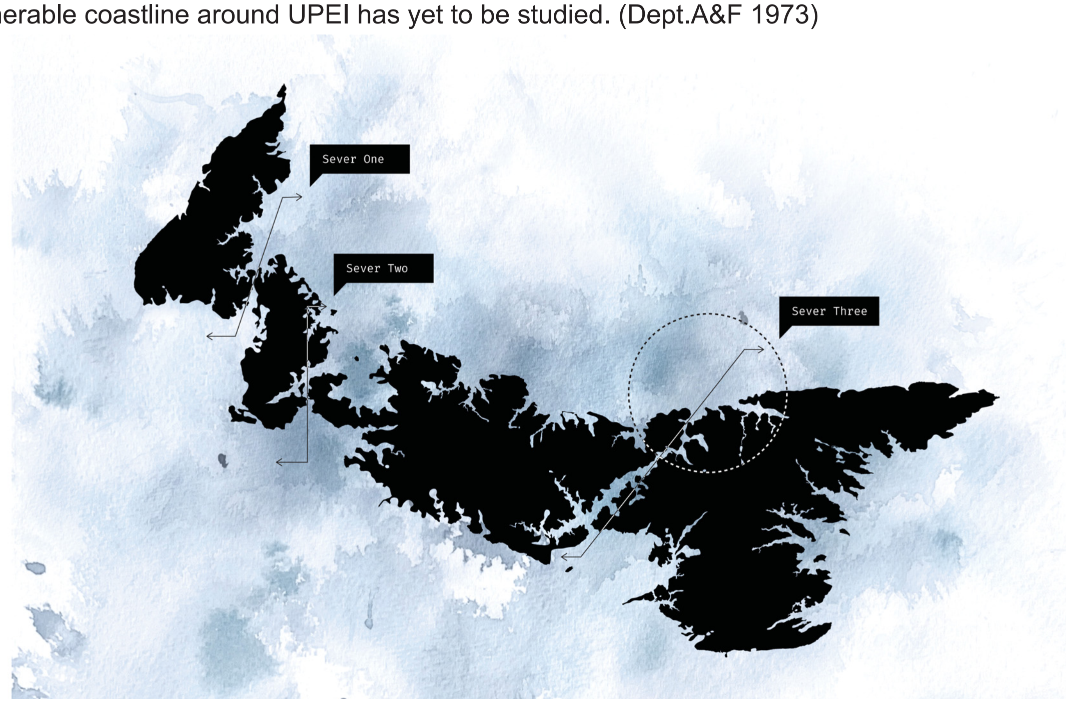
The bivalve is both resilient in its collective formation and its preferred habitat is protected from the full force of the ocean. Reef systems are a powerful network in the regulation of water flows and natural protection of shorelines. They mitigate waves by absorbing the initial force and leaving calm water in the wake. These semi-submerged and submerged reefs act as a shield against powerful water flows, both close to the seabed as well as the water propelled by wind on the surface. This natural formation of bivalve habitat around the Atlantic behaves as a porous barrier to the vulnerable adjacent shoreline.

The strength but also temporality of the reef habitat is what makes this ecosystem so resilient. Understanding this dynamic boundary can provide many lessons, and strategies for not only protecting the land we have, but how humans can also thrive at this ecological interface. The Island has an abundance of human activity focused on the production of food and visitors vacationing in the summer months. The North Shore has also been gathering interest for research. UPEI has begun to set up a climate lab near St. Peter’s Bay to study the erosion and wave action along the North shore. This lab space is meant to bring students closer to the edge that is being studied and further monitor conditions. Lennox

Island is also the site of exploration for coastal mitigation methods, particularly involving living breakwaters. The vulnerability of the shoreline that fronts the Atlantic, and its unique geological conditions have brought the attention of many researchers interested in these natural processes.



The north shore of the Island is being researched around Lennox Island, but the remaining vulnerable coastline around UPEI has yet to be studied. (Dept.A&F 1973)



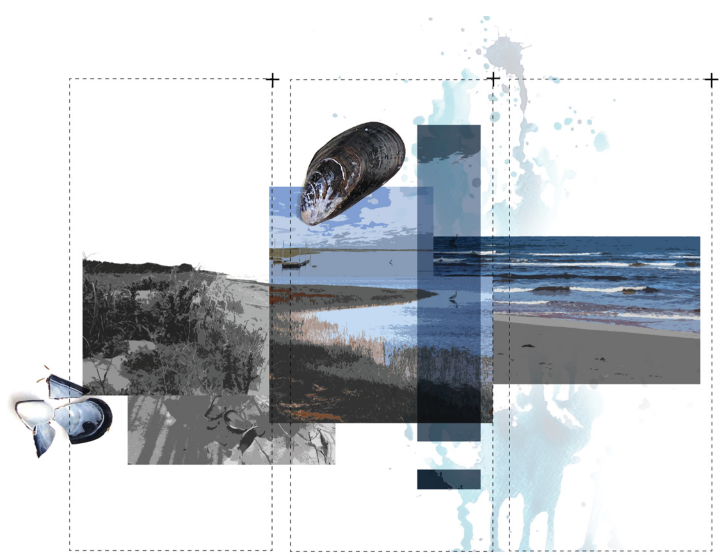
An estimation of Prince Edward Island after a rise of 4 degrees of ocean temperature. The Island has flooded in three major areas, creating multiple fragments. (Dept.A&F 2000b)

Forming a Dynamic Edge

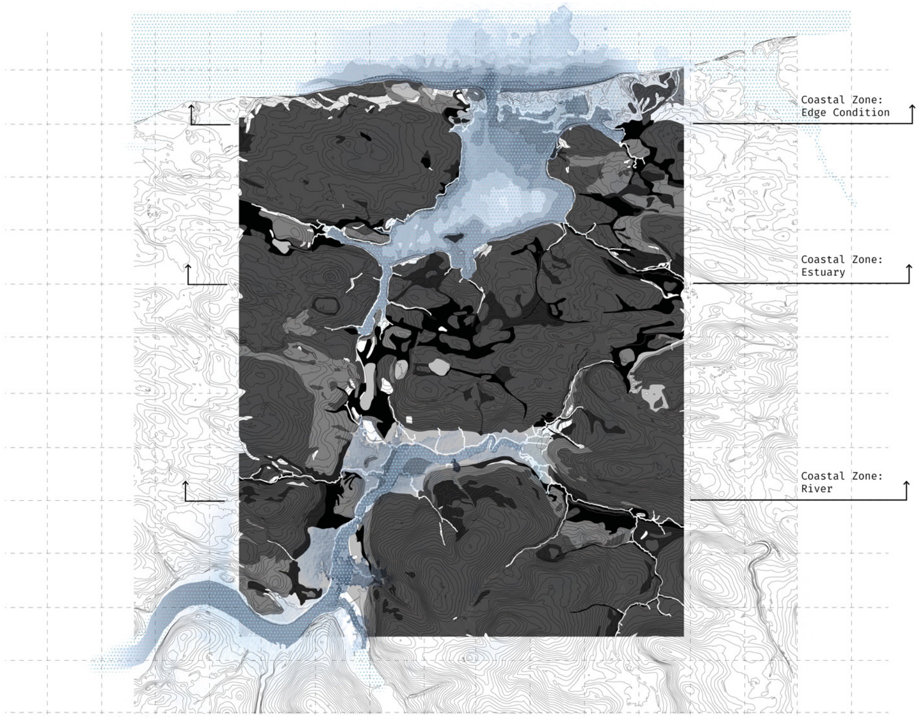
It is currently predicted that the seas could rise to three meters in the next century. This rise will split Prince Edward Island into three separate Islands, which is a great concern for the local inhabitants. When an increase in water levels merge with high tides and strong winds, coastal flooding quickly becomes another cause for concern. These storm surges are becoming common occurrences, leaving behind destruction on coastal infrastructure. Particularly at risk is the North Shore of the Island due to its geological composition. As the Island becomes further divided by water, the area where land and sea collide increases. The landscape becomes increasingly more transient and reshaped constantly by local ecology and natural forces.

Savage Harbour is a small inlet that exists along the sandy north shore of PEI. This stretch of land is home to many residents such as farmers and fisherman, as well as temporary residents at the resorts and cottages in the area. In addition to human activity, the barrier beaches are also important spaces for birds and other coastal creatures that make their home along the shoreline. As the ocean continues to warm the Hillsborough River, the body of water is expected to overflow and connect to the mouth of Savage Harbour. This will result in one of the three major disruptions of the Island creating a divide between the eastern shore and central PEI. The combination of the low-lying sandy edge of the North Shore, and the river being susceptible to high tides creates a clear pathway for water to travel, allowing a deep separation of the Island that will be unpreventable. All of these changes are predicted to occur within the next century. Today, the sandy barrier islands that front a large wetland area is in the process of deterioration and into ruin. The sand is disappearing, risking a loss of all habitats beyond.

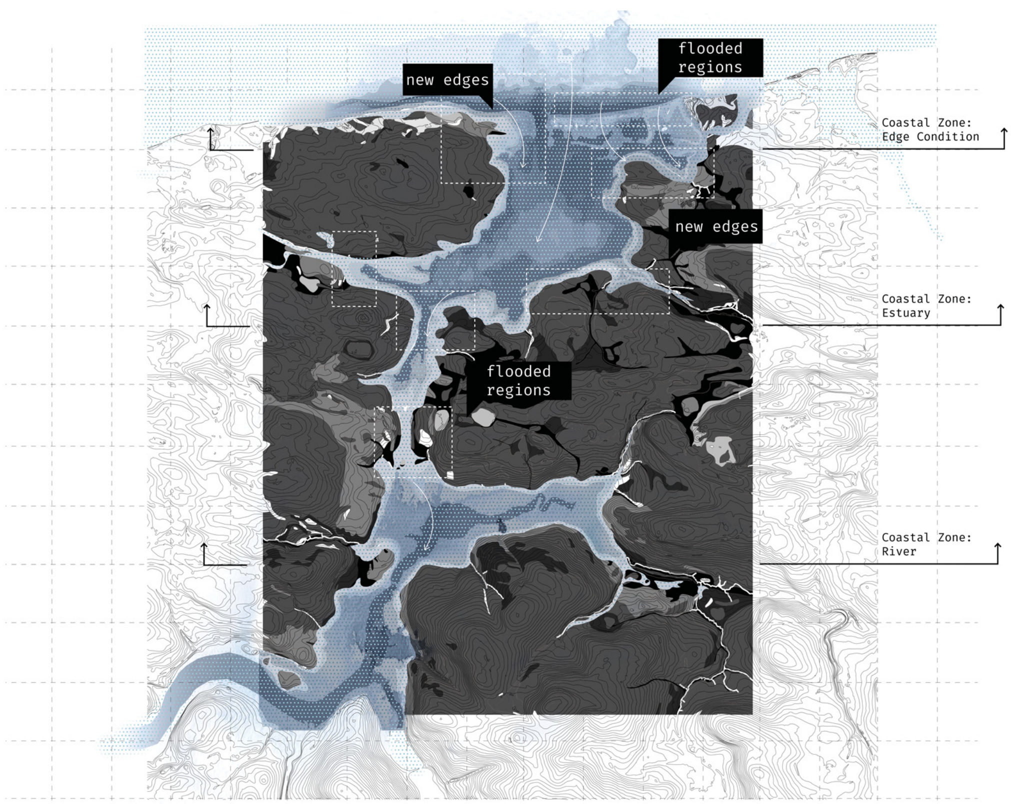
Savage Harbour has the common features that most inlets along the Island share; access to the ocean, active aquaculture, flourishing productive land and beaches frequented by vacationers and locals alike. Its vulnerable location along the North Shore allows for the exploration of this edge condition within a changing climatic environment. The bay can serve as a case study for the entirety of the Island by pursuing ways to create new edge conditions, reclaiming flooded space, and building off the existing areas. The Bay can provide a laboratory for experimentation by formulating alternate ways to inhabit the spaces whether it be for humans, birds, and or aquatic life. Amid all this destruction, we can explore ways to create a new resilient coastline- A space that rises from the flood and creates new opportunity from the ruin.



