The Architecture of Aquaculture

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Abstract

Modern methods of food production have accelerated climate change, but can sustainable practices aid in reversing it? *The Architecture of Aquaculture* seeks to explore the restorative effects of seaweed aquaculture through an adaptive reuse of British Columbia's controversial salmon farms. This project examines the role seaweed aquaculture can play in mediating climate challenges through the development of a new building typology that utilizes program and built form to articulate the relationship between humans, the built environment, and nature. The following chapters emphasize seaweed's importance along British Columbia's West Coast, and the positive environmental effects it can have on the land, sky and, sea. The final design proposes an adaptive reuse of 19 salmon farms within British Columbia's Discovery Islands and Powell River.

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Thesis

The Architecture of Aquaculture seeks to propose a new building typology that articulates the relationship between man, the built environment and nature while employing seaweed aquaculture as the mediating force.

Introduction

Seaweed aquaculture is the process of cultivating and harvesting seaweed. Though this practice has a long history in coastal areas of Asia and Europe, it is now becoming recognized around the globe where demand is steadily increasing (Flavin, Flavin, and Flahive 2013, 1). The majority of global seaweed production is cultivated for human consumption, but also finds important applications in a variety of industries from cosmetics, to pharmaceuticals and fertilizers (Kerrison, Stanley, and Edwards 2015, 230). By scaling up the industry of seaweed aquaculture, strides can be made towards the use of seaweed as a low-carbon alternative to traditional animal feed, biofuel, and tool in offsetting the effects of climate change (Seaweed Revolution 2020, 2).

Figure 1.1 - Seaweed uses by industry

Species Classification

Seaweeds are classified into one of three categories based on colour. This includes brown, red or green algae; scientifically referred to as Phaeophyceae, Rhodophyceae or Chlorophyceae. Brown algae are physically the largest, with species such as giant kelp measuring 20 metres long. Red algae, or Rhodophyceae, is a classification that includes seaweeds that aren't necessarily red but share a variety of similar characteristics. Green algae and red algae are of similar size, with species capable of reaching a metre in length (McHugh 2003, 1).

Wakame *(Undaria pinnatifida)*

Undaria pinnatifida is a brown alga commonly referred to as Wakame, and is often served in soups and salads.

Irish moss *(Chondrus crispus)*

Chondrus crispus is a red alga that contains carrageenan, a popular thickening agent.

Aonori *(Monostroma latissimum)*

Monostroma latissimum is a green alga commonly known as green lavar or aomori and is a popular seasoning for Japanese dishes.

(Flavin, Flavin, and Flahive 2013)

Wild Harvesting

For centuries, coastal communities have harvested wild seaweed for use as food, fertilizer and, feed (Monagail et al. 2017, 371). The earliest account of seaweed harvesting has been traced back to the fourth century in Japan where it was used as food (McHugh 2003, 1). Though global seaweed production has increased steadily year over year, wild-harvested seaweed maintains stable production and continues to play a significant role in maritime cultures. Wild seaweed has historically been gathered at low tide, often cut by hand from monospecific plants such as rockweed or kelp (Monagail et al. 2017, 372-373). Plant clippings are often favoured over the removal of the entire specimen, which slows regrowth and bed regeneration. In addition, a high percentage of wild-harvested seaweed is gathered from storm-cast fronds, which wash up along beaches and intertidal zones. Nets are often cast out by pairs of harvesters, who pull them through shallow bays to collect the crop (McHugh 2003, 11).

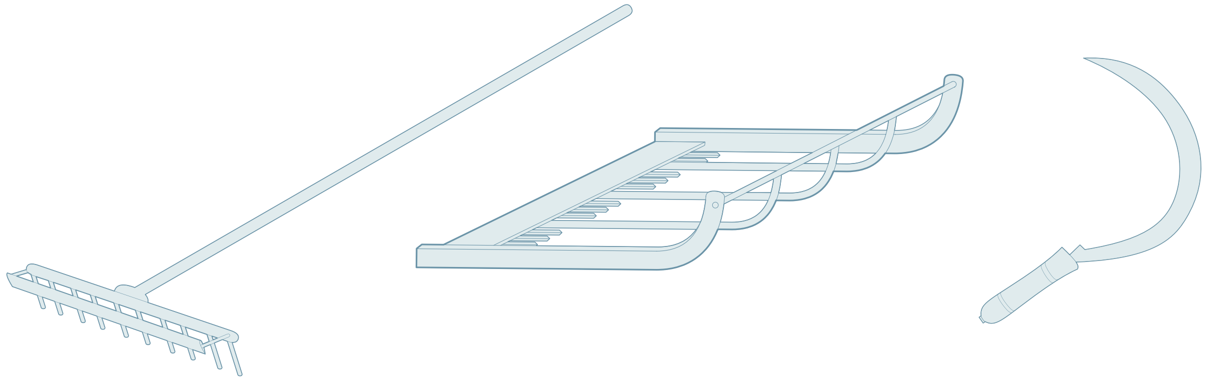
Figure 1.2 - Wild sea spaghetti is harvested from rocks at low tide

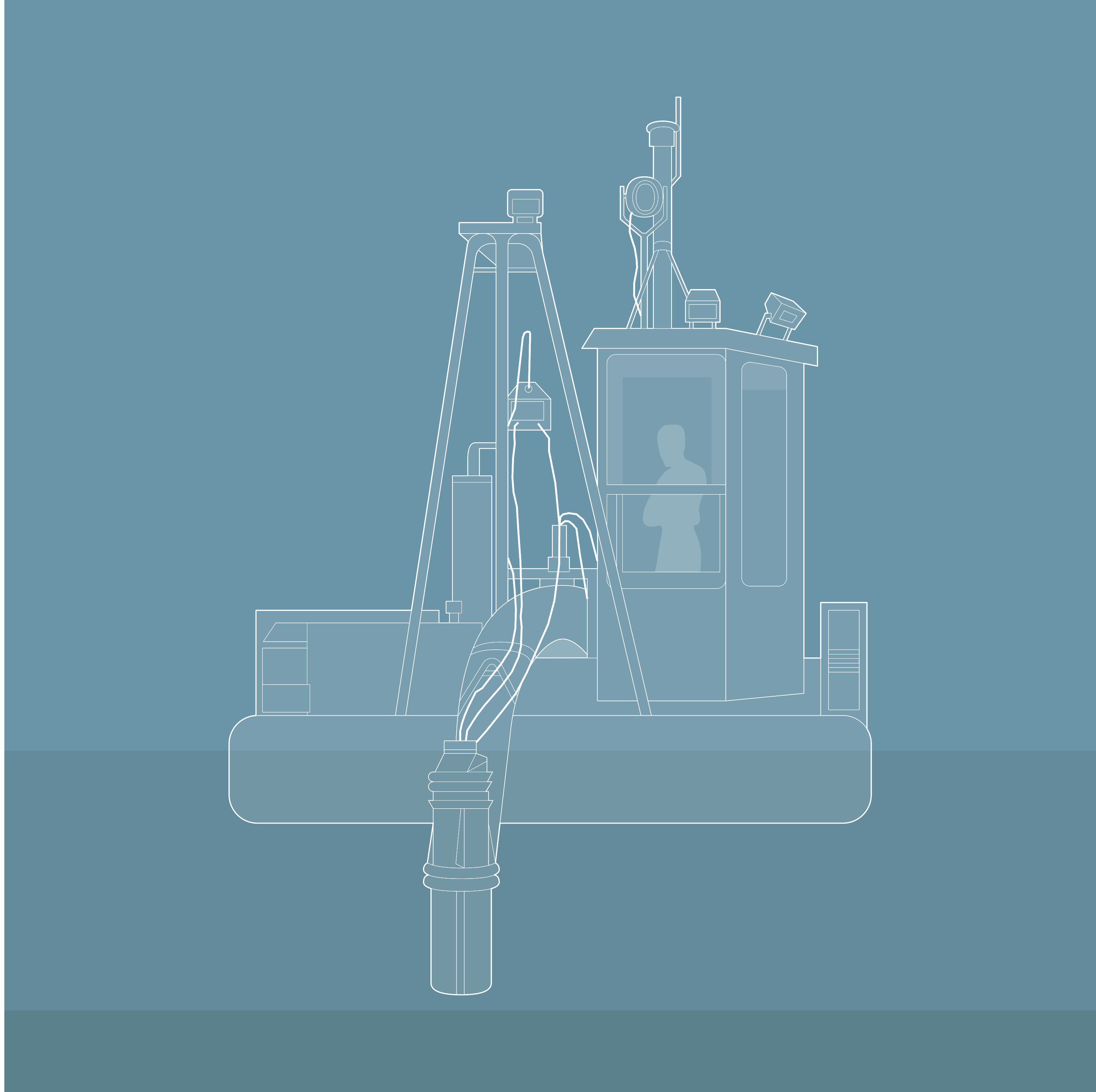
Wild Harvesting Tools

The 20th century brought an increased demand for seaweed, leading to the development of new forms of harvesting technology such as boats, rakes, and diving apparatus. These tools allow for a larger harvest compared to traditional collection at low tide. The first commercial harvest of wild seaweed in Canada occurred in Nova Scotia, where drag rakes were used to efficiently harvest Chondrus crispus, known as Irish moss. This technique soon led to the destruction of the seaweed stock, and the drag rake was retired in favour of hand-held cutting implements. Years later the Canadian Maritimes adopted the Norwegian suction cutter, but once again, it was clear this tool was not suitable, as it led to uncontrolled over-harvesting. Ultimately, a cutting rake was deemed the tool of choice, as it can trim seaweed from the upper canopy while leaving the remainder of the plant intact (Monagail et al. 2017, 374, 376).

Figure 1.3 - (Below) Seaweed harvesting tools from left to right: cutting rake, drag rake and hand sickle

Figure 1.4 - (Right) Norwegian suction cutter often used in Eastern Canada for the harvest of ascophyllum nodosum





Commercial Wild Seaweed Harvesting in BC

British Columbia presents a greater range and abundance of seaweed than most other regions of the world, leading the government to implement a pilot project to examine the province's potential for commercial-scale wild seaweed harvesting. From 2007-2013, the province issued licenses to operators in Deep Bay near Parksville, allowing the harvest of the non-native red algae, Mazzaella japonica. The seaweed would be collected from the beach by hand using pitchforks, before being transported to drying facilities. This experiment ultimately revealed that the seaweed, whether dead or alive, is integral to the ecosystem, and its removal at commercial scales would negatively impact adjacent ecosystems (Hume 2013).

Figure 1.5 - Man uses pitchfork to harvest Mazzaella japonica from public beach in Deep Bay, BC

Farmed Seaweed

With new tools come new challenges, as over-harvesting directly impacts marine biodiversity leading to negative ecological responses. This has led to the development of seaweed aquaculture grown at specially designed floating farms. Not only does this provide the opportunity to sustainably grow and harvest seaweed, but it allows farmers the opportunity to carefully select species that provide the desired attributes such as hardiness and taste (Flavin, 1-2). Saccharina japonica, a brown algae more commonly known as kombu, and red algae Eucheuma sp. are cultivated in the greatest quantities, together accounting for 66% of global seaweed production. These two species find applications in cooking, biofuel, and cosmetics (Campbell et al. 2019, 2).

Figure 1.6 - Layout of commercial seaweed farm using ropes and buoys

Cultural

Seaweed holds cultural significance for many of British Columbia's coastal indigenous peoples, who value seaweed for its nutritional content and practical applications. Often added to soups or served dried or toasted alongside eulachon grease or rice, seaweed is a versatile source of nutrition. Red laver is viewed as the most important variety of edible seaweed to British Columbia's coastal indigenous people due to its high quantity of vitamin A, vitamin C, and riboflavin. Traditionally, women harvest large quantities of seaweed from their canoes during late spring, while the men were fishing (First Nations Traditional Foods Fact Sheet, 22-23).

Rockweed *(Fucus spp.)*

Rockweed is used for it's medicinal properties. The gelatinous liquid stored within the blades is used to treat burns, similar to aloe vera. It is also useful to sooth sore eyes, and when used as a salve can alleviate muscle aches.

Bull kelp *(Nereocysris)*

The fronds of bull kelp are added to soups and stews, while the stipe is sliced into thin rings and pickled for later consumption. After being processed, the stipe may also functions as a sturdy anchor line or fishing line.

Giant kelp *(Macrocystis)*

Giant kelp is placed in herring spawning areas. Eggs deposited by the fish stick to the fronds of the kelp, and once enough eggs have accumulated, the plant is harvested and brought back to shore for processing.

Sea Palm *(P. palmaeformis)*

Sea Palm is valued by the Nuu-Chah-Nulth peoples for its qualities of strength and resilience. By burning this algae and applying the charred remnants to the spines of babies, it is said that they would grow to be as tough as the sea palm.

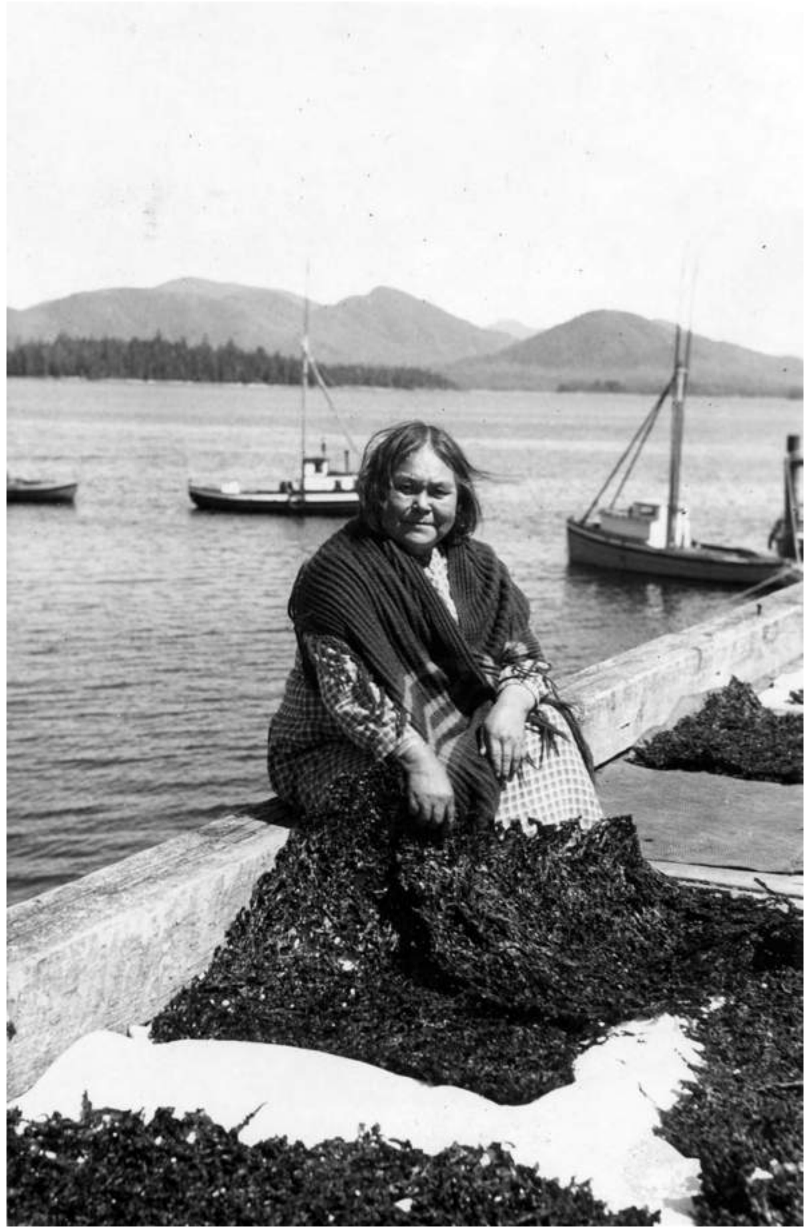
Red laver *(Porphyra spp.)*

Red laver is a popular seaweed eaten in great quantity, and is valued for its nutritional value and mineral richness. This seaweed is a valuable trade item with inland indigenous peoples who would otherwise have limited iodine in their diets.

Sea lettuce *(Ulva Lactuca)*

Sea lettuce is thought to be eaten by coastal indigenous peoples, but is also valued for medical purposes, as it can be placed over the eyes to treat inflammation or infection.

(Turner 2001)



Following a successful harvest, seaweed is processed in several ways to improve its digestibility and allow it to be stored for trade and periods of hardship (Turner 2003,283). The Gitga'ata arrange seaweed in 60cm squares along rocks where it's left to sun dry (Turner 2016, 5), while other communities place harvested seaweed on cedar frames or hang it to dry on open-air racks (First Nations Traditional Foods Fact Sheet, 23). During seasons where fish and game are scarce, seaweed becomes an ever more valuable resource. Due to its high nutrition and mineral content, seaweed is also a valued trade item between coastal and inland communities, which would otherwise have limited access to iodine-rich foods. The Gitga'ata peoples, for instance, are known to have traded dried squares of seaweed with the Haisla and Nisga'a in exchange for smoked eulachons and eulachon grease (Kuhnlein and Turner 1991, 5, 17).

Figure 2.1 - An indigenous woman dries squares of seaweed on a dock along British Columbia's West Coast (Kopas 1920)

Environmental

Land

It is estimated that the world population will reach 9.7 billion people by the year 2050, with the majority of this population growth seen in developing countries. Following current trends, this will result in an increasingly urban, richer population, placing greater demand on the global food system. The Food and Agriculture Organization of the United Nations (FAO) estimates an increase of 70%, or 5.4 thousand million tons of food production is required to sustain this growing population (FAO 2009, 11). Achieving this becomes increasingly difficult due to inadequate freshwater and land resources, and pressure placed on and caused by these systems due to climate change (Schubel 2019). As sea levels rise, and productive agricultural land is depleted, the sea serves as an untapped frontier for sustainable food production.

Agriculture is now focusing on its capacity for production increase rather than land expansion. There are considerable land reserves around the world, but only a few possess the qualities necessary to support crop growth. The majority of these land reserves are located within a limited number of countries including Latin America and Sub-Saharan Africa and serve important ecological functions that would be placed at risk following land-use change. As climate change continues to impose challenges such as extreme weather events, changes in precipitation and risk of disease and pest outbreak, available land reserves and existing agricultural lands face increased pressures. This pressure will negatively impact agriculture's capacity for food production, placing strain on global aspects of food security including availability, stability, and access (FAO 2009, 3, 9, 29).

Figure 3.1 - A farmer plants crops in a field experiencing drought

Today there are several innovative practices at play that have the potential to increase the production of nutritious foods through agricultural practices such as natural ecosystem mimicking permaculture, and precision agriculture. Though these systems show promise, their potential to mitigate environmental impacts relies on changes at a larger, governmental scale that takes time to implement. Coastal regions are capable of kickstarting change by bridging sustainable land-based agricultural practices with ocean-based aquaculture to meet growing food demands (Schubel 2019). By increasing the use of seaweed as a food source and biofuel, land-use change needed for increased land-based agricultural production can be reduced.

The majority of the world's surface area is ocean, yet the sea only contributes 2% to the global food supply. Of the 29% of the earth's surface area that is land-based, agricultural land consumes nearly half of this ice-free area. As we reach the limit in regards to what we can ask from the land, the ocean may provide support. By implementing sustainable aquaculture, it is possible to generate a sustainable source of food for humans and animals alike, while minimizing unfavourable impacts associated with land-based agriculture and contribute to a sustainable ocean ecosystem (Schubel 2019).

The focus given to seaweed aquaculture as a means of offsetting agricultural emissions and land dependence doesn't necessarily signal a drastic increase in our consumption of seaweed. Instead, an increase in seaweed production can effectively be used to offset the quantity of cropland used for growing grains for livestock consumption such as corn, barley, oats, and sorghum. Today, 33% of agricultural land is specifically used for the production of animal feed (FAO 2009, 10). This number has the potential to be offset through seaweed aquaculture as the demand for seaweed additives within animal feed increases. Not only does this provide a suitable diet for livestock, but it is also a low-carbon alternative to traditional grain feed (Seaweed Revolution 2020, 8).

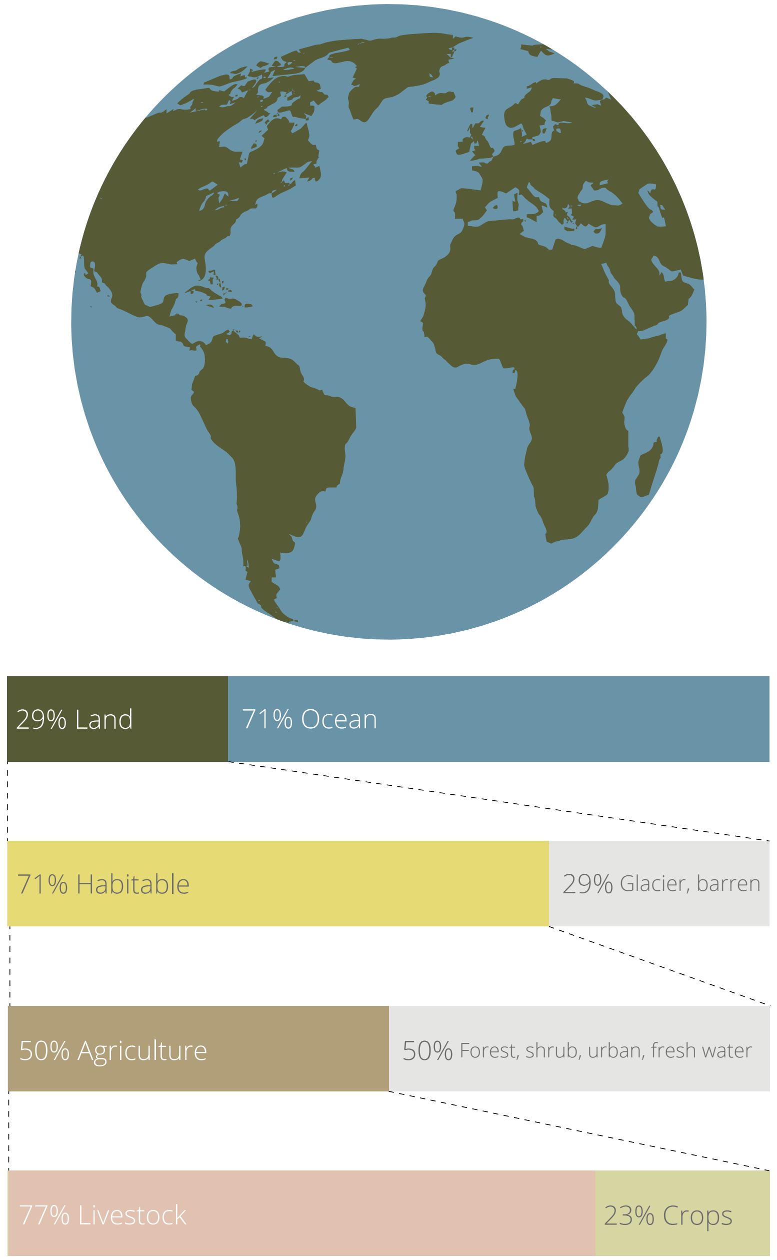


Figure 3.2 - Global land use for food production

Emissions

Current food production accounts for 26% of global greenhouse gas emissions. These emissions are emitted from sources including ruminating livestock, fertilizer, and conversion of carbon sinks such as grasslands and forests into cropland. This process creates a positive feedback loop whereby food production contributes to climate change, while climate change places pressures on our food system through rising temperatures, weather volatility, pests, and disease outbreaks (Ritchie 2019). In addition to contributing greenhouse gas emissions, agriculture requires a high quantity of freshwater, and contributes to the eutrophication of the ocean and bodies of fresh water, while livestock reduces biodiversity as the quantity of livestock far outweighs the population of wild mammals (Ritchie 2020).

