People of the Water

A SEMI SUBMERGED HABITAT FOR THE YEAR 2100,

IN THE CONTEXT OF A 5 METER SEA LEVEL RISE IN BANGLADESH

KAZI NAJEEB HASAN

11108027

Submitted in partial fulfilment of the requirements for the degree of Bachelor of Architecture

Department of Architecture, BRAC University

Bangladesh

SEMINAR II . ARC 512

FALL 2015

THESIS TITLE:

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Figure A: A group of floating, semi submerged habitats in the year 2100, Bay of Bengal.

ABSTRACT

Mankind is always evolving. Ever since man stepped into the cave from his forest dwelling millenias back, he has evolved in different ways in his desire to achieve a higher level of civilisation. That has caused him to face increasing complexities in living, and as such, their habitats too have evolved hand in hand in order to respond to such complex scenarios. As we have reached into the 21st century, we have generated near-dystopian situations that threaten our survival in many parts of the world, chief among them: climate change.

This begs the question: will climate change, and its following consequence of sea level rise in reality be as dystopian as we fear, or is it actually an incentive for man, and for his habitat to evolve to another level? Have we all this time, actually misunderstood climate change?

This thesis explores the possibilities for mankind's survival in the context of severe climate change 'impacts' in the timeline of the 22nd century. This thesis questions the prevailing dystopia enshrouding climate change, and takes up the challenge for the vision of a human habitat on and within water, for the future inhabitants of Bangladesh, when the sea will devour around 25% of our landmass with a 5 meter rise in the sea level.

This thesis progressed in two phases. The first phase aimed to break the main barrier to this thesis process- our limitations to predict future time, and evolution of different elements of our lives, namely technology and human society. Regardless, a faithful study was taken up in order to conclude on projections that would help construct the year 2100 timeframe. These studies involved areas of environment, technology, economics, sociology and other life & social sciences. The first phase also looked much more closely into the engineering aspects of designing a habitat on the water. Mother nature was paid more heed to than we do now, and studies on the previously mentioned have led to the proposal of a future ecosystem that would reconcile our habitats with nature once more, just like the caves.

The second phase dared on creating the dream, my own dream of our future. As such, many questions arose: how would we live? How would we travel? How would our future generations learn? Will there still be a God?

The second phase took on the buck from the first and tried to look into the future based on the current development of science and technology, to safeguard the design from turning into science fiction. As such, flying transportation, aerial construction techniques, popular use of hologram technology, etc has been predicted to occur a hundred years from now, and as such been incorporated into the future thinking. The design, in totality, concerns a habitat for a thousand people, incorporating our future understanding of housing, centers of knowledge, centers of faith, centers of cultural expressions, workplaces, shopping, etc. All these programs were attempted to be incorporated directly in the eco-cycle of this habitat, so that the spaces and the structures themselves directly generate power or clean up human waste. Predictions of the

future also had one other important aspect: a deliberate intervention to envision a more ideal society for the concerned populace- the Bengali nation. As such, the vision of a future society was based on the study of the ideal Bengali habitat, which ultimately led to the conclusion that spirituality, knowledge and culture should be more intertwined in the future, just as it was in our past, for a more thoughtful functioning of society.

Lastly, this habitat attempts to mimic the behaviour and arrangement of a water lily, which stood out among other aquatic species as the closest to cue the creation of a water habitat. Even though many portions of the current Bangladeshi landmass will submerge under five metres of water, the proposed design is built for a depth of 20 meters in the Bay of Bengal. Holistically, the habitat- which is at the scale of the present understanding of a 'neighbourhood'- incorporates basic urban functions to propose an integrated vision of the future that will tie the habitat, and its people, closely with the water.

ACKNOWLEDGEMENT

This thesis has formally spanned over a duration of 8 months, and unofficially for 1.5 years during which period data collection and the process of gaining permissions started. Over this long period, different faculties, professionals, friends and family have lent their knowledge, experience, support and confidence in me to achieve this immensely stressful and difficult task. I am immeasurably grateful to all of them.

My faculties Abul Fazal Mahmudun Nobi and Shakil Ahmed Shimul has strongly shaped my thinking for the last few years that included orienting me towards this thesis, as well as supporting me in different ways. Special thanks to Professor Dr. Fuad H Mallick for the interest he took in my work, and for allowing me to do pursue this quest. I am grateful towards my design faculties Ar. Naim Ahmed, Ar. Dr Md Habib Reza and Ar. Emil Theodore for their continuous support and sincere guidance throughout the final stages of this project. My friends Suhailey Farzana, Rafid Reasat Hai, Tanzil Idmam Shafique & Asif Iqbal have played the role of mentors, supporters and critiques during different stages of this process, for which I am very grateful. I am also indebted to Bidoura Mosharraf, Sayem Ahmed Kausar, Badruzzahan Ahmed, Zillur Rahman, SS Alam Zohan, Nuha Annoor, Syeda Naasiba Hossain, Nasheen Jahan, Faiza Ali, S M Nuruddin Reyad, Ehsanul Hoque, Sumaiya Ara Simi, Kazi Rafid Bin Zaman, Zaki Wamia, Bibi Mariam, Tahsin Minhaj, Fahim Rubby, Sarah N Hussain, Tausif Sabir & Rezwanul Habib.

My resource people in their respective fields gave me the first hand consultancy I needed with different aspects of this thesis, for which they have earned my sincere gratitude. Special thanks to Capt. Kazi Ali Imam, Ex-officer of the merchant navy, Nur Muhammad Zayeed Ahmed, Professor of Geography at Dhaka City College, Dr. Kawser Ahmed, Professor & Chairperson of the Dept of Oceanography at the University of Dhaka, Ar. Kazi Khaleed Ashraf of the Bengal Institute, Anthropologist Prashanta Tripura and Economist Adnan M.S. Fakir of BRAC University.

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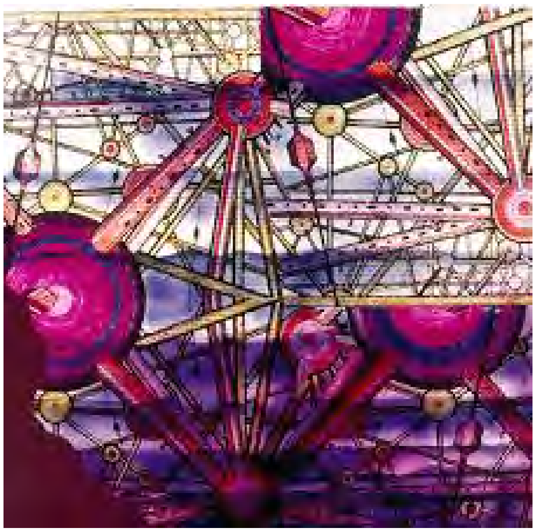
CHAPTER 01

Introduction

1.1 Background of the Project



Left: Figure 1.1.A Underwater city proposal by Archigram

Source: https://www.flickr.com/photos/jrosenk/303668797

Right: Figure 1.1.B Floating farm platforms for the Nile Estuary, Egypt

Source; http://inhabitat.com/7-futuristic-floating-cities-that-could-save-humanity/floating-silt-lake-city-city-egypt-3-2/

Consider the table lamp. It could be viewed as a modern version of the torch - fuelled by wood, lit by the first modern humans during the Pleistocene period hundreds of thousands of years back, or it could be seen as a copying of the candle stick but fused with modern technology. Both the cases nonetheless point to the evolution of the light.

Only technology has evolved to provide alternate solutions for adapting to man's latest needs. (Ruso, 2003)

Same is the case with human habitats. The timeline of our habitats begins with tree dwellings and caves to the intelligent buildings we avail today, and in between, different stages of evolutions; evolution to meet new needs of functional, environmental, economic, and social and of course needs of physiology and psychology. While the basic need of shelter is constant, emerging needs arise due to exponentially increasing complexity of human survival. Our habitats have evolved faster than us, and have adapted to our needs in almost all spreads and altitudes of the planet save one part- the oceans.

The aim of this thesis is to identify the next stage of habitat evolution on or within the Earth's oceans- the final frontier for habitation on Earth- with the intention of providing an alternate and efficient adaption to human needs for the timeline for the next 100 years. (Ruso, 2003)

The oceans cover over 70% of the Earth's surface, containing 97% of the Earth's water, yet 95% of it remains unexplored and unutilized. While over the decades we have invested heavily in space technology, the oceans, much nearer in proximity to us in have been left relatively untouched. Oceans and seas are not only a vast empty surface, they actually provide a vast empty volume, and are at the same time a treasure house of untapped marine resources that could further advancement in the realms of energy mining, environment research, aquaculture and agriculture, and especially, in the expansion of human habitation. As the Earth's population continue to grow, so does Bangladesh's, and a point in time may ultimately arise where Bangladesh will need to look to the seas to expand our habitats. For the last few years, the above mentioned problems have posed one particular question in the minds of many all across the globe: "Has the time come for floating cities?"

Oceans pose certain advantages over land, although the initial thought of living permanently among the waves give rise to basic fears of survival. Although the oceans are vast and spacious and are unhindered by surface topography on land, they are also prone to extreme weather conditions such as storms or wave swells. Perhaps the most dominating fear of living in a permanent ocean habitat is posed by the fluidity of water- the threat of sinking. The proximity from land also plays a role, and many societies might not be able to adapt to the whole notion of 'water urbanism'. All the above are all grounded to reality, however, seeing them as obstacles to further advance the evolution of habitats is not a viable option. Human habitats, over the millenias have evolved only due to the enduring perseverance of human beings to challenge the world technologically – starting from the first humans who emerged out of the safety of their cave habitats to those who currently dwell upon building a lunar or a Martian colony. Oceans and the seas must be challenged with the same spirit to take our habitat evolution to the next stage. Going by Darwin's iconic statement: the most intelligent of beings are those who are best able to adapt. The oceans provide a potential chance of functional and economic adaptation to future problems coming up on humanity's shores.

The threat of global warming and in particular- the rise of the sea levels presents an even greater problem of land shortage for a country with already the highest density of people per square unit of land.

Bangladesh, along with many other nations face the inevitable threat of rising seas. Conservative estimates of sea level rise by the Intergovernmental Panel on Climate Changes [IPCC] project increases of more than half of a foot to two feet by the year 2100. More up to date analyses by the Arctic Monitoring and Assessment Program, which accounts for the effects of melting ice sheets across the globe, suggest that sea level will rise three feet to as much as five feet or more by 2100. At the present rate of 8mm a year, it may take only about 25 years to raise levels 20 cm, enough to permanently waterlog and destroy the land and drinking water of as many as 10 million people in the south of the country. A one meter rise along the only partly defended 1150 mile (720 km) Bangladeshi coastline would result in nearly 20% of the country submerged and 30 million more people being displaced.

A semi submerged, floating sea habitat might answer to the future need of an alternate living system when one day, the precious little land we will be left with will either reach a saturated capacity to contain any more cities, or be reserved largely for nature and agriculture. Although the vision is that of an entire city, the designed portion for the duration of the thesis will include only a small part of the city- a small prototype- that focuses on energy production or the design of an energy hub incorporating living facilities for those operating it.

The idea of ocean colonization has been indulged in by many before, ranging from scientists, engineers, architects, film makers, etc. Historical references to this can be found in ancient Europe as well, particularly in Greece and Rome. In the modern era, architects such Frank Lloyd Wright, Buckminster Fuller and the British group Archigram have all come up with their proposal of floating cum underwater habitats. The time line of underwater habitats point to different temporary to permanent habitats, either built or in the process of being constructed, with the main bulk of them still proposed. The uses of such structures range from marine research to undersea hotels and museums. The envisioned semi submerged habitat aims to take cues from the previous examples in the aspects of engineering, architecture and technology to develop the design as a whole.

1.2 Project Brief

The project envisions a semi submerged, floating habitat, or a city in the Bay of Bengal that responds to the crisis of energy and land and resource shortage in future Bangladesh in the timespan of the twenty second century. One of the prime focus of the design will be to make the habitat self-sustaining in terms of renewable energy. However, for the purpose of a thesis initiative, a particular part or prototype of the city will be designed whose primary function will comprise of producing electricity to the city through different renewable energy sources. This energy production hub will incorporating living facilities for those operating the hub. The site will be situated in the Bay of Bengal, off the coast of the city of Chittagong, and will house a small community of a particular number of families. The aim of the thesis will be to prove that living permanently in a semi-aquatic landscape is feasible and possible, that life support systems can function just as they do on land, and that energy efficiency can be optimally integrated into the design of the city. Topics of study during the thesis project therefore, will include renewable energy generating features in future Bangladesh in particular to the region of the site, predicted impacts of climate change to Chittagong city, calculation of the predicted population of Chittagong the envisioned city aims to replace, case studies on built and proposed ocean habitats, and mainly, designing the megastructure of the city and developing an architecture suitable for water. Formation of an ecological cycle incorporating the semi submerged city as part of the ecocycle along with the natural energy sources such as the waves, wind and the sun, along with all sorts of aquatic life present underwater in the form of vegetation and marine creatures is another focus of the design.