A collage representing the land, the sea and the in-between



Savage Harbour's soil makeup and hydrology as of today. The black ribbons depict clay sediment throughout the zone as well as the light grey depicting organic or wetland soil types. (Dept.A&F 1973)

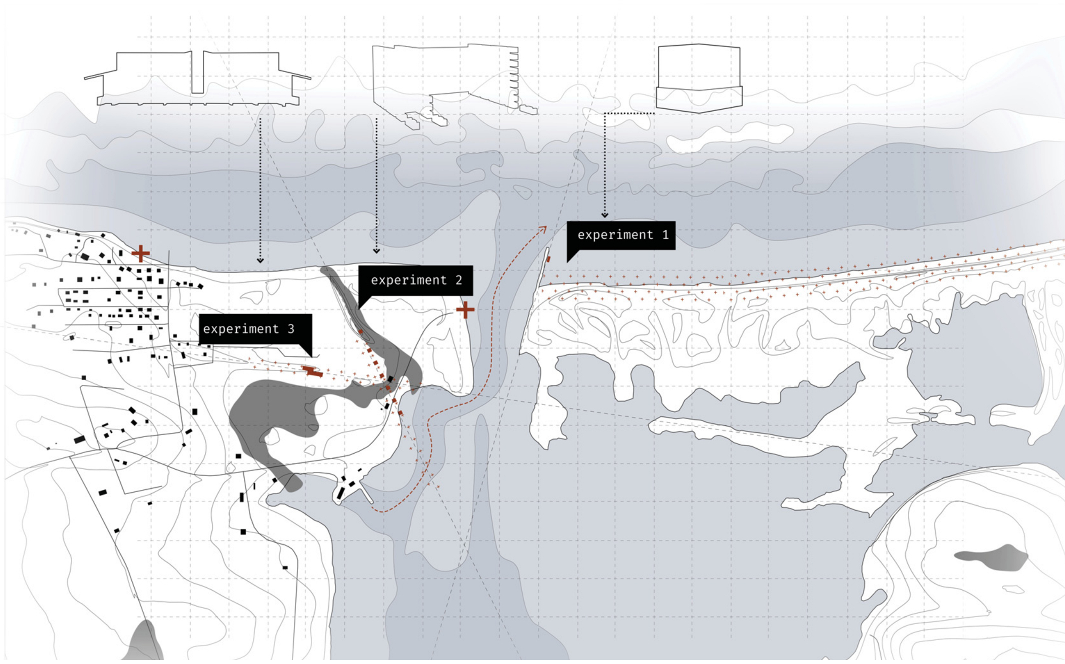


An estimation of Savage Harbour after a rise of 4 degrees of ocean temperature. The edges between land and sea are expanding and resulting in a sever between the ocean and the Hillsborough river beyond. (Dept.A&F 1973)

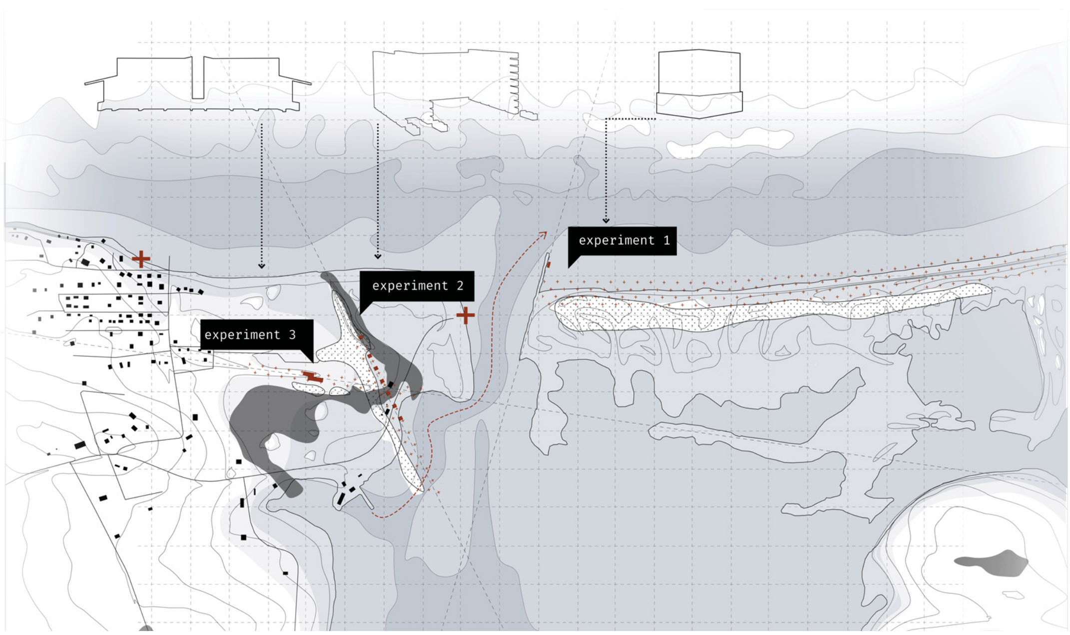
Chapter 6: Designing for Change

Designing within a dynamic boundary, like that of the coastline, entails not only creating adaptability but a design that works within natural processes. Through embracing natural forces and local ecology, we can develop an architecture that is created to transform alongside the earth surrounding it- eroding, accumulating, and depositing sediment throughout time. Savage Harbour serves as a laboratory to explore various ways of mitigating rising seas and testing transformative methods of design. Three different experiments are located along this shifting edge between land and the Atlantic Ocean. Three different experiments are located along this shifting edge between land and the Atlantic Ocean. Each study explores how to both maintain and form new edges while protecting marsh and land beyond. Using natural forms of defence seen in the intertidal zones, these reef networks can grow over time to create a line of defense against rising seas and stormier conditions. The experiments create a natural infrastructure that will accumulate over time developing an armature of change- one equally within natural processes and a part of the earth systems and its architectures. These lines of defense are implemented at varying degrees of ocean temperature change and through a layered approach to allow for gradual protection as well as critical shifts through time. As one experiment transforms into ruin, the next experiment can begin to take shape and change with the evolving environment. The experiments all engage natural processes of erosion, accretion, and deposition to create new edges or maintain existing areas. Through the layering of experiments, the temporal nature of the edge is explored illustrating the rising seas as well as the conditions of the existing coast. As the coastline changes, so does the implemented architecture and our relationship to the edge. The strategy looks ahead designing for inevitable ruin and building off remnants of the past shoreline. The various experiments can be used to maintain a connection and relationship to the past, as well as establishing new edges and protection against the ever-changing seas of our future.

Oysters are also examined as a key actor in the ecology between land and sea- An organism that is a master of adaptation. The researchers can examine these creatures as well as find ways to embrace their adaptive qualities, creating a new way of inhabiting a slowly sinking world. An architecture of change is created through engaging all the critical actors of the boundary between land and sea. The forces of hydrology, geology, wind, humans, and non-humans alike all influence the shape of the land and allow for new forms of life to develop from the ruin.



The edge at 14 degrees Celsius-current Ocean temperature. The three experiments are all tethered to existing geological composition or eventual ruin of a past shoreline. Experiment one, the unit, maintains the memory of the existing barrier islands while also tethering off a past groin infrastructure. This is the first experiment to be implemented. The second experiment, the structure, creates a new edge as the shoreline floods fixing itself to a high point in the geology, creating an island or ruin of a past landscape. A new edge is enforced while experiment one is still transforming below sea level. Experiment three, the building, begins to transform as ocean temperatures rise from 14 to 18 degrees tethering itself to a high piece of land behind the new edge created by experiment two.



The edge at 18 degrees Celsius- a change of 4 degrees in ocean temperature.

Designing with Natural Forces: A Material Exploration

> Architecture comes to life, vibrates, breathes, and transpires, absorbs and disgorges, becomes calcified and oxidized. Its structures become overgrown with moss and all sorts of organic matter, germinate and flower, and get colonized. It also trembles, burns, corrodes, becomes flooded, silted up with sand and mud, breaks up, scatters and is erased. As soon as architecture forms, only just emerging from the mind's reasoning, it changes, alters, and forms all over again in the ceaseless impacts of matter and living organisms. Architectures are pieces of the Earth already metamorphosed and still transforming, fragments that make the world. (Trevelo 2022, 167)

Architecture can be viewed as fragments of the earth equally subjected to natural forces and transformations over time. Natural processes of erosion, accretion and deposition are explored through different materials and methods to capture this change. The age and weathering of materials are emphasized through design embracing the inevitable ruin and analyzing site over long periods of time. Natural forces can become a collaborator by embracing these changes to material, while also fostering its evolution. By designing with these elements of transformation and moments within the material's life cycle, architecture can become a tool of measure illustrating the effects of nature on built form as well as evolving alongside the earth itself.

A collage of the movement of sand with a structure influencing deposition

The effects of hydrology, the movement of geology and the growth of ecology are all represented through material studies. At the larger scale, the different experiments all work together to influence sand deposition. The creation of new edges and influence of sand deposits is crucial for the evolution and longevity of the Island as a whole. Implementing structures to impede longshore sediment transport and allow sand to collect is a strategy seen throughout the experiments. The structures are made

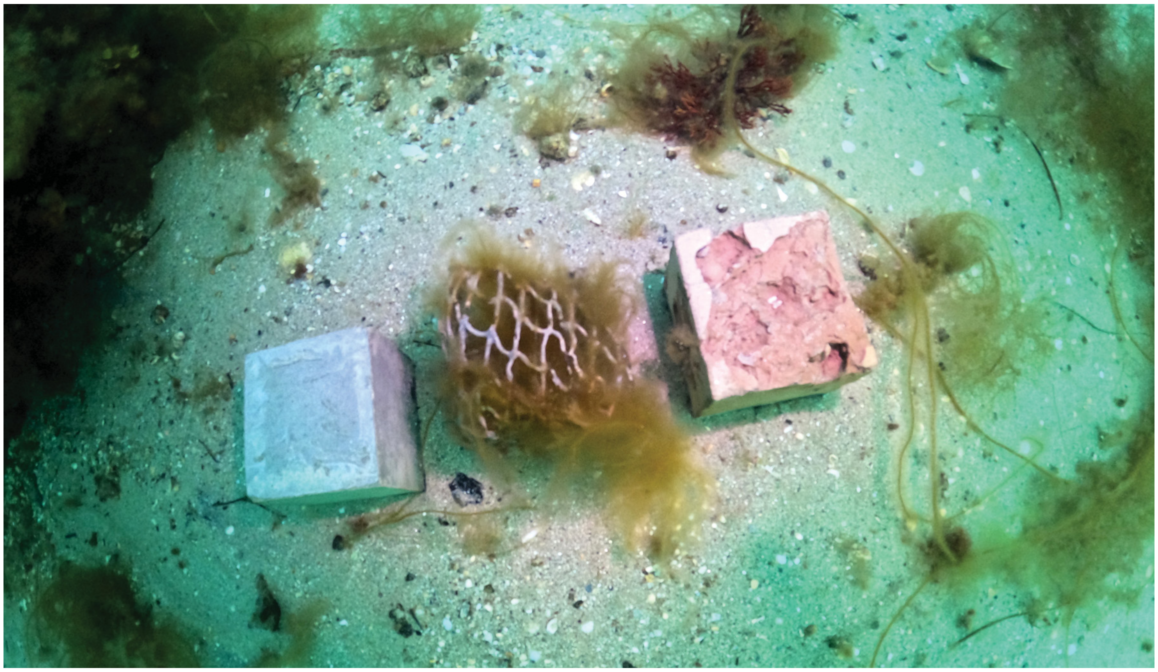
A prototypical concrete block

The Netting Block

The Erosion Block

to not only influence sediment transport but also create natural infrastructures that can change over time. Each experiment allows for the growth of oyster reef to protect existing shorelines, dampen wave action, create sand re nourishment, as well as increase biodiversity.

The study began through analyzing what material or design can be implemented to create different infrastructures with the dual ability to shift sands and create a catalyst for aquatic growth. The prototypical concrete block became a starting point in this exploration. The smooth sides and regular formation create a less than ideal condition for the accretion of aquatic life. Reef formation develops from complexity for the structures on both a micro and macro scale. Small bumps and ridges are aimed at the growth of algae and smaller life forms, while larger nooks and holes are made for small fish looking for refuge. The netting block, was created to be a catalyst for aquatic life and create a space for growth - a block designed for accretion. In contrast, the erosion block, is designed to transform in the salt water, creating complexity through the forces of the ocean itself - a block designed for erosion in turn becoming a catalyst for growth. The concrete mixture was also changed to better mimic that of artificial reefs. If calcium carbonate is added as a form of fine aggregate, the prototype will be identified as existing reef or that of shells by bivalve creatures. This allows more life to accumulate on the structures and in turn, creating an even larger and beneficial reef to interrupt sediment transport.