Figure 3.3 - A farmer sprays crops with pesticides

Contrary to traditional agricultural practices, seaweed aquaculture doesn't necessitate the use of land, freshwater, or fertilizer. As photosynthesizers, seaweeds and microscopic algae consume carbon dioxide, water, and sunlight, and release oxygen in the process. The oxygen produced by seaweeds and microscopic algae contributes to 50% of the world's oxygen supply (Seaweed Revolution 2020, 6). Challenges associated with the quantity of methane released by ruminating animals such as cows, sheep, and goats has the potential to be improved by seaweed as well.

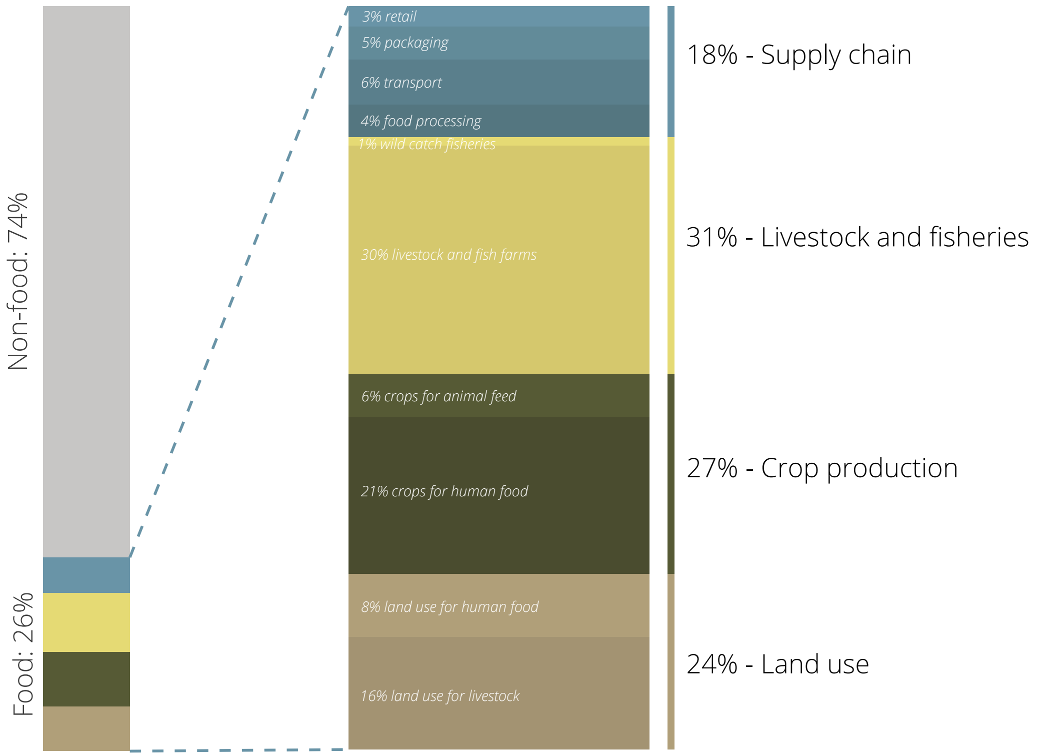


Figure 3.4 - Global greenhouse gas emissions from food production

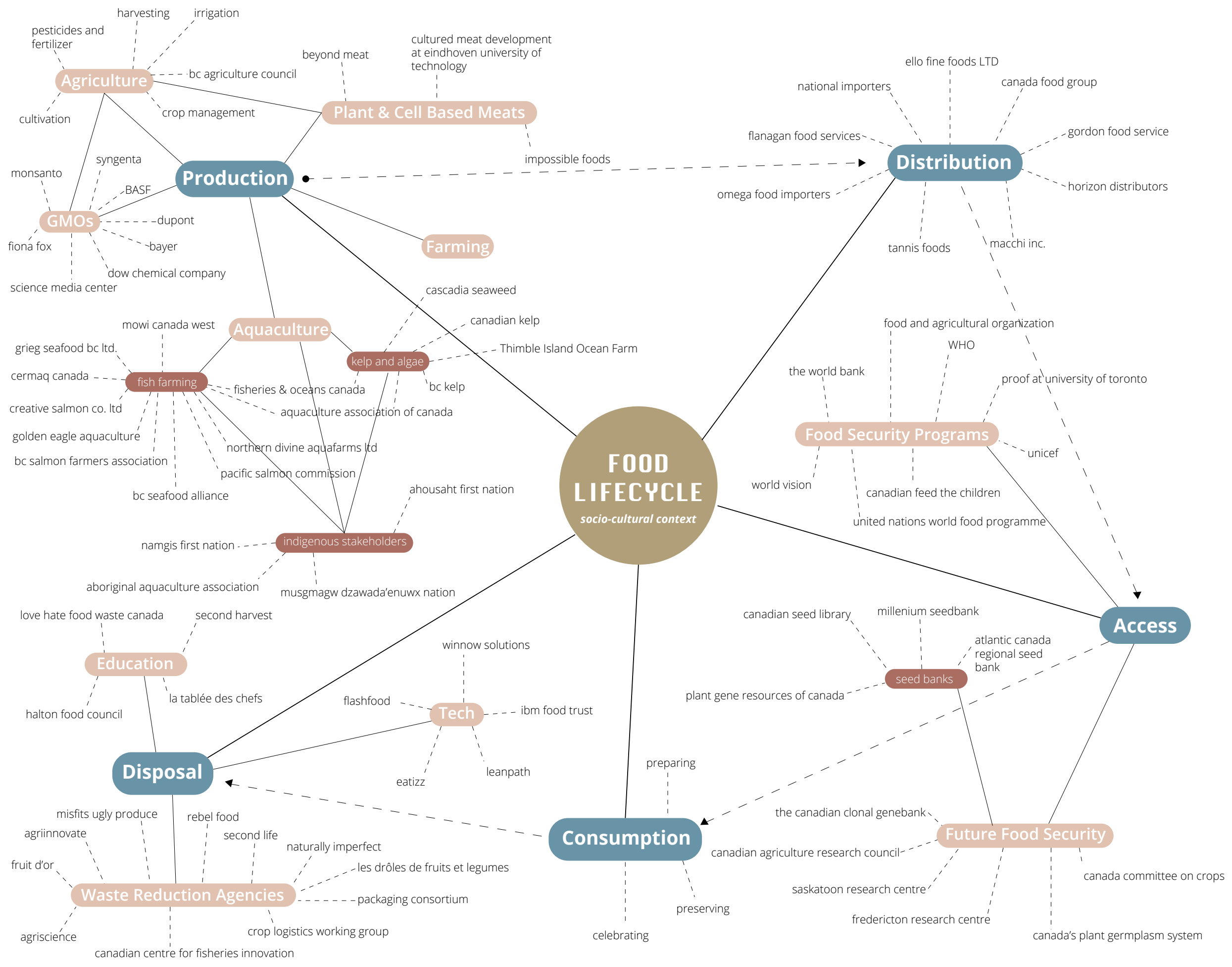


Figure 3.5 - Socio-cultural context of the food lifecycle

Image removed due to copyright

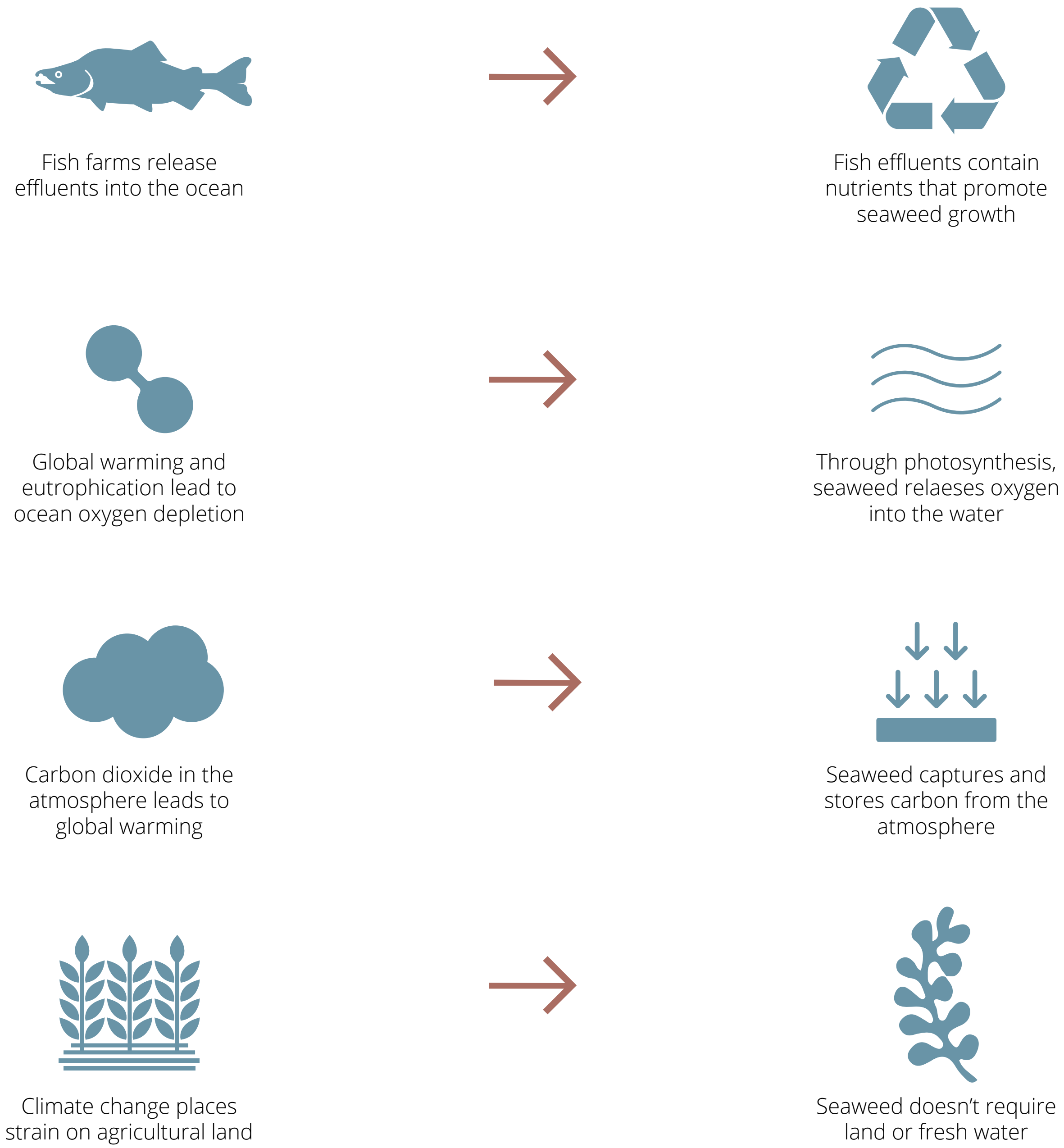
As of 2016, research has also been conducted into the use of specific microalgae, Asparagopsis taxiformis, as an additive in animal feed due to its ability to reduce methane production in ruminating animals. With an inclusion rate of 5% algae to traditional animal feed, methane production within a test group of American dairy cows has shown to be reduced by 95%. This is due to the algae's concentration of bromoform, an antimethanogenic compound that prevents the production of methane. Not only does seaweed aquaculture hold the potential to offset carbon emissions associated with agricultural practices, but it can also have a positive effect on the number of harmful emissions released from livestock as well (Roque et al. 2019, 6).

Figure 3.6 - A lamb munches on seaweed along the Scottish coastline. On this island in Scotland, farmers bring their sheep to the beach to feast as difficult winters place limits grass availability (Gardiner 2017)

Sea

Seaweed aquaculture is capable of addressing challenges associated with climate change and food security while making the most of the byproducts of sea-level rise and depleting agricultural land. Seaweed acts as a carbon sink by removing carbon from the ocean, and also holds the potential to alleviate ocean acidification and de-oxygenation by elevating the ocean's ph level and supplying oxygen to the waters (Roque et al. 2019, 6). Beyond simply being a sustainable industry, seaweed aquaculture has the potential to bring abundance and biodiversity back into the world's oceans by serving important ecosystem functions, while providing a habitat for marine life (Seaweed Revolution 2020, 6).

Figure 3.7 - A seal swims through dense kelp beds



Fish farms release effluents into the ocean → Fish effluents contain nutrients that promote seaweed growth

Global warming and eutrophication lead to ocean oxygen depletion → Through photosynthesis, seaweed relaeses oxygen into the water

Carbon dioxide in the atmosphere leads to global warming → Seaweed captures and stores carbon from the atmosphere

Climate change places strain on agricultural land → Seaweed doesn’t require land or fresh water

Figure 3.8 - Benefits of seaweed

In addition to seaweed’s environmental benefits, it also is a nutritious food source for humans and animals alike. According to the Seaweed Manifesto, seaweed is “low in fat and rich in proteins, carbohydrates, minerals, vitamins (B12, A, K) and essential micronutrients (iodine, zinc, iron)” (Seaweed Revolution 2020, 6). By focusing on the growth of the seaweed aquaculture industry, pressure on land-based agricultural production can be alleviated, while a healthy source of food is grown.

Seaweed also plays an important role when it comes to ocean nutrient absorption. The ocean receives nutrients from a variety of natural and manmade sources, causing fluctuations in nutrient levels. Pollutants from finfish aquaculture, agriculture, and urban wastewater often find their way into the ocean and contribute to increased levels of phosphorous and nitrogen. This fluctuation in nutrient levels has the potential to trigger harmful algae blooms. Seaweed grown through suspended cultivation systems effectively removes these inorganic nutrients from the ocean and can have net benefits when the amount of nutrients removed by the seaweed is equal to the number of nutrients from anthropogenic sources that find their way into the marine environment (Campbell 2019, 2).

Along British Columbia's West Coast are several open-pen fish farms. Though controversial due to the risk of pathogen transmission from farmed fish to wild stock, the nitrogen released into the water by fish effluents present nutrients important for the growth and development of seaweed. Of these fish farms, 90% are owned and operated by three Norwegian companies: Cermaq, Grieg Seafood, and Mowi Canada West (Findlay, 2018). Cermaq Canada owns and operates twenty-eight fish farming sites on Vancouver Island where they farm Atlantic salmon. They area currently the only fish-farming operation in North America to receive the Aboriginal Aquaculture Association's Aboriginal Principles for Sustainable Aquaculture Standard. Grieg Seafood operates twenty-two fish farms along Vancouver Island and the Sunshine Coast. Twelve of these fish farms operate under an impact benefit agreements with local First Nations, while engagement with the remaining First Nations communities are still listed as priorities (Grieg Seafood 2020). Within the province, Mowi employs 500 people and produces more than 40,000 tonnes of farm-raised Atlantic salmon per year.

Figure 3.9 - Locations of fish farms along British Columbia's coast

Technical

Growing Conditions

Seaweed aquaculture requires specific physical and chemical conditions which must be carefully considered during the preliminary stages of planning (Kerrison et al. 2015, 229). In general, the site must provide sufficient nutrients, salinity, and temperature suitable to the species of seaweed being cultivated, as well as an adequate water movement to contribute to the transfer of nutrients (Campbell 2019, 2). These qualities greatly affect the speed of growth and biomass yield (Kerrison et al. 2015, 229). In addition, it's important to avoid protected shorelines and areas that support diverse eelgrass communities, which already face risk due to shoreline development and pollution (Campbell 2019, 4).

Seaweed aquaculture can occur in a variety of conditions, from near-shore environments to sites further out to sea (Yarish et al. 2016, 7). Both environments present unique sets of challenges and opportunities. Shallow sites with rocky bottoms too close to shore can present challenges due to breaking waves capable of causing damage to infrastructure. This has the potential to occur in regions where the tidal depth dips below 10 metres. Deeper sites located further out at depths greater than 60 metres may experience greater drag forces upon the elongated mooring systems (Campbell 2019, 4). In either case, the site must be located within a lee where aquaculture operation will be protected from severe weather or ice floes which would otherwise cause wear upon the infrastructure (Flavin, Flavin, and Flahive 2013, 2).

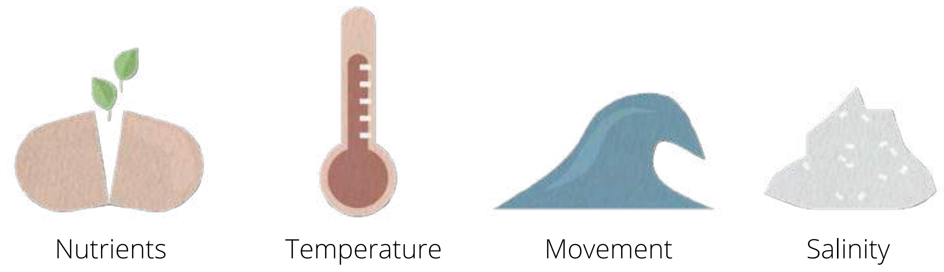
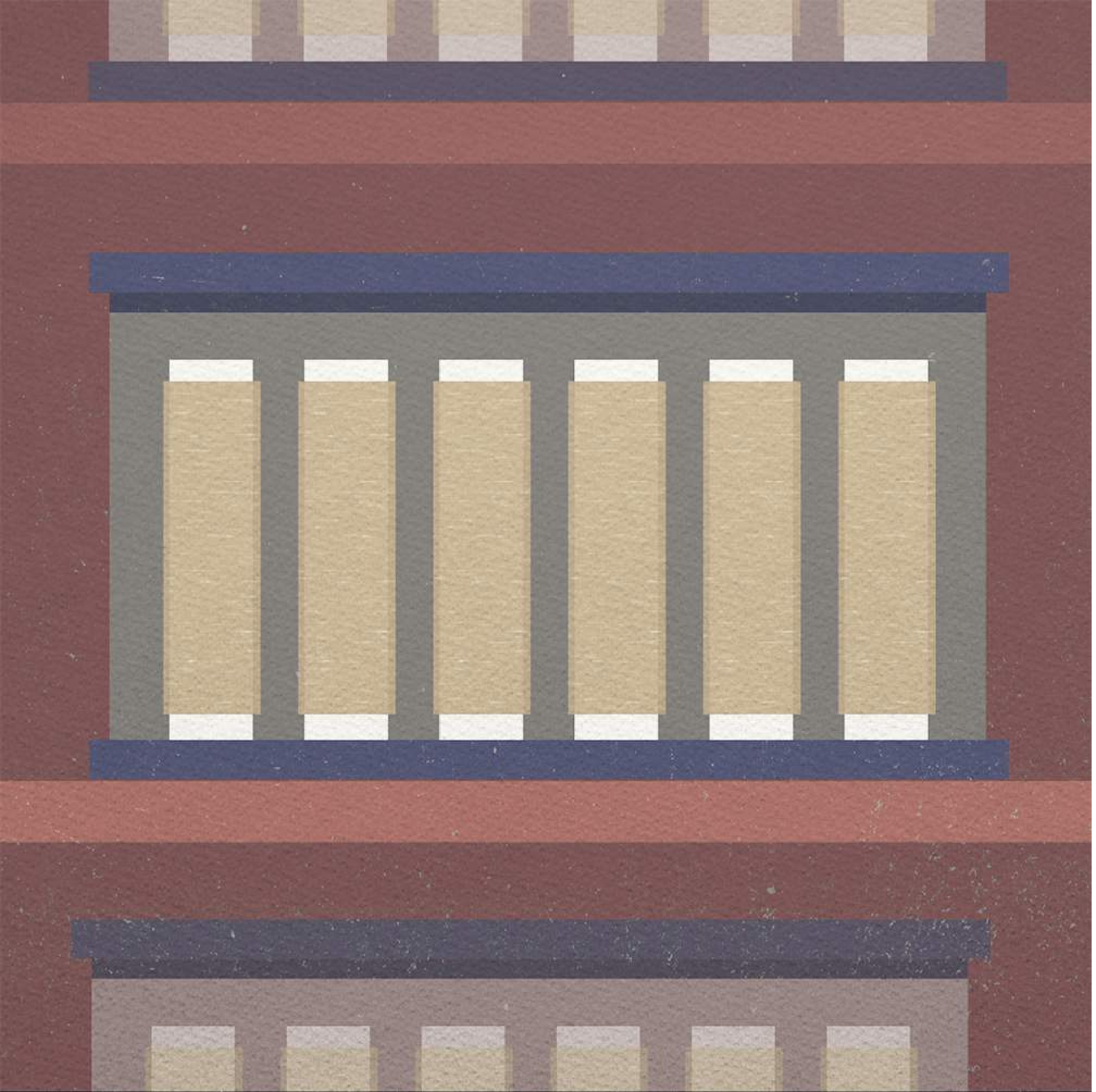


Figure 4.1 - Site requirements for seaweed cultivation

Sufficient nutrients are needed within the environment to encourage seaweed growth (Yarish et al. 2016, 7). In near-shore habitats, nutrients such as nitrogen and phosphorus may enter the water column through human-related effluents such as agricultural runoff and wastewater treatment (Campbell 2019, 2). The excess nutrients generated by these systems can effectively fuel seaweed growth. In turn, the seaweed performs bioremediation by reducing the impact these pollutants would've otherwise had on the aquatic ecosystem. Due to seaweed's bioremediation capabilities, seaweed aquaculture is often grown in proximity to fish farms which produce an excess of nitrogen. This nitrogen would otherwise contribute to eutrophication and oxygen depletion within the ecosystem (Kang et al. 2020, 2). In similar regard, the presence of heavy metals within the water should serve as a warning sign, as seaweed accumulates these elements making it unfit for human or animal consumption (Yarish et al. 2016, 7).