1.3 Project Introduction

Making a habitat on a place previously uninhabited by human beings implies a sort of colonization of that particular place. Over the centuries, colonization has followed a particular pattern of sequences, beginning with the securing the concerned area militarily, develop a network of transport systems and afterwards set up a resource mining hub to power either the colony or more often than not, the home colony or country. The first factor, being irrelevant in the context of building on one's own territory, and the second factor will not be needed until the entire city grows at one point. The only sensible start for a future habitat therefore, remains to be an energy mining hub, which will provide energy to both the present times as well as to the future city once the need surfaces. The energy mining hub will act as a 'floating battery' for present and future cities, that will harvest energy from renewable sources such as the tide, waves, sun, wind, biomass, ocean thermal energy and even sound. The movable habitat, will contain spaces both over and under water, and the design will respond to the hydrology of water, ocean engineering, marine life and especially, the technological advancement that will be made in the time span of a hundred years.

As mentioned before, the city will grow incrementally in different phases. The first phase will involve only the segment or element of the city involved with power production. This will be the design proposal for the duration of the thesis. This power production plant will be of enough capacity to provide power for the whole of the envisioned future city, thereby in effect becoming the energy nucleus of the entire floating city. Since the envisioned city, according to preliminary study, will be built of numerous floating platforms (hereafter referred to as cells), the designed part of the envisioned city will only be the energy producing cell.

The energy cell will consist of power plants extracting energy from the renewable energy sources mentioned earlier. The employees of the plant responsible for managing, operations and maintenance will be the permanent residents of the city. This cell or segment of the city will consist of housing facilities for these employees and their families, an emergency health care unit, a primary school, stores and markets and a law enforcement unit. It will also consist of a multimodal transport terminal incorporating different future modes of transport. Religious and recreational facilities will also be included. Any further functional components typically found in cities is not included since the concerned segment is just tasked with power production, and also because of the fact that as this will be the first phase of the city, it will only have sub-urban features. For availing secondary functions, the inhabitants will have to travel to other parts or cells of the envisioned city once it starts incrementally growing, or temporarily avail such functions from the existing Chittagong city as it was earlier pointed out that the floating city will gradually replace Chittagong in different phases. Chittagong will likewise, be phased out gradually. As of that time, both the cities will need to rely on each other.

The main design element of the energy cell (and the entire envisioned city) will be the megastructure on which it is built. Underwater and floating architecture engineering will be of a prime concern. Developing the orthodox program of a power plant into a recreational and multipurpose activity will also need to be pondered upon.

1.4 Aims and objectives of the project

The primary aim of the project is to develop a prototype living system for an aquatic habitat, self-supporting in terms of energy. This will be executed through designing a system where the primary components of a city such as housing and schools, as well as the basic function of the proposal, i.e., the power plant all work together successfully at an urban scale.

The secondary aim is to develop an aquatic ecological cycle of which the habitat will be a part of, incorporating aquatic marine life such as vegetation and other marine creatures such as dolphins and corals, as well as the natural energy sources such as the sun, wave and wind. The natural elements will be related to the city either functionally in terms of production of energy or as a food source, or even with the structural integrity of the city. Apart from the primary aim of ultimately making the city energy efficient, adopting a responsible stance to the existing ocean habitants and the existing ecosystem is of a prime concern.

Another secondary objective of the city is to design for a proper response to natural disasters, in particular, storm surges and tropical storms or cyclones.

Re-envisioning a power plant, incorporating recreational facilities to it will remain another aim. This will be to prove the functioning of water architecture. The power plant will be designed to architectural scale detail, unlike the other functions or components of the energy hub which will be designed only at a certain scale. Ultimately, the overall engineering cum design of the megastructure remains the overall challenge.

1.5 Given Programme

The project will be a power plant for harvesting tidal, wave, solar, wind, and bio energy from bio mass. It will however, incorporate other basic elements of a city, such as living facilities (housing) for the families of those operating the plants, a health care unit, market facilities, transportation hubs for future modes of transportation such as underwater transport, flying buses, and other sorts of transport incorporating three dimensional movement, primary and secondary schools and recreational facilities. Religious structures will also be included.

Housing will comprise of three types – each for a different number of family members: families of 5-6 members, of 2-3 members, and single person residence. The school will provide only primary education since it is assumed that future transportation in the 22nd century will make daily transport to Chittagong city for secondary level students quite convenient. The hospital will only serve as an emergency care unit, as an extension of the mother hospital in Chittagong. The law enforcement unit for the cell will function in a similar manner.

Chapter 02

Site Appraisal

2.1 Environmental considerations, site and surrounding plans, photographs, topography

The project envisions a semi submerged floating habitat to be operational during the future time period of the 22nd century, more specifically in the year 2100. During that time period, a sea level rise of 5 metres is predicted to be the worst case scenario for Bangladesh, and this figure is the one based upon which the thesis has progressed, as has been discussed in much detail in chapter 7.3. With a water level rise of 5 metres, a large portion of Bangladesh will be submerged as shown by the contour cum bathymetry map below. As such, the semi submerged habitat can be situated at any of the submerged areas, or in the current coastal areas, or in the open seas as well. After the establishment of the hypothesis in the latter phase of this thesis, a particular habitat has been designed for a more specific site context: areas with at least 20 metres of underwater depth. Depth, along with many other factors are a huge determinant in the nature of a floating, semi submerged habitat. This is as since the name describes: when an object, be it an architecture or a piece of a city is floating, depth is not only a technology, it is also a volume or space. This is distinct from our understanding of the term 'underground', where soil has to be excavated to create space. In the case of water however, its fluid nature allows us to build comparatively much easily.

Another aspect of the site is its extent. The extent of the module (synonymous to an unit or portion of the city) that is being designed during the duration of the thesis (as opposed to designing the entire city which is merely envisioned) depends primarily on the number of occupants who will inhabit the proposed module. Since the primary function of the proposed module is to harness renewable energy, the number of permanent occupants will have to be either calculated from the energy requirements of the entire future city, as well as the derivation of the number of employees needed to generate the total energy that will be in demand by the cities inhabitants in 2100. The number of employees and their families will be the permanent inhabitants of this proposed module. This method however has failed since the data that would reveal the growth or fall of employees needed to generate power over the decades is not available, and also, the technological development over the future decades is out of the scope of an architecture student or even scientists to predict. Another method could be to project the population for a fixed size of land (in this case, the habitat square footage), based on the knowledge of the future urban population of Bangladesh and the current population density growth. That figure again, yields too less a number of people needed for a functioning habitat. In the end, a population of 1000 people has been assumed for this habitat.

The extent of the module, therefore, also remains open and speculative. Only determining the minimum size of the habitat remains an objective of this thesis, the habitat can afterwards, grow or shrink depending on the circumstances of the time. This will be discussed in detail in chapter 7. For now, only the point of inception of the proposed module has been indicated on the map.

From top:

Figure 2.1.A Key map of Bangladesh showing suggested habitat location

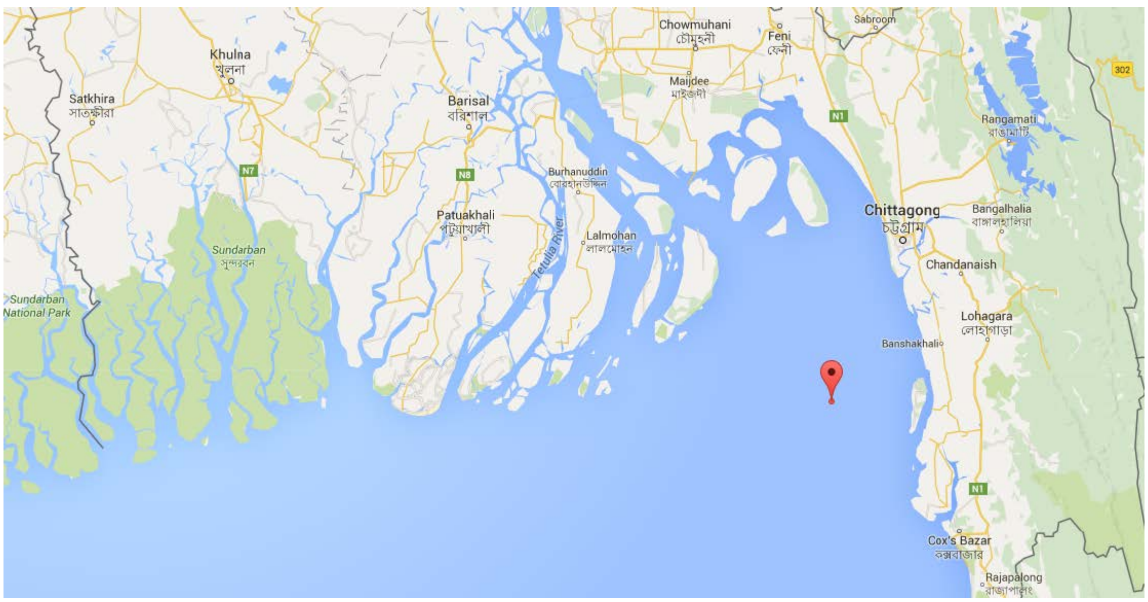
Source: maps.google.com

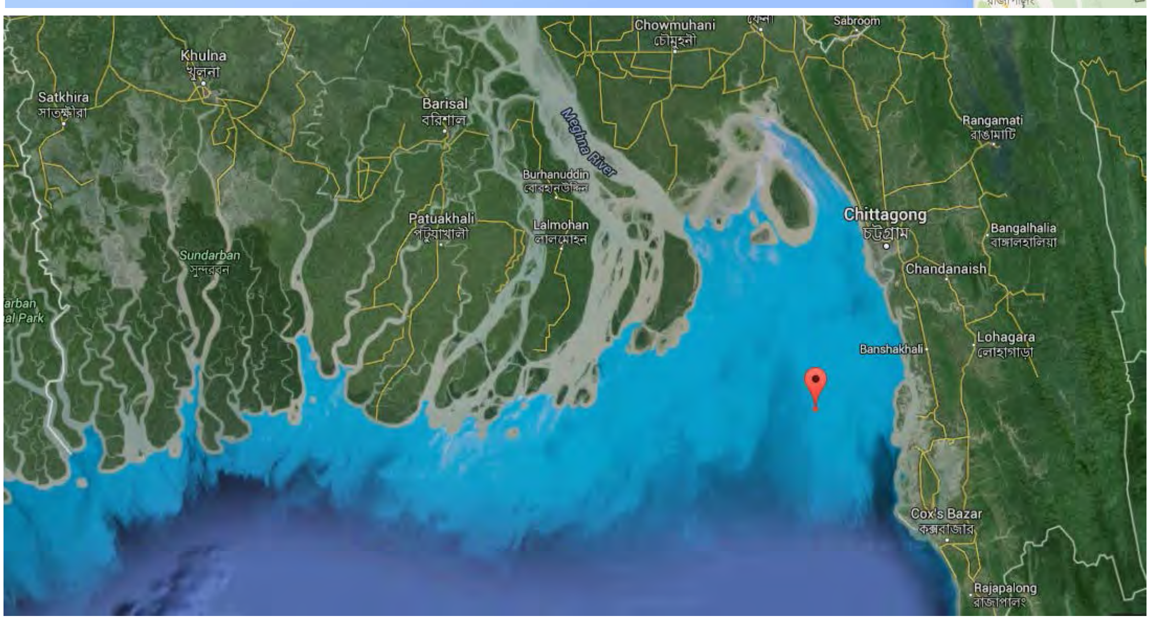
Figure 2.1.B Close up map of the suggested habitat location

Source: maps.google.com

Figure 2.1.C Satelite imagery of the suggested habitat location

Source: Google Earth





Information regarding other site aspects, such as climatic and environmental profile, has been provided however.

The site is located on the Bay of Bengal, within 26 km of the current (2015) Bangladesh coastline, and within 60km of the city of Chittagong. The proposed location is 21°50'50.06"N, 91°34'24.56"E. This is the primary location of the future city, and the point of inception of the future city is the proposed module. Chittagong city has been chosen as such due to the fact that the existing city will mainly respond to the assumed dystopian future of Chittagong, which is the main urban center along the entire 170 km Bangladesh coast. As sea levels steadily rise during the course of the next 80 years, Chittagong will gradually succumb to the waves, and one by one of its urbanised areas will become subject to permanent flooding and even water stagnation. This will give rise to changes in biodiversity, formations of swamps or swamp-like patches, loss of urban and agricultural lands against a bigger population than the one the city currently holds. It is therefore expected that the Chittagong urban population will therefore gradually migrate to the new envisioned semi submerged city, allowing it to grow incrementally. The envisioned city, which will grow incrementally (with the proposed module being the first stage of its growth) will therefore need to be in close proximity to an existing urban center in order to connect best to it functionally, to allow for better flow of resources, both human, capital, energy, etc). A water buffer of 60km has been maintained as to allow for movement of marine vessels adjacent to the Chittagong coastline. The distance also helps to maintain a visual buffer. Moreover, the bathymetry of the area beyond the 15km range is expected to go against the engineering aspects of the envisioned city or module. The site is, as expected, well within the area of Bangladesh's maritime boundary.