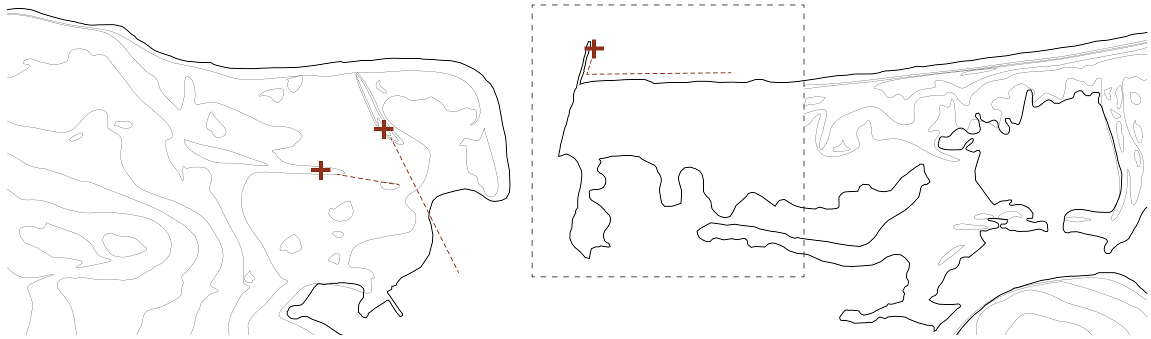


The three prototypes were placed 15 feet below sea level for 30 days to analyze initial accretion. The smooth block had the least accumulation, while the netting block seemed to attract the most algae and creating home for fish. The eroding block had many small life forms growing in the organic patterns, while multiple snails were seen throughout the larger cavities.

The erosion block collecting snails

The netting block coated in algae.

Over the month of exposure to the elements below the sea, the blocks began to accumulate different forms of life. The experiment illustrated the potential these different prototypes had in terms of accumulating aquatic life and creating new homes for fish. Over the passage of time, these prototypes can grow and build off each other to form new structures initiated by the inhabitants of the ocean. Using natural forces of the water as well as the actors in these spaces can be a catalyst for new life and influence the movement of sand from beneath the seal level.

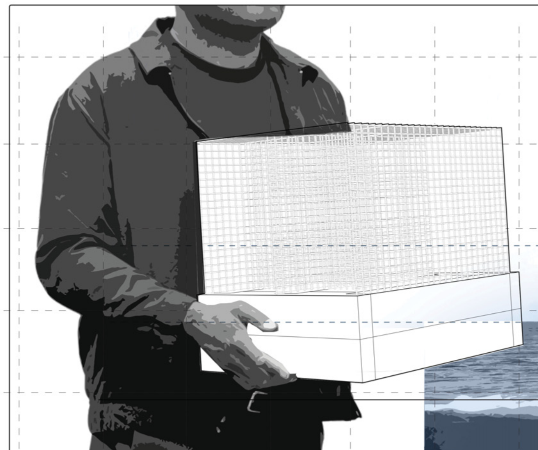


Location of experiment one.

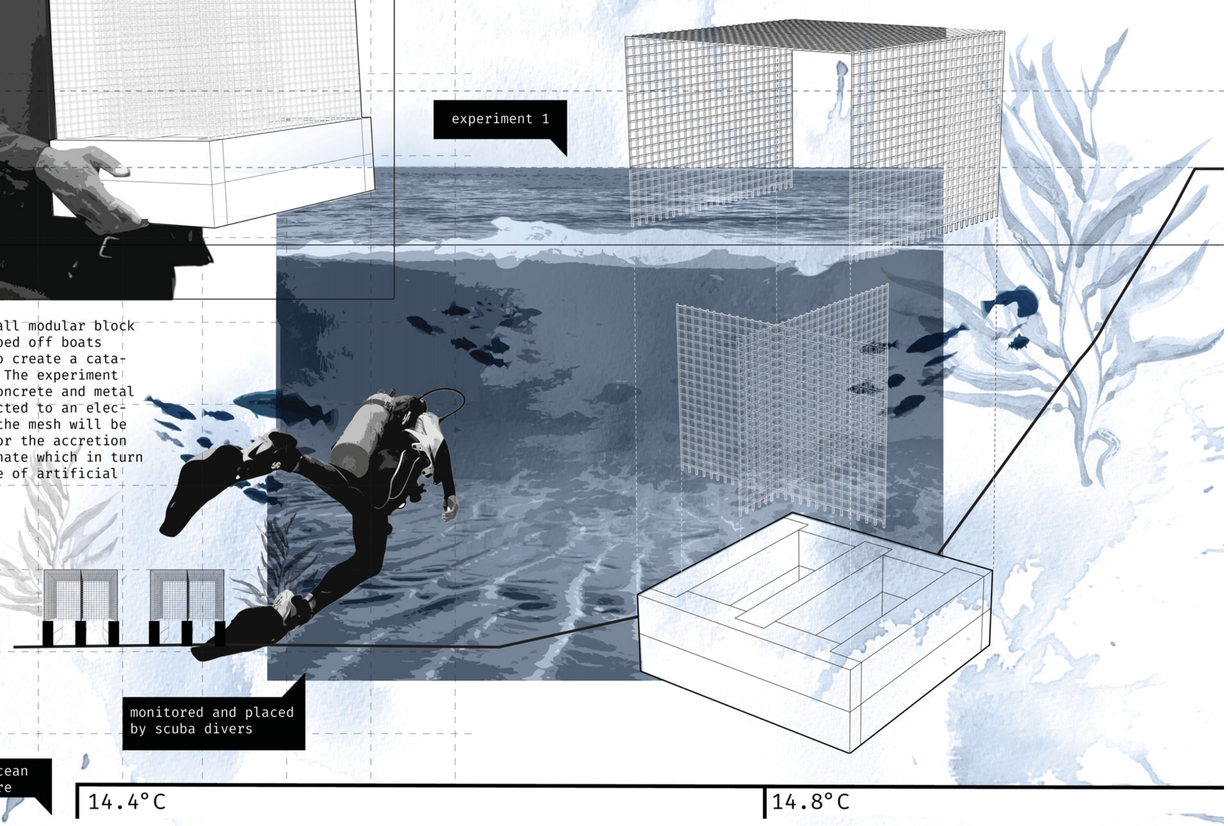
The unit builds off from the netting block. A structure designed for accretion.

Experiment One: The Unit

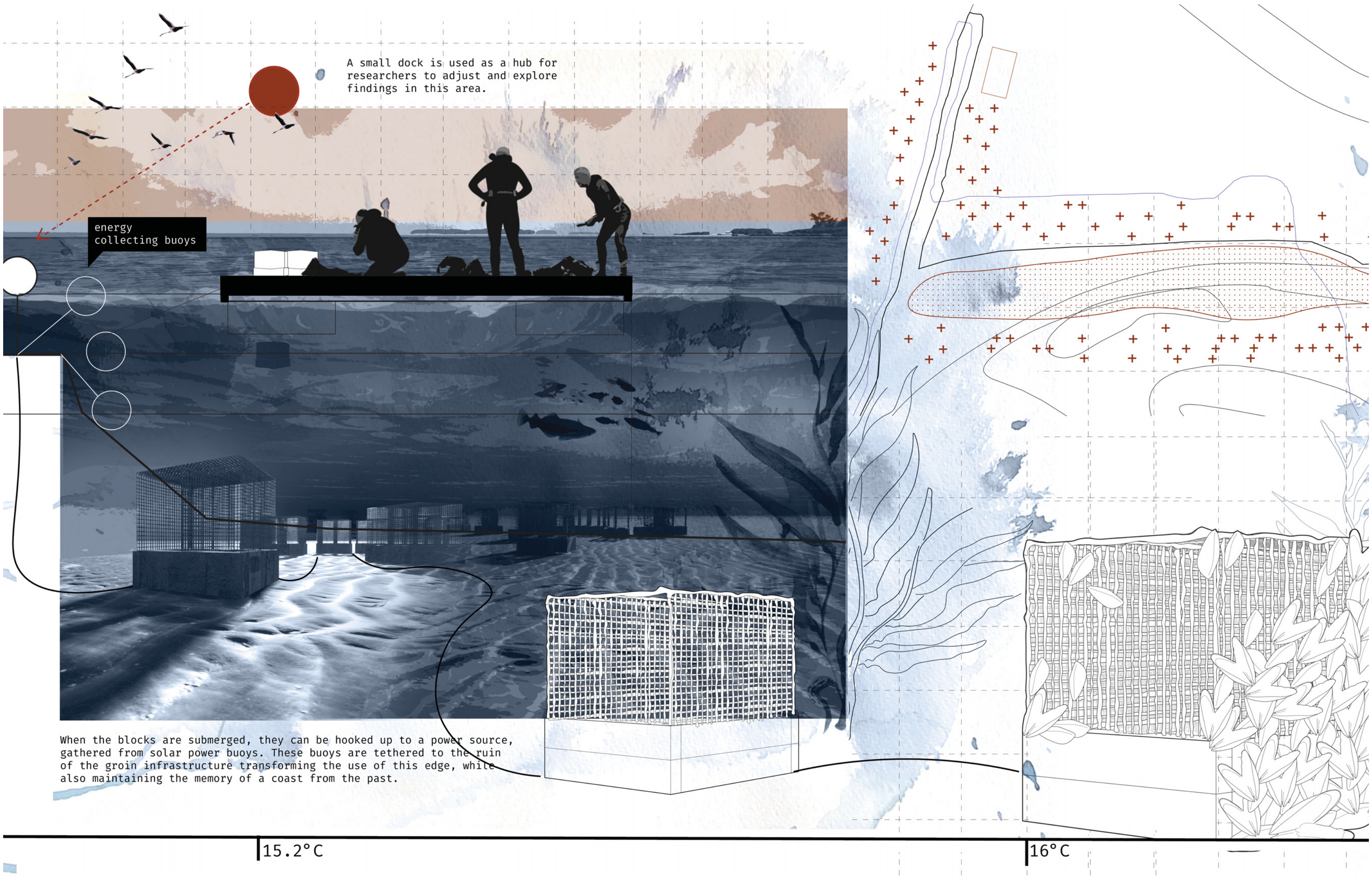
The first experiment is a modular prototype that is designed to accumulate aquatic life and form a reef structure over time. The unit is made from a new technology created for artificial reefs called *Biorock*. The wire netting on the blocks can be attached to a power source and over time, through the natural processes of accretion, collect calcium carbonate. This build-up of calcium carbonate forms a natural reef material, allowing for the accumulation of aquatic life. The experiment is focused on transformations through accretion over time to reinforce edges and maintain sand deposition protecting wetlands beyond.



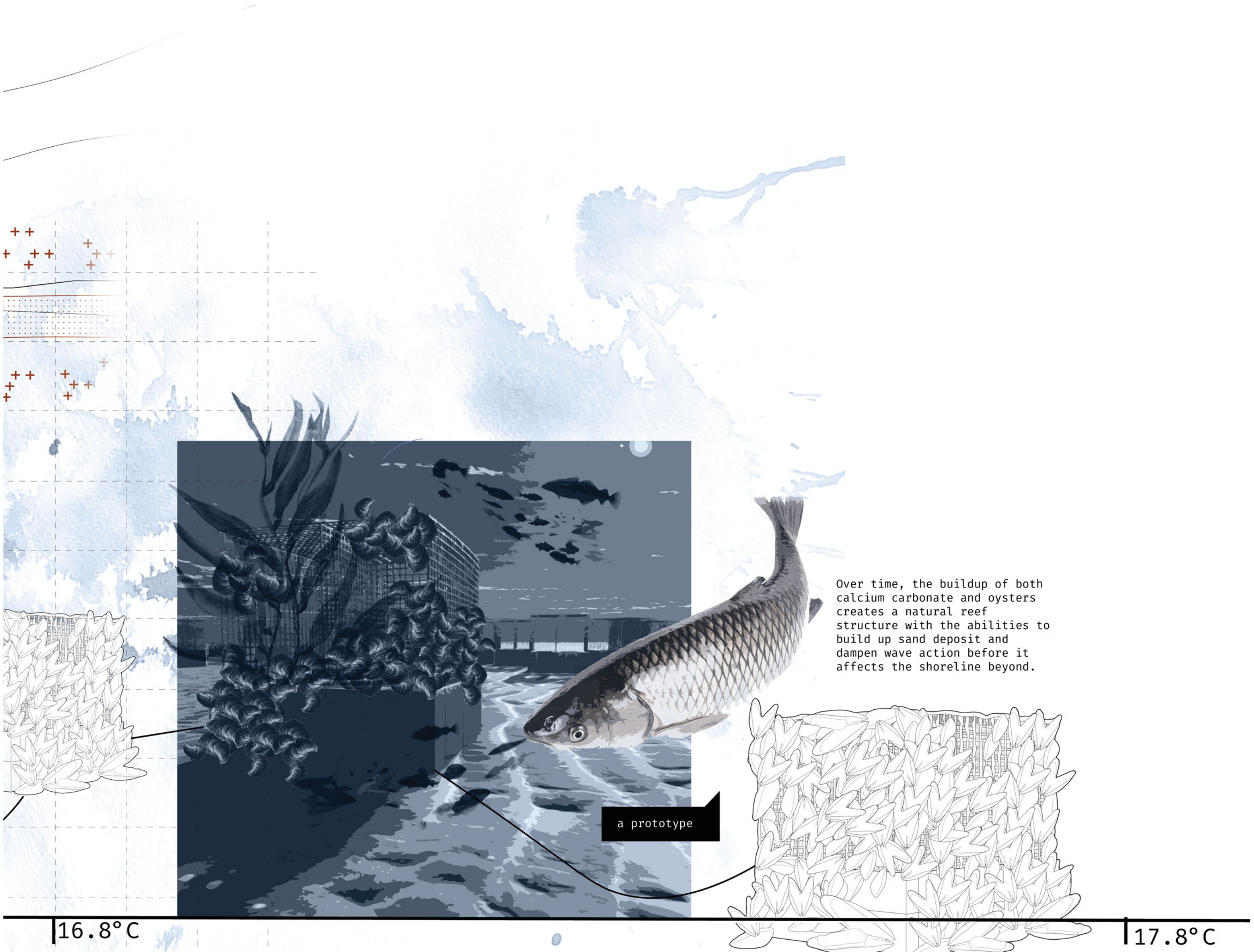
The unit is a small modular block that can be dropped off boats along the edge to create a catalyst for growth. The experiment is composed of concrete and metal mesh. When connected to an electrical current, the mesh will be used as a host for the accretion of calcium carbonate which in turn is used as a mode of artificial reef



Experiment One: The Unit



Experiment One: The Unit



Over time, the buildup of both calcium carbonate and oysters creates a natural reef structure with the abilities to build up sand deposit and dampen wave action before it affects the shoreline beyond.