Cultivating

The process of commercially cultivating seaweed occurs between fall and late spring and requires minimal attention once planted. In late fall, seaweed spores are placed in PVC tubes containing spools of cotton thread. These tubes are incubated within aquariums that are carefully monitored for salinity, temperature, and water movement. The spores attach to the thread and continue to develop over the subsequent weeks until the plant is ready to be transferred to the ocean. By November, the thread is wound around ropes suspended between buoys, where it's left untouched until it's ready to be harvested. By April, the seaweed can reach lengths of 6-9 feet, at which point it's lifted from the ocean, rinsed, and hung to dry before being packaged and distributed (McHugh 2003, 6).

Figure 4.2 - PVC tubes incubating kelp spores sit in aquarium tanks

Harvesting

Similar to harvesting agriculture, harvesting methods for cultivated seaweeds vary based on the scale of the operation and can be done by hand or through mechanized processes. Hand harvesting allows for the highest quality product, as contaminants and debris are removed on site. Mechanized harvesting utilizes boats equipped with winches or cranes that pull ropes onto the boat where the crop is cut from the lines. Either method can accommodate total or partial harvesting. Partial harvesting ensures sufficient material is left behind, allowing the crop to regrow and provide for multiple harvests. A total harvest may be required at the end of a growing season to prevent the crop from otherwise being damaged by seasonal changes (Tiwari and Troy 2015, 42-44).

Figure 4.3 - A man lifts ropes of farmed seaweed from the ocean using a boat and winch

Drying

Once harvested, seaweed is rinsed of any contaminants in fresh or saltwater before being dried, packaged, and shipped to distributors. Due to seaweed's high water content, the drying process ensures the product maintains a long shelf life while reducing its weight and volume (Cote-Laurin, Berger and Tamigneaux, 2016, 40). Species such as Laminaria japonica, commonly known as kombu, are rinsed and hung to air dry, whereas other species are processed while still wet (McHugh 2003, 81). Porphyra, for example, known as nori or purple laver, is dried through a highly mechanized process similar to papermaking. The wet seaweed is washed and chopped into a slurry before being poured into frames that are stored in a drying room. Here, the moisture is removed from the seaweed, resulting in paper-thin sheets that are bundled and packaged (McHugh 2003, 75).

Figure 4.4 - Harvested seaweed is hung to dry on a simple timber structure

Processing

The processing stage sees dried seaweed cut down in size, packaged, and shipped off to businesses or restaurants.

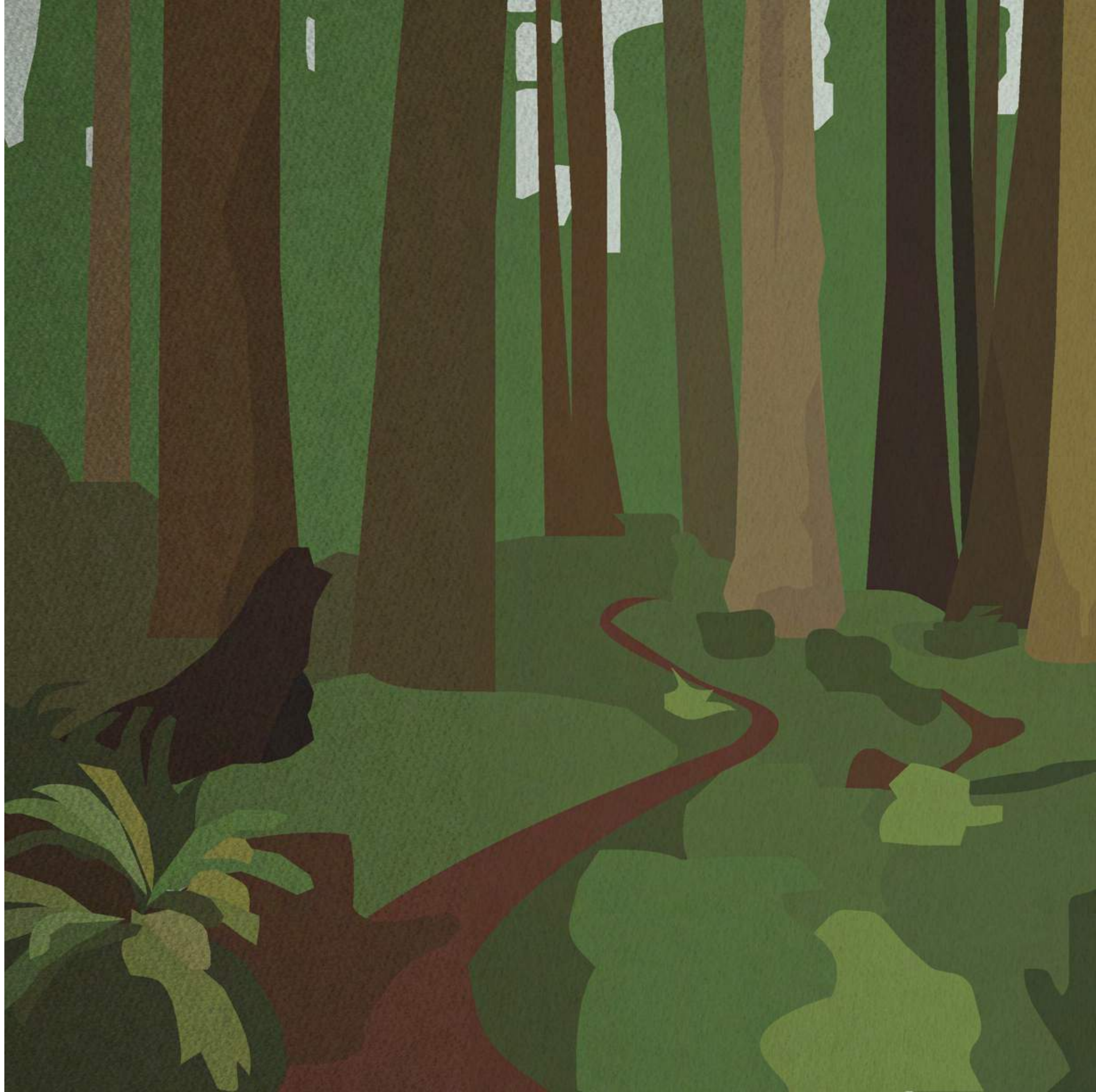
Figure 4.5 - Dried kelp is cut down in size

Architectual

Cities and Nature

As humans, we are inherently drawn towards the natural world. First coined by social psychologist Erich Fromm, biophilia is defined as “the innately emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature” (Beatley 2016, 4). Human predisposition towards geological features of the landscape such as wide vistas and caves have historically offered advantageous sites for survival and refuge (Beatley 2016, 6). Today, whether one walks through the untouched wilderness or a manicured Japanese garden, the environment has a positive influence on the mind and spirit as nature stimulates all senses (Pallasmaa 2012, 41). According to Stephen Robert Kellert, an emeritus professor of social ecology at Yale and leader in the study of biophilia, access to nature is an essential component of urban life, and must not be overlooked. In the process of urbanization, nature must be conserved and injected into the city in new and interesting ways (Kellert 2005, 10).

Figure 5.1 - Humans have a predisposition towards natural landscapes



Georg Simmel has written much about the experience of life within the industrialized city versus a rural setting through his text “The Metropolis and Mental Life (1903),” touching on the psychological attributes of residents from either region. This text highlights the condition of working-class neighbourhoods, painting a vivid picture of the urban setting at the time (Simmel 1950). The nineteenth-century saw a renewed interest in parks and green spaces as a means to counterbalance the negative effects of the industrial landscape. It was believed that the balance of nature had been disrupted, causing an influx of contagious particles within the atmosphere. Sunlight, fresh air, and trees were needed to cleanse the air and absorb any harmful particles within the city. The need for “breathing spaces” and a harmonious balance of nature led to the back-to-nature movement. Frederick Law Olmsted and Andrew Jackson Downing were major players in this movement, leading to the vast acquisition of public parkland and preservation of wilderness landscapes (Boyer 1984).

Figure 5.2 - New York’s Central Park provides a taste of nature within an urban environment (Jaeger 2006)

Today, there's renewed scholarship in the understanding of nature and its effects on mood and cognitive performance. Modern society is focused on urbanization, which demands the development of cities, and the taming of wild landscapes in favour of productive lands. Ecologically diverse landscapes are transformed into industrial-scale monocultures required to support the growing homogenous aesthetic of modern cities. Though there's a general understanding of nature's significance on one's wellbeing, its importance is often overlooked in the development of modern urban society (Kellert 2005, 9). Our understanding of nature's role in regards to human wellbeing, as well as our desire to control it in the pursuit of urbanization presents two contradictory premises.

Figure 5.3 - Vancouver has prevented development within Stanley Park (GoToVan 2018)

Biophilic Design

The implementation of biophilic design principles can aid in bridging the divide between the urban environment and nature. Biophilic design takes two approaches in building multi-sensory experiences: organic design and vernacular design. Organic design seeks to mimic qualities of nature within the built environment through the use of natural materials and landscaping, as well as mechanical building systems such as natural ventilation and lighting. On the other hand, vernacular design seeks to draw a connection between the geographic context of a building with ecological, cultural, or historical meaning (Kellert 2005, 10). Successful biophilic design in an urban environment serves to supplement rather than substitute time spent in outdoor natural landscapes (Beatley 2016,20).

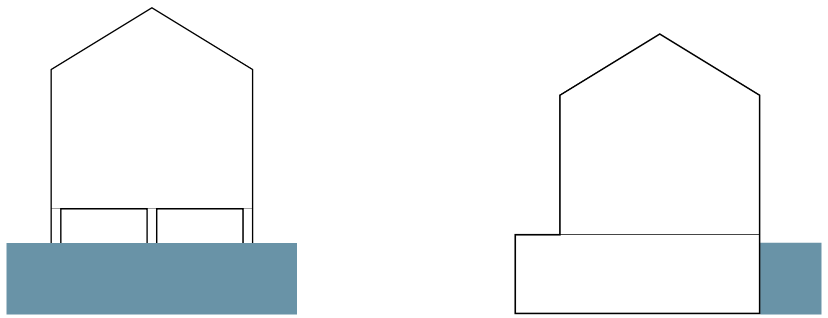
The multi-sensory experience of biophilic design strengthens one's connection to the built environment and nature. The western world prioritizes the sense of sight, often ignoring the remaining senses which are integral in our understanding of the world. A walk through nature has positive effects on the mind and spirit as the surroundings play upon all sense modalities (Pallasmaa 2012, 39-41). According to Juhani Pallasmaa, a Finnish architect and professor with a focus on architecture and the senses, "architecture is essentially an extension of nature into the man-made realm, providing the ground for perception and the horizon of experiencing and understanding the world. It is not an isolated and self-sufficient artifact; it directs our attention and existential experience to wider horizons" (Pallasmaa 2012, 41). The most impactful architecture is that which plays upon all senses.

Figure 5.4 - Fallingwater by Frank Lloyd Wright is an example of biophilic design, as the interior and exterior spaces appear to seamlessly flow together (Wright 1935)

Typology: Above Water

Buildings elevated above the water's surface are the most common form of 'aquatecture,' and are often supported by structural posts made from concrete, timber, or aluminum. These structures are static and maintain their position in relation to the ground below. When built above water, the structural posts must be firmly attached to the seafloor by driving the structural posts or piles into the ground (Barker and Coutts 2016).

Figure 5.5 - Above water building typology precedents



Elevated

Land's Edge

Instances

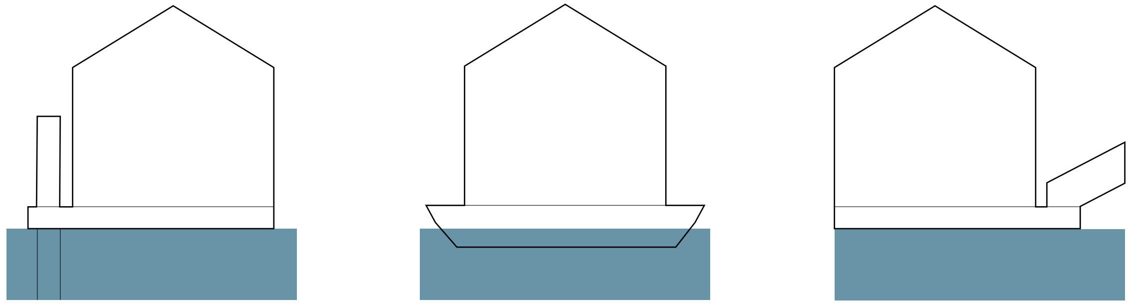
Aluminum Forest
by Micha de Hass

Oslo Opera House by
Snøhetta

Typology: On Water

Buildings that float upon the water's surface are often constructed from lightweight building materials and rely upon a buoyant base to allow the structure to rise and fall with the tides. To stay afloat, the buoyancy of the base must exceed the weight of the superstructure. In most cases, the depth of the water must exceed 1 metre, though taller structures will require greater depth to accommodate larger buoyancy floats. These structures are most feasible in sheltered areas such as lakes and docks where there is protection from storm surges (Barker and Coutts 2016).

Figure 5.6 - On water building typology precedents

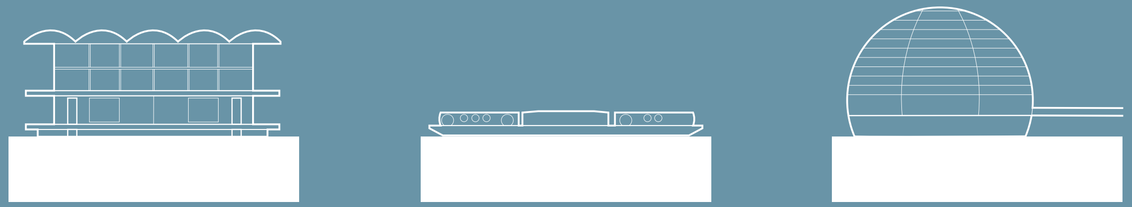


Moored

Ship-like

Connected

Instances



Floating Farm by Goldsmith

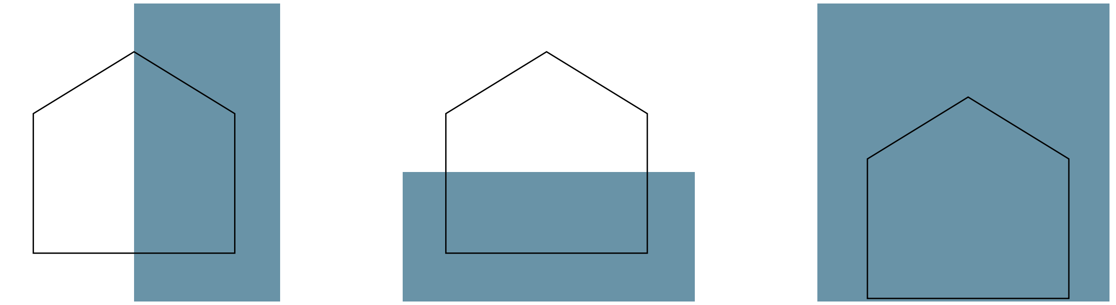
Point Counterpoint II By Louis Kahn

Apple Store by Foster + Partners

Typology: Below Water

Structures that sit below water are dry-proofed using a water barrier and water-resistant materials to create an impermeable structure. These structures must be strong enough to withstand the pressure exerted on them from the surrounding water (Barker and Coutts 2016).