The other primary consideration of the site location is the bathymetry. Unlike the site locations for most projects on land which is almost always treated as a surface plane (in some cases, a shallow volume), the site for this proposed thesis is entirely a volume, made of water. The underwater topography, or the bathymetry, is therefore a valid concern. The range of the area on which the city can move when needed is within 100km of the Bangladesh coastline. This is since the bathymetry of this range does not exceed 200m of depth. 150m depth of water, equivalent to roughly 500 ft is the level of water on that sunlight penetrates underwater. The sunlight penetration factor is important since part of the city will be submerged underwater. Also, the depth during these ranges is convenient for anchoring the entire megastructure to the sea bed if ever needed or if it is proposed during the course of the study. This particular factor therefore, accommodates flexibility in design. The primary proposal of the module of the city is however, limited to only calm waters, and will be suitable to move on to the high seas (i.e., the extent of the 100 km range) when it grows further and becomes functionally self sufficient. The proposed location is shown by the red marker in the map below:

Figure 2.1.D Contour & Bathymetry Map, site area extended

Source: Department of Oceanography, Department of Geography, University of Dhaka; Bangladesh Navy

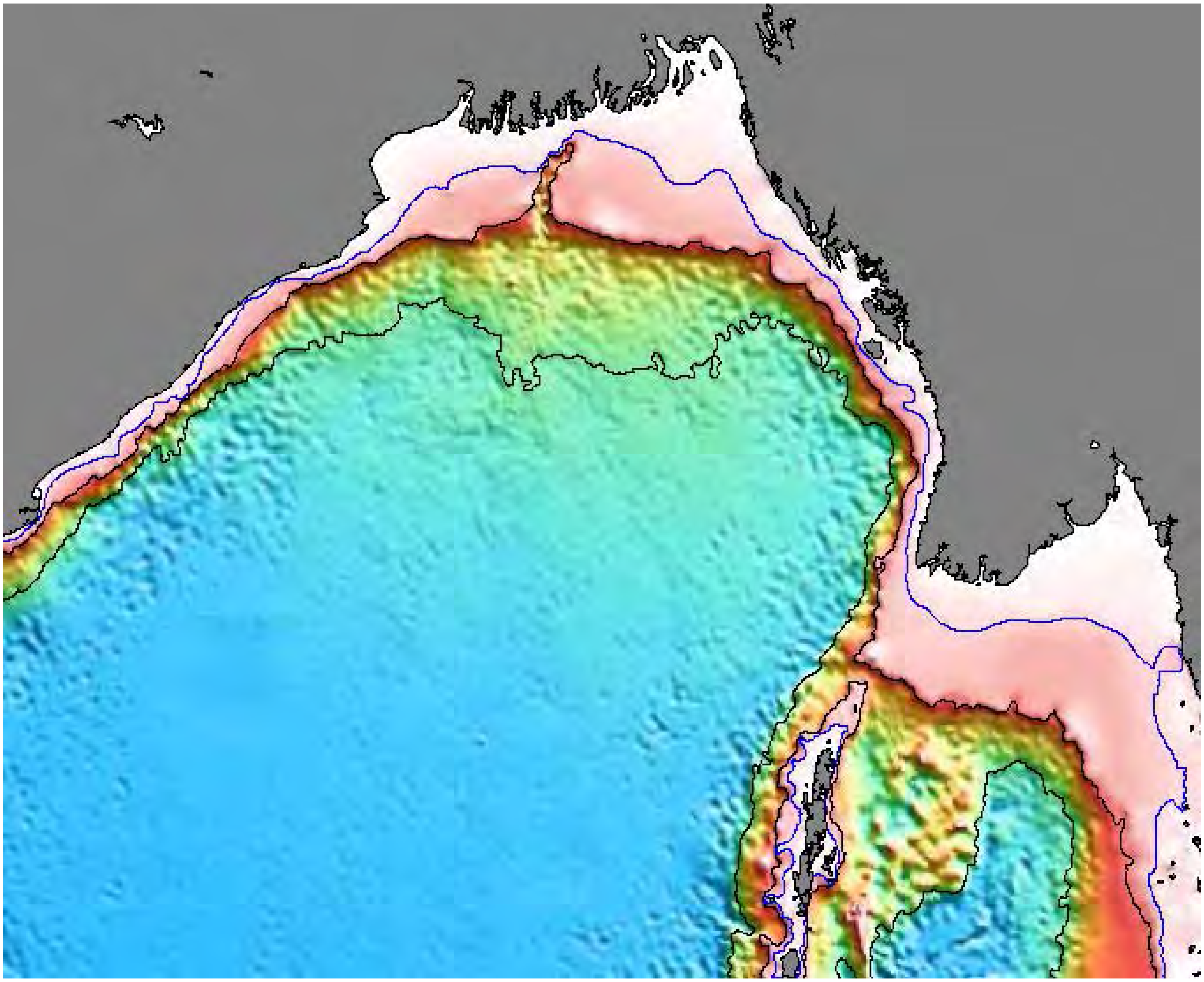


Figure 2.1.E Bathymetry map (colored)

Source: http://cmtt.tori.org.tw/data/App_map/maplist.htm

As can be seen from the maps, the continental shelf – expressed clearly through the pink gradients in the second map – varies gradually from a depth of around 5m to 200m in its periphery. The entire pink region denotes the movable area of the envisioned city. The left side map shows a more detailed topographical feature of the underwater realm along the coast. Most of the soil content is deposited silt, and the Bay of Bengal receives over 9 billion of tonnes of sediments each other from the Ganges-Brahmaputra river system. The area of the sea bed within 20 m of the coastline is mainly sand, while beyond that is largely a mixture of sediments and clay.

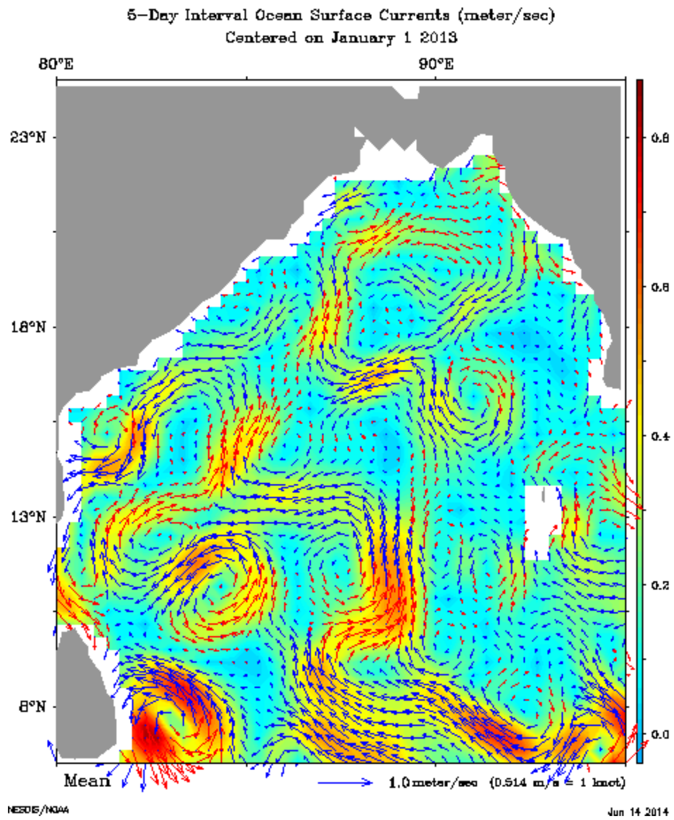


Figure 2.1.F Current circulation map for January

Source: http://mapsnmaps.blogspot.com/2014/06/surface-current-in-bay-of-bengal.html

The ocean surface current map shows the direction of the wave motion. The semi-diurnal type of tides, i.e., two high and two low tides during the period of 24 hours and 52 minutes. Surface circulation is found to be generally clockwise from January to July and counter-clockwise from August to December, in accordance with the reversible monsoon wind systems. The flow is not constant and depends on the strength and duration of the winds. The effects of a strong wind blowing for a few consecutive days are reflected in the rate of flow. Currents to the northeast generally persist longer and flow at greater speed because of the stronger southwest monsoons. An important vertical circulation in the Bay of Bengal is up-welling. In this process, sub-surface water is brought toward the surface, and conversely a downward displacement is called down-welling or sinking. Wind direction and intensity is shown in the map below:

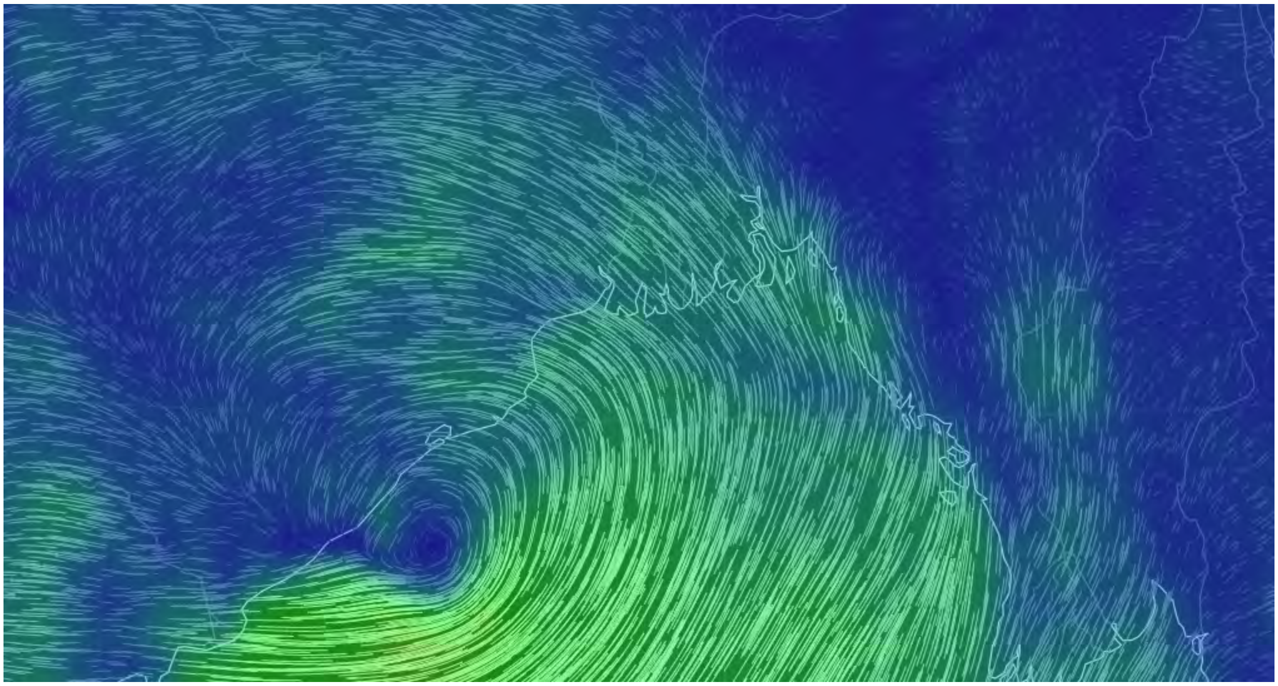


Figure 2.1.G Wind Circulation Map

Source: Interactive Globe Software

The following map shows the ocean surface temperature:

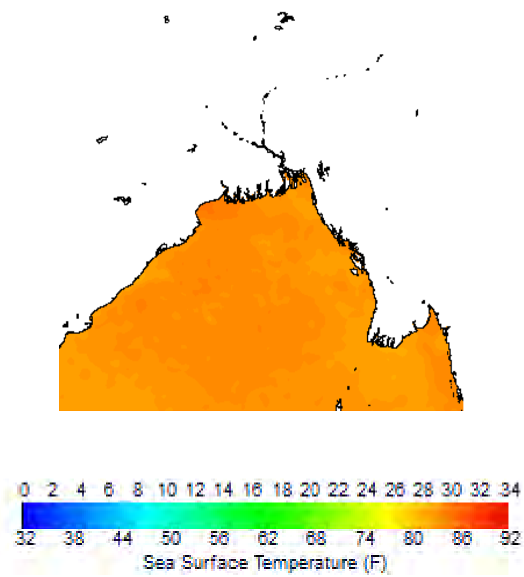


Figure 2.1.H Ocean surface temperature

Source: http://www.vagaries.in/2011_05_01_archive.html

The mean annual temperature of the surface water is about 28°C. The maximum temperature is observed in May (30°C) and the minimum (25°C) in January-February. Information for wave height is shown in the following map:

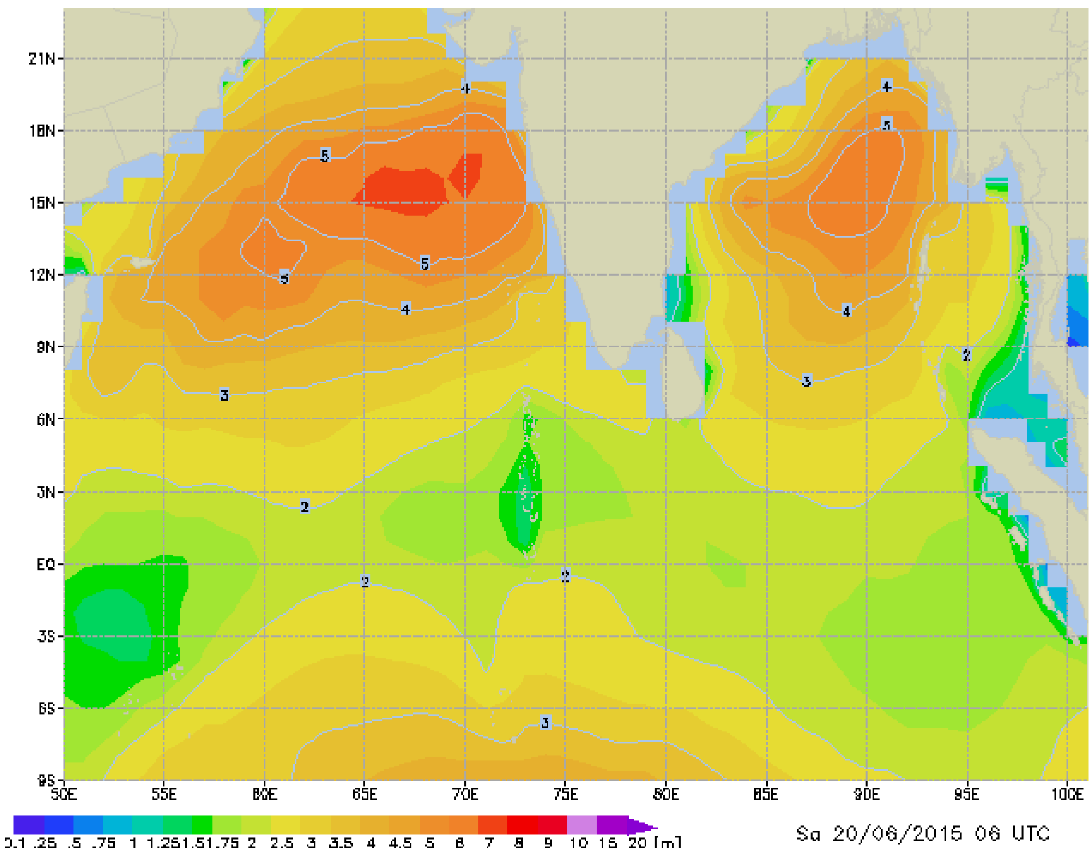


Figure 2.1.I Surface wave heights

Source: http://www.weatheronline.co.uk/marine/weather?LEVEL=5&MEER=inoz

The general color of the Bay is dark blue that gradually changes to lighter shades of blue and green as it approaches the coast. Along the Bangladesh coastline however, due to the huge presence of silts in water, the water mostly appears in a silvery- brown shade, sometimes bluish. The water is less transparent here compared to other parts of the Bay. Transparency is within 40-50m in some places. In the central part of the Bay of Bengal, the anticyclone circulation is generated and in the center of this lies the zone of convergence. This region is characterized as a rule by high transparency of water. Regions of low transparency and turbid water are available in the limited area of the pre-deltaic part of the rivers Ganges and Brahmaputra.

In the coastal region varies from 10% to 25%. But at the river mouths, the surface salinity decreases to 5% or even less. The coastal water is significantly diluted throughout the year, although the river

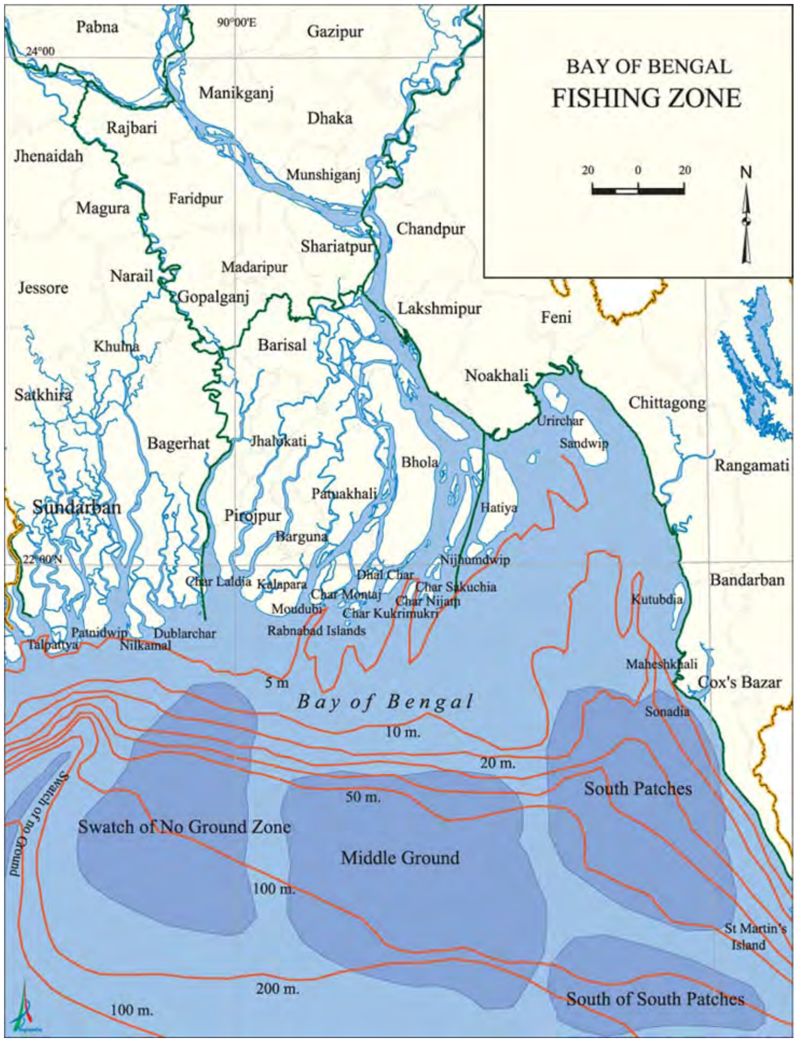


Figure 2.1.J Current Fishing zones

Source: http://www.weatheronline.co.uk/marine/weather?LEVEL=5&MEER=inoz

water is greatly reduced during winter. Along the coast of the Ganges-Brahmaputra Delta, salinity decreases to 1% during summer and increases up to 15% to 20% in winter. Salinity gradually increases from the coast towards the open part of the Bay. Salinity of water also changes vertically. The influence of the fresh water is experienced up to depths of 200-300m. From the surface, the salinity gradually increases downward and at about 200-300m it reaches 35% and at about 500m the salinity is more than 35.10%.

The occurrence of marine species - both plants and animals - has largely been controlled by the physic-chemical properties of ocean water. Water discharges from the surrounding river catchments carry huge influx of sediments full of nutrients to the Bay, particularly along the near shore region. This has turned the Bay into a fertile marine fishing ground of the region. The near-shore up-welling zone not only has a high yield of nutrients, but also is a high primary production area for the phytoplankton and related zooplankton zones.

The hydrological conditions of the Bay of Bengal is favorable for a variety of shrimps and fishes. Although fishes remain scattered in the Bay in some places they get concentrated and constitute important fishing grounds. Four fishing grounds have been identified so far. They are south patches, south of south patches, middle ground and Swatch of no Ground.

Other site information relating to economics, defense, environment and other activities are provided in the charts below:

1st row, from top left

Figure 2.1.K Maritime Boundary & EEZ, Bangladesh, India & Myanmar

Source: Dept of Marine Sciences, University of Chittagong

Figure 2.1.L Shipping Lanes

Source: Dept of Marine Sciences, University of Chittagong

Figure 2.1.M Navy Firing Zones

Source: Dept of Marine Sciences, University of Chittagong

Figure 2.1.N Miscellaneous coastal zones

Source: Dept of Marine Sciences, University of Chittagong

2nd row, from top left

Figure 2.1.O Ecological zone, Bangladesh coastal waters

Source: Dept of Marine Sciences, University of Chittagong

Figure 2.1.P Current Fishing zones

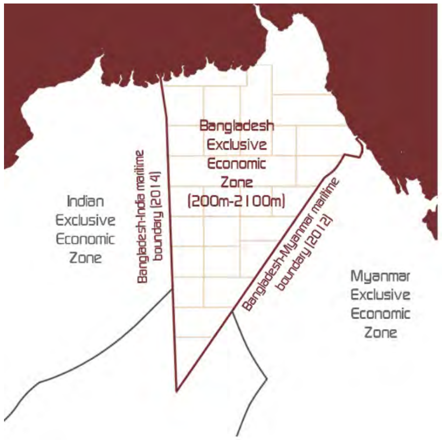
Source: Dept of Marine Sciences, University of Chittagong

Figure 2.1.Q Cyclone tracks

Source: Wikipedia

Figure 2.1.R Cyclone tracks along the coast

Source: Department of Geography, University of Dhaka

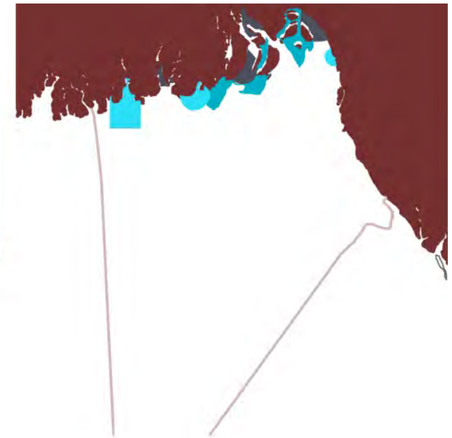


The maritime boundary gives enough region for future cities to expand incrementally

EXISTING & PLANNED SHIPPING LINES
POTENTIAL ROUTES
THIRD PARTY TRANSIT

There is considerable potential for the future cities or elements of the cities to position themselves along shipping lines for acting as floating ports, etc.

NAVY FIRING RANGE
SECURITY ZONE



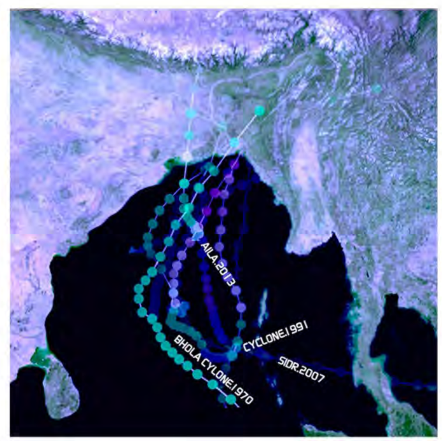
HILSA BREEDING GROUND
LAND RECLAMATION SITES
PORT LIMIT AND ANCHORAGE

In future, sea cities that will be near the chaning (growing) mainland will need to adapt particularly to the ecology and the edge threshhold between the land and the sea.

GEOLOGICAL RESEARCH/ECOLOGICALLY CRITICAL AREA
PROTECTED AREA
OFFSHORE WIND FARM

Eventually, the semi submerged cities can integrate particularly with the character of of the region that it may choose to inhabit. For example, those within protected areas can be programmed particularly for research, etc.

They can also be programmed to serve the fishermen in one way or the other on the regions of the fishing habitat.



The Bay is a particularly intense cyclone hit region with most passing through the Bangladesh coastline.

Zoomed in, the map shows the importance of the movability factor for floating cities due to the cyclone paths spread out evenly along the Bangladesh coastline.

The marine profile of the area was analysed to account for marine species living in the coastal waters of Bangladesh currently. Due to the lack of further data on their particular habitat, migration routes and frequently travelled area, the impact of a floating semi submerged human habitat could not be properly assessed on such creatures. However, it has been decided as a design principle to design for these creatures as well so that they benefit directly from the human habitat.

Category	Total number of species
Flora	
Algae/Seaweed	168
Fauna	
Sponges	3
Corals	66
Mollusks Marine	336
Shrimp/Prawns	56
Crabs (Marine + Freshwater)	16
Lobsters	3
Echinoderms	4
Fish	442
Amphibians	22
Reptiles	17
Birds	628
Mammals (Marine + Inland)	3

2.2 Historical and social backgrounds

The particular location chosen for the floating habitat is a surface of water on the Bay of Bengal, off the coast of Chittagong port. While this particular location does not have any significant historical data, (and to that extent, a very low possibility of being a site to any significant historical event or character), the Bay of Bengal itself and the port of Chittagong does contain some significant history. The port was mentioned long back in ancient Greek and Chinese chronicles, especially in those of Ptolemy. The Arabs had used the port as a gateway to trading with this part of the world. Chittagong was also a site for building the navies of the Mughal and Ottoman Empire, during which period, it was named as Islamabad. This was after the Mughals expelled the Arakanese army previously controlling the area. The Portuguese had established this later on as Porto Grande or the Grand Port. It was finally developed by the British well into the colonial times.