Experiment One: The Unit

Mixture with chunks of clay throughout

Mixture with clay used as aggregate

Mixture with clay pressed into the mold

Eroding Concrete

The first experiment is centered around the notion of designing for growth. Creating prototypes with complexities to elicit the accretion of aquatic life and in time, influence sediment transport. The question became, can the salt water itself be an instigator of change, eroding the material to allow for complexity? This can be accomplished by designing with the natural forces throughout to allow for accumulation and growth of new life.

Prince Edward Island consists of many layers of clay ribbons scattered throughout the Island, making this material abundant. This sediment is also critical to the longevity of wetlands and marshes. Clay allows for the collection of water, as well as the growth of marsh vegetation, in turn creating habitat for animals who live in these conditions. Water and clay's relationship reaches beyond that of the marshy landscape. When hydrated, the quality of the material is more malleable with a mud-like texture while in drier conditions, the clay can become a rigid building material. Additionally, when this material is glazed or fired, the material has a longer life span. This glazed version of the material can act similarly to oysters by layering onto a structure and creating a protective coating. Thus, clay is not only locally abundant, but also has the potential to react to water levels and change material properties over time.

Therefore, this exploration of eroding concrete with the addition of salt water includes elements of clay. The blocks were first tested using hydrated clay in the mixture resulting in a more brittle structure. As the percentage of clay in the mixture was increased, the more the sample would crumble with the flow of salt water. This created a rough texture that would only be beneficial for certain kinds of algae. To create the complexity needed for oyster reef formation, the block would need to erode even more.

To continue the study, clay was added to the mold instead of into the concrete mix. This allowed the concrete to fuse itself to the clay pieces, creating a block composed of both parts concrete and clay. When placed in water, the clay reacted by slowly eroding away from the block and revealing intricate

Making the concrete mixtures

The experiment began with exploring different ways to add clay to the mixture and how this reacted to salt water.

patterns and organic complexity in the concrete left behind. The clay changed material states from a rigid surface to that of loose sediment.

The amount of clay, hydration of the material, and patterns were all created making several blocks that would erode and transform with the immersion of salt water - A material transformation, instigated by the ocean itself.

This experiment created a new way to work with material properties that not only illustrates natural processes but


The initial block


After 24 hours in salt water


After 48 hours in salt water


The initial block


After 24 hours in salt water


After 48 hours in salt water


The initial block


After 24 hours in salt water

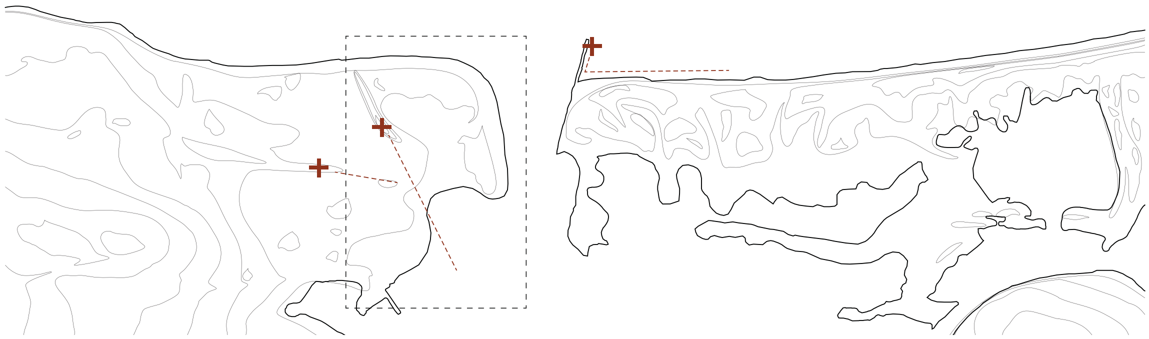
Salt accumulation

Salt accumulation

Continually, the samples were left for 30 days partially submerged in salt water. Salt slowly built up along the edge of the block exposed to air. The salt was absorbed by the submerged areas of the block and crystallized when it met the air above. This created intricate patterns illustrating the movement of water within the tank. The prototypes not only eroded due to the salt water, but also engaged in accretion. This transformation of the samples changed shape over time by erosion, illustrating the beauty of accretion.

Salt accumulation

The two samples collect salt in similar yet different ways. Each had a build-up mainly around the edges, while the tops slowly filled in as time progressed, creating a white cast over the blocks. Some blocks accumulated salt at a faster pace than others. The clay left in pieces of the block may have absorbed more of the salt than the block with no clay left in its structure. The experiments tested not only accretion, but also a possible device to illustrate the change of water levels in a temporal way.



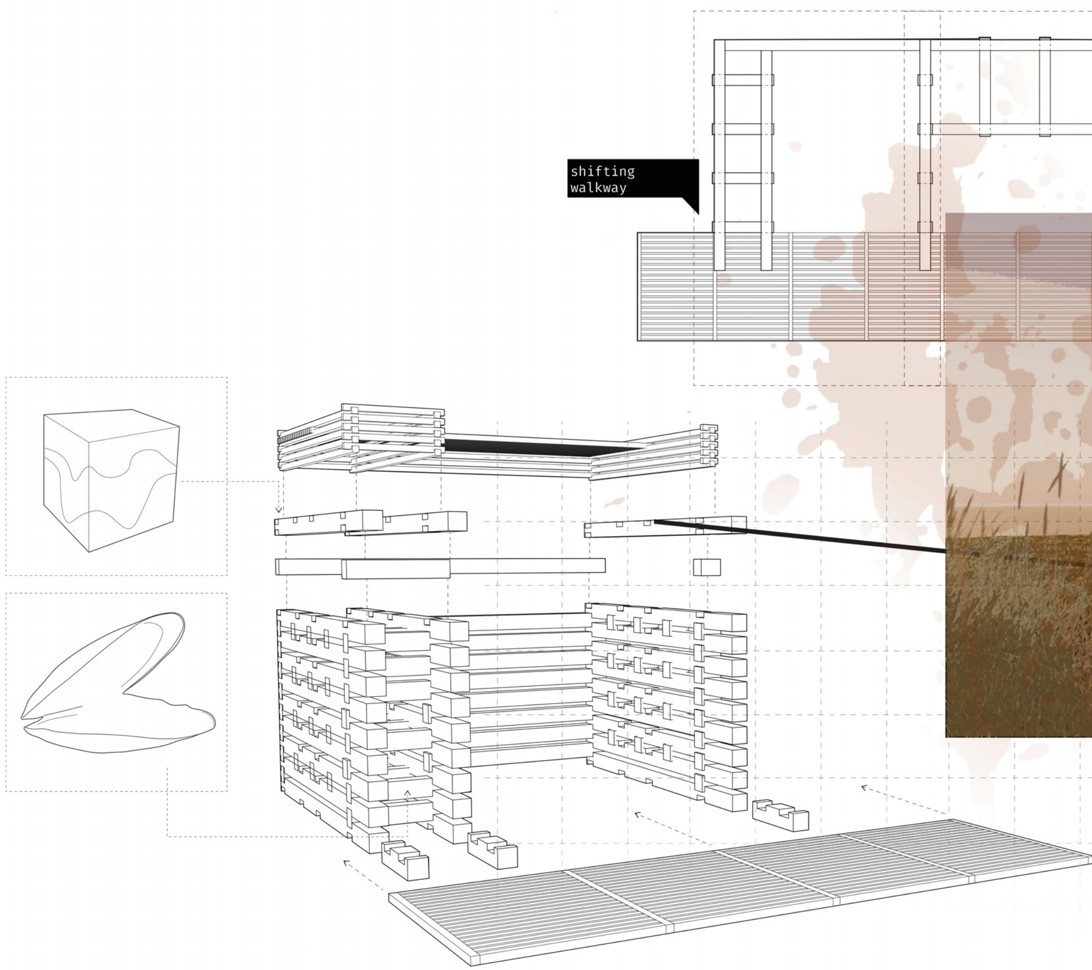
Location of experiment two.

The unit builds off from the erosion block. A structure designed to instigate new life from erosion.

Experiment Two: The Structure

The first experiment is centered around the notion of designing for growth that can be utilized as the first line of defense to mitigate flooding. The second experiment is about the idea of designing for erosion, in turn allowing for accretion of reef structure. As the sea levels rise, the edge moves further and further into the land mass continually creating new spaces vulnerable to the forces of the ocean. New edges can materialize and create an architecture that transforms alongside erosion and accretion to create a new boundary between land and sea. The experiment applies the concrete and clay as a way of leaning into the power of the ocean and allowing erosion to bring new opportunities for life.

The cube is translated from a small unit to a rectilinear member. The experiment relies on stacking as a human based form of accruement, being easily assembled or disassembled along the new edge. The modular structure provides space for storage, pathways when the seas are still low, and can slowly become a catalyst for reef structure when the water rises. The structure creates a space not only for residents traversing the landscape, but also creates multiple ways for researchers to monitor the rise of seas. The modules themselves illustrate the changes as well as the tower positioned towards the mouth of the harbour.



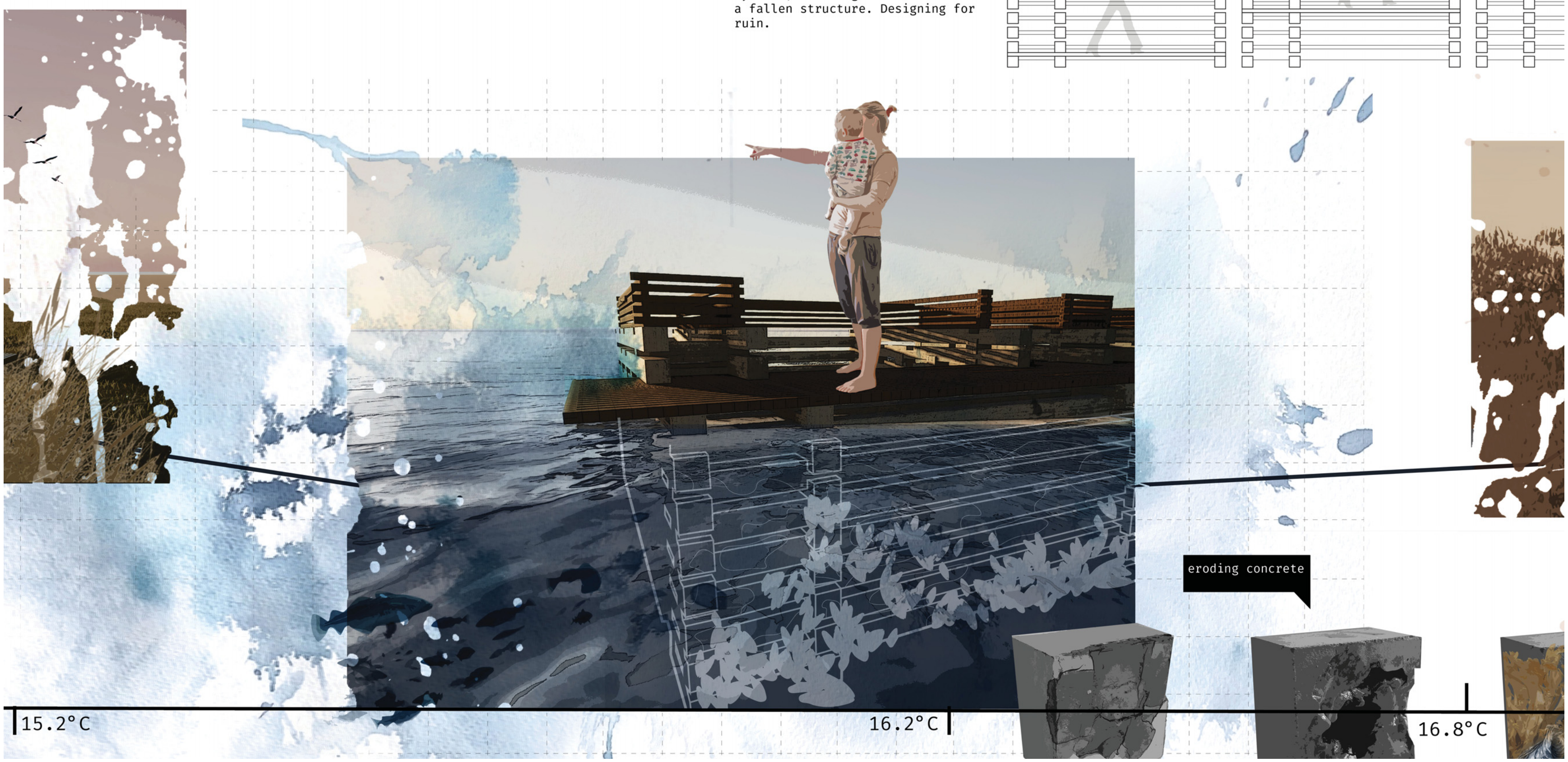
It utilizes this concrete material and wood by creating a cribbed form that is not only modular, but easily built by farmers and residents alike. The structure can be placed along this new edge giving flexible storage space, as well as shell collection to make more concrete pieces as needed.