Figure 5.7 - Below water building typology precedents

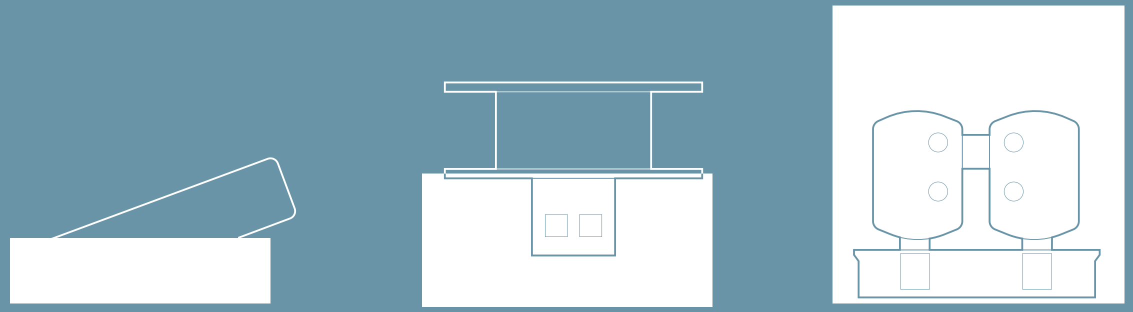


Bridging

Dropped

Plunged

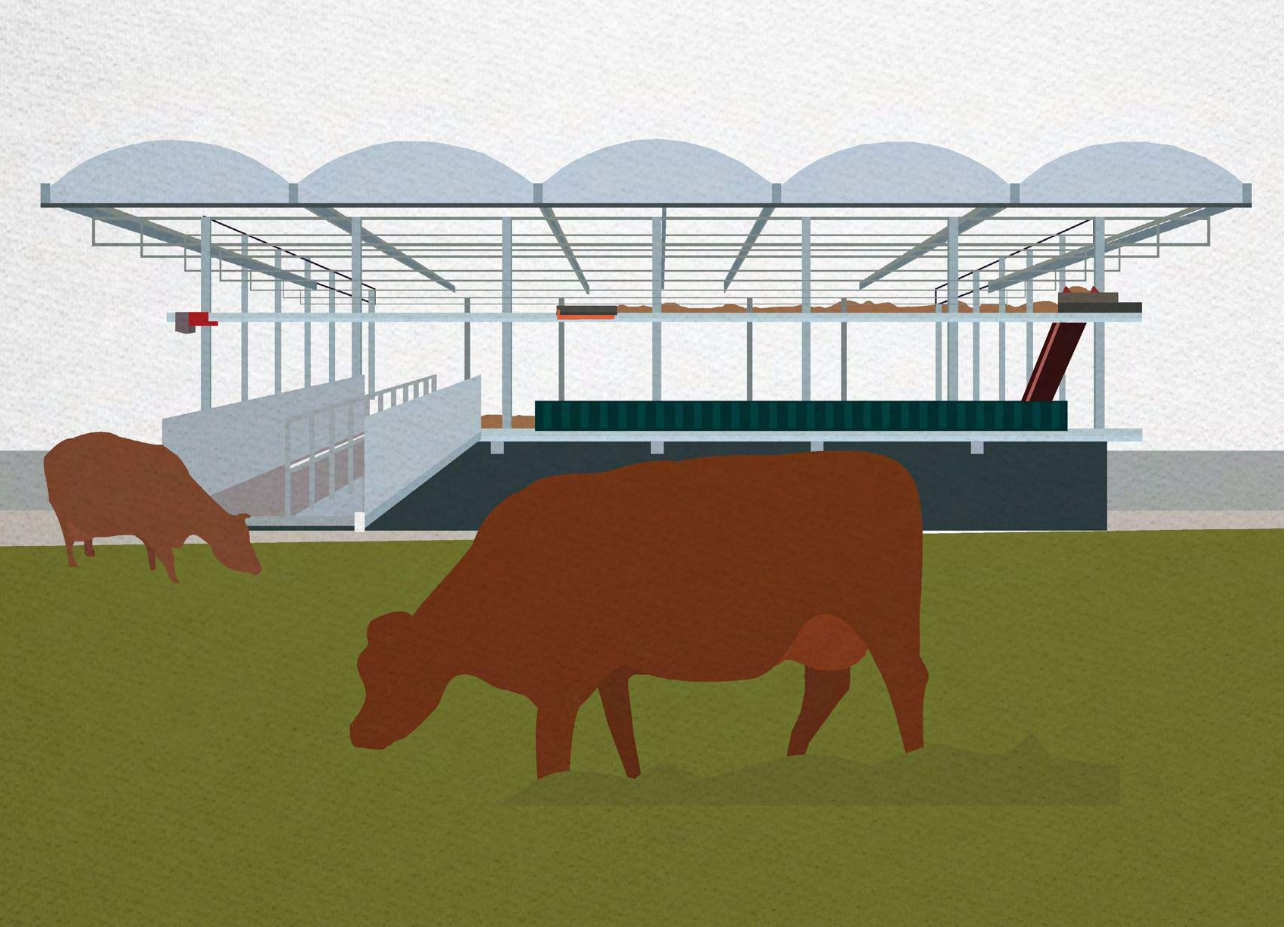
Instances



Under by Snøhetta

The Manta Resort by Mikael Genberg

Tektite Habitat by NASA

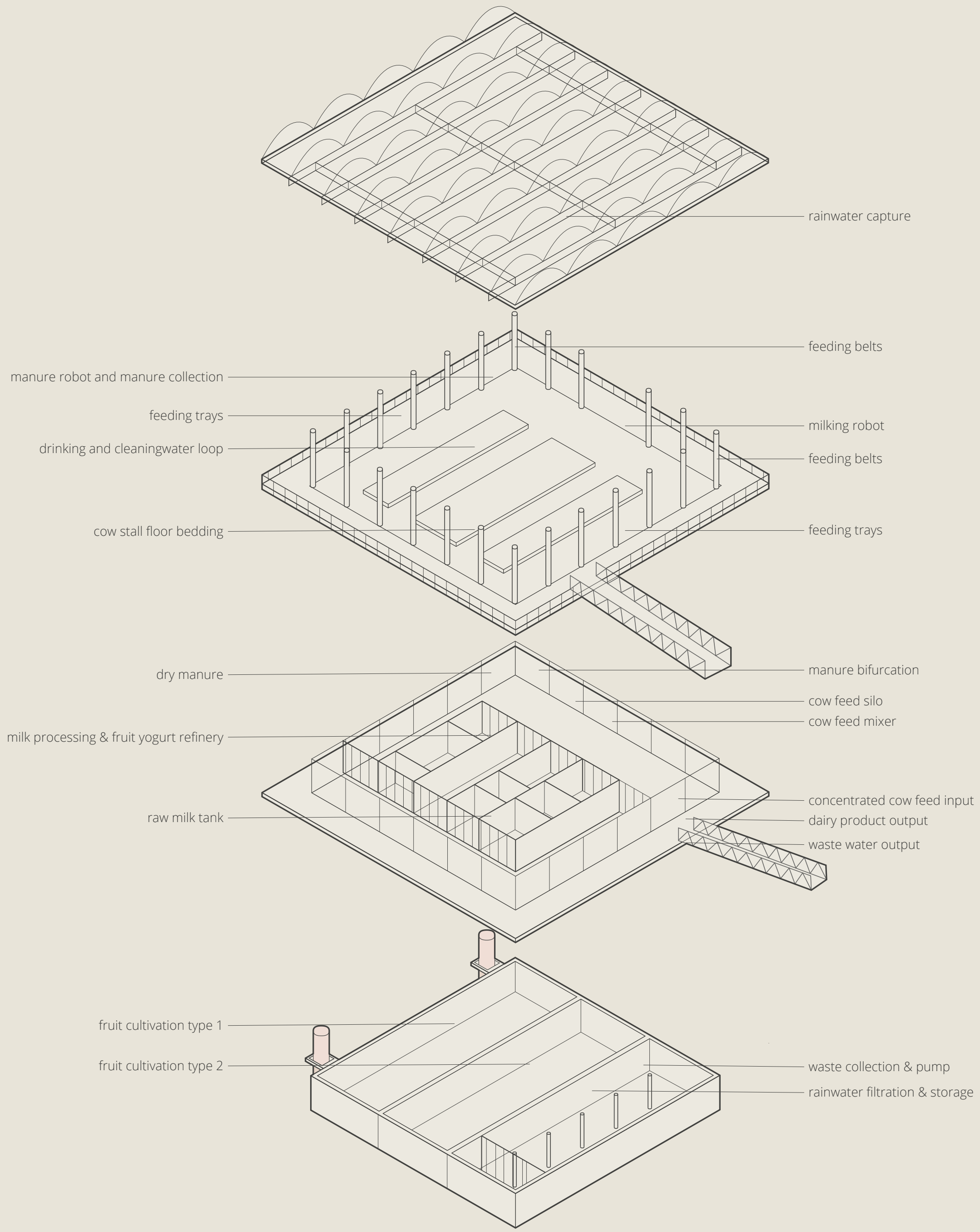


Precedent Studies

Floating Dairy Farm

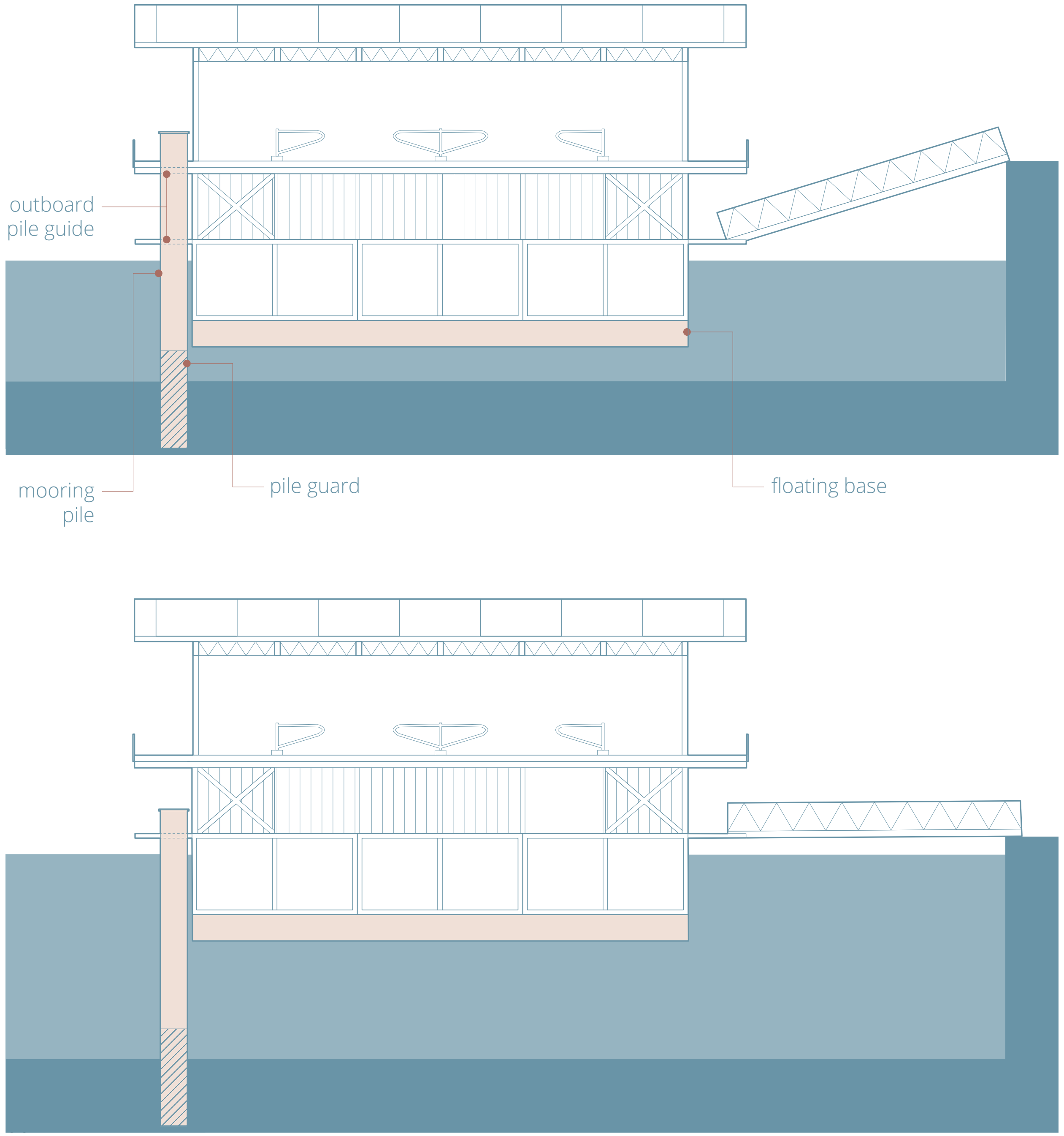
The threat of rising sea levels is a concern in the Netherlands, where flooding is already a frequent occurrence. Designed for a future where agricultural lands are compromised due to flooding and the effects of climate change, Floating Dairy Farm by Goldsmith Architects displays a sustainable model for urban farming that has minimal impact on the city's resources and the environment. This structure is built upon circular design principles, by which electricity is generated through a series of nearby floating solar panels, fresh rainwater is collected and purified, and animals are fed the city's grass clippings and brewery scraps.

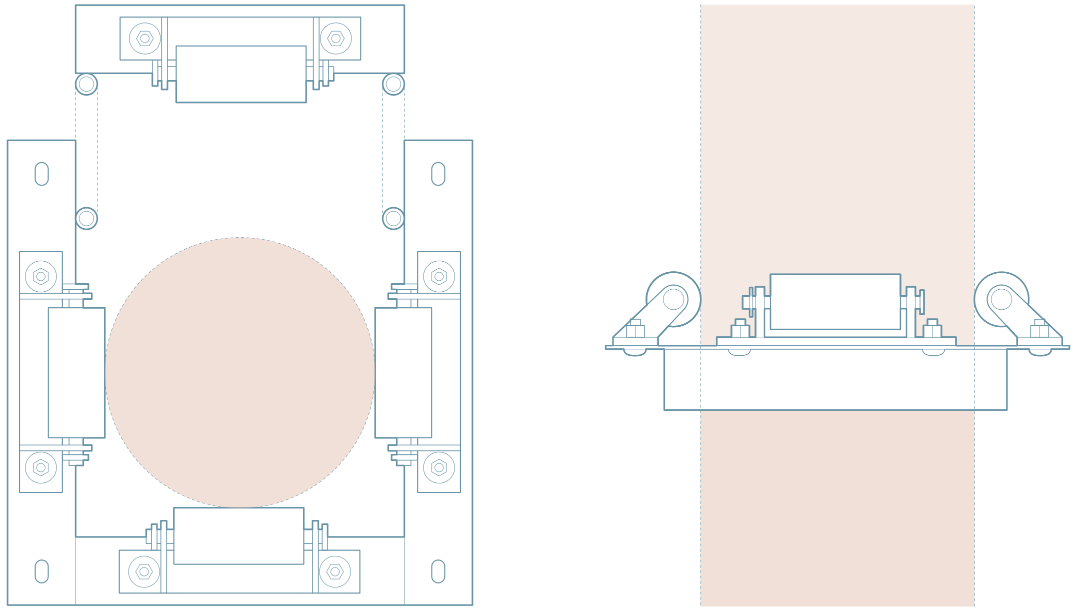
Figure 5.8 - Floating Diary Farm by Goldsmith Architects



The concepts this farm ties together are integral in the development of my project. The siting of this project within the urban centre of Rotterdam allowed the architects to develop educational opportunities for the public and inform them of where their food comes from. The form of the structure, situated atop a floating platform, highlights ways architecture can embrace rising sea levels and compromised agricultural land while forming a relationship with the waterway. The methods used in future-proofing the floating dairy are of interest to me and are something I'm looking to develop through the siting and structure of my grad project.

Figure 5.9 - Exploded axon of Floating Dairy Farm showing programming





A floating base ensures the building stays above water, while the mooring pile preserves its position within the marina. As the tide fluctuates the building slides vertically against the mooring pile, which has been driven into the seabed. The aluminum outboard pile guides are equipped with wheels along the interior edge, which allow for smooth movement while safeguarding the pile from horizontal forces.

Figure 5.10 - (Left) Section of Floating Dairy Farm featuring flotation and mooring system

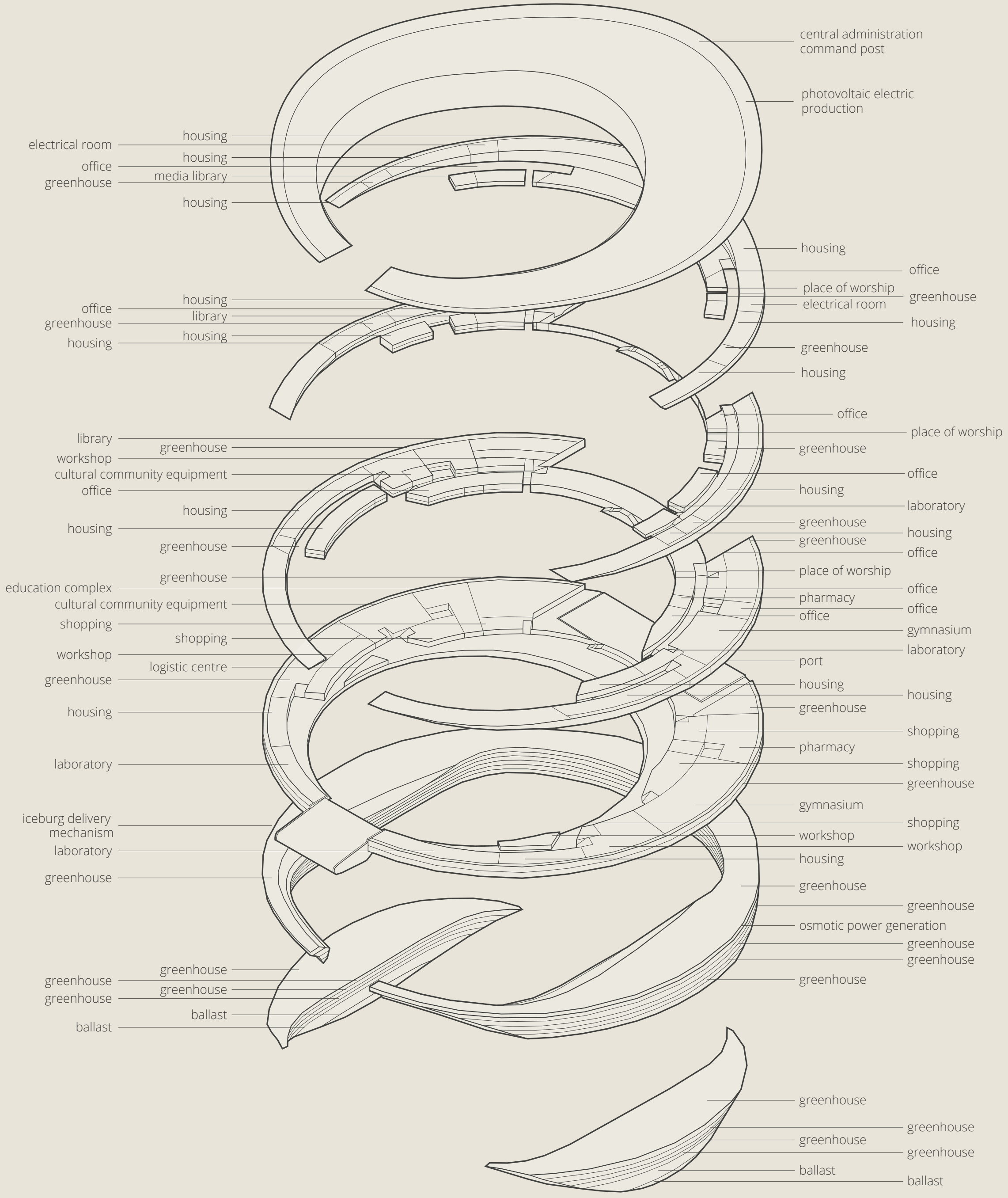
Figure 5.11 - (Above) Mooring post and pile guide detail

Arctic Harvester

The Arctic Harvester was designed in response to Greenland's dependence on the import of fresh fruit and vegetables. This structure highlights the relationship Greenlanders have with the sea while providing the community with agricultural independence. This project takes the form of a circular, floating facility that drifts between Greenland and Canada, making use of the nutrient-rich freshwater collected from icebergs that float into the centre of the circular structure. This freshwater is used by hydroponic farming systems within the built form, which allows for soil-less agriculture. The plants grown here can be used to feed residents in Greenland or be sold for profit.

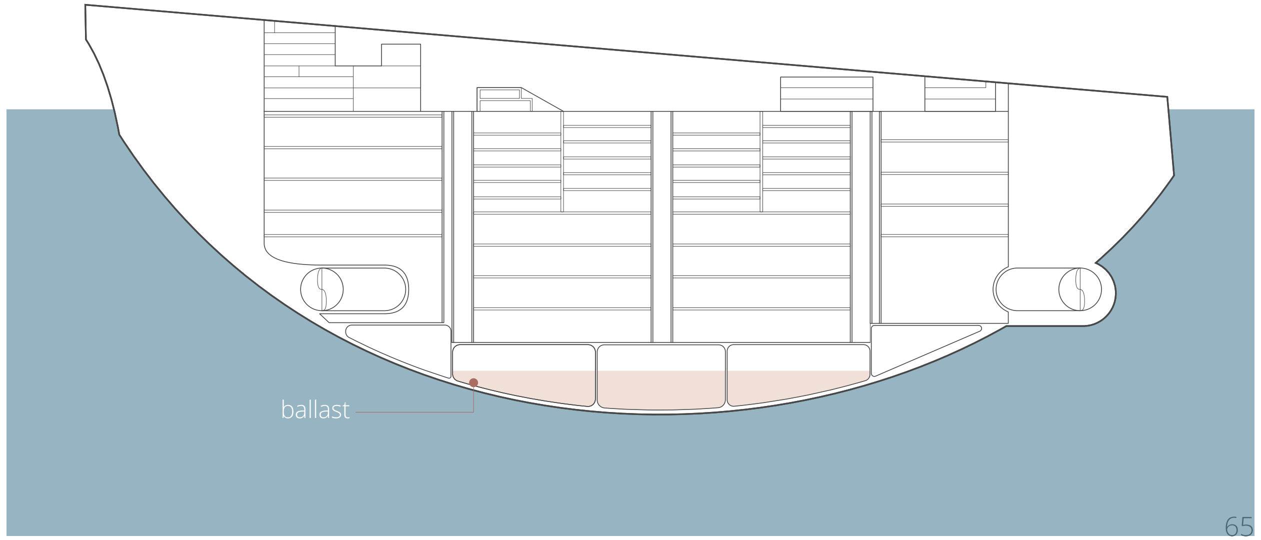
Arctic Harvester effectively harnesses the ocean's resources to develop a mutually beneficial relationship between the environment and Greenlanders in regards to agriculture and economic security. This proposed design is innovative in the methods it uses to address sustainability and the material exploitation of climate change, while formally drawing upon the community structure of bayside Greenlandic villages. I'm interested in the siting and innovative form of the structure, which offers a reproducible model that can generate a series of floating constellations of hydroponic gardens throughout the Atlantic Ocean.

Figure 5.12 - Arctic Harvester



Arctic Harvester is built similar to a cargo ship and relies on ballast to maintain stability. The ballast tanks are found on the lowest level of the structure and are filled with free moving water which is leveled out until the assembly reaches equilibrium. This ensures that the upper weight of the Arctic Harvester is counterbalanced by the weight of the water in the ballast tank.

Figure 5.13 - (Left) Arctic Harvester exploded axon featuring programming
Figure 5.14 - (Below) Arctic Harvester section featuring ballast



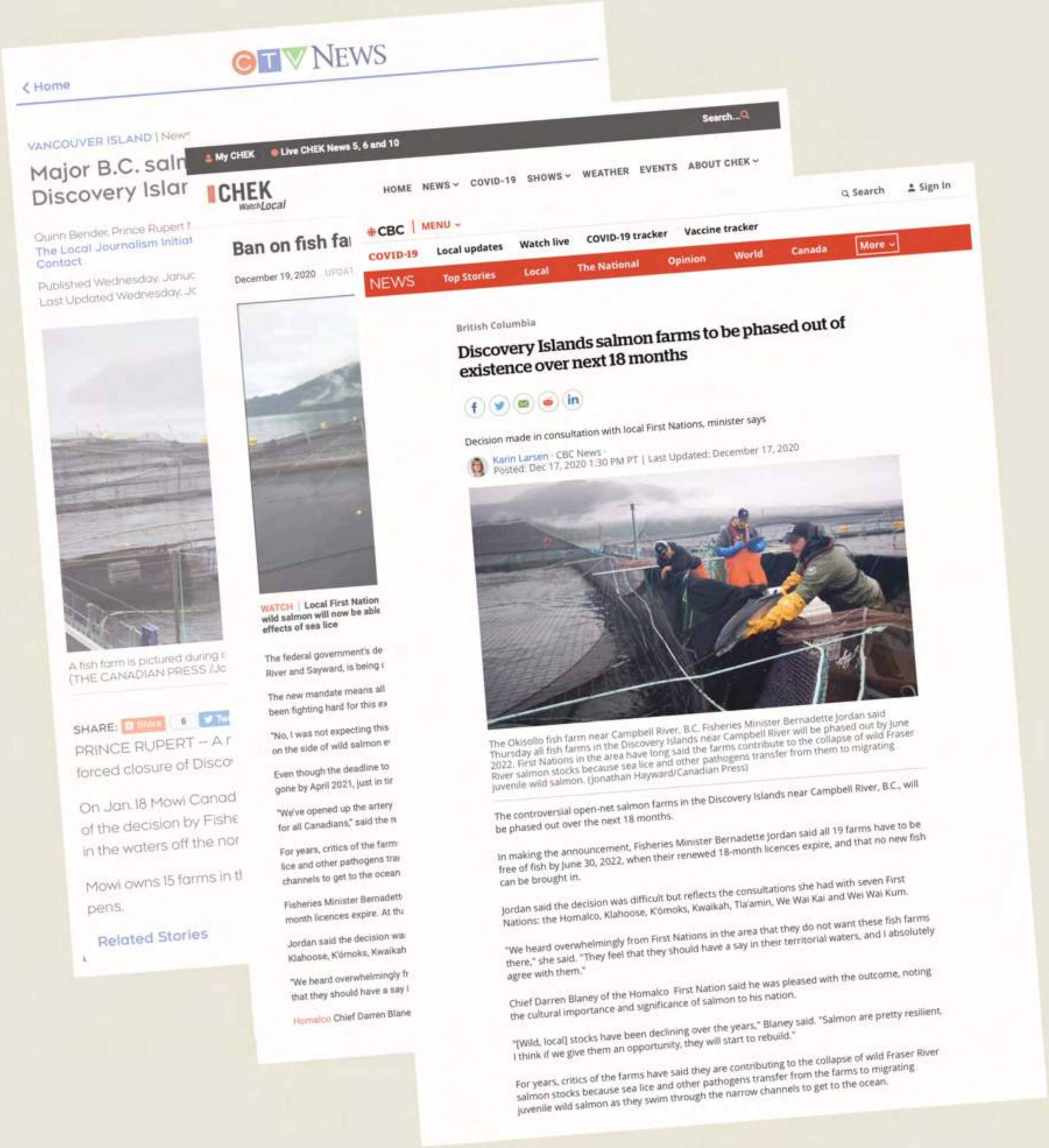
Comparison of Arctic Harvester and Floating Dairy Farm

Though visually very different, at the core, Floating Dairy and Arctic Harvester share similar values in regards to community and architecture's response to climate change. Though the design for Arctic Harvester is unrealized, it proposes an innovative constellation of floating communities that focus on hydroponic farming supported by the nutrient-rich freshwater from melting icebergs. Floating Dairy on the other hand is an exemplary built example of how architecture can harness the effects of climate change. This floating farm addresses challenges associated with depleting agricultural land and sea-level rise, while providing fresh milk and fruit yogurt to the city.

Though the Arctic Harvester's proposed site is within the Atlantic Ocean between Greenland and Canada, the design can be duplicated and transplanted into any ocean that contains icebergs. In a similar sense, the Floating Dairy serves as a model of what is possible and can be duplicated in regions with similarly tempered waterways.

Though both are floating structures, their compositions are quite different. The Floating Dairy relies on the placement of two piles, that have been driven into the ground below to secure the structure. Arctic Harvester is designed to be in motion and floats about the sea in a similar manner to the icebergs it captures. The lowermost level is constructed with a double hull design and is filled with ballast to stabilize the structure in rough waters.

The Arctic Harvester's bottom-heavy design is similar to the programming of the Floating Dairy, with all heavy technical and structural components are located on the lower levels, while the lightweight more visible components are located on the top floors. The programming of both structures is dispersed amongst several floors, though the Floating Dairy takes a more streamlined approach. Arctic Harvester has a variety of programming dispersed amongst wings and levels without a clear reason why. Overall, the Floating Dairy and Arctic Harvester take different approaches to challenges brought on by climate change, while providing nourishment for their local community.