2.3 SWOT analysis

The site possesses a few obvious strengths, the first being its close proximity to an existing urban area- Chittagong city- which it seeks to replace in the timespan of a hundred years. It is situated well within the continental shelf, meaning that maximum depth of the water in the particular location does not exceed 15 m. This provides good opportunities for significant underwater building design due to sunlight penetration within that range. Also, the ocean surface temperature, which is 28 degrees Celsius on average provides a good opportunity for OTEC (Ocean thermal energy conversion). The other significant strength of the site is its tidal range, which is 7ft on average. This provides good opportunity for wave energy conversion. Also, the tidal currents across the region is generally strong, and along with the significant wave height, provides scopes for different forms of tidal energy conversion such as tidal array, tidal lagoons and tidal barrages. The site receives a fairly good amount of sunlight throughout the year, suitable both for solar energy conversion and providing a descent life supporting system for the inhabitants of the floating city. The site is also out of the existing fishing areas or patches, and does not disturb the existing or future fisheries industry. The area is not under threat from any dangerous underwater creatures.

One of the major disadvantages of this site is the frequency of storms and tropical cyclones in this area of the Bay of Bengal. However, the structure will be designed specifically for this disadvantage and will be able to move to a different location once disaster strikes. Another weakness is the transparency of water. Due to the huge influx of element from the Meghna estuary, the water is significantly filled with sediments that increases its turbidity.

Chapter 03

Literature Review

3.1 Climate Change and its impacts on Bangladesh

Bangladesh, being situated on the Ganges delta, the largest delta in the world is one of the most vulnerable nations on the planet to the effects of the manmade phenomenon known as climate change or global warming. The primary effects of the different faces of climate change will be many- in the form of increased natural disasters, change in precipitation and temperature pattern, the rising sea levels, increased salinity of water, etc.

On a more focused level, one author writing on the impacts of climate change points out that Bangladesh by default has historically faced a barrage of natural crises in the form of tropical storms and cyclones, mainly due to its existence on a low lying, flat alluvial plane known as the Ganges Delta; the other main reason being the geographical location of the delta, which is in close proximity to the equatorial belt. The inclusion of the socio-economic condition of the country, such as Population density, Poverty, Illiteracy, Lack of Institutional setup etc. - grounds the analyses of climate change impact more effectively to the ground. (Biswas, 2014)

The impacts on agriculture are perhaps one of the fiercest of climate change impacts. the economy of Bangladesh is based on agriculture mainly, with two thirds of the population engaged (directly or indirectly) on agricultural activities; this is also accompanied by the fact that Bangladesh's advance towards industrialization is quite slow, therefore the main brunt of climate change impact will fall on the agriculture center of the economy. On a more detailed scale, other impacts such as extreme temperature, drought, and salinity intrusion etc. are also responsible for the declining crop yields in Bangladesh. Temperature and Rainfall changes have already affected crop production in many parts of the country and the area of arable land has decreased to a great extent. (Biswas, 2014) Salinity intrusion has also been pointed out as an issue, further decreasing crop yields in coastal areas. Overall, the findings suggest that the remaining fertile soil we have left would be best utilized if left to produce agricultural products instead of urban activities.

Sea level rise affecting the coastal areas of the countries is another cause for concern the article intends to uphold. As Biswas further writes, ''Almost one fourth of the total population of the country live in the coastal areas of Bangladesh, where majority of the population are directly or indirectly affected by tidal surges, river-bank erosion, increasing salinity, tropical cyclones etc. With the rise of sea-level up to one meter only, Bangladesh could lose up to 15% of its land area under the sea water and around 30 million people living in the coastal areas of Bangladesh could become refugees because of climate change impacts. The particular components that will therefore be affected include the industry, infrastructure such as schools, hospitals, roads, bridges and culverts etc., livelihoods of people, marine resources, forestry, biodiversity, human health and utility services.''

He points out that ''The average elevation range of Bangladesh is 16 m from the sea level, and does not come to much benefit in the battle against the rising seas. Since most of the country is less than 10 meters above sea level and almost 10% of the population of the country is living below 1 meter elevation - the whole coastal area is highly vulnerable to high tides and storm surges. Moreover, the Bay of Bengal is located at the tip of the north Indian Ocean, where severe cyclonic storms as well as long tidal waves are frequently generated and hit the coast line with severe impacts because of the shallow as well as conical shape of the Bay near Bangladesh.'' It is stressed here that the urban settlements around the coast are the most susceptible to sea level rise and storm surges. These include major cities and town like Chittagong that are at risk of facing severe damage. Direct impacts may occur through the increased floods, drainage congestion and water logging as well as infrastructure damage during extreme events. In the area of public health, scarcity of saline free drinking water will increase highly. There are fears that coastal low lying embankments may become completely inundated. Another issue is increased humidity- a waterlogged city will see more evaporation of water than any time before.

A near gloomy scenario has been painted through this and other similar such authored works- all of them are successful at pointing out that this nation is indeed one of the most vulnerable to the effects of our changing climate. The write up is successful in orienting the work of this thesis in the direction of ocean colonization which will be discussed the following sections.

3.2 Floating Architecture

Floating cities, as they have been named, are one of the most revolutionary outcomes from visionary architects. Straight out of our imaginations from centuries, floating city were brought to life in the early 1960s by Buckminster Fuller, but it didn't come into recognition till the last decade. Through Koen Olthuis and the design team at Waterstudio the future has been envisioned. It is now being seen as an essential method due to the increase in rural-urban migration and natural hazards.

As R Keeton affirms in his article, ''Of course the self-supporting mechanism and holding a large population has not yet been worked out completely; however the engineering has been figured out. The process might have been easier than most people imagine. Based on Olthuis's sketches the process is pretty easy, therefore betting with the investors' money properly.''

He stresses that ''Imagine if the static cities turned dynamic, having the ability to move around more frequently and according to its necessity. With the technology and popularity in its correct place and form, political issues and ownership factors are hindering its progress.'' It can be said that this feature is not being accepted yet; for instance as mentioned in the text "People have trouble imagining an urban future where city halls can be swapped for theaters on opening night, or entire Olympic villages can simply be towed around the world instead of rebuilt every four years."

The revolutionizing idea would put water into good use and remove the pressure on land. Water would enable three things; space, safety and flexibility. A more adaptable option than built forms on land, the buildings constructed can get accustomed to changing needs more promptly and proficiently. (Keeton, 2014)

Affirming the governments' opinion in this specific sector is the business model that building upon water presents. Expansion upon water would mean new scopes for real estate business besides being a major solution for many problems. He writes that the profit that can be earned from them is unmarketable currently.

A fair attempt to provide counter point is shown in the writing as well. The article stresses that creativity of the matter is unbearable to some; the thought of floating unevenly makes some squeamish. As he puts it ''However, the good news is that this would not be the case for bigger projects. Moreover, bigger projects would also cut down the cost at a wider scale rather than building a single house.''

Some of the groundbreaking projects are Alvaro Siza's recently completed chemical plant in Huai'An City, China, was built on the water, and BREAD Studio recently designed a floating cemetery to be rafted off the coast of Hong Kong – a city long on elderly citizens but short on space, a floating skate park on Lake Tahoe now and floating freshwater pools in the River Thames. There's even a floating cinema in London by UP Projects, echoing Aldo Rossi's iconic Il Teatro del Mundo from 1979. (Keeton, 2014)

In the developing countries, floating structures can be considered as a ground-breaking invention for a system "where we bring in floating schools, sanitation, electricity, water treatment facilities, bakeries, internet cafes, or whatever is most needed. We can connect these floating functions to the slums or disaster sites and they will slowly help upgrade these areas.'', as Keeton goes on to write further.

He points out that the Seasteading Institute's Floating City is another outcome of the government accepted projects. Waterstudio is being called a "scarless" design.

''The next step is to build designs like the 'Sea Tree', a floating natural habitat, that ensures small fish a sanctuary, increase the oxygenation of water, and potentially collect trash as it drifted about.''

The write up also attempts to set the right perspectives on the matter; it stresses that attitude towards water should be the amicable. The safety issues raised by natural hazards are gracefully handled. Those still unaware of this technology are advised to know it better; since it is the most desirable answer for a doubtful future. "A floating city is only something that works when it makes sense economically, socially, spatially — and should also look nice. It should be a normal development that is open to everyone, rather than an alien form for an elite few" – according to Olthuis.

Like the following articles, this is helpful in providing shallow, but important insights into the different dynamics into the design and functioning of floating cities. Different cues ranging from engineering, function, costs, ability to psychologically cope have been talked about. The write up, overall is helpful in giving directions to proceed on and factors to consider when engaged in the design of such infrastructure.

3.3 Ocean Colonisation

Ocean colonization in the form of futuristic habitation has great potentials. Considering the fact that much of the oceans, over 90% of it has been left unseen and untouched, there is a lot of space and resources the ocean has to offer. Nonetheless, there has been much negligence when it comes to research regarding the oceans -more at home than abroad- whether it is related to ocean habitation, or simply marine resources. When the topic of ocean colonization arises, many more issues come forward with it, such as its location. Concerning location, one of the research regarding Biosphere 2- a proposed underwater colony- says that the location can be somewhere soothing, like the Baltic Sea or Tierra del Fuego or maybe anchored near the equator. These places, the article opines, will attract people to invest on programs like this. (Tsuchiyama, 2011). But one serious issue gets overlooked and that is whether the location is vulnerable to climatic hazards- such as tsunamis- or not.

There are some research that focused on other factors of ocean colonization other than just the marketing side. As R Tsuchiyama explains in his article, ''Ocean scientists would be able to point the location where warm surface water as well as deep cold water will be accessible where surface water will help increasing aqua farming and cold water will provide pure drinking water for the inhabitants.''

The same article also states that regarding power supply in these area it is quite evident that fossil fuel derived electricity will not sustain such habitats in the long run. Natural energy sources such as solar power, wind, ocean thermal Energy Conversion (OTEC) will be viable substitutes. They also pointed the benefits of the location being tourist friendly as there would be beach homes, malls, hotels etc. These explanation makes the area selection more valid.

Yet, these research will remain incompetent if it they don't proceed towards implementation level but this is not as easy as it seems as the article puts, because it will require a large amount of investment. One of the ways of getting funding can be individual investments. As Tsuchiyama, points out, ''the process might accelerate but chances also arises of it becoming only a promotional project to gain recognition. On the other hand, small but efficient funding can be arranged as well. Programs like sea amusement parks will attract visitors and may provide a continuous source of financial support to the research and implementation process.'' This way the scientists are expected to get full freedom of work and the possibilities of deviating from the actual goal will reduce.

The article is helpful in that it attempts to give an overall scenario of our current thoughts and experiments regarding water colonization. It tries to cover diverse topics such as protection against the ocean elements, energy and functions of such ''could-be'' structures with a certain degree of facts. The main success of this article seems to be in its ability to give a hint about the number of different parameters and the scale of thoughts involved with the design and function of an ocean habitat. This will help broaden the vision for the design of such structures as well.

Ocean colonies nonetheless, comes with different advantages and disadvantages. Even though ocean colonization is a good futuristic suggestion yet the rich industrialists are not approaching towards it. In spite of having the equipments and facilities they are still being quiet. As B Eichman writes, ''One of main reason behind it can be that after going through the pros and cons they are not convinced that this would bring enough profit for them.''

He believes the major weakness of ocean colonization will come out even from an offhand examination. The writer emphasizes that ''The economic motivations to live all the time in the ocean environment is very few in number or maybe close to none. Our sophisticated fleets of ships and submarines have moderately fulfilled the current industrial, scientific and political needs. What will rationalize the efforts behind the ocean colonization in the future decades are the uncontrollable human curiosity, political desperation and a good understanding of the future needs even though the amount of money to be made in ocean colonization is unexpectedly more which cannot be made by using existing ocean technology of ships and drilling platforms.''

This statement indicates that it is unlikely that enough money can be made to rationalize ocean colonization. It means that some existing industrial resource gathering or manufacturing process can bring profit but this ocean colonization program. An ocean colony will not be able to compete with the existing industrial base at its landside ports when it comes to mining manganese or oil, harvesting fish because such industries supply products to the market at a low infrastructure and capital cost whereas building a similar kind of productive ocean colony will cost higher. As a result the ocean living spaces will be notably expensive than the work and living spaces of land based buildings. Nonetheless, economic opportunities may arise with a view to funding and supporting such expensive ocean colonies. (Eichman, 1993)

Some of the economic opportunities can be pharmaceuticals, biotechnology, tourism, international banking, and privacy and security services. Surprisingly, the author goes on to write that ‘’However, there is another opportunity that might be the least expected and that would be field of organized crimes, manufacturing and smuggling drugs to be specific. People have made billions of dollars in this field. This would require extensive level of networking, confidence and brilliance. Nevertheless one of the biggest weak link of this is such business would require land to operate on. This makes the success rate of organized crime on ocean colony pretty much uncertain.’’