today's ocean temperature

14.4°C | 14.8°C

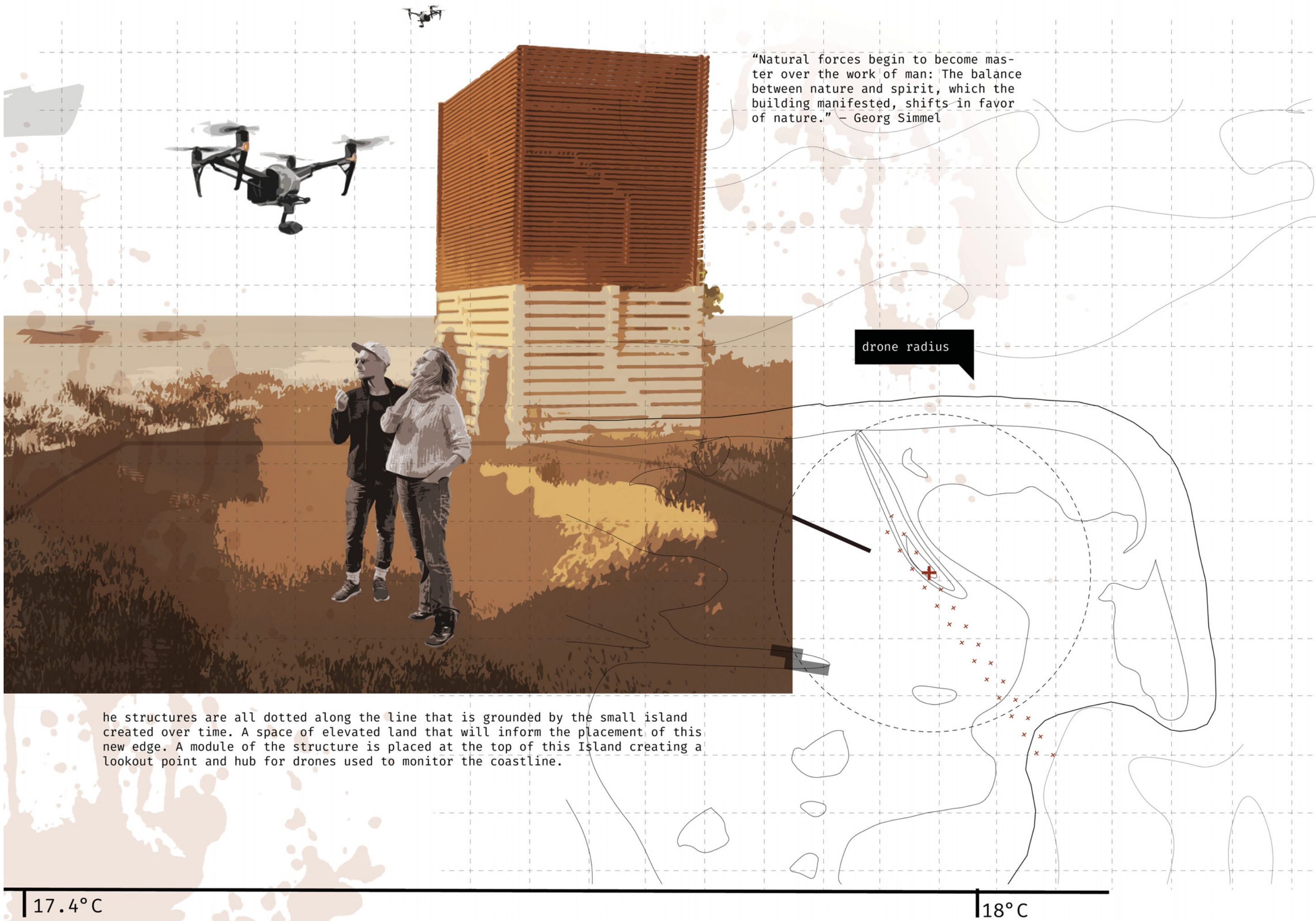
Experiment Two: The Structure

As the oceans rise, more concrete can be slid into place, creating an even more robust structure. As the water rises, the clay erodes back into sediment leaving behind space to elicit the growth of oysters, creating new life from a fallen structure. Designing for ruin.



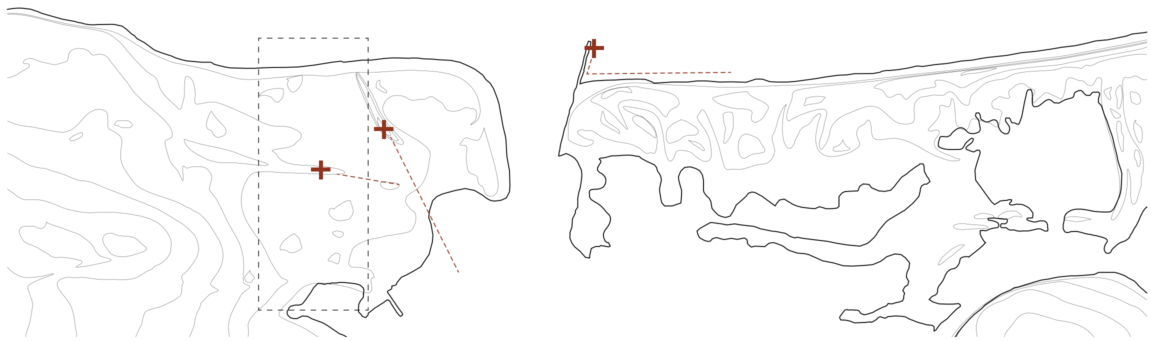
Experiment Two: The Structure

“Natural forces begin to become master over the work of man: The balance between nature and spirit, which the building manifested, shifts in favor of nature.” – Georg Simmel



he structures are all dotted along the line that is grounded by the small island created over time. A space of elevated land that will inform the placement of this new edge. A module of the structure is placed at the top of this Island creating a lookout point and hub for drones used to monitor the coastline.

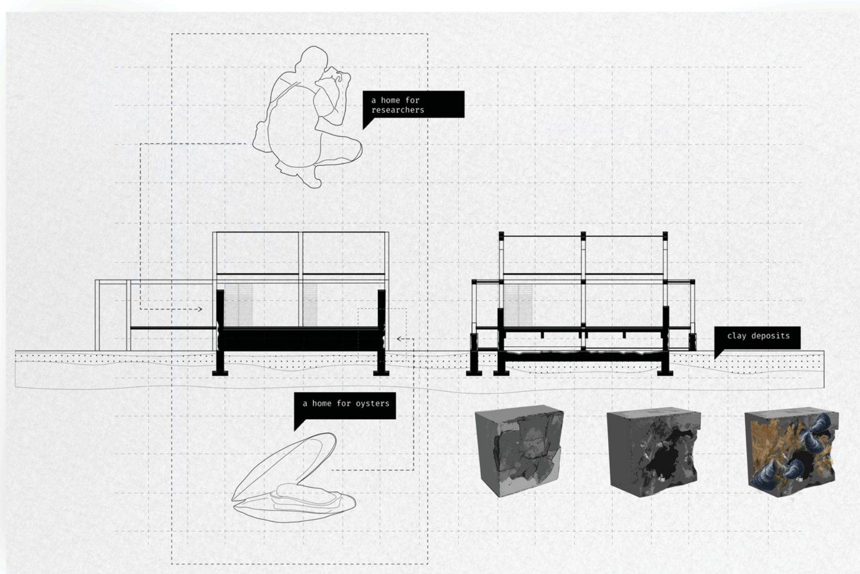
Experiment Two: The Structure



Location of experiment three.

Experiment Three: The Building

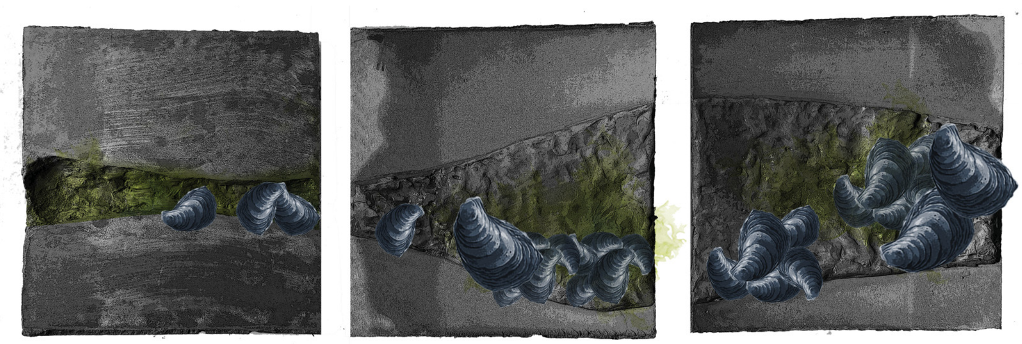
Experiment three is an architecture that embraces storm surge and flooding conditions as the first two experiments become engulfed in water. As time progresses, the structures and building components are designed to engage with natural processes to create space for both humans and aquatic life alike. The experiment is designed for both the researcher and oyster as a primary actor, while embracing an architecture of erosion, accretion and deposition.



As the water rises the erosional concrete can be used foundationally to create home for aquatic life. The sediment in the blocks can return to the earth surrounding the building allowing the spaces to act as wetland or marshy ecosystems. This increase in sediment and reef infrastructure can help in mitigating storm conditions and reinforcing a soft edge as the shoreline creeps forward.

Another design component which is in collaboration with nature is the idea of concrete wall panels. These panels can begin as elegant walls with clay mixture. The clay can be placed in the mold in a similar fashion to that of the blocks, creating a panel of both clay and concrete. The panels explore ways to create design or pattern and control what part of the panels erode.

As the water rises and affects the wall, the clay will slowly begin to erode, exposing the intricate patterns of the ridges left behind in the concrete.



This contrast between the smooth concrete and the more complex geometry will create a clear divide in growth when submerged in the ocean. This pattern left behind will allow growth to be designed. Accretion of aquatic life such as algae and oysters will collect along the eroded pieces and leave the smooth parts of the panel relatively untouched.

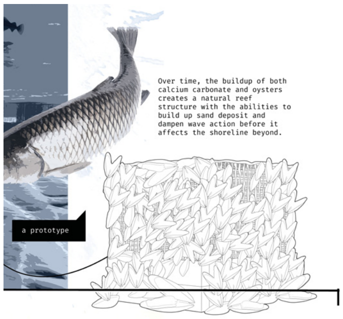
Designing with Ecology: Oysters and Humans

Oysters are creatures found in Prince Edward Island's intertidal zone and are often farmed in various bays and inlets around the Island. This zone of the ocean is in constant flux due to changing water levels, making the oyster able to thrive both in and out of the water. This specific adaptation to survive in a dynamic environment is critical to the ways in which humans can also inhabit this landscape. The reef structures and the way the oysters behave can provide lessons of how to design for a space that often clashes with waves.

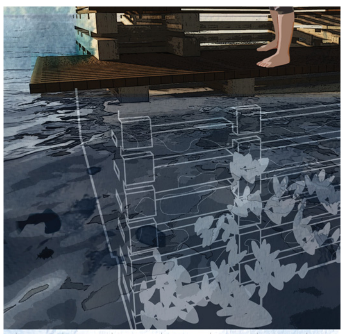
Learning from the Oyster Through the Unit and the Structure

The oyster reef can be used as a primary tool for sea level rise mitigation and influencing the build up of sand. The shorelines can be protected through creating structures that collect oysters over time and form a sense of natural breakwaters, the shorelines can be protected. Experiment one and two both utilize the oyster as an actor to influence growth of aquatic life and to use the implemented structure as a catalyst to create larger reefs. Through this eventual build-up of reef structure, sand can be further deposited, strong waves can be mitigated, and biodiversity can be reengaged back into an overfished ocean. The oyster can be a critical actor in designing new edges along land and sea.