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WATCH | Local First Nation
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Homalco Chief Darren Blane

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British Columbia

Discovery Islands salmon farms to be phased out of existence over next 18 months

Decision made in consultation with local First Nations, minister says

Karin Larsen · CBC News ·
Posted: Dec 17, 2020 1:30 PM PT | Last Updated: December 17, 2020

The Okisollo fish farm near Campbell River, B.C. Fisheries Minister Bernadette Jordan said Thursday all fish farms in the Discovery Islands near Campbell River will be phased out by June 2022. First Nations in the area have long said the farms contribute to the collapse of wild Fraser River salmon stocks because sea lice and other pathogens transfer from them to migrating juvenile wild salmon. (Jonathan Hayward/Canadian Press)

The controversial open-net salmon farms in the Discovery Islands near Campbell River, B.C., will be phased out over the next 18 months.

In making the announcement, Fisheries Minister Bernadette Jordan said all 19 farms have to be free of fish by June 30, 2022, when their renewed 18-month licences expire, and that no new fish can be brought in.

Jordan said the decision was difficult but reflects the consultations she had with seven First Nations: the Homalco, Klahoose, K'ómoks, Kwaikah, Tla'amin, We Wai Kai and Wei Wai Kum.

"We heard overwhelmingly from First Nations in the area that they do not want these fish farms there," she said. "They feel that they should have a say in their territorial waters, and I absolutely agree with them."

Chief Darren Blaney of the Homalco First Nation said he was pleased with the outcome, noting the cultural importance and significance of salmon to his nation.

"[Wild, local] stocks have been declining over the years," Blaney said. "Salmon are pretty resilient. I think if we give them an opportunity, they will start to rebuild."

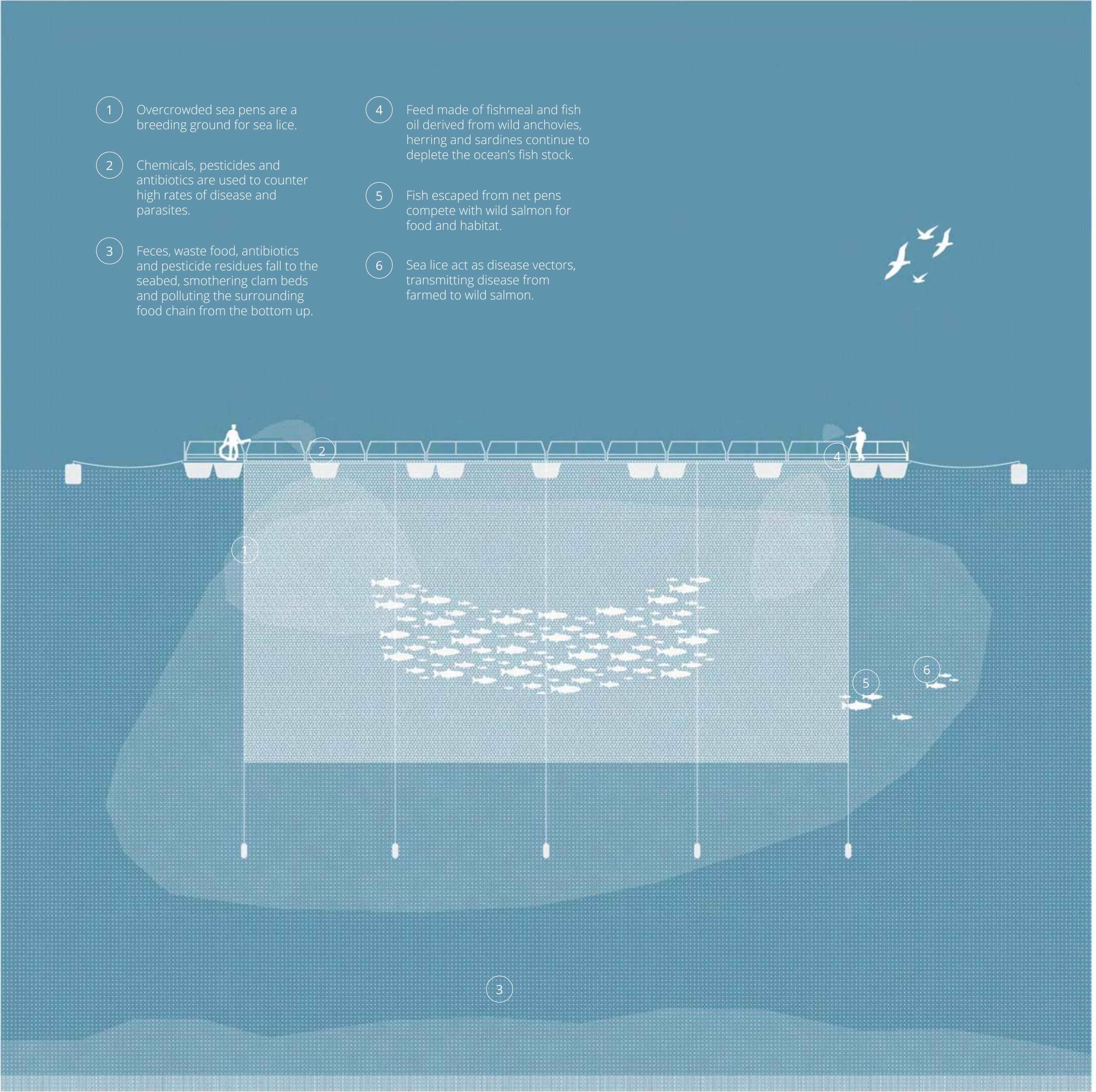
For years, critics of the farms have said they are contributing to the collapse of wild Fraser River salmon stocks because sea lice and other pathogens transfer from the farms to migrating juvenile wild salmon as they swim through the narrow channels to get to the ocean.

Proposal

Adaptive Reuse of Salmon Farms

In December of 2020, Fisheries and Oceans Canada announced that all open-pen salmon farms in the Discovery Islands would be phased out over 18 months. This decision was made following consultations with local First Nations who feared for the health of local sockeye salmon (Larsen 2020). This project proposes an adaptive reuse of these vacant floating facilities, transforming the controversial open-pen salmon farms into sustainable seaweed farms. This process sees positive regenerative effects on the local ecosystem which otherwise faces increased pressures due to pest and disease transmission, eutrophication, and toxic algal blooms.

Figure 6.1 - News clippings of salmon farm closures



1. Overcrowded sea pens are a breeding ground for sea lice.
2. Chemicals, pesticides and antibiotics are used to counter high rates of disease and parasites.
3. Feces, waste food, antibiotics and pesticide residues fall to the seabed, smothering clam beds and polluting the surrounding food chain from the bottom up.
4. Feed made of fishmeal and fish oil derived from wild anchovies, herring and sardines continue to deplete the ocean's fish stock.
5. Fish escaped from net pens compete with wild salmon for food and habitat.
6. Sea lice act as disease vectors, transmitting disease from farmed to wild salmon.

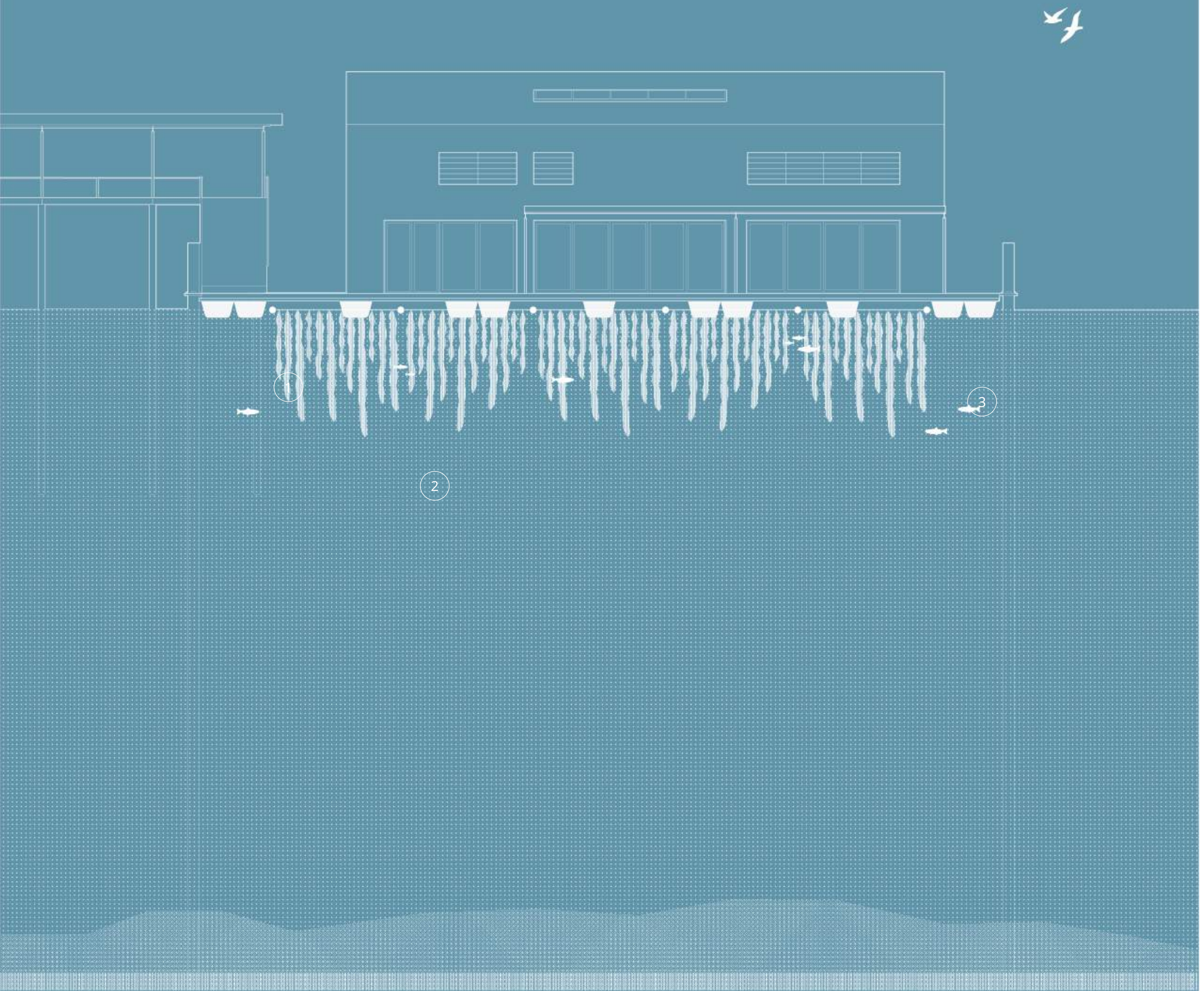
Ecological Phasing Sage 1 - Existing Salmon Farm

Open-net salmon farms pose a threat to British Columbia's population of wild salmon and the immediate marine environment. Salmon farms take advantage of the coastline's natural current to deliver oxygenated water to the salmon while dispersing the waste through the waterway. In open-net systems, this permeable net is the sole barrier between farmed salmon and their wild counterpart, which allows for pest and disease transmission. 2020 saw the lowest Fraser River sockeye salmon run in history, which many attribute to parasites and pathogens contracted by migrating juvenile salmon as they pass through areas with farmed salmon (Wilson 2021).

The majority of the province's open-net salmon farms produce Atlantic salmon, a species that is not native to British Columbia but is favoured by salmon farmers for its quick and consistent growth (Flatt 2017). Atlantic salmon are susceptible to piscine orthoreovirus (PRV) which can lead to heart and skeletal inflammation disease (HSMI) that has the potential to cause high mortality rates in the overcrowded salmon farming pens. Due to the economic loss that such diseases may bring, antibiotics are administered to ward off disease.

The overcrowded nature of open-net salmon farms also contributes to sea lice infestations. Sea lice are a naturally occurring parasite that can often be found in limited numbers on the skin of adult salmon, but the dense concentration of farmed salmon breeds the perfect environment for the sea lice to rapidly reproduce. These parasites can be detrimental to the livelihood of juvenile salmon. Chemicals are released into the pens to prevent sea lice infestations, but due to the permeable nature of the netting, the antibiotics, and other vitamins and herbicides that are used for salmon farming are being pumped directly into British Columbia's coastal waters (Salmon Aquaculture 2019).

Figure 6.2 - Ecological phasing stage 1



① Once planted, seaweed doesn't require additional inputs such as feed or fertilizer.

② Seaweed naturally filters large quantities of nitrogen and phosphorus from the ocean, preventing against eutrophication

③ Seaweed farming stabilizes the ocean's local pH value by absorbing and storing CO2, preventing ocean acidification

Ecological Phasing Stage 2 - Introduction of Seaweed Aquaculture

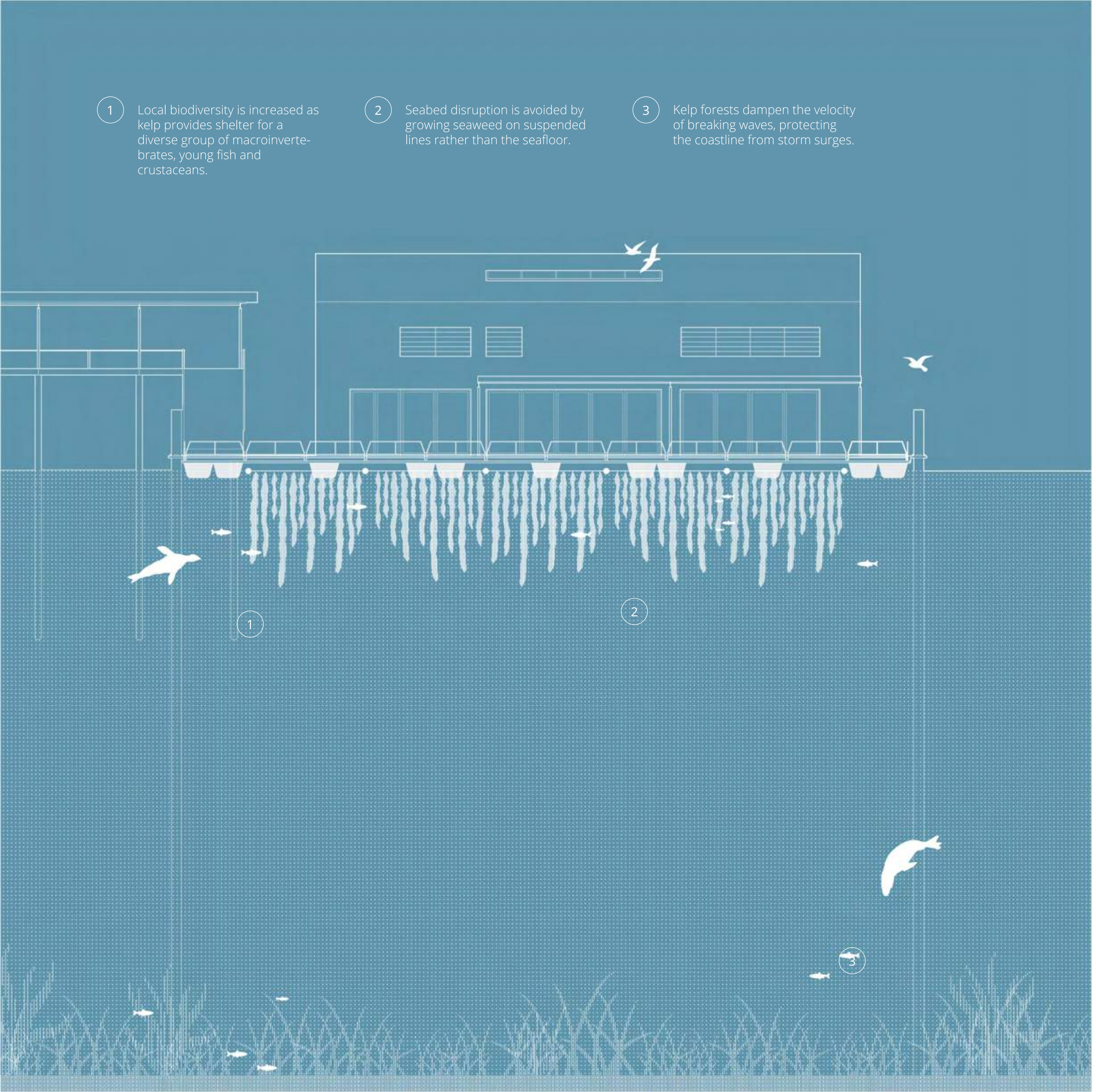
As the salmon are replaced with seaweed, the stresses on the marine environment are alleviated. The previously existing salmon farm relied on inputs of introduced food, antibiotics, and pesticides, but the new seaweed farm thrives off the power of the sun and nutrients existing in the waterway. Once planted, the seaweed requires no additional care or attention until it comes time to harvest.

The remnants of the salmon farm are reflected in elevated levels of phosphorus and nitrogen in the immediate body of water due to the release of fish effluents. This abundance of nutrients is known as eutrophication and is reflected in the deterioration of water quality. This leads to increased algae production and fish mortality. The introduction of the seaweed farm sees the quality of the water improve, as the seaweed absorbs these nutrients and filters them from the ocean. This highlights the role seaweed plays in natural bioremediation, while the nutrients fuel the growth of the seaweed.

Figure 6.3 - Ecological phasing stage 2

Ecological Phasing Stage 3 - Established Seaweed Aquaculture

Over time, local species abundance and biodiversity increase due to the bioremediating characteristics of the kelp grown on-site. The benthic quality index (BQI) monitors indicators such as benthic infauna, mobile macrofauna, benthic oxygen flux, dissolved nutrient concentrations, and species abundance within the local environment, and reflects positive environmental changes. The canopy of kelp provides a habitat for marine life, as increased populations of gastropods, amphipods, and brittle stars are found on site (Howell 2020). This increase in biodiversity builds greater ecosystem resilience.



① Local biodiversity is increased as kelp provides shelter for a diverse group of macroinvertebrates, young fish and crustaceans.

② Seabed disruption is avoided by growing seaweed on suspended lines rather than the seafloor.

③ Kelp forests dampen the velocity of breaking waves, protecting the coastline from storm surges.

Figure 6.4 - Ecological phasing stage 3

Site Selection

In total, this project addresses 19 individual salmon farms. 18 of these sites are located in British Columbia's Discovery Islands, an archipelago between Campbell River, Vancouver Island, and mainland British Columbia. As these sites are fairly remote and accessible only by boat, an additional salmon in nearby Powell River will provide more public-facing programming.

Figure 6.5 - Selected sites

Powell River 1:40 000

Powell River

The main 'gateway' site is located at Ahlstrom Point in Powell River. This site was specifically selected due to its proximity to existing road networks and nearby communities. Compared to the location of other salmon farms in BC, this site is easily accessible by the public and will therefore serve as a community-facing site.

Figure 6.6 - Powell River site map

Discovery Islands

The remaining 18 sites are located in the Discovery Islands. These locations form ‘satellite’ farms for the production of seaweed aquaculture as they’re located in remote areas accessible only by boat. These sites were surveyed to determine the type and scale of salmon farms in operation. The vast majority of these sites utilize open-net steel cages in rectangular configurations, with the one exception being Brougham which uses an octagonal plastic cage. These steel cages are optimal for use in this project due to their durability and rectilinear configurations that will support the growing lines for the seaweed farms. Most sites also offer outbuildings or feed barges which will provide a foundation to support the programming.

Figure 6.7 - Discovery Islands site map

1 Shaw Point

2 Althorpe

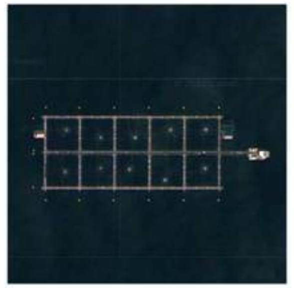
3 Hardwicke

4 Lees

5 Chancellor

6 Bickley

7 Philips Arm



8 Farside

9 Freddie Arm

10 Brougham

11 Thurlow

12 Sonora Point

13 Venture Point

14 Sonora Island

15 Barnes Bay

16 Brent Island

17 Cyrus Rocks

18 Raza

Modular Steel Pen Salmon Farm

The selected salmon farms utilize steel pens. These structures are modular and can support between four and twenty interconnected cages. The materials are durable, and only require occasional maintenance and inspection of hinge pins and floatation systems. The galvanized steel surface is naturally draining, preventing water or debris accumulation on the floating platform. These steel structures are supported by medium-density polyethylene floats, which have a life expectancy of 30 years.