Even though all these filed have potential, the author believes only tourism can go for rapid execution. The rest will require substantial amount of investment in accessories, trained professionals, infrastructural support and retailing.

Chapter 04

Contextual Analysis

4.1 Power Consumption in 2100 & calculation of the total number of inhabitants

As mentioned earlier, the core objective of this thesis is to develop a floating habitat that could provide a solution to the mal effects caused by the rising seas and climate change as a whole, as well as to provide an alternate, more sustainable way of living through decreasing our carbon footprints and taking advantage of all that the sea has to offer. An essential aim of the 'sustainable' living approach is the integration of renewable energy sources to provide power for this proposed habitat. Ocean energy from the waves and tides, ocean thermal conversion (OTEC) as well as wind and solar power are potential enough in the site to provide electrical power for the whole city. As such, it is necessary to calculate the total energy requirement of the whole habitat in 2100 which will lead to justification of the total number of employees who will live (and generate power) on the floating energy hub (the designed portion of the thesis). The number of employees in this floating power plant will be doing so with their entire families, so the employee figure will give way to the total number of people living on the energy hub.

There has been a bi directional approach to calculating the total number of inhabitants. One approach was made towards establishing the number of employees it takes with current technology to produce 1 MW of electricity. Data from various renewable power plants incorporating modern technology have been taken into consideration from all across the world for this purpose:

TECHNOLOGY	(Jobs/MW) O&M	COUNTRY	YEAR OF ESTIMATION
Wind (on shore)	0.72	South Africa	2007
	0.1	United States	2010
	0.4	Greece	2011
	0.41		
Wind (off shore)	0.2	OECD Countries	2010
	0.2		
Solar Photovoltaics	0.3	OECD Countries	2007-2011
	0.73	South Africa	2007
	0.2	United States	2011
	0.41		
Bio Mass	5.51	South Africa	2000

		5.51		

	FACILITY	CAPACITY (MV)	COUNTRY	COMM
Tidal Energy	Annapolis Royal Generating Station	20	Canada	1984
	Rance Tidal Power Station	240	France	1966
	Sihwa Lake Tidal Power Station	254	South Korea	2011
	Swansea Bay Tidal Lagoon	240	United Kingdom	2015-2017

Figure 4.1.A Renewable energy power plant capacity, and other facts

Source: (IRENA, 2013)

Performing an average calculation of all the data above, it is found that it requires 1.33 jobs, or over one person to produce 1 MW of electrical power from renewable energy sources. This figure however, does not take into account technological advances that will be made in the timespan of almost a hundred years.

The other approach that was taken was to calculate the total energy demand of the habitat from the per capita power demand of an average Bangladeshi citizen in 2100. Since the floating city is to replace the port city of Chittagong incrementally within the next 80 years, the targeted population is that of the Chittagong city’s predicted population in 2100. It has been calculated as such:

CALCULATION OF TARGET POPULATION

Population growth in 2100

Current population (2015) : 160,411,000

Predicted population in 2100: 182,238,000

% increase: (182,238,000-160,411,000)/160,411,000 * 100 = 21827000/160411000 *100 = 0.136 * 100

Population growth across country in 2100 = 13.6%

Average population of a Chittagong city police station

Name	**Status**	**Population Census 2011-03-15**
Bakalia	City District (Thana)	262,703
Bayejid Bostami	City District (Thana)	211,355
Chandgaon (Chāndgaon)	City District (Thana)	256,411
Chittagong Port (Bandar)	City District (Thana)	208,260
Double Mooring	City District (Thana)	361,154
Halishahar	City District (Thana)	151,515
Khulshi	City District (Thana)	278,623
Kotwali	City District (Thana)	319,972
Pahartali (Pahārtali)	City District (Thana)	190,637
Panchlaish	City District (Thana)	219,132
Patenga	City District (Thana)	132,677
Average		**235,676.27**
Total		**2,592,439**

Figure 4.1.B Chittagong city population by ward

Source: Chittagong City Corporation

Expected population in 2100:

2,592,439+ 13.6% of 2,592,439

= 2,945,010.7

The CIA world factbook reveals that the average power consumption of Bangladesh country is currently 28 Watts per person. From that data, Power demand of Chittagong City in 2100 has been calculated as such:

2,945,010.7 X 0.000028 = 82.5 MW.

This figure reveals the total number of employees on the energy hub as such:

82.5 MW X 1.33 jobs/MW = 109.7 = 110 (Technology advancement multiplier ignored).

If an average of four family per person is taken into consideration, then the total number of people in the entire hub will stand somewhere around 400.

4.2 Physiological and Psychological context induced by site conditions

Basic to living underwater is breathing underwater. At 33 feet sea water, we breathe twice as much than we do on the surface since oxygen in the air is comprised to about half the volume than that on the surface. Proper ventilation and recycling of air must be provided throughout. Newer technologies, such as the extraction of oxygen from sea water can be incorporated rather than pumping air from the surface (in case of a submerged habitat). It is preferred that a submerged habitat is provided with the surface air pressure conditions of 1atm pressure rather than staying at ambient pressure (the water pressure of the depth at which the object stays submerged). This is since at ambient pressure, the composition of gases we normally breath on the surface cannot be breathed- that would give rise to the need for decompression (gradually adjusting the body from the concentrated air pressure at ambient condition to the surface air pressure) before returning to the surface. Decompression time may last anywhere between several hours to a few days depending upon the depth from which the person is trying to surface. Insufficient decompression time might result in a medical situation known as the ‘bends’, where the concentrated gases try to escape from the body at a fast rate. This may even lead to death. It is therefore suggested that 1 atm pressure – the same as that of the surface – be provided at all depths. This would require a high structural integrity of the underwater architecture.

Apart from the above, air conditioning for temperature control and dehumidification, a combination of natural and artificial lighting as well as removal of toxins in the air is a prime concern. The waters of the Bay of Bengal are cooler compared to the air, and will absorb much of the heat built up within the structure. Emergency oxygen systems must be provided. Compressed air vessels are to be provided for maintaining the structure’s buoyancy and stability.

Acoustic treatment is important for undersea dwellings, and acoustic treatments for surface structures may not apply under water where their effectiveness could be diminished. The use of compressible buffers, suspension springs and heavy insulation on all vibrating materials can shield other spaces from noise.

Creating an ambience that responds positively to the senses is a high priority for submerged spaces since they will generally be devoid of the outside air. This will need a combination of sensitive lighting, choice of colours and space creation.

4.3 Fluidity of the site

Unlike a conventional building site, the site for this proposal is purely water- a fluid voluminous medium. Building on water brings forth factors determining the feasibility of any floating structure or megastructure, such as buoyancy, anchorage, corrosion, natural disasters that the site faces such as tsunamis and cyclones, etc.

Bouyancy is an upward force exerted by a fluid that opposes the weight of an immersed object. In a column of fluid, pressure increases with depth as a result of the weight of the overlying fluid. Thus a column of fluid, an object submerged in the fluid experiences greater pressure at the bottom of the column than at the top. The same would happen for any floating structure for the sea, i.e., the site. This difference in pressure results in a net force that tends to accelerate an object upwards. The magnitude of that force is proportional to the difference in the pressure between the top and the bottom of the column, and (as explained by Archimedes' principle) is also equivalent to the weight of the fluid that would otherwise occupy the column, i.e. the fluid or the water displaced by the object. For this reason, an object whose density is greater than that of the fluid in which it is submerged tends to sink, and is thus said to have negative buoyancy. A positively buoyant object, having density less than that of the water it displaces or if the object is shaped appropriately (as in a boat), the force can manage to stay afloat. The density of the building material plays a significant role in this regard.

The structure will need to endure water pressure, erosion from water and water currents and possibly even from aquatic creatures. This will need to be addressed by the material used. The semi submerged structure also needs anchorage to achieve horizontal and vertical stability. Horizontal forces, or frictional drag from wave motion can be calculated, as well as the vertical water pressure. Stability is a measure of the platform’s resistance to tilting. When waves or other forces tilt the platform, the center of buoyancy moves to the direction of the tilt, because this side now displaces more water. The upward buoyant force will counteract the tilting motion and in combination with the downward weight of the platform, it rotates back to its equilibrium. The distance between the forces of buoyancy and gravity is referred to as the righting arm. A larger platform has more resistance to tilting, because more water needs to be displaced in order to tilt the platform.

A structure that is less than half a wavelength in size will tend to mostly follow that wave; if the structure is more than twice the wavelength, its response will tend toward zero. In depth investigations into all the above factors will determine the design parameters that will eventually translate into architectural spaces. However, due to the limited scope of this course and paper, such investigations will have to be discussed in the following chapter 7 that concerns the design phase.

4.4 Section of the open ocean & water threshold

The open seas, or even the water threshold in a pond has many interest features as different depths or areas of the section are habitats to different marine species, both flora and fauna. After a study of the open ocean sections and the marine life inhabiting them, as well as another study of water threshold in a pond, the following diagrams were compounded:

OPEN OCEAN

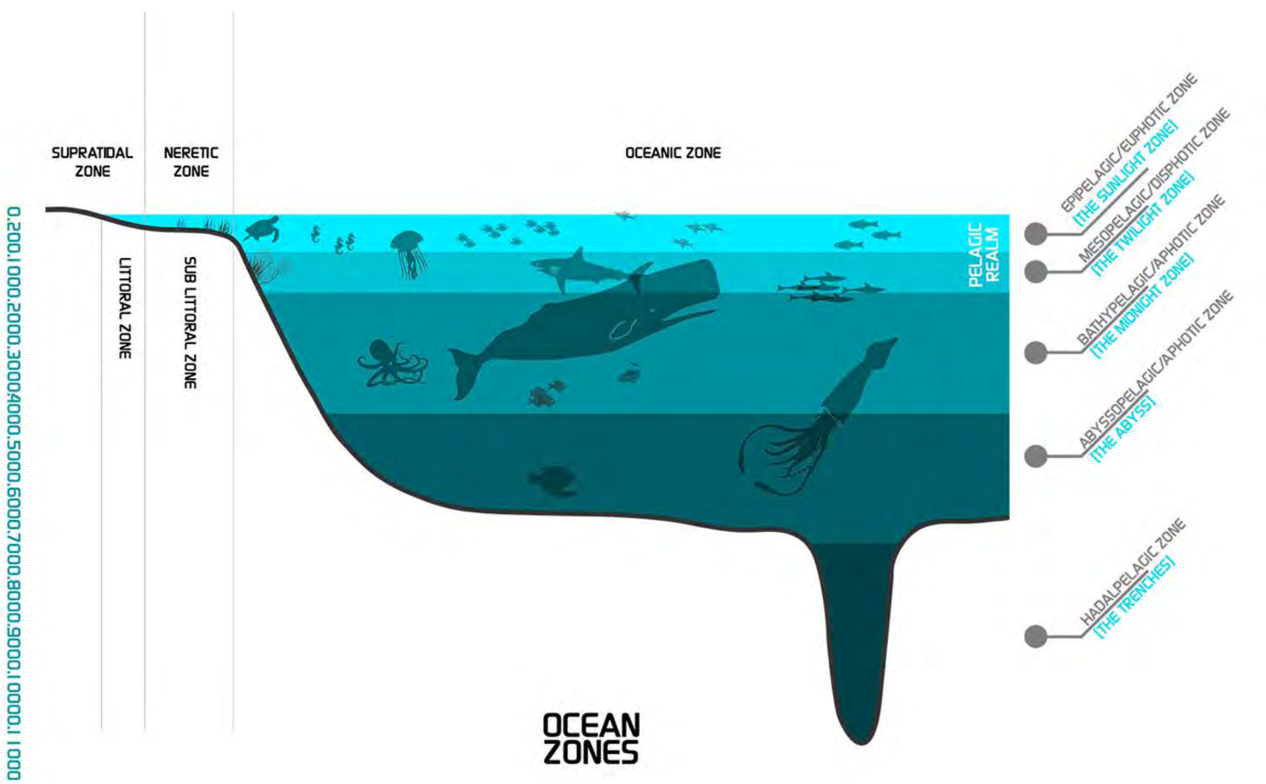


Figure 4.4.A Open Ocean section

Compiled

The following zones were identified to have certain features particular to each zone. All these zones have certain potentials to accommodating a human habitat, whether floating or underwater. It might even seem that some zones seems to forbid humans from ever settling there:

A. **EPIPELAGIC ZONE**

LIGHT: Only faint, filtered sunlight during the daytime. This zone appears deep blue to black in color.

DEPTH: extends down to around 200m

TEMPERATURE & PRESSURE: Varies from regions of the planet since it is profoundly affected by sunlight.

HABITAT: Vegetation, Fish, sea mammals, corals and other sea life commonly observed

B. **Mesopelagic Zone**

LIGHT: Only faint, filtered sunlight during the daytime. This zone appears deep blue to black in color.

DEPTH: In clear water, begins from 600 feet; in murky water, it can start at only 50 feet deep. The amout of light decreases with depth. Because of this, food is not abundant.

TEMPERATURE & PRESSURE: 41 to 39 degrees F) and decreases with depth. The pressure can be up to 1,470 psi.