Oyster reefs are adaptable forms which can release from one another in storms but come back together to form new structures when the weather has subsided. The oyster's ability to regenerate in a cycle of growth and falling apart is key to its survival. Additionally, bivalves attaching to



Oyster reefs seen in experiment one, The Unit.

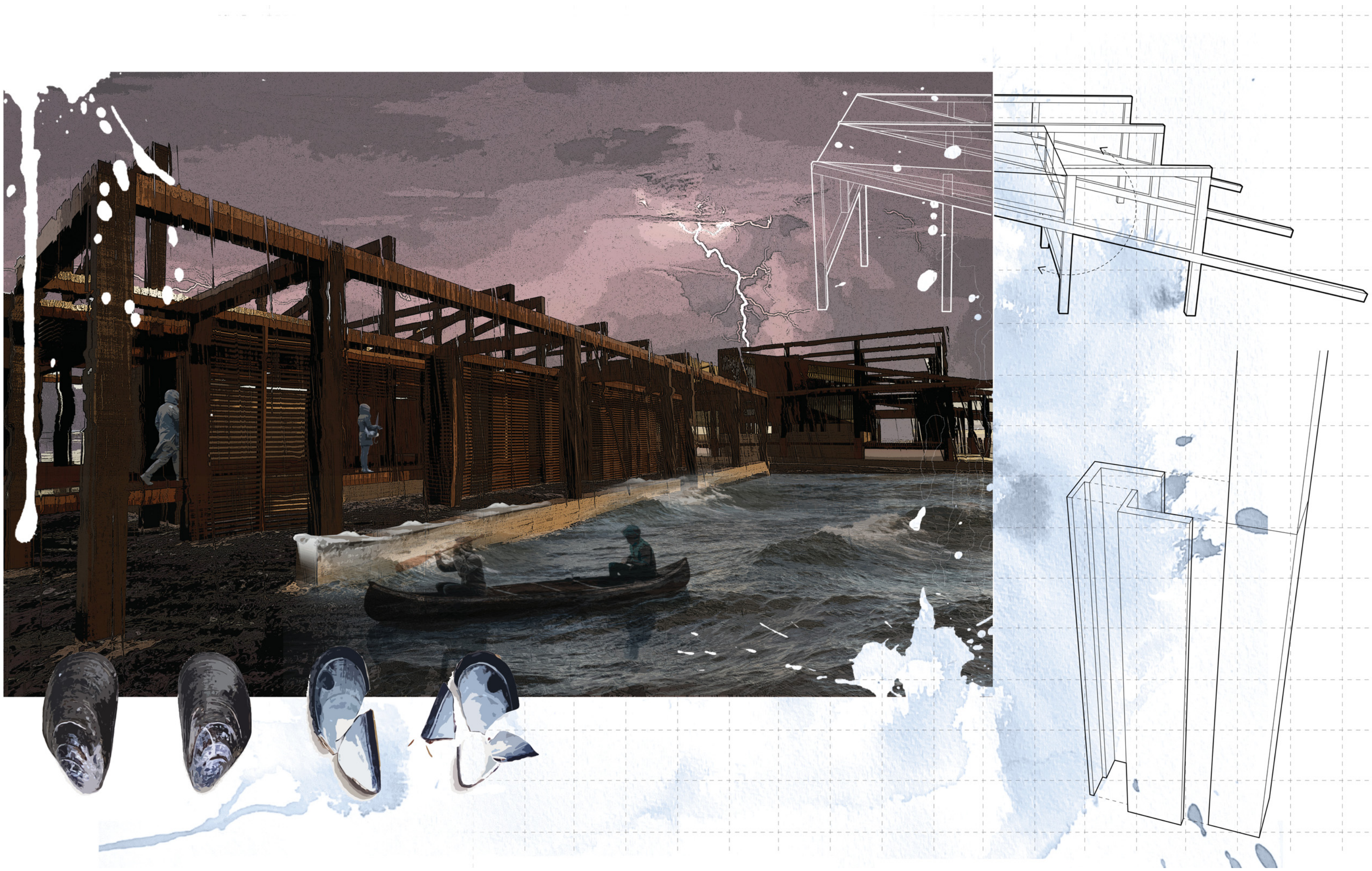


Oyster reefs seen in experiment two, The Structure.

each other or a reef structure can be a catalyst for growth. As seen in the first two experiments, this parasitic quality creates a new material off the old and preserves the shape and form of the concrete block that once was. The block becomes engulfed in reef, extending the materials life and transforming it into something new. The wood components in experiment two do not have the same quality, resulting in the pieces decaying as the concrete reef evolves to serve new purposes. Oysters as an actor can preserve and create new life off ruin. These lessons from the first two experiments working with reef structures can inform and apply to building methods that allow the oyster to be a part of this adaptive architecture.

Experiment Three: A Habitat for Researchers and Oysters

As the water rises, the remaining land is subject to storm surge conditions, working in a similar way to that of an intertidal zone. A space suddenly crashed with waves or left to dry. The building creates an opportunity of such conditions by utilizing the eroding concrete to make reef for aquatic life in the space infiltrated by water. The building adapts to these storm conditions by not only creating home for the oyster but also using it as a model for building. Fired clay tiles are used in a similar fashion to oysters by attaching to certain pieces of structure, protecting it from the water to extend its overall lifespan. This lesson taken from the previous experiments will allow the wood structural elements that are partially submerged in the water to extend its lifespan. The building uses this parasitic quality of the oyster to protect certain pieces and create a layered approach to protection using fired clay as an element of longevity.



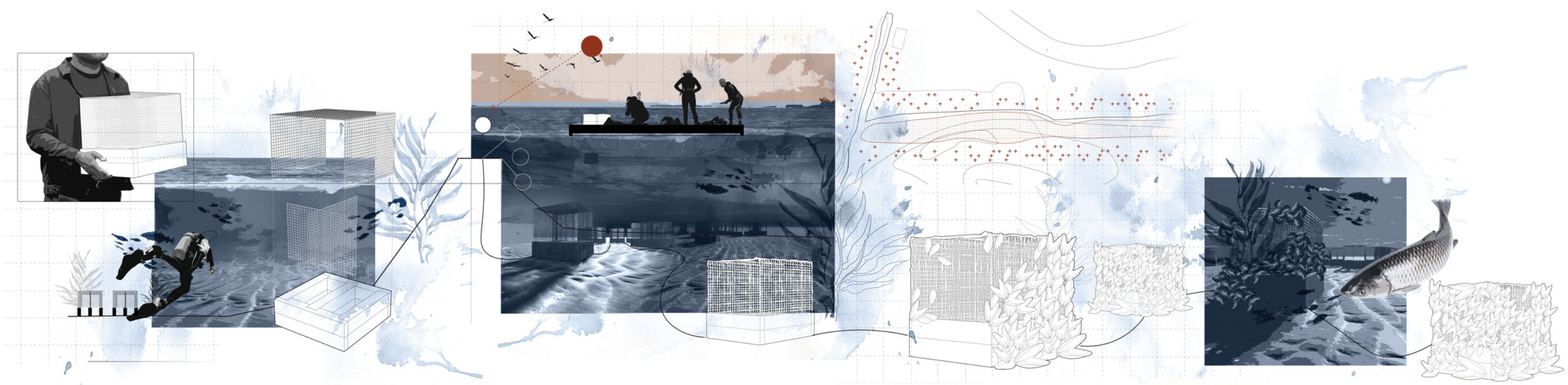
In storms, the oyster is made to break apart and come back together. The roof of the flexible room can be dropped in a storm allowing the wind to easily pass through and come back up when the storm has subsided. Additionally, the storm shutters can be used to close off the classrooms in inclement weather or open them to the concrete boundary to examine the way the ocean erodes and creates home for aquatic life, and how salt accumulates on the edge. The salt becomes a clear indication of water level and changing of daily tides.

The experiment shows wood wrapped around a layer of clay and then cast into the concrete foundation. Concrete is used as a foundational element, and wood as structural.

When the clay has turned to sediment after being placed in the salt water tank, the wood becomes free from the concrete base. Using life cycle as a means for change within the architecture.

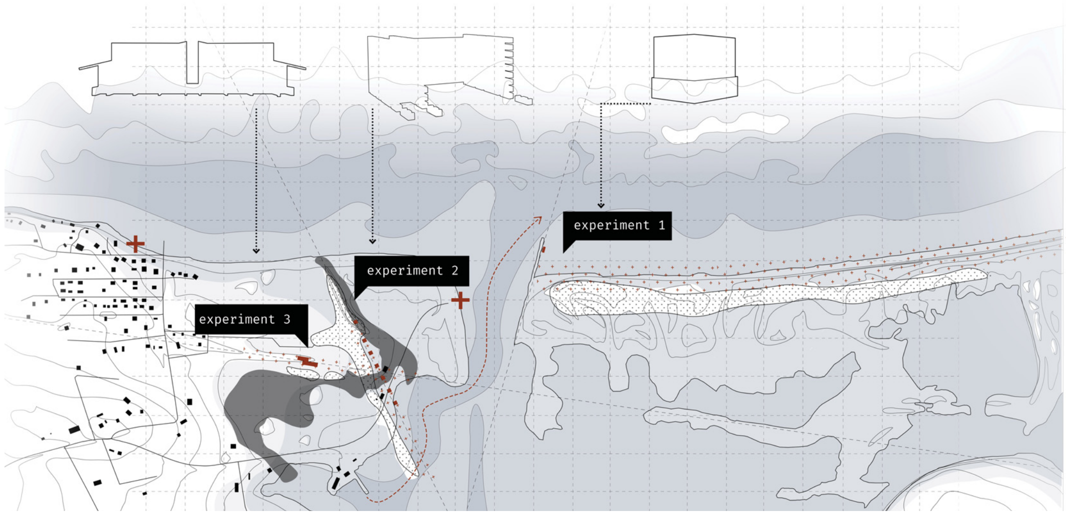
Designing for Ruin: An Architecture of Change

The three experiments all design for an eventual ruin and a way for the architecture to transform over time. Through designing in collaboration with natural processes and ecological actors, new life can grow alongside inevitable decay. As the water rises, some elements are left to weather, while others form new ways of life. This adaptability is a critical aspect to an ecosystem's longevity allowing for a circular system where death brings new life. The life cycle of materials allows for some aspects of the architecture to transform faster than others, creating new uses at different paces. Clay and concrete are seen throughout the experiments as a contrasting element of temporarily. The clay erodes at a faster pace, leaving behind a ruin of concrete. As the clay transforms into sediment, it can provide more clay for wetland space and surrounding vegetation, while the concrete becomes encased in oyster reef extending its life even further. In contrast, fired clay is also utilized to prolong the life of this material and allow it to be an element of permanence. Fired clay has the longest life span of all the materials, allowing for it to be used to protect and create moments of permanence. Wood is another element that can be considered temporal in certain instances. It can be more temporal as seen in experiment two, or be encased in fired clay to allow for a more permanent role, as illustrated in the building. Utilizing lifespans of material can result in a way to influence or control what decays and what becomes ruin. The notion of designing for change is seen throughout the experiments as a key factor for adaptation within a changing climate.



The Unit creates a ruin when it is placed in the water. It is designed to be a catalyst for growth, and changes from the moment it's set in the water column. The block transforms from a concrete netted structure to a large oyster reef over decades of accumulation. The blocks eventually form one large network of reefs holding an existing edge that will succumb to the ocean's power.

The Structure creates a ruin over time as the water rises and the concrete structure erodes into a space for oyster reef to take form. The experiment begins as a walkway in the fields and a space for shell collection while slowly evolving into a mitigation tool at the boundary between land and sea - an architecture which is designed to become ruin.



Location of the building

Experiment Three: The Building as Ruin

As time progresses and the ocean temperature continues to rise, researchers have been monitoring erosion and the growth of reef structure from the lookout tower in experiment two. The first experiment has now grown a system of oyster reef habitat to mitigate wave action, while the second experiment is entirely engulfed in water - creating a secondary system of reef. The concrete members illustrate the sea level rise by the amount of oyster growth and erosion created by incoming waves. The ocean temperature has risen by four degrees Celsius resulting in the majority of Savage Harbour's coast to flood. The final place of human habitation is experiment 3 - the building, built as a research hub situated at the highest elevation.