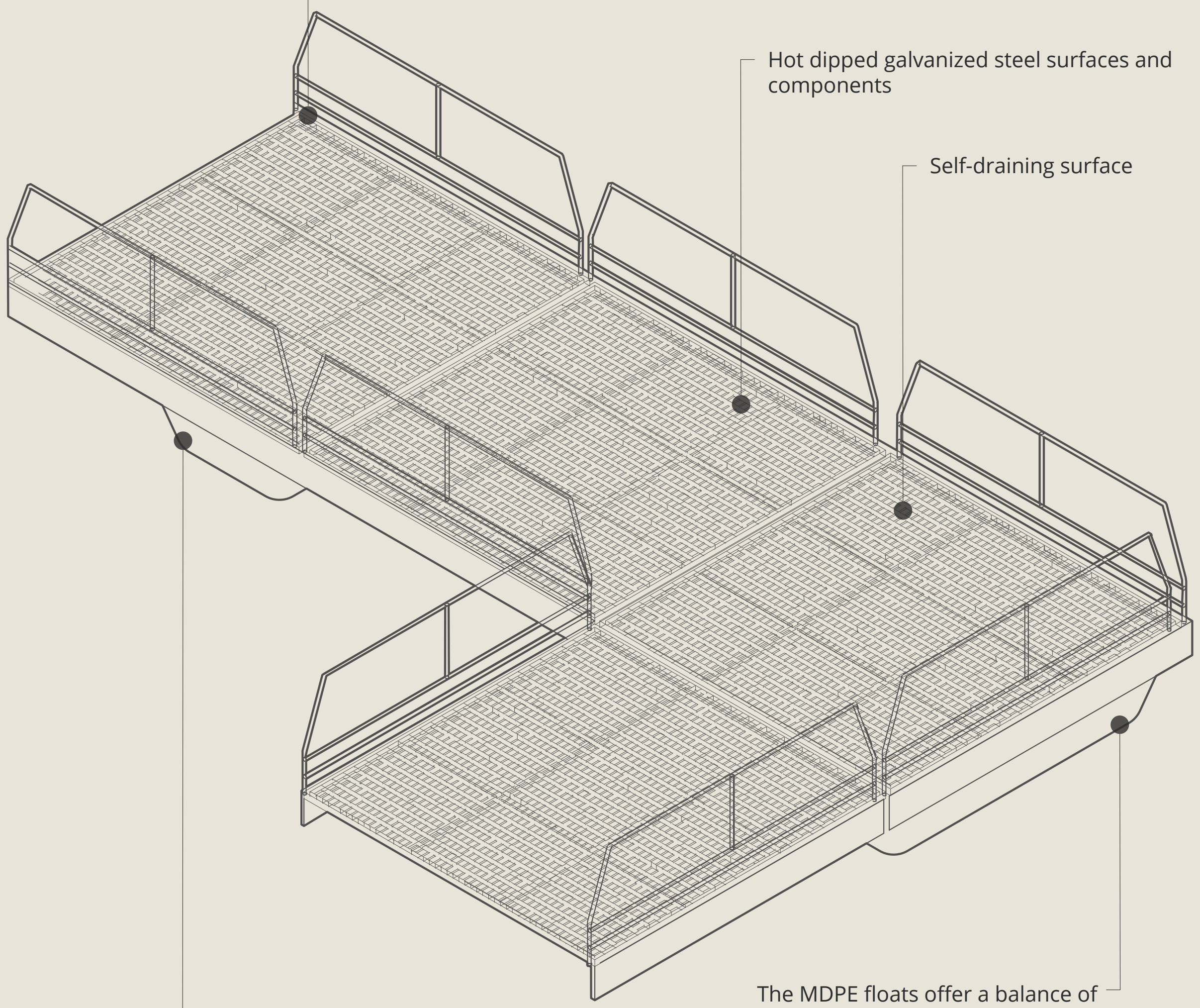


Figure 6.8 - Steel pen axonometric

moulded rubber hinge system allows the cage structure to adapt to the wave profile, thereby reducing loads on the member and ensuring longer life of the cages

Hot dipped galvanized steel surfaces and components

Self-draining surface

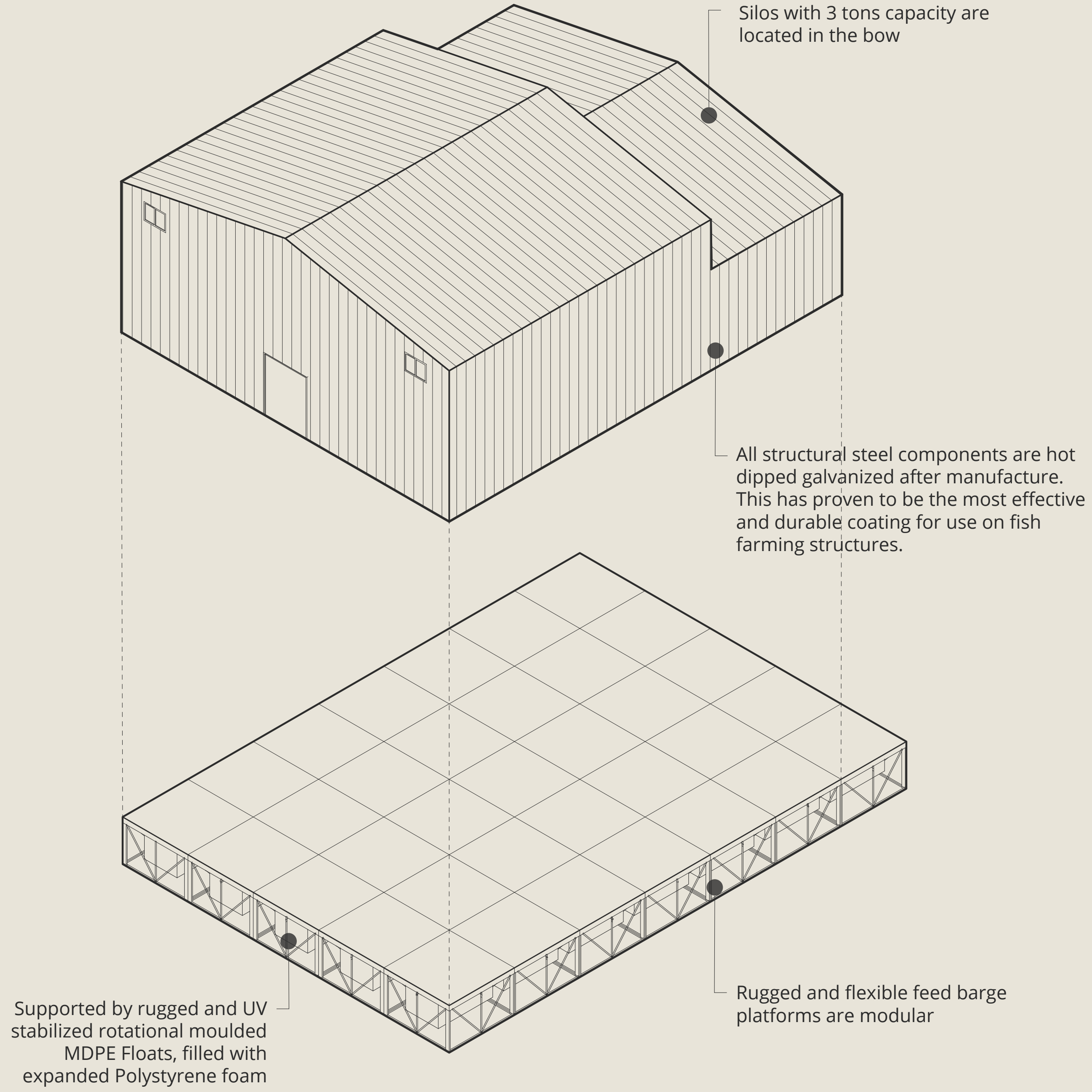
UV stabilized rotational moulded MDPE floats, filled with expanded polystyrene foam

The MDPE floats offer a balance of toughness, rigidity, and cold temperature impact performance, which ensures a lifespan of 30 plus years

Feed Barge

The salmon farms are equipped with feed barges. These buildings float alongside the steel pens and provide the programming necessary to support the salmon farm. Most often, these structures include salmon feed silos with 3 tons capacity, as well as control rooms, sensors, and cameras. Similarly, these structures are also supported by a system of medium-density polyethylene floats.

Figure 6.9 - Feed barge axonometric

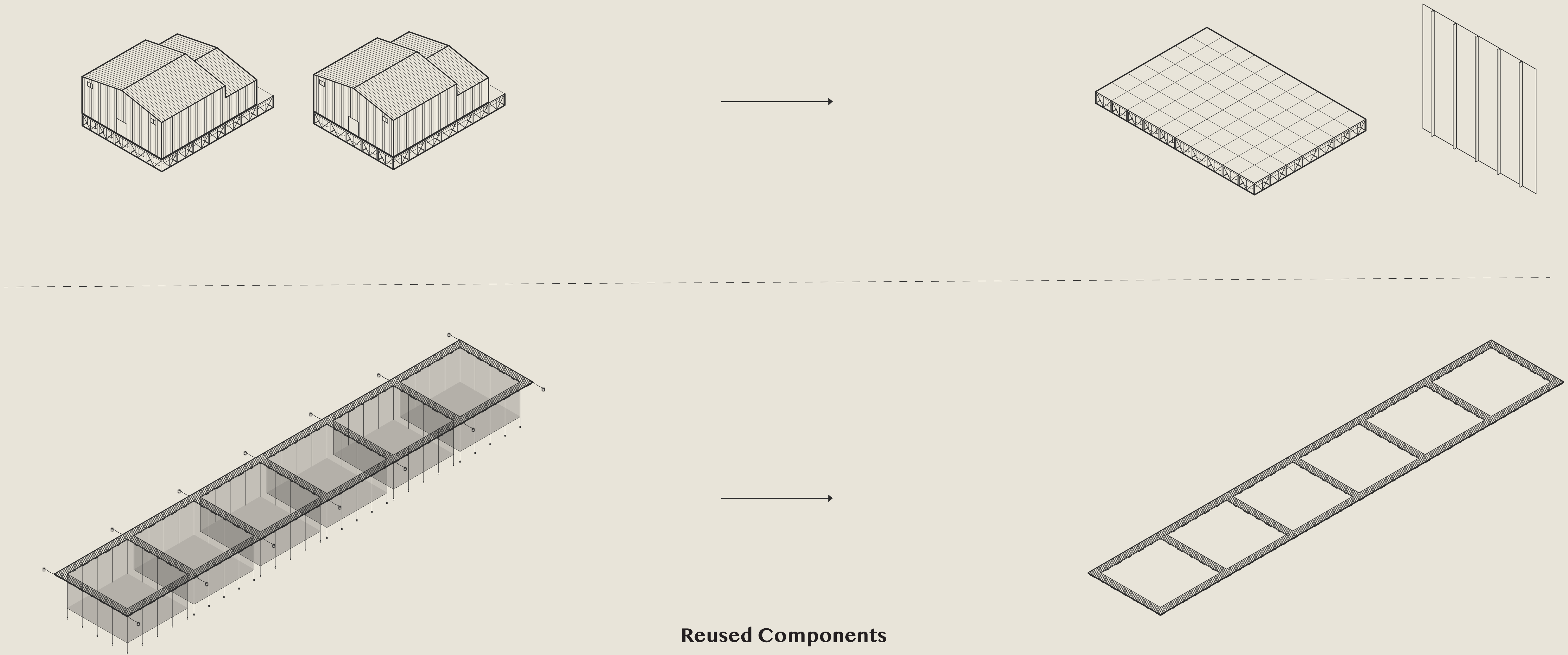


Silos with 3 tons capacity are located in the bow

All structural steel components are hot dipped galvanized after manufacture. This has proven to be the most effective and durable coating for use on fish farming structures.

Supported by rugged and UV stabilized rotational moulded MDPE Floats, filled with expanded Polystyrene foam

Rugged and flexible feed barge platforms are modular



Reused Components

In the instance of the Powell River site, the existing salmon farm is equipped with two feed barges and a 6 module open-net pen. From these components, we're carrying forward the floating platforms that rest underneath the feed barges, as well as their steel cladding. And as for the pen, we're removing the netting and adapting the floating structure to support the seaweed production. Similar reuse of components is also seen at the Discovery Islands sites.

Figure 6.10 - Reused components diagram

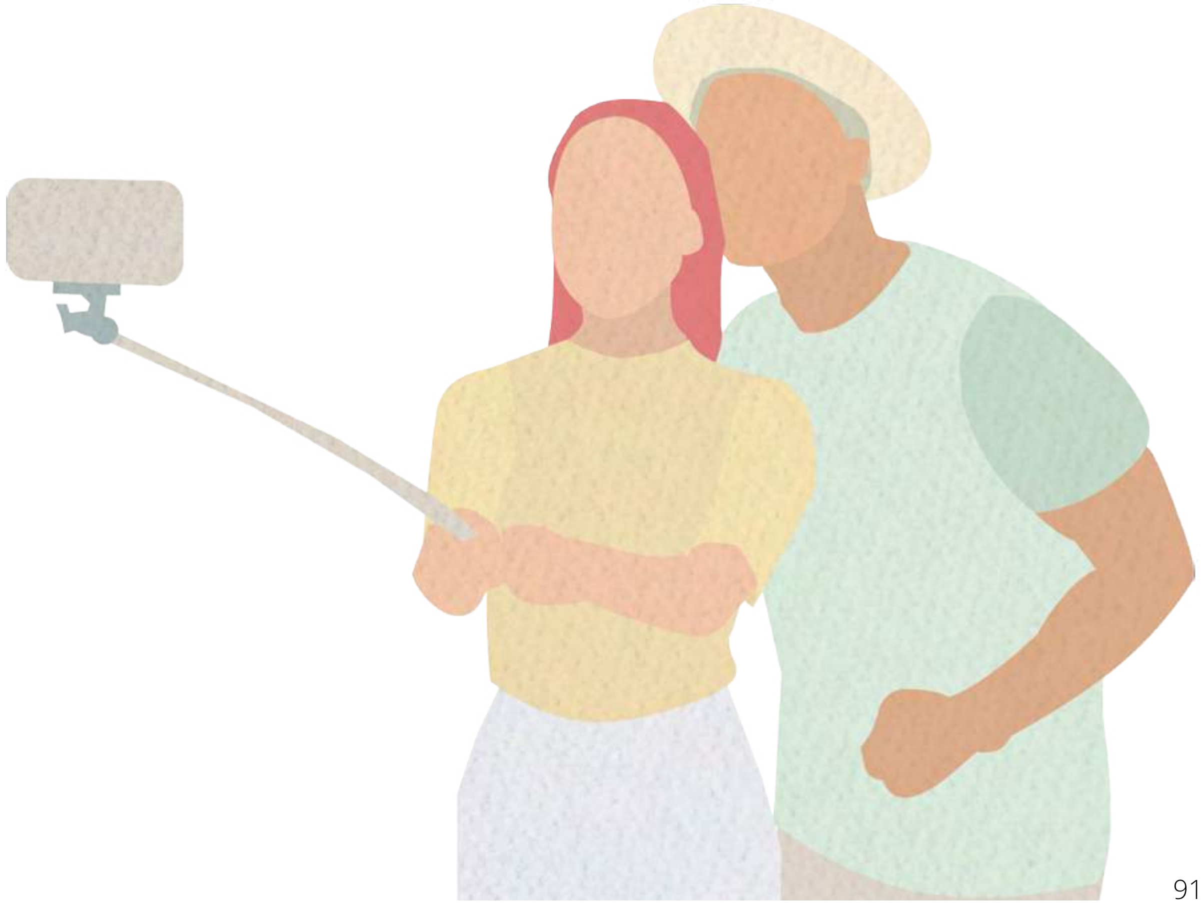
User Personas

User persona studies were conducted to determine what programming would be most beneficial to the local community. Users from various backgrounds were considered which aided in imaging who may visit this site in the future, and what they may hope to gain from their visit.

Name: Sam and Mo
Motivation: Overseas Travellers

Sam and Mo are visiting British Columbia from overseas and want to experience all aspects of the province from its natural setting to local culture and cuisine. They're interested in finding unique experiences that they can't find back home while exploring different corners of the province. After reading about the seaweed farm meets restaurant experience on an online design site, they've decided it is a must-see destination during their travels. The architecture intrigues them as they've read about its use of regenerative design solutions as well as its dedication to achieving Living Building Challenge standards. Sam and Mo can't wait to share photos of their visit with friends and family back home.

Figure 6.11 - Sam and Mo user persona study



Name: Lee
Occupation: Business Owner
Location: Powell River

Lee is a marine biologist who has a long-standing interest in seaweed. They have been running the seaweed farm on the site for some time, and have finally decided that they're ready to invest in building a structure that will attract visitors from near and far. They've hired an architect who shares similar regard for environmental sustainability, who has convinced them to design the most efficient building possible. Together they decide a restaurant concept will be the most effective way to attract visitors who'll come back time and time again, while passively aiding in fostering a greater appreciation of seaweed and sustainability.

Figure 6.12 - Lee user persona study

Name: Drew
Occupation: Retired
Location: Powell River
Motivation: Retired local

Drew lives in Powell River and is proud of where they come from. Having been retired for a few years, Drew is looking for a part-time job that provides meaningful work while allowing them to contribute to their community. This business caught their attention due to its welcoming atmosphere and dedication to sustainability. This establishment is a point of pride within the community due to its focus on the environment and its work to educate others in regards to the ocean, sustainability, and food security.

Figure 6.13 - Drew user persona study

Name: Alex
Occupation: Software Developer
Location: Vancouver
Motivation: Visiting from nearby

Alex recently moved from Toronto to Vancouver after landing a job at a local tech company. They enjoy riding their bike to work on sunny days and finding new activities around the city. Now that Alex lives in Vancouver, they're interested in using their long weekends to explore nearby communities.

In this instance, Alex has traveled to Powell River on British Columbia's Sunshine Coast, a region that offers outdoor adventure, water-based exploration, and relaxing coastal days. Alex wants to explore the best Powell River has to offer through nature and adventure while trying their best to experience the region through the eyes of a local.

After a day spent hiking the Tin Hat Mountain Trail, Alex wants to find a unique spot to relax over dinner that carries the day's theme of nature and adventure through to the evening. They're in search of a spot that highlights the best Powell River has to offer while fostering a connection with the local surroundings.

They ultimately select to dine at this establishment due to its dedication to sustainability, local cuisine, and the support it provides to the nearby community.

Figure 6.14 - Alex user persona study

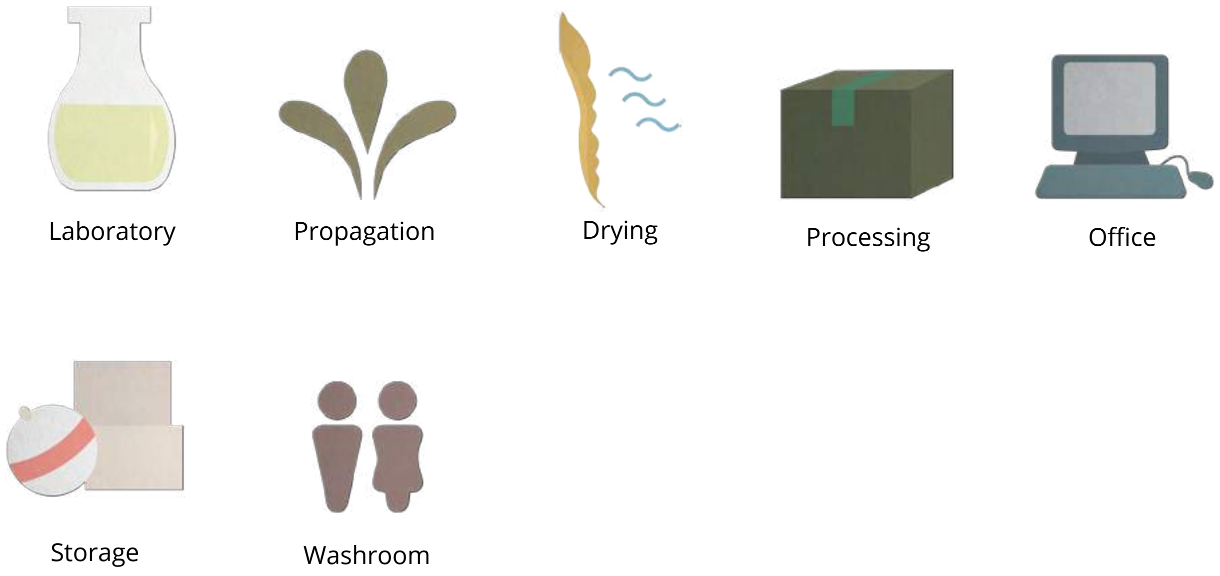


Figure 6.15 - Discovery Islands programming diagram

Discovery Islands Program

The program offered at the Discovery Islands sites includes spaces to facilitate the seaweed cultivation cycle including a laboratory, propagation space, and drying room. As these sites are remote and only accessible to the workers, the programming has been simplified to include only necessary spaces.

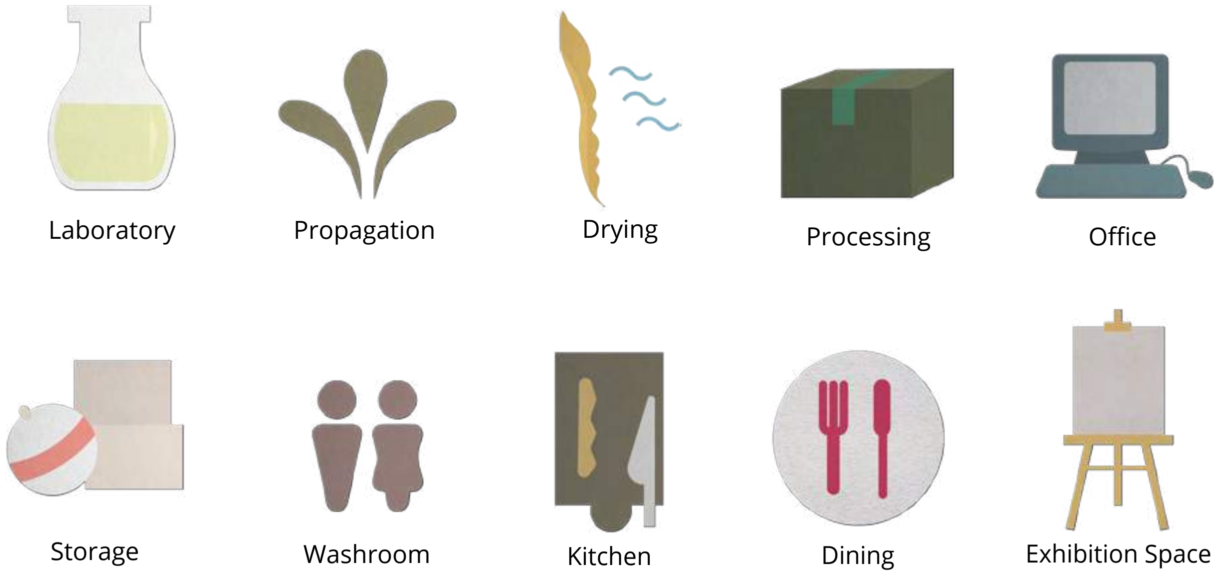


Figure 6.16 - Powell River programming diagram

Powell River Program

The Powell River site builds upon the spaces offered at the Discovery Islands sites by additionally including a restaurant and exhibition space which will help attract visitors, and bring them back time and time again.

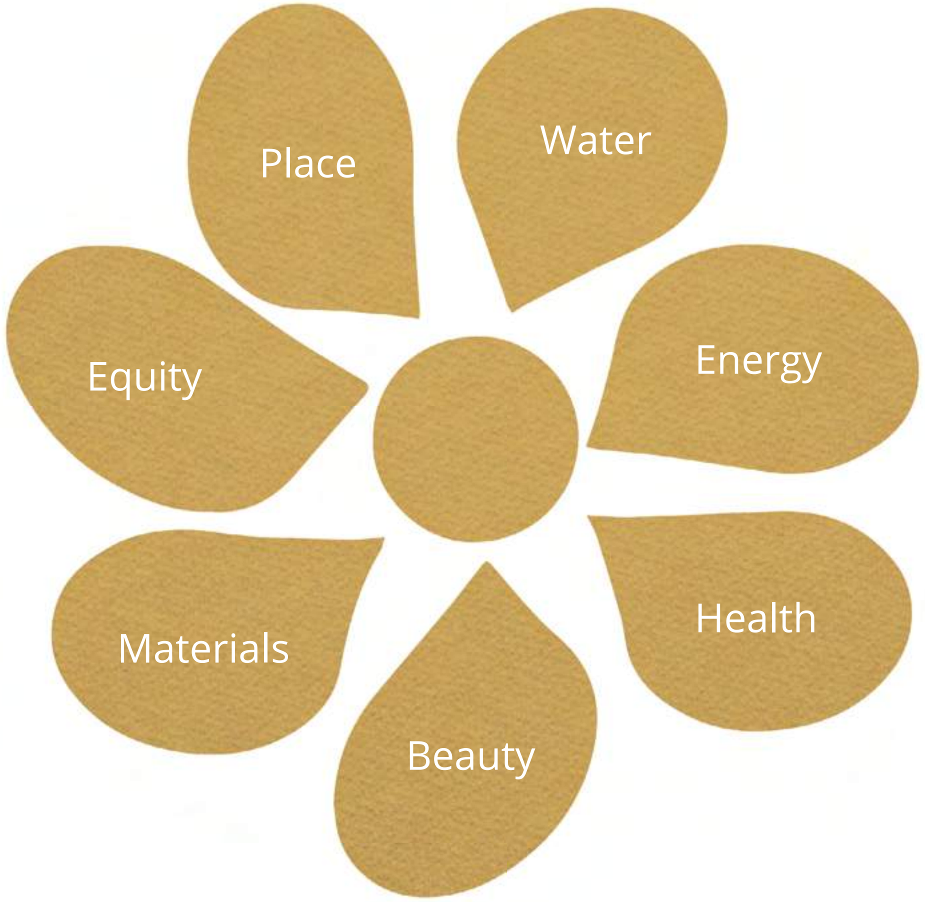
Living Building Challenge

This structure is designed with the living building challenge guidelines in mind, which stipulate a rigorous set of criteria that speak to the site, energy and water consumption, materials, health, beauty, and equity of the project. The place petal helped guide the decision to focus the construction on the floating platform, rather than disturbing the pristine Greenfield to the North. This petal also includes a component of on-site food production, which is inherently present in the nature of the seaweed farm.