HABITAT: In the disphotic zone, there is enough light to see during the day, but not enough light for photosynthesis to take place, so no plants live in this zone.

Bigscale fish, the Firefly squid, Ctenophore, Hatchetfish, Dragonfish, Snipe eels and Siphonophores

C. **Bathypelagic Zone**

LIGHT: The only light is from bioluminescent organisms

DEPTH: 1000m to 4000m

TEMPERATURE & PRESSURE: Colder and more pressure than the Mesopelagic zone.

HABITAT: Fish, molluscs, jellies, and crustaceans. Sperm whales can dive down into this zone when hunting giant squid. Vampire squid, Snake dragonfish, Angler fish, Amphipod, Slimestar

D. **Abyssopelagic Zone**

LIGHT: The only light is from bioluminescent organisms
DEPTH: 4000m to the sea floor.
TEMPERATURE & PRESSURE: Colder and more pressure than the Bathypelagic zone.
HABITAT: Deepwater squid, octopus, echinoderm such as sea cucumbers & basket star, large shrimp.

E. **Abyssopelagic Zone**

Areas found in deep sea trenches and canyons, extends from 6000 ft to below. The temperature of the water is just above freezing, and the pressure is an incredible eight tons per square inch. Invertebrates such as starfish and tube worms can thrive at these depths.

WATER BODY THRESHOLD IN PONDS/WETLANDS

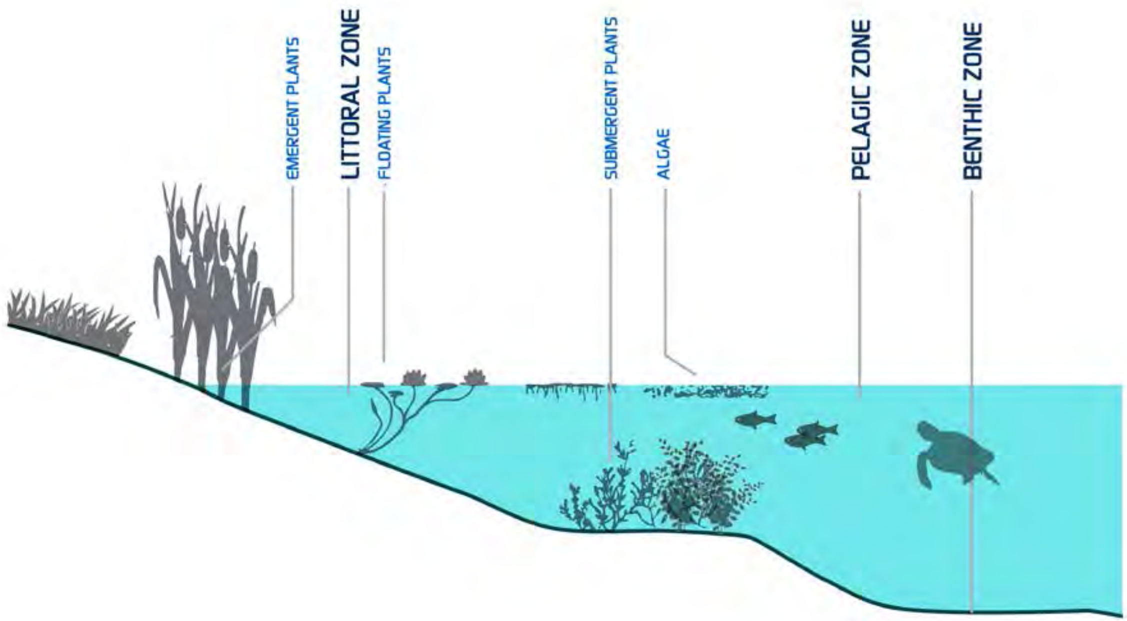


Figure 4.4.B Water body threshold in ponds/lakes

Source: Chittagong City Corporation

Chapter 05

Case Studies

Numerous underwater habitats have been designed, built and used around the world since the early 1960s, either by private individuals or by government agencies. They have been used almost exclusively for research and exploration, but in recent years at least one underwater habitat has been provided for recreation and tourism. Research has been devoted particularly to the physiological processes and limits of breathing gases under pressure, for aquanaut and astronaut training, as well as for research on marine ecosystems.

On the other hands, floating habitats have been long in existence for at least over 400 years on this planet, namely on in China. There, the Tanka people have managed to sustain themselves in their watery habitat for centuries fleeing persecution from the former Imperial Chinese government. Floating villages have been in existence in Vietnam comprising a community who rely on fishing and trading with the mainland for their survival. It is only very recently that architectural proposals for modern floating cities have been brought up as a cautious step towards providing solutions to current and future problems. (China's floating fishing cities: The wooden houses that are home to 7,000 'gypsies of the sea' who refuse to conform to modern living and want to remain on the ocean, 2013)

Figure 5.1.1.A Floating village, Vietnam

Source: http://picsant.com/12688702-halong-bay-vietnam.html

Figure 5.1.1.B Tanka Community, China

Source: http://www.dailymail.co.uk/news/article-2451023/Chinas-Tanka-boat-peoples-floating-homes.html

Both a floating and an underwater habitat has to meet the needs of human physiology and provide suitable environmental conditions, for example the physical environment such as light, pressure, the erosion of waves, temperature, air to breath, biological environment such as regulation of microorganisms and fungi, chemical environment such as food and removal of toxins and waste material. (Underwater Habitat, 2014)

Conshelf, was a series of undersea living and research stations undertaken by Jacques Cousteau's team in the 1960s off the French coast. (Underwater Habitat, 2014) Three were completed with a maximum depth of 100 metres (330 ft). Much of the work was funded in part by the French Petrochemical industry, who, along with Cousteau, hoped that such manned colonies could serve as base stations for the future exploitation of the sea.

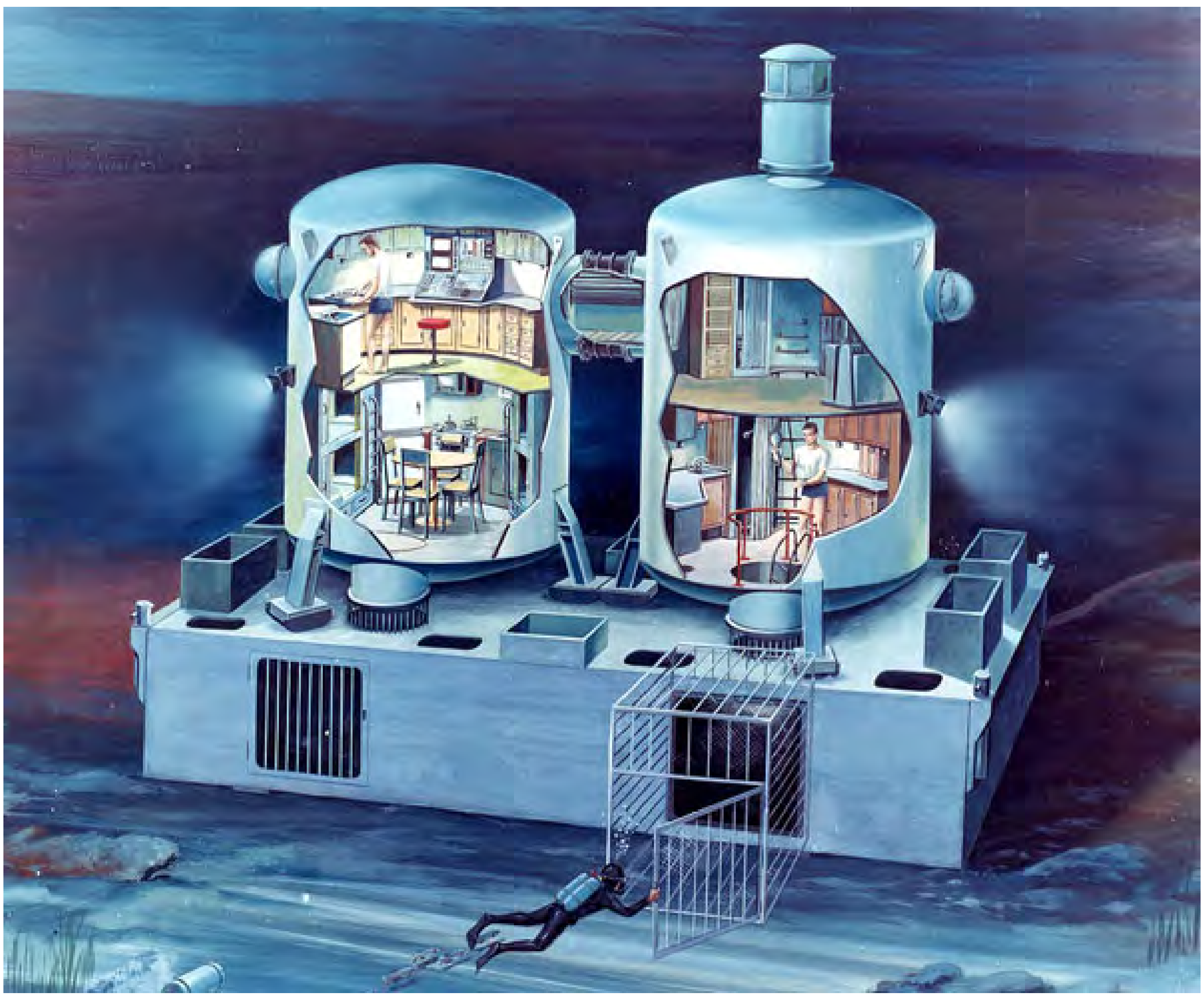


Figure 5.1.1.C Drawing of the Tektite habitat

Source: http://www.thetektitedocumentary.com/

The Tektite underwater habitat was constructed by General Electric and was funded by NASA, the Office of Naval Research and the Department of the Interior in 1969. Tektite was the first saturation diving project to employ scientists rather than professional divers. (Tektite Habitat, 2014)

Aquarius is presently one of the world's only three operational underwater laboratories. It is located adjacent to a coral reef in the Florida Keys National Marine Sanctuary.

Left: Figure 5.1.1.D Galathee

Source: https://commons.wikimedia.org/wiki/File:GALATHEE.jpg

Right: Figure 5.1.1.E Aquarius

Source: http://www.noaanews.noaa.gov/stories2007/s2916.htm

The Marine Lab underwater laboratory is the longest serving seafloor habitat in history, having operated continuously in an unbroken service since 1984 under the direction of aquanaut Chris Olstad at Key Largo, Florida. The seafloor laboratory has trained hundreds of individuals in that time featuring an extensive array of educational and scientific investigations from United States military investigations to pharmaceutical development.

Galathee, the first underwater habitat built by Jacques Rougerie was launched and immersed on 4

August 1977. The unique feature of this semi-mobile habitat-laboratory is that it can be moored at any depth between 9 and 60 metres.

Besides such small underwater scale research facilities, larger scale examples can be found in recent times.

The emirate of Dubai is building a semi submerged, underwater hotels off its coast, while an underwater museum is being built on a site of submerged ruins off Alexandria in Egypt. Chinese and Japanese construction firms have been collaborating on building entire cities that float on water with local and foreign expertise.

Architecture on water has gained a significant interest in both the academic and industrial communities during the last few decades. Most of the following proposals dwells on responding to global issues of climate change, in particular- sea level rise and the shortage of land, over population, as well as the energy crisis of the future.