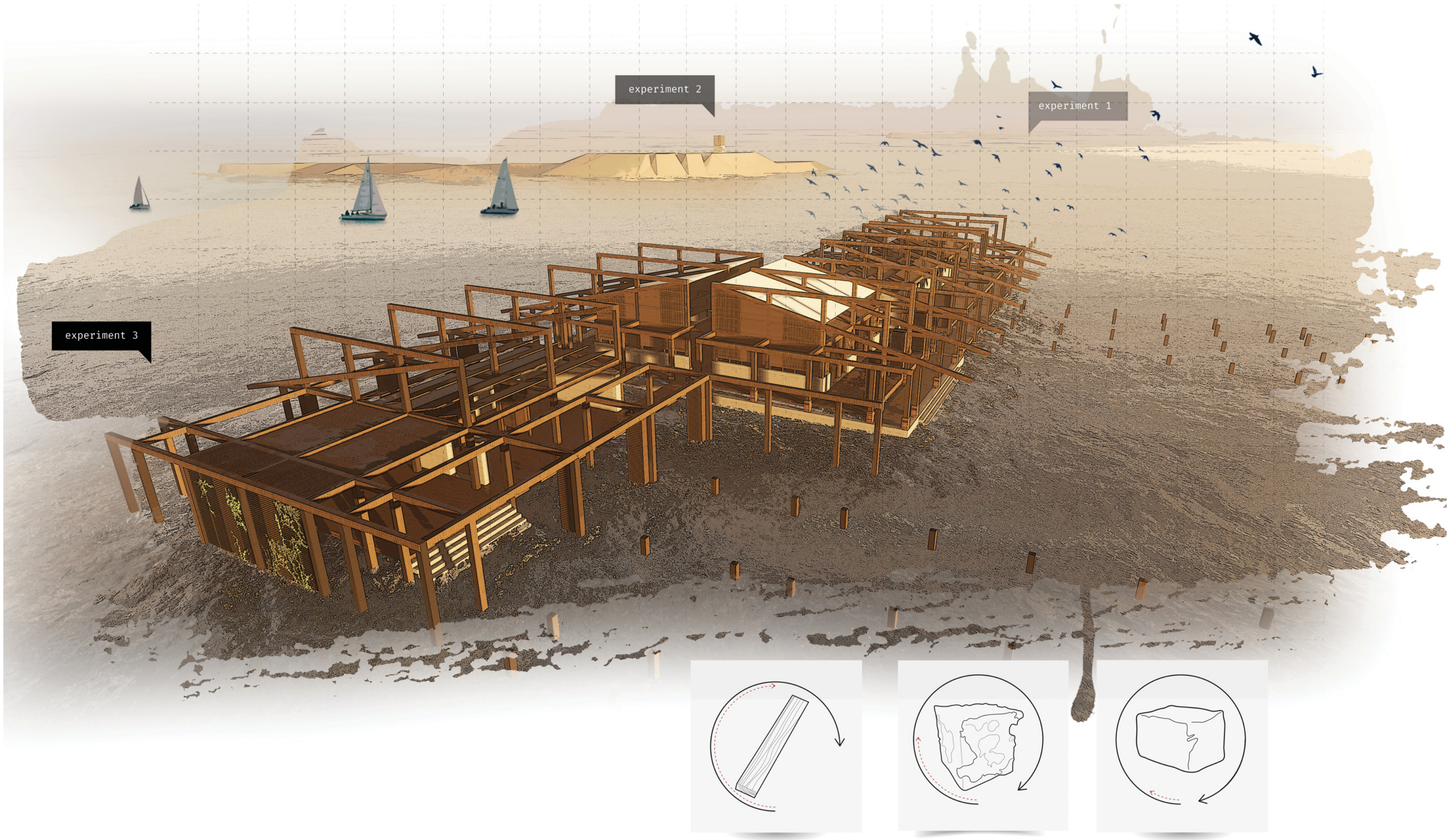
Experiment three, like that of the first two, is designed with consideration to natural systems of the surrounding hydrology, geology, and ecology of the Island. The structure is created to become ruin and transform in function over time. Through material strategies, programmatic flexibility, and creation of habitat, the architecture can evolve with its environment. The structure is formed through a layering

Using clay as an erosional element designed to instigate new life from from decay using large areas of complexity.

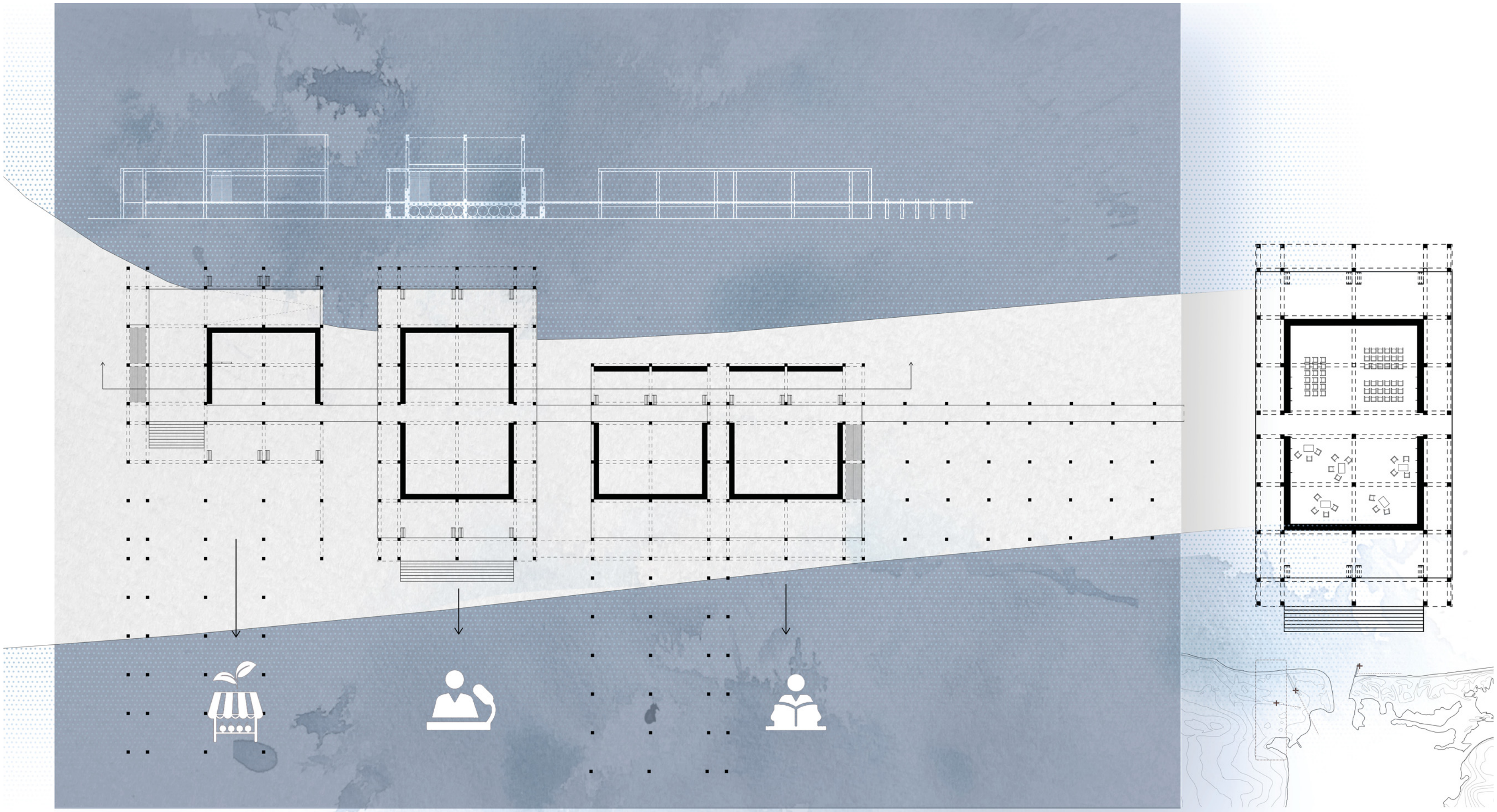
Using clay to design moments of intricacy and smaller levels of complexity.

Using the life span of clay with other materials to create an architecture of change.

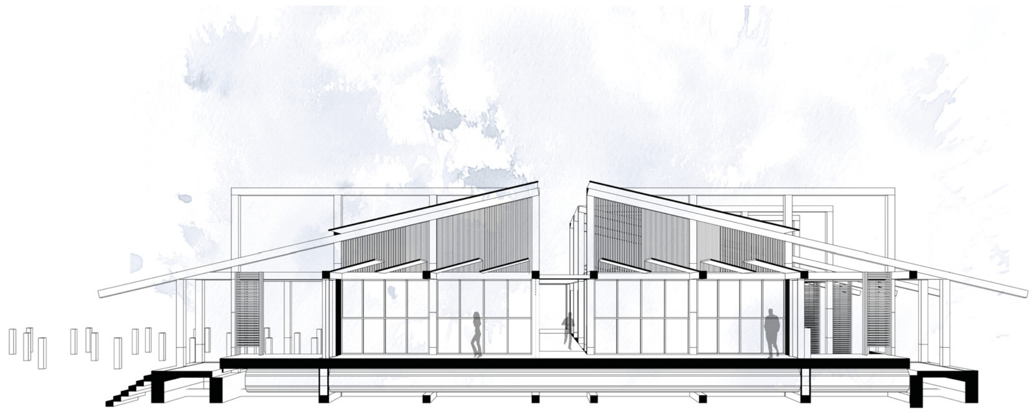
process like that seen at the scale of the infrastructure. By designing with a material's natural life cycle, the building can shift as elements decay or erode into the rising seas. The experiment embraces temporality as well as permanence to create a structure in motion with the surrounding landscape. The material elements become modes of monitoring for researchers, to understand temperature increases as well as ecological conditions of the area. The building houses oysters and researchers simultaneously creating a space built for both human and non-humans. Erosion, accretion, and deposition give way for both the growth of oyster reef and provide spaces for researchers to study our changing environment. As the climate changes, so does the function of the building itself. The water is allowed to engulf certain spaces, transforming program from that of land focused research to oyster reefs, allowing for underwater research to ensue. The building creates a shift in program as sea levels rise, while still maintaining a structure useful for both researchers and oysters- designing growth through decay.

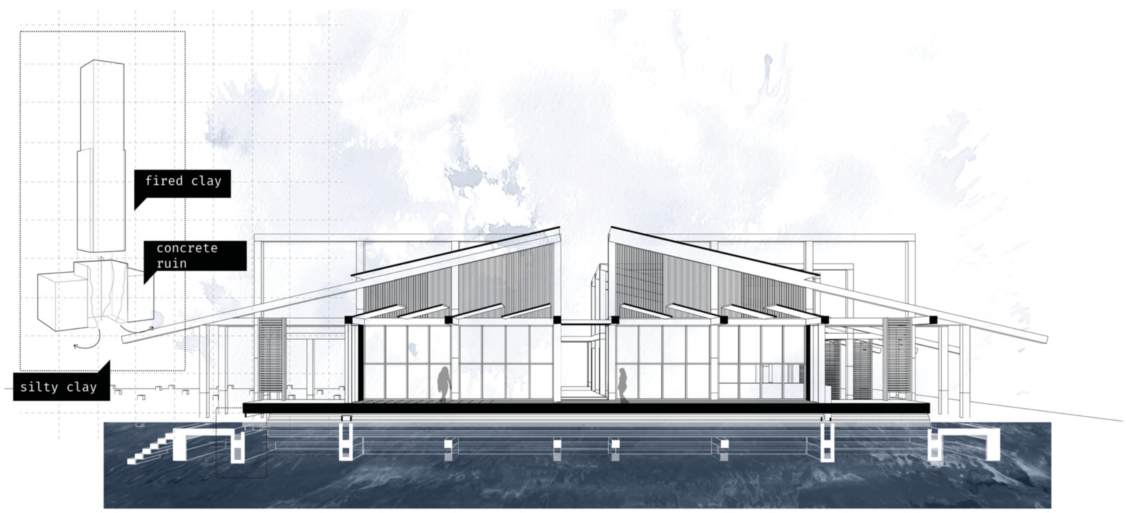


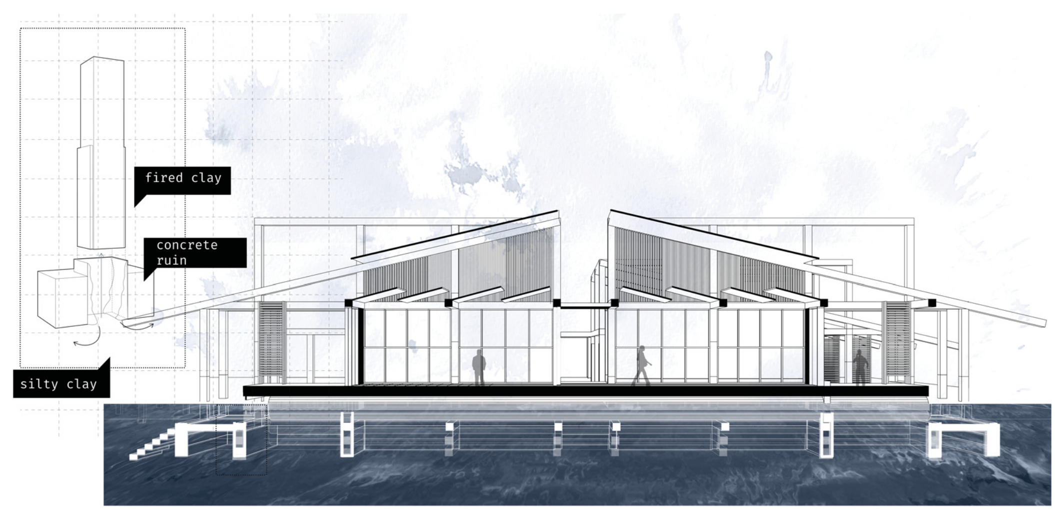
Different time scales are illustrated throughout the building through materiality. Fired clay has the longest enduring lifespan in water while pure clay is seen with the shortest. The concrete not only erodes with time but also is a catalyst for new life either for aquatic life or salt accretion. Wood on the other hand will have a longer lifespan when either fully submerged in water or completely removed. Experiment 3 explores a material's temporality as well as its permanence.