In addition, the floating walkway that supports the seaweed farm, as well as the floating platform that rests under the building were recycled from the previous salmon farm, contributing to the material petal. The energy petal guided the orientation of the building and the pitch of the roof, which also helped facilitate rainwater collection necessary for the water petal.

Healthy spaces are created that allow all species to thrive by connecting people to nature while ensuring indoor spaces have access to natural air and daylight. These spaces are designed to be welcoming and accessible to all people, ensuring equitable access to fresh air and sunlight. Even without the additional influence of the Living Building challenge, these characteristics remain important to the design of the structure on this particular site and speak to the ethos of the project.

Figure 6.17 - Living builiding challenge petals

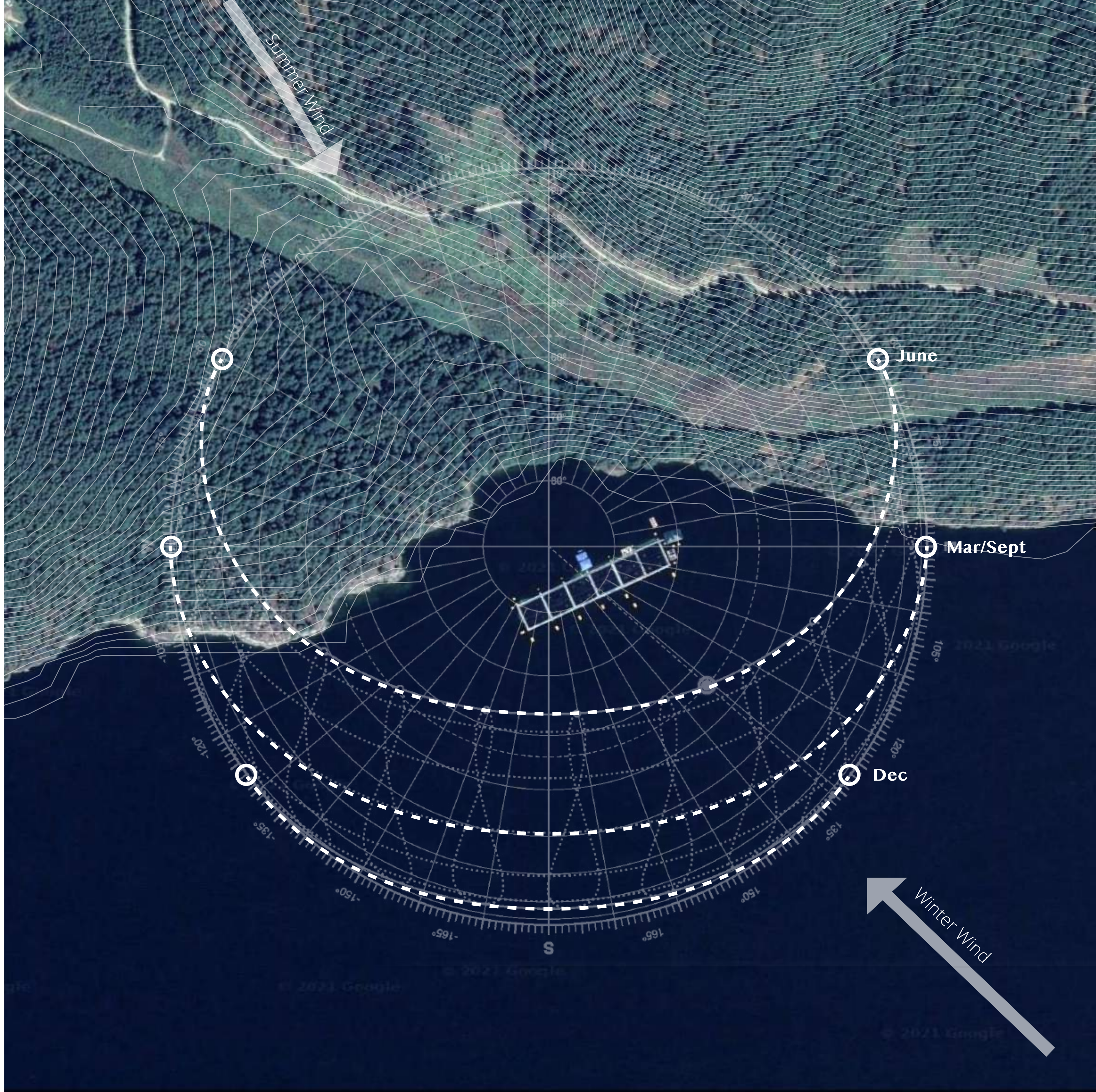


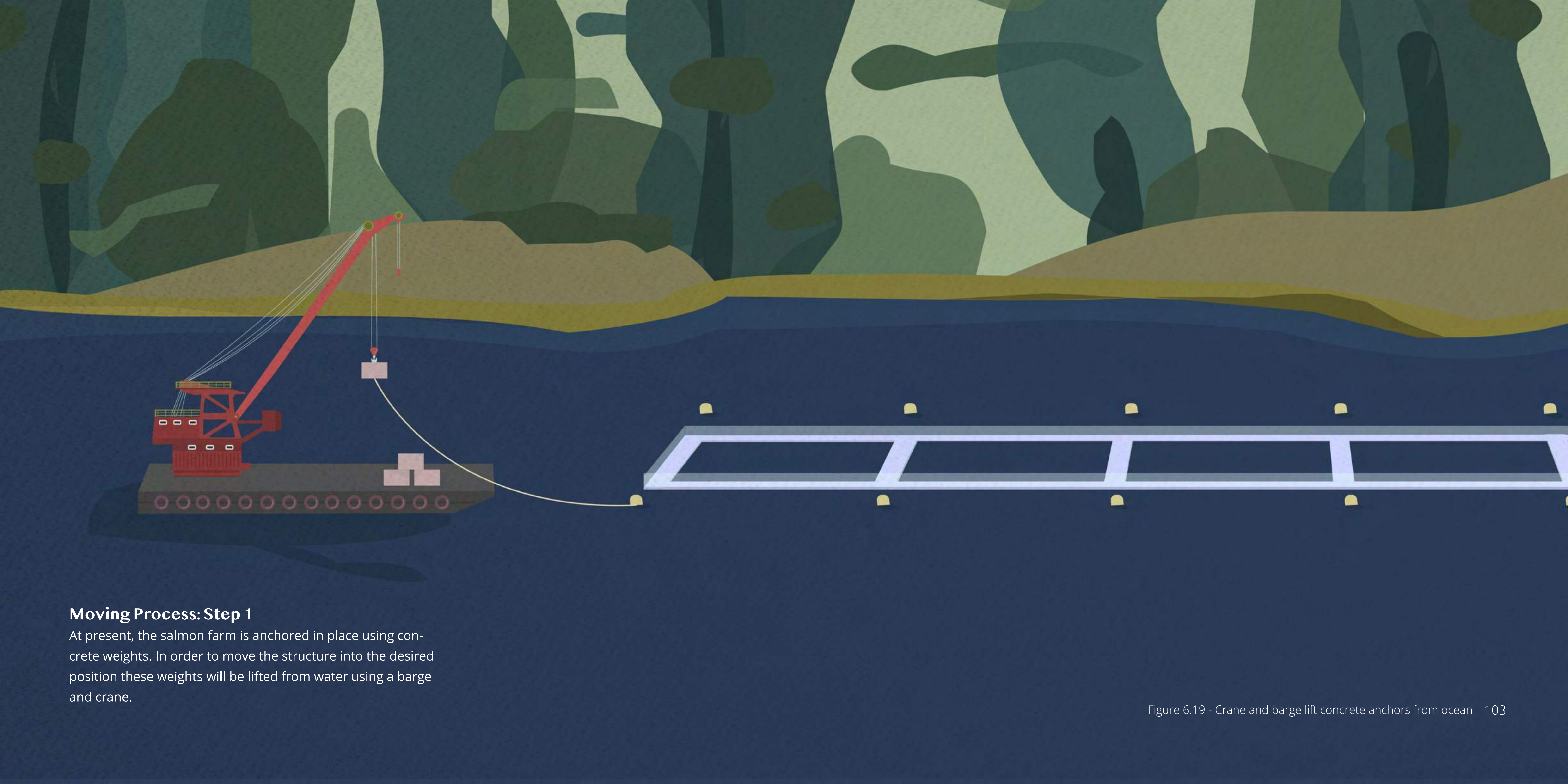
Powell River Site Analysis

This project will aim to achieve Living Building Challenge specifications, a certification program that promotes the most advanced measurement of sustainability in the built environment. The site analysis is important in determining performance criteria surrounding place, water, and energy.

In order to maximize solar gains and forge a stronger connection to the shore, the floating structure will be rotated and placed perpendicular to the land to the north. This will allow the building to be oriented along the east-west axis, maximizing natural lighting and solar heat gains.

Figure 6.18 - Powell River site solar study





Moving Process: Step 1

At present, the salmon farm is anchored in place using concrete weights. In order to move the structure into the desired position these weights will be lifted from water using a barge and crane.

Figure 6.19 - Crane and barge lift concrete anchors from ocean

Moving Process: Step 2

Once the anchors are removed, tugboats are able to carefully manoeuvre the floating walkway, positioning it perpendicular to shore. From here, mooring posts are added to fix the structure in place.

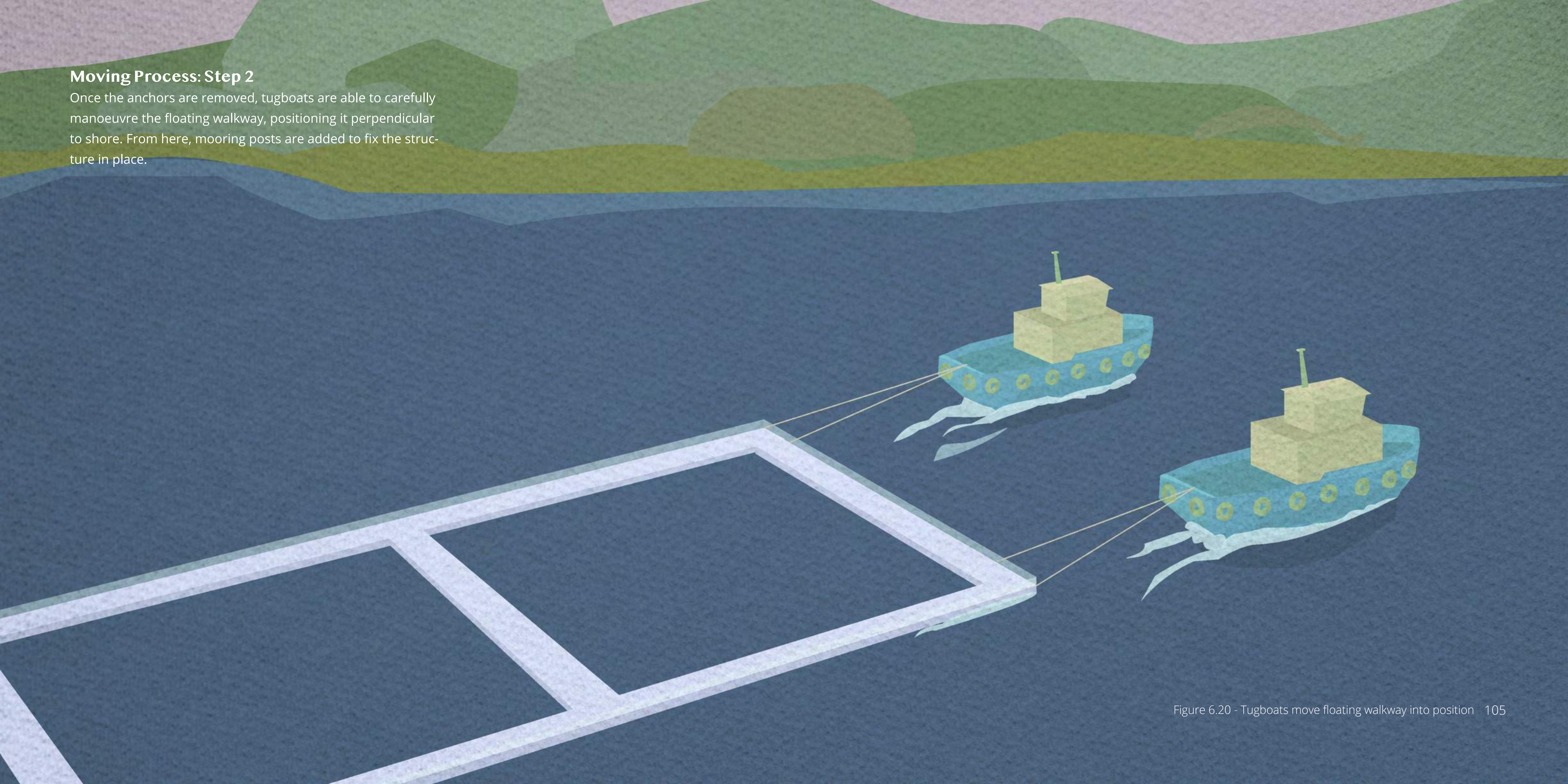
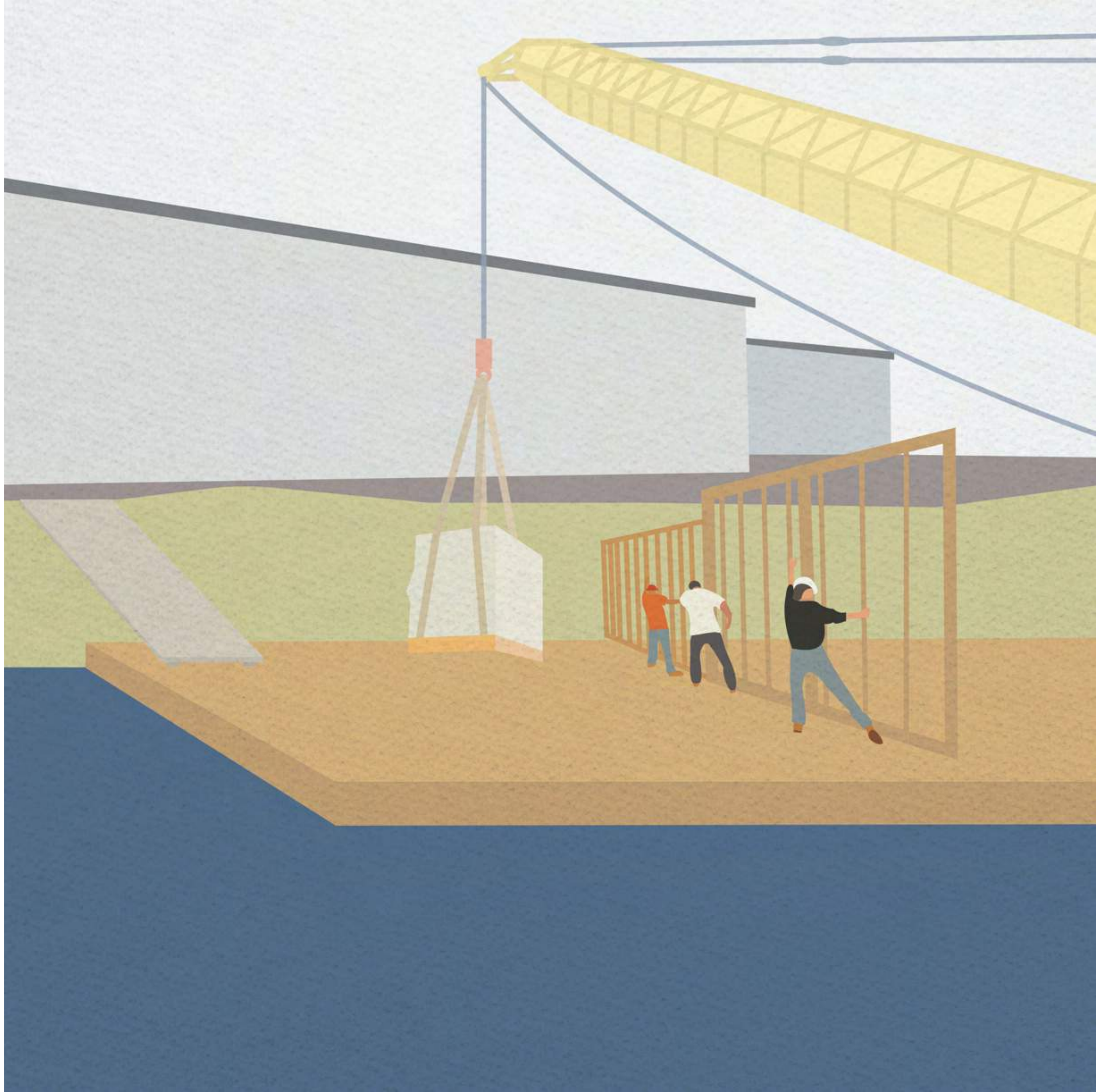


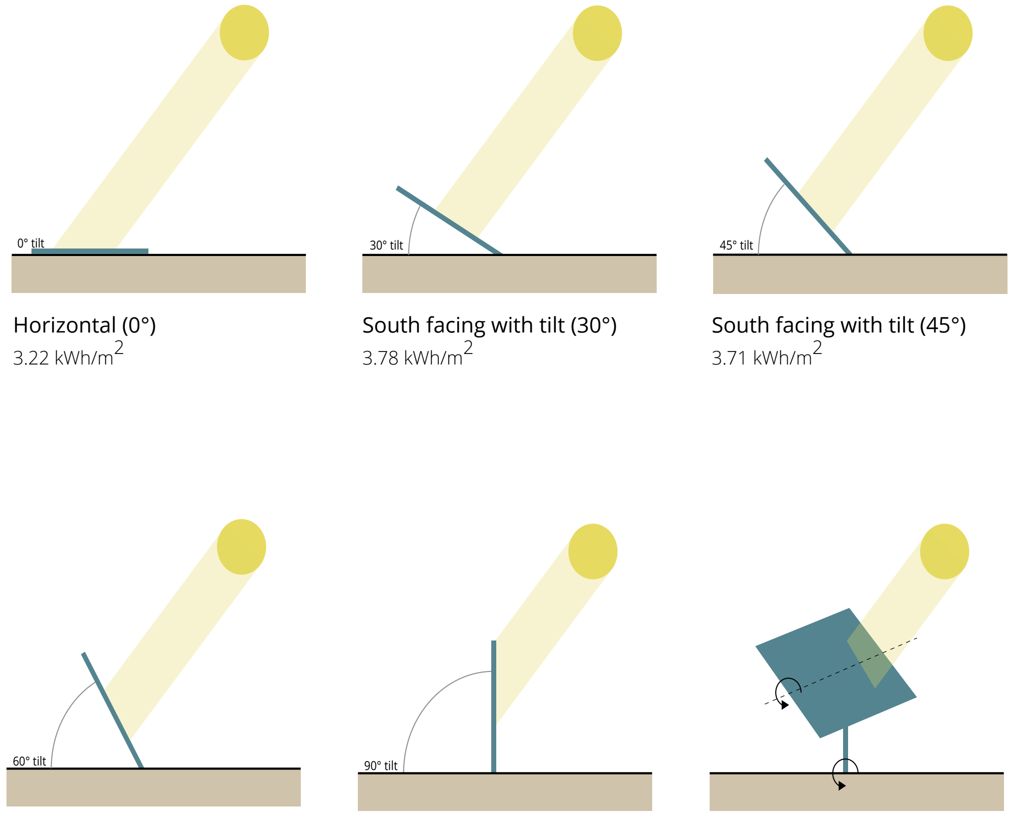
Figure 6.20 - Tugboats move floating walkway into position

Construction Process

To limit the disruption to the sites and ensure materials and laborers are in ready supply, the structure is built at a nearby port and towed into place upon completion. In this case, the buildings may be built in Vancouver or on the Fraser River where the build process can be streamlined rather than shipping all of the individual materials and workers out to these remote sites and building the structures there.

Figure 6.21 - Building is constructed on land before being moved to the site





Horizontal (0°)
3.22 kWh/m^2

South facing with tilt (30°)
3.78 kWh/m^2

South facing with tilt (45°)
3.71 kWh/m^2

South facing with tilt (60°)
3.46 kWh/m^2

South facing with tilt (90°)
2.68 kWh/m^2

Two axis tracking
5.25 kWh/m^2

Figure 6.22 - Powell River PV Orientation (mean daily insolation)

Energy and Water Demands

Photovoltaic panels will be used to generate the electricity needed to meet onsite energy demands. The placement and orientation of these PVs are important in harnessing optimal solar power. By examining mean daily insolation (exposure to the sun's rays) of PV's positioned at varying angles, it is clear that south-facing panels at a 30° tilt are most effective and budget friendly compared to other orientations and tracking systems.

The Living Building Challenge 'water' petal stipulates that all water demands must be met through onsite harvesting and be purified without the use of chemicals. Fortunately, Powell River receives a significant amount of rainfall throughout the year which will be collected and stored in a cistern. This cistern will be sized to accommodate enough water to supply the driest months of June, July, and August. On-site water demand will remain constant month-to-month, with greater usage during March, April, and May when the seaweed is harvested.

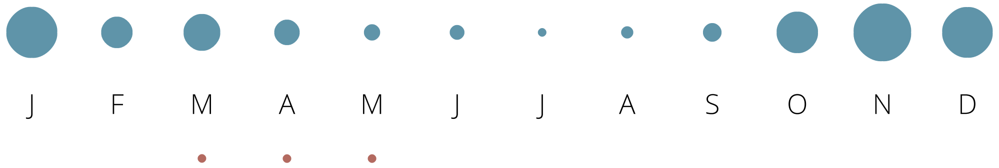


Figure 6.23 - Powell River monthly rainfall

Design: Powell River

Figure 7.1 - Powell River north east perspective

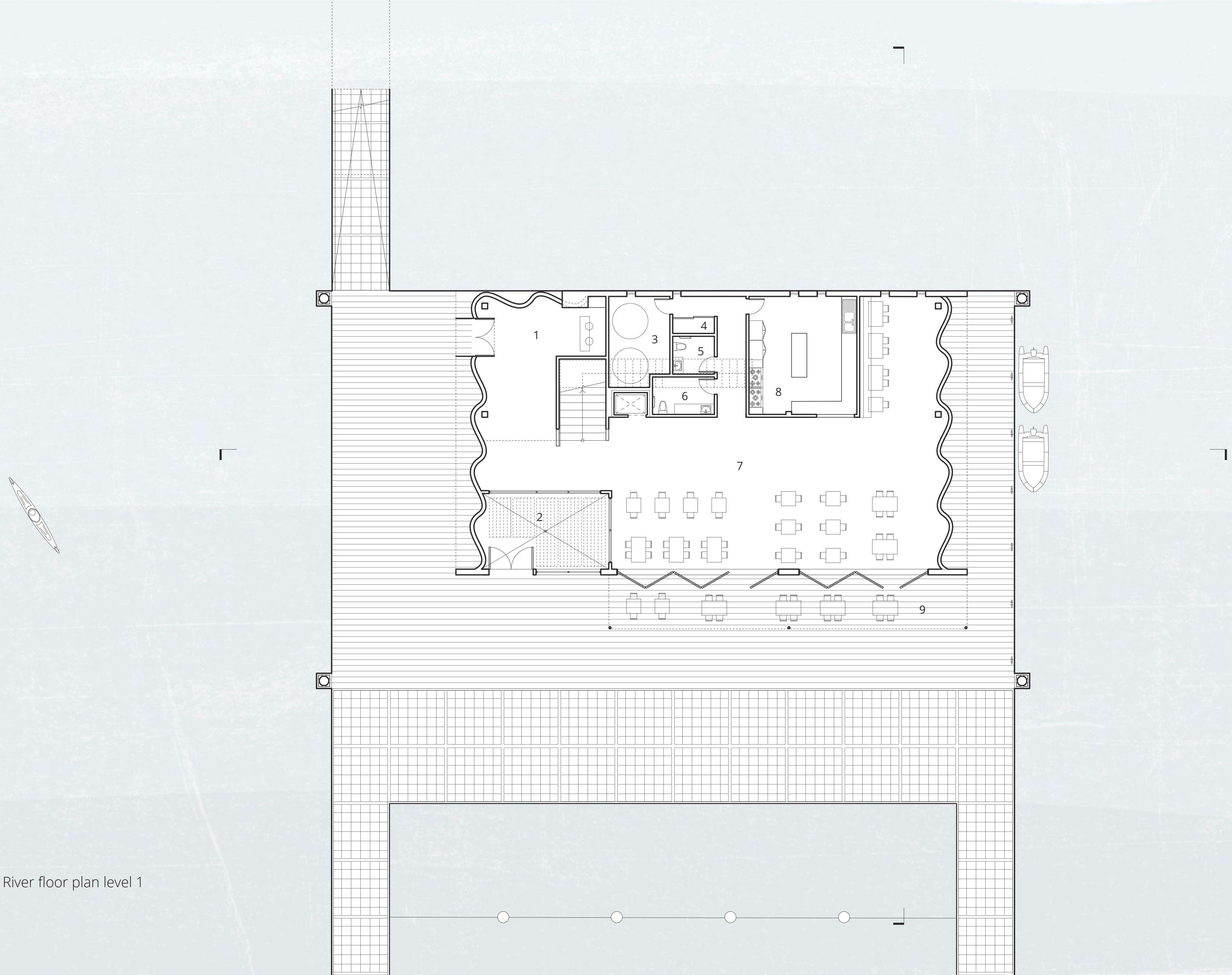
Site Plan 1:2500
Powell River

Powell River Site Plan

This site plan shows the new orientation of the floating structure, with the building lying at the northernmost edge. This placement maximizes southern exposure while featuring views of the seaweed farm without casting shade upon the growing pens. A covered platform on land provides a gathering place for visitors and connects to the nearby trail network and roadway.

In order to make minimal changes at land due to the important nature of the riparian zone, visitors arriving by car are expected to park along the quiet roadway and walk 200m to the site. To ensure an equitable experience, the connecting trail from the road to the floating farm offers a boardwalk for smooth travels.

Figure 7.2 - Powell River site plan



1	Entry
2	Drying
3	Rain Water Cisterns
4	Storage
5	Washroom
6	Washroom
7	Dining
8	Kitchen
9	Patio

Level 1 Plan
Powell River

1m 5m

Figure 7.3 - Powell River floor plan level 1

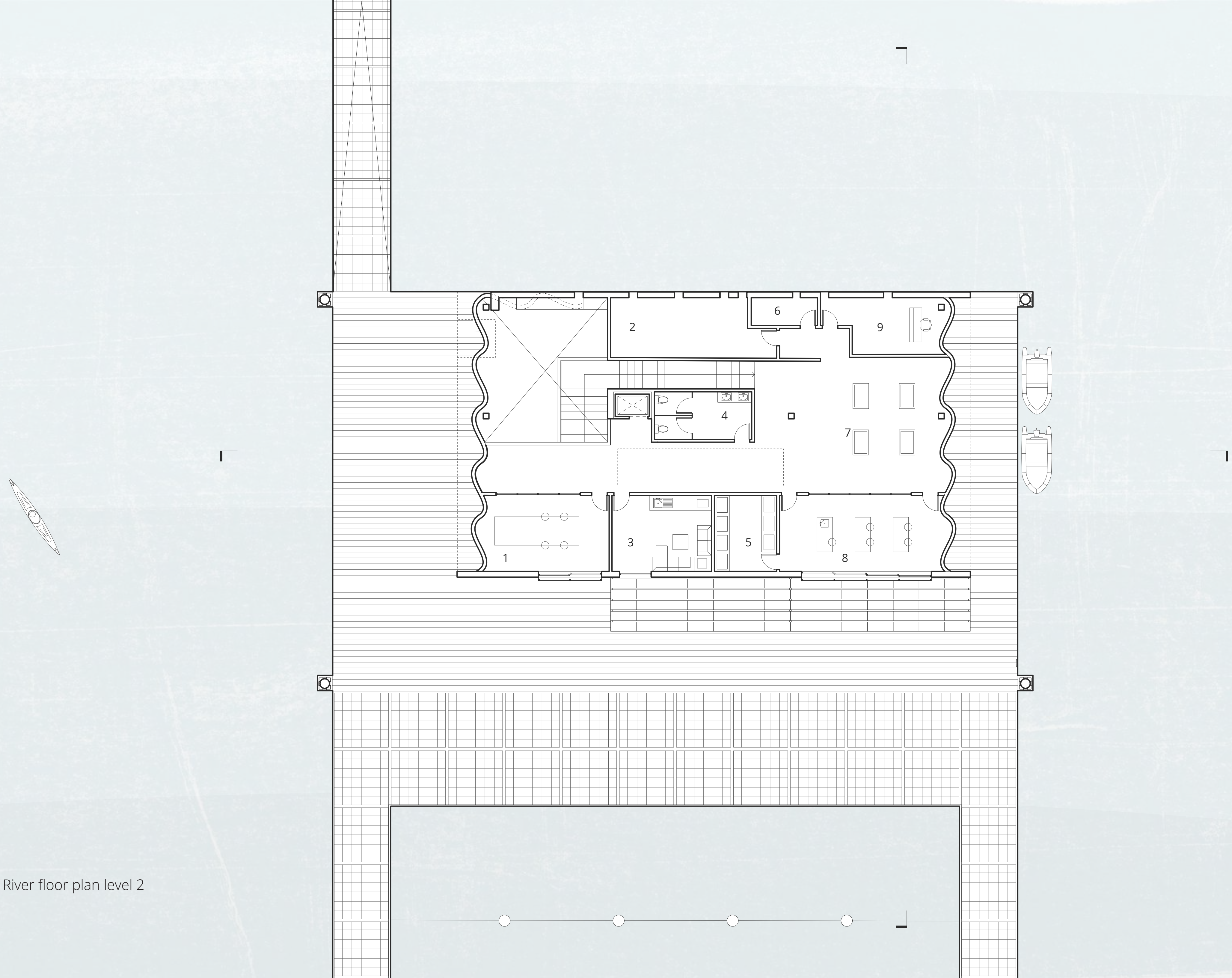


Figure 7.4 - Powell River floor plan level 2

1	Processing
2	Mechanical
3	Staff Room
4	Washroom
5	Propagation
6	Storage
7	Exhibition Space
8	Research Lab
9	Office

Level 2 Plan
Powell River

1m 5m

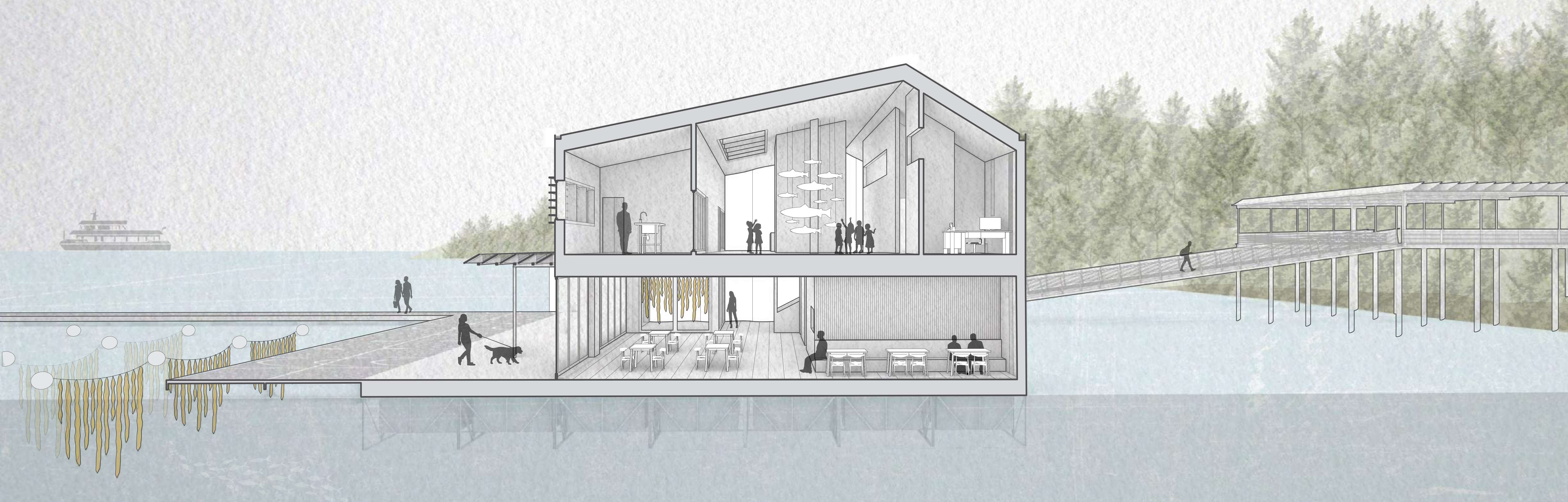


Figure 7.5 - Powell River perspective section

Section Perspective
Powell River

Figure 7.6 - Powell River perspective section

Section Perspective
Powell River

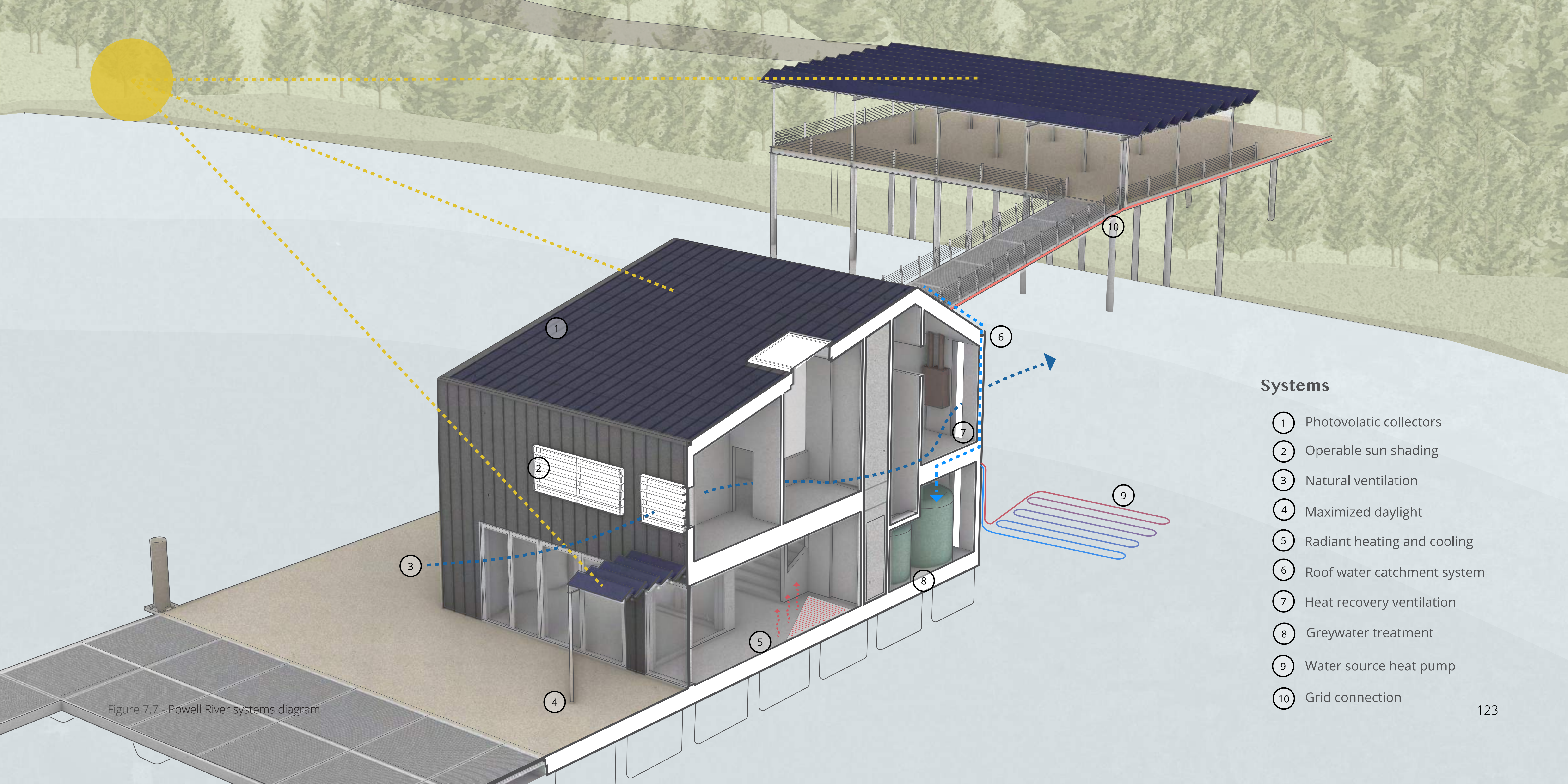


Figure 7.7 - Powell River systems diagram

Systems

① Photovolatic collectors
② Operable sun shading
③ Natural ventilation
④ Maximized daylight
⑤ Radiant heating and cooling
⑥ Roof water catchment system
⑦ Heat recovery ventilation
⑧ Greywater treatment
⑨ Water source heat pump
⑩ Grid connection

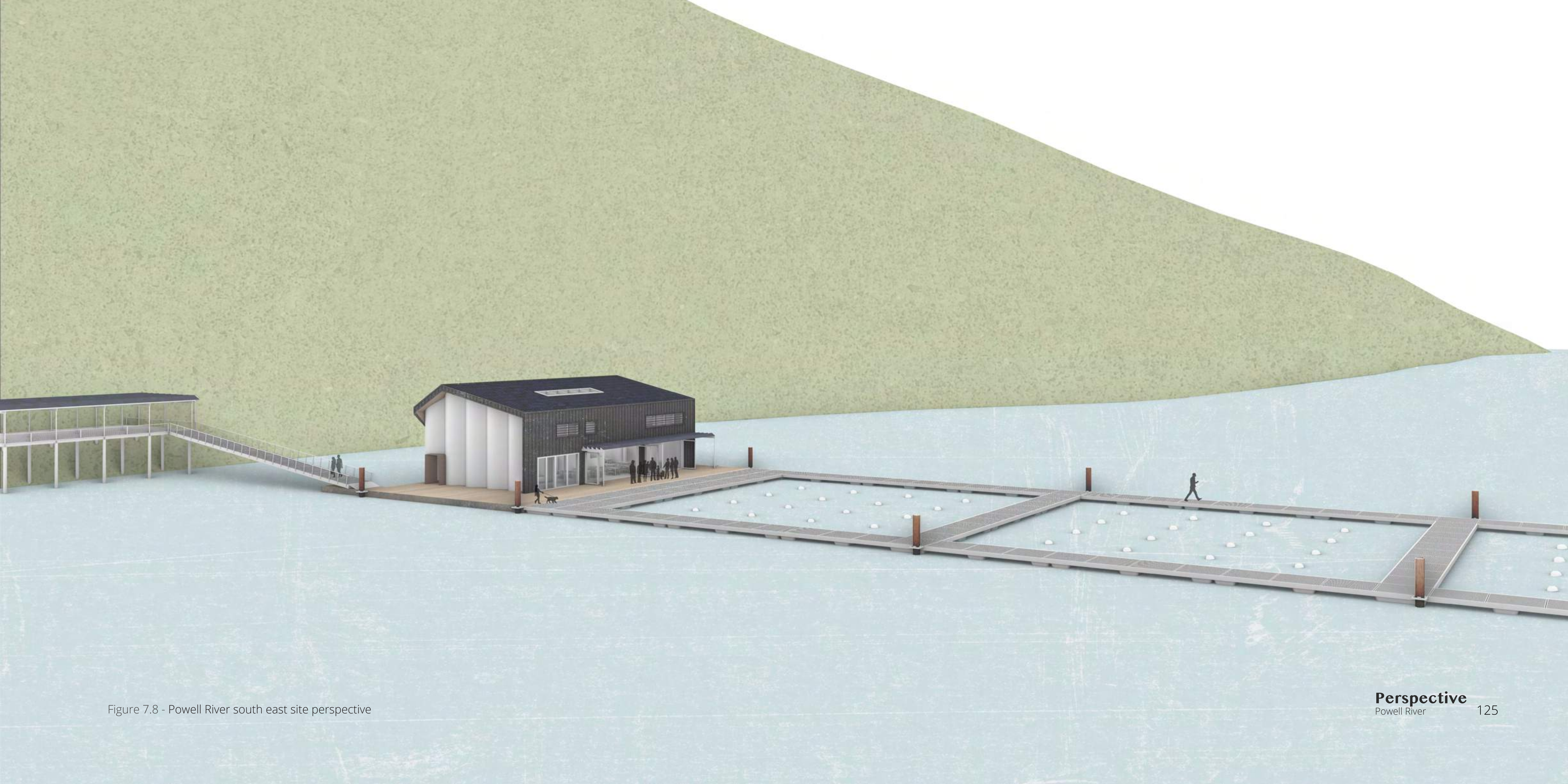


Figure 7.8 - Powell River south east site perspective

Figure 7.9 - Powell River exterior daytime render

Figure 7.10 - Powell River exterior night render

Design: Discovery Islands

Figure 8.1 - Discovery Islands site perspective

Figure 8.2 - Discovery Islands perspective section

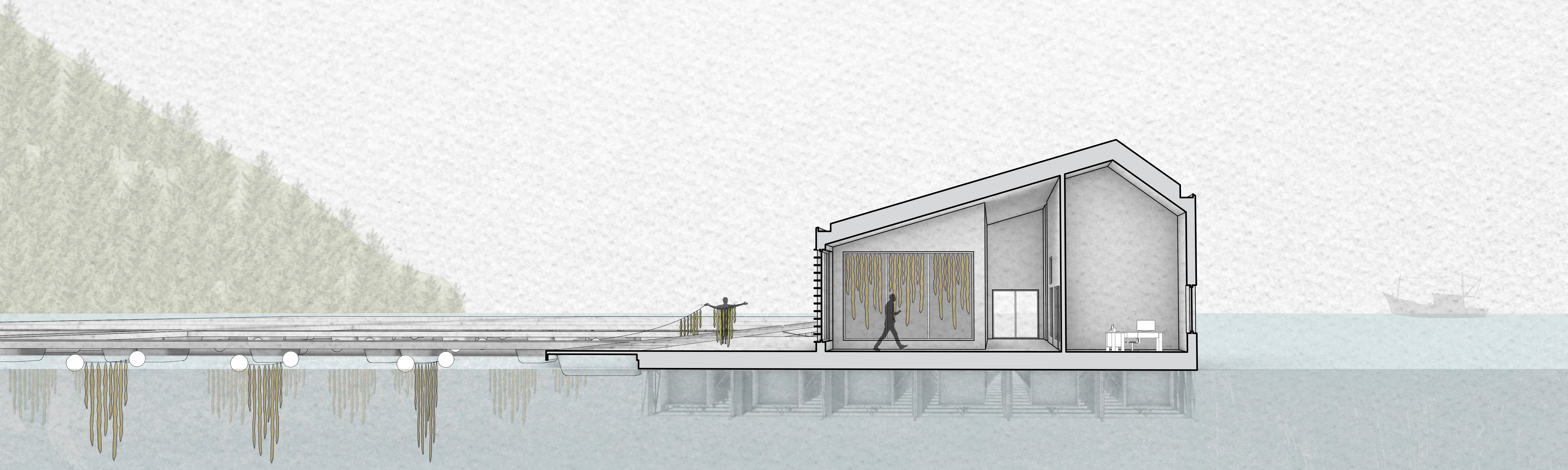


Figure 8.3 - Discovery Islands site perspective

Section Perspective
Discovery Islands

Figure 8.4 - Discovery Islands exterior render

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