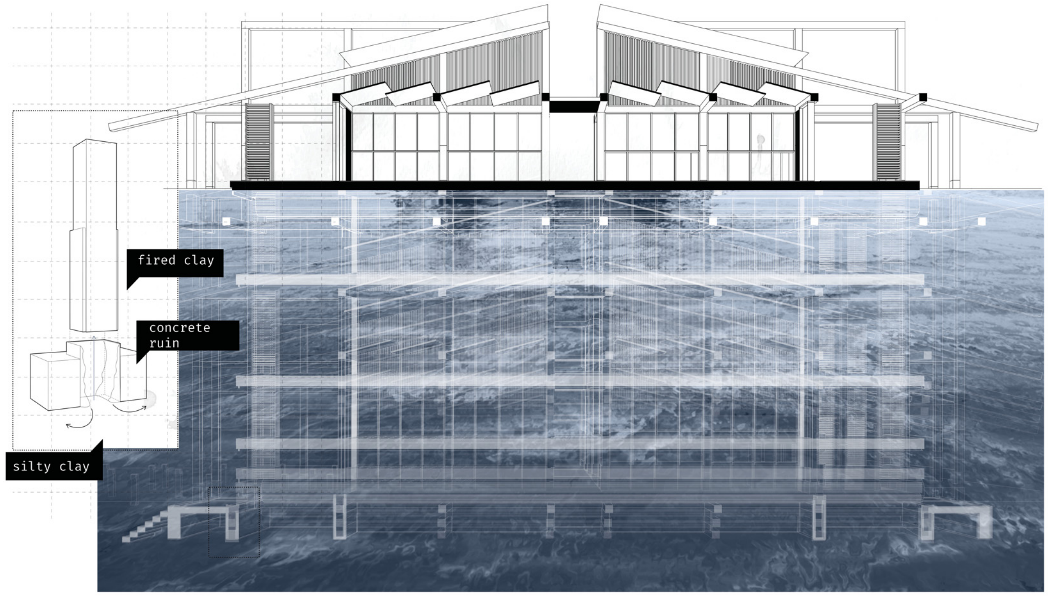
The building sits along the new edge stretching off a piece of high ground into the future shoreline. The building provides outdoor market space for local farmers, as well as promote the experimental farming surrounding the building which looks for ways to grow crop within salt water conditions. On the end closest to the water's edge, classrooms and lab space exist for researchers from UPEI who can use this sheltered area as a hub for exploring the edge conditions and ways for the Island to adapt. The in between structure houses a flexible room large enough to house symposiums, environmental conferences, or large lectures alike. The space can be used for community engagement, experimental farming, educating the public, and even for officials visiting the Island through the university. The room itself is designed for uncertainty in mind.



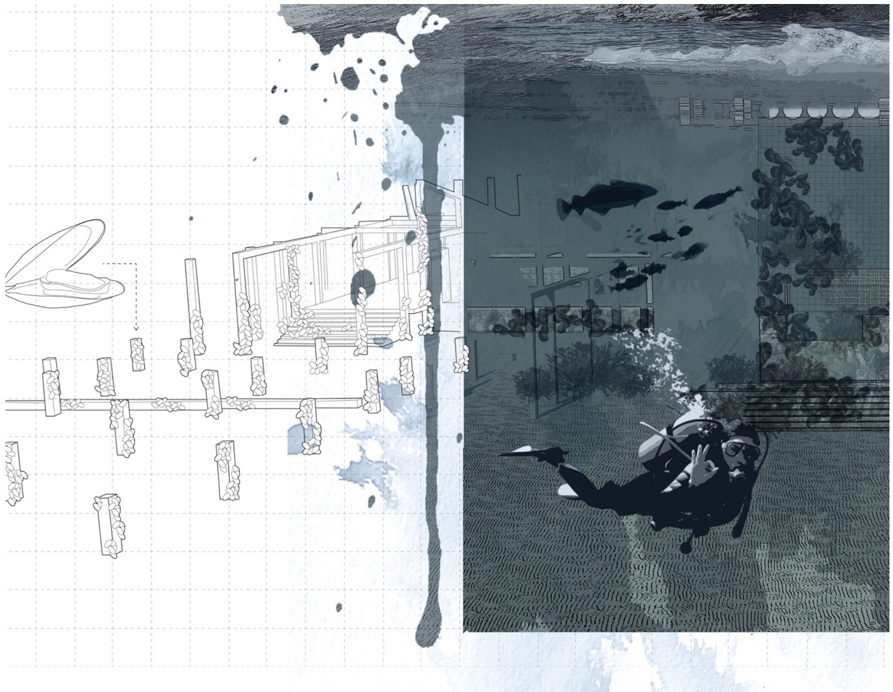




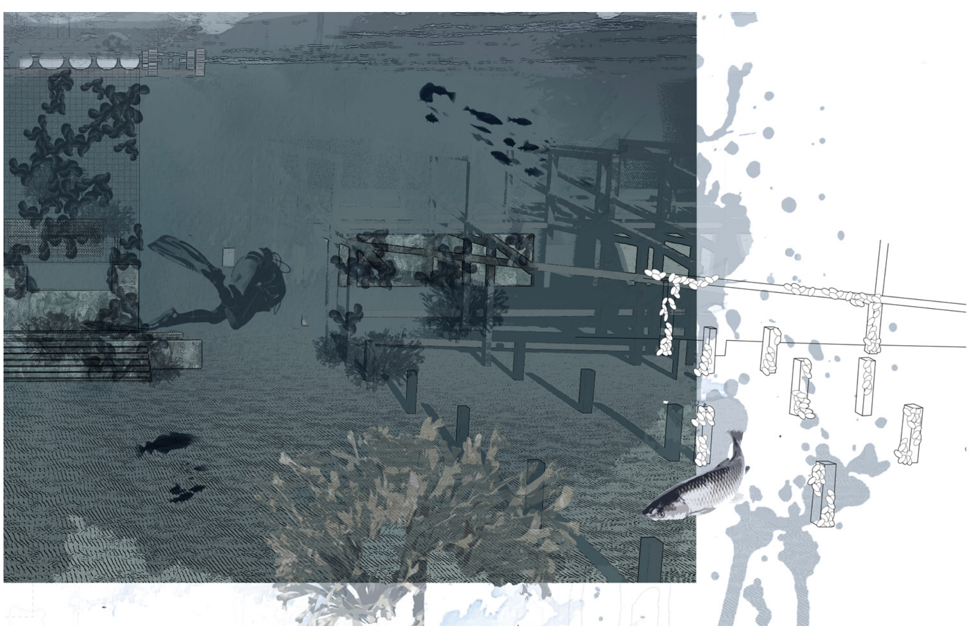
As the water begins to rise, the center room also becomes a tool of measure. The structure begins to float.



The wood beams are placed in the concrete structure and surrounded with a layer of silty clay and fired clay. As the water enters the structure, the silty clay releases the beam from the concrete wall while the fired clay protects the structure from water. This release with rising seas is what allows the room to float, and change positions in alignment with the waves. The architecture creates a relationship between permanent and temporal materials allowing lifespans to inform the design. The weathering of materials is embraced to allow for new forms and ways of living to take place.



By a 4 degree increase in ocean temperature, the water is set to continue to rise. The outdoor rooms have become weathered with salt water and is left as concrete and netting ruins, allowing for new life to take hold through aquatic reef. These reefs will improve biodiversity, build up sediment and create yet another new edge, dampening incoming waves as well as a space to provide production of oysters.



The building continues to be propelled upward while tethered to the ruin below. A net is unraveled, stretching from the concrete structure to the floating clay deck. This allows for the entire water column to be a space for the production and growth of oysters.

Over the timeline stretching hundreds of years, the floating structure becomes a ruin. Failing structure and weathered boards. But the fired clay is still intact, allowing the deck to be used periodically by divers, oyster farmers and birds to make home on this fragment of an Island that once was.

Chapter 7: Conclusion

In designing for the temporal dimensions of a coastal edge, this thesis proposes a set of strategically placed experiments that engage with and embrace the natural forces of this dynamic condition. The architecture is used to study and measure this gradual change through the erosion and deposition of material, ecological accruement, and shifting programmatic uses - all instigated by the temperature shifts of the ocean. Through multiple scales the notion of creating new life from ruin can be used to not only mitigate the effects of sea level rise but maintain productive space in an otherwise flooded landscape. As the sea levels continue to rise and the province becomes engulfed in waves, the ultimate ruin of PEI holds the potential to create new habitat and a new edge for the rest of Canada, as it slowly becomes calcified in reef structure. The prototypical experiments, if placed throughout the entire Island, can form a new edge between open sea and the rest of Atlantic Canada maintaining existing boundaries, mitigating wave action, creating habitat for aquatic life, and maintaining productivity for an otherwise sunken world. Shifting from a land of farming and agriculture to a land of oyster reef and fish habitat, allows for even more aquaculture opportunities and an increase in biodiversity. Through allowing materials to decay, erode, accrue, and change through time, a more resilient coastline can be birthed from a seemingly dismal existence.

The thesis looks at design as a means of collaboration between natural forces and systems inevitably in conversation with structures. Through this relationship with water, air, earth, and ecology, an architecture of change can be created to move with time and it's surrounding environment. The various materials which compose the experiments were analyzed in close relation to its life cycle and means of decay. Through layering elements with varying cycles, the forces of erosion, accretion and deposition can be properly analyzed and designed to create new opportunities. The material experiments focusing on clay, concrete and wood create a fruitful exploration in the ways materials react to outside influences, as well as how to design for the understanding of life cycles. To continue this study, I will pursue further testing and expand on the way that materials change over time, as well as interact with natural processes. Experimenting with how wood behaves in water and its potential for both accretion and decay, would provide more richness to the materials explored. I would for instance be interested in further incorporating wood and salt in the production of both habitat and ruin to realize the full potential these experiments could have on the dynamic coastline. Investigating a materials collapse, and ultimate ruin allowed me to not only better understand the material being explored, but also learn from its failure. This shift in perspective of architecture composed of pieces of the earth and situated within various cycles of earth systems and material processes, has been an exciting journey in better understanding material properties and the potential role of architecture in our world.

In accordance with exploring material conditions, ecological networks were also examined within this changing timeline. As the architecture changes and shifts throughout time, so does the inhabitants of the building as well as the spaces being created through the rise of waters. The thesis focuses on both the researcher and oyster as key actors, in tandem with the architecture, as facilitators and proponents for adaptation. The relationship between human and non-human was explored through design of habitat and creating an architecture that shifts between their two worlds- one of land and one of sea. To continue this exploration other actors and species such as the piping plover, a migratory bird and their specific habitat, could add another temporal dimension to the study and like the oyster could be the driver for the design rather than human centric. The tower in experiment two could be well suited for this and the researcher's part might be secondary to the functioning for birds. In this way designing for other actors, designers and humans must rethink their relationship and appreciation of the multi species and natural systems with whom we must inhabit the Earth. In engaging with rather than fight against we can emphasize the ecological strategies, while also shifting our ideas around creating habitat. I learned the importance of all species within the ecological networks, and how architecture is simply a mode of making home. Designing with all actors in the environment will not only benefit the local ecology, but also encompasses the potential to create a more protected and fruitful land for humans alike.

By engaging with natural forces instead of fighting against, we can create new edges, establish home for all creatures that inhabit the environment, as well as use inevitable decay to provoke new life.

> A glimpse into what architecture might become if it invests its creative capital less in the struggle against gravity and more in seeing what might happen when we let go. (Woods 2004, 8)

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