The Dutch firm 'Deltasync', has been involved in this school of thought and have successfully constructed floating civic infrastructures such as parks and pavilions for Rotterdam, and is

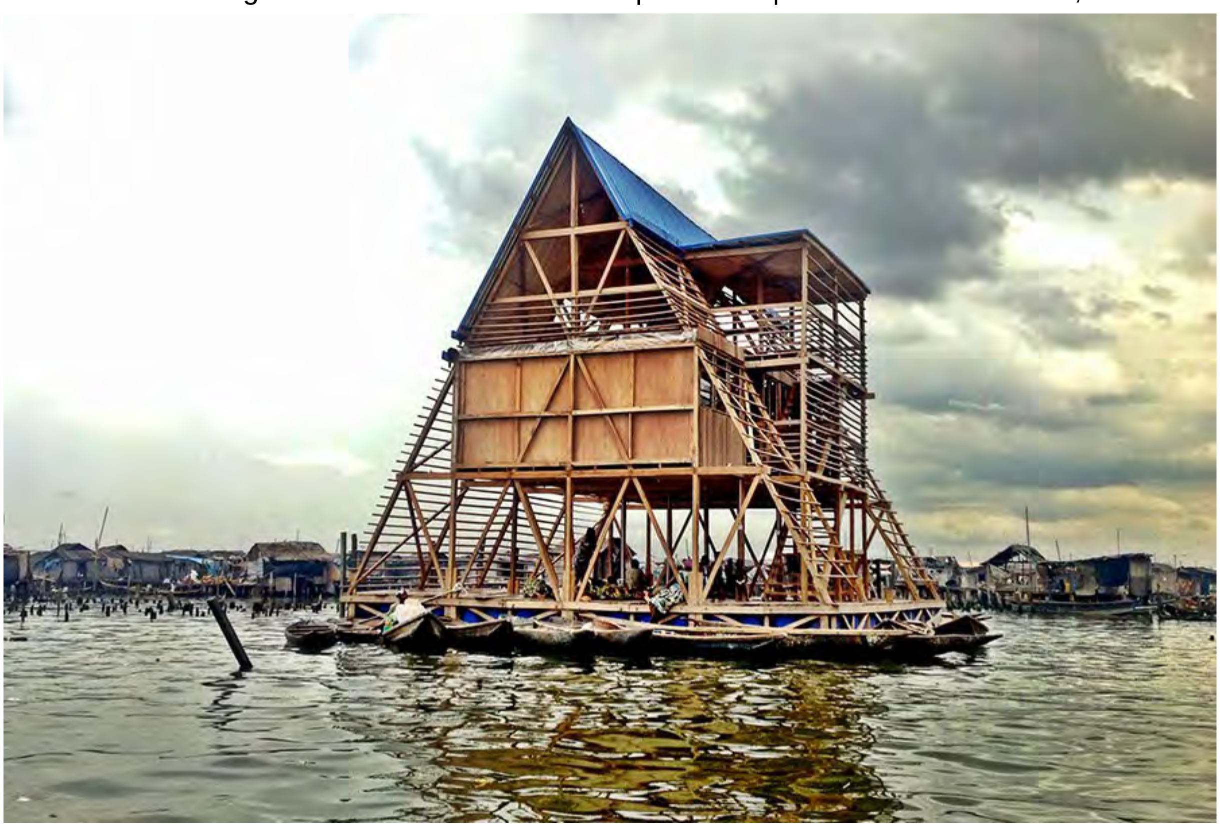


Figure 5.1.1.F Mokoko Floating school, Nigeria by NLE

Source: http://www.metalocus.es/content/en/blog/makoko-floating-school-0 currently involved in constructing a small neighbourhood of 6 homes. They believe the floating city concept- a proposal for the Netherlands - can solve the food-energy-fresh water nexus as the proposed habitats will be self-sustaining in terms of resource production and recycling.

Another such similar self-sustaining approach, but this time through vernacular means has been proposed by the Nigerian Urban Design Group NLE for their homeland, (Makoko Floating school, 2013) where a proposal to build a floating low cost habitat entirely of wood for the refugees of climate change in Nigeria. It will contain small wooden homes, schools and other necessary infrastructure, aimed at the lower income groups. A floating school for 400 pupils has already started operating.

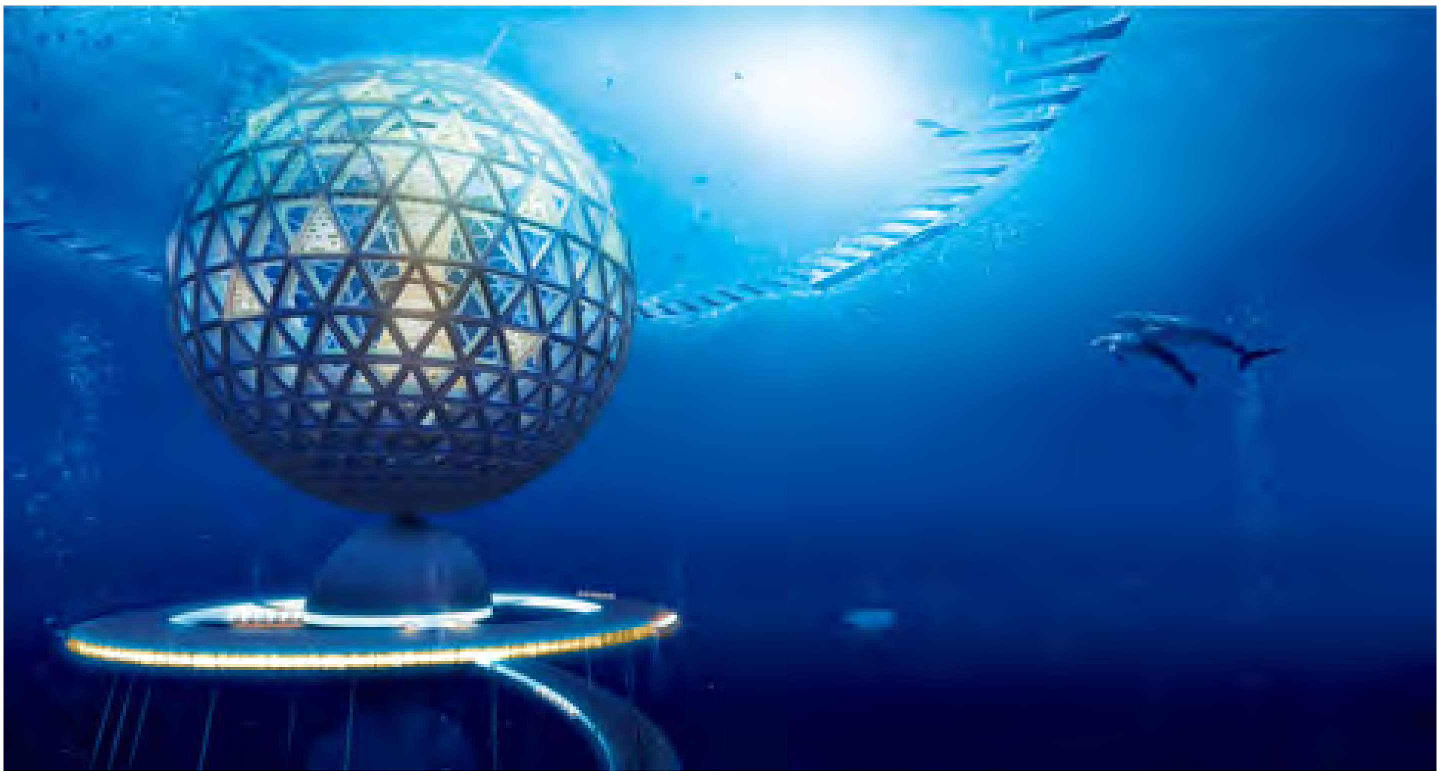


Figure 5.1.1.G 'Ocean Spiral', floating city by Shimizu Corporation, Japan

Source: http://edition.cnn.com/2014/12/10/business/gallery/shimizu-under-sea-city/

One such large scale approach to such an idea has been proposed by a Japanese firm Shimizu Corporation for a utopian floating city that will generate its own power, provide its own food and fresh water and recycle its own resources. ('Ocean Spiral' proposed as giant underwater city, 2014) Designed for the equatorial pacific, Green Float is a concept for a series of floating islands with eco skyscraper cities, where people live, work and can easily get to gardens, open space, the beach and even "forests". Islands are connected together to form modules and a number of modules grouped together form a "country" of roughly 1 million people. Energy for the islands would be generated from renewable sources like solar, wind, and ocean thermal, and they also propose to collect solar energy from space.

Arup Biometrics has designed a semi submerged solution for rising sea levels for Australia, known as the Syph. Syph evolves into a collection of organisms with specialized functions like energy generation and sustainable food production that work together to form a new underwater city.

Apart from these, many other conceptual examples can be helpful in assessing the possibilities of water habitation, like the carbon dioxide absorbing floating tower, floating agriculture land to regulate flooding in the Nile Valley in Egypt, (Silt Lake City by Margaux Leycuras, Marion Ottmann and Anne-Hina Mallette, 2014) and even buildings 'grown' with corals.

Due to the limitation of this paper, only four examples will be discussed and analysed in detail in the following sections.

5.1 Local and abroad

Over the decades, scientists (particularly with a vision to investigate new environments or to further research aims), designers, engineers and visionary people from other fields have all given their fair share of contribution to the development of underwater and floating spaces, supported by the appropriate technology. While most of these have been built in an extremely minute scale in comparison to the undertaking this paper proposes, most of them in fact provide valuable clues and guidelines to the development of exactly such a project. Four examples have been presented for the purpose of this paper out of compiled studies of a pool of examples and cases. Not all the cases presented here have been built in reality.

5.1.1 Floating city

The Seasteading Institute, based in the Netherlands have teamed up with the Dutch 'Aquatecture' firm Deltasync with a strong aim to build the world's first floating city by 2020. (Institute, 2014) As such, they have advanced based on a preliminary design and have already achieved a sufficient amount of crowd funding to finance further design and research efforts. The institution is in talks with various governments whom they have targeted to act as potential hosts for the city. Their proposal is entirely a floating habitat that will grow incrementally at different stages, the last stage enabling the city to become self-sufficient. The entire city has been proposed as a collection of

Figure 5.1.1.H Floating city proposal by DeltaSync in partnership with the Seasteading Institute

Source: http://www.propertyweek.com/first-floating-city-to-be-piloted-in-pacific/5065642.article

individual polygonal platforms joined together in different combination. In brief, the city will be able to float in the high seas, will have characteristics of movability and- according to the institute- will have the ability to rearrange their layout, or have a ‘dynamic geometry’- as the name suggests. The city has been designed as such to use renewable energy sources entirely as a fuel source, and have incorporated some of the most recent technological advances in renewable energy production. Design of the floating megastructure has been given priority at first, with the second most important concern belonging to the economics and the functional feasibility of the entire project. Various options have been laid out for the different inhabitants of the city as far as their housing, transport and food source is concerned. The habitants have also been given choice of ‘shifting’ their neighbourhoods if they so require. The floating city has been envisioned so much as to achieve the status of political independence if permitted by the collective will of its inhabitants.

Advancements in underwater technology have lead architects to search for new styles and concepts. Investors have been demanding for places that grant more than basic functions and includes new experiences for the customers. Underwater resorts and restaurants have revolutionised the design process during recent years. Underwater hotels have emerged as "a different type of lodging". It would be a sanctuary for the curious and adventurous group providing them with a taste of experiencing the unknown. The quest to create new spaces have thus been in continuous practice during the different eras. The concept of underwater design initiated a competition between architects and engineers to become "the first". At present, there are realistic projects that qualify as architectural approaches in underwater design. The design and construction process of these structures vastly differ from the conventional structures on land. Examples of underwater hotels and restaurants in construction and completed are discussed below.

5.1.2 Poseidon Undersea Resort

Left: Figure 5.1.1.I Poseidon Resort from exterior

Source: http://dopepicz.com/14742807-poseidon-undersea-resort-fiji-underwater-hotel.html

Right: Figure 5.1.1.J Interior of a room

Source: http://luxatic.com/the-breathtaking-poseidon-undersea-resort-in-fiji/

Poseidon Undersea Resort is a "permanent sea floor one-atmosphere resort". (Koyuncu, 2007)The construction is ongoing in a private island in Fiji. The structure will be situated 40 feet (12.19 m) below the water level. The interior of the resort remains at continuous surface pressure. The resort is just a part of a complex that includes 20 bungalows and other entertainment functions. The structure is linked to the shore by a service tunnel in addition to the main access via a dock. It was designed by engineers of U. S. Submarines, Inc. a company involved actively in the design and construction process of civil submarine for 13 years. Basically there are two kinds of units in different sizes for different facilities connected with a tunnel acting as a corridor. The underwater structure consists of a central passage and suites, besides service areas with two main units in the form of a submarine attached to it. The main axis (central passage) is a steel cylinder with a diameter of 2.5 m. The main units at the end of the axis have a curvilinear wall and a dome made from acrylic. The suites are 10m x 5.1m and comprise 51m² of floor space. These curvilinear forms are made from steel plates and acrylics. The wall structure consists of a 25 mm steel plate that follows the same curve which is 100 mm thick. The acrylic window sections were set into a steel frame 3.05m in length along the curve and 1.75m wide. The floor consists of two 50 mm steel plate set 600 mm apart. The most important aspect of this project was to maximize the underwater view, and using curvilinear surfaces with transparent material established this concept. The acrylic provides strength as well as transparency in curved surfaces; 70% surface of the suits are transparent. The entrance was designed over the water on the pier. Motorboats transported people; an elevator created access to the foyer and reception area under water through a tunnel. A second tunnel was used for service. The project were designed and constructed as individual modules connected to the main axes. Each suite has an integral high-tech carbon fiber door that opens outward to maintain the unit's watertight integrity. The release of the module is simply accomplished by closing both doors and flooding the space between. The central corridor is permanently fixed to the structural base on the sea floor. On the other hand each unit is “neutrally buoyant”.

5.1.3 **Ithaa Undersea Restaurant**

Figure 5.1.1.K Ithaa Sea restaurant, the Maldives

Source: http://dopepicz.com/25764553-maldives-underwater-restaurant.html

Ithaa- The Hilton Maldives Undersea Restaurant was opened on 15 April 2005 as a part of the Hilton Maldives Resort & Spa sites, in the Indian Ocean on Rangali Island. The structure sits 5 meters beneath the water surface. It is surrounded by coral reefs and provides panoramic underwater view. The restaurant was built by M. J. Murphy Ltd. using the same technology commonly in public aquariums. The whole structure is 9 m x 5 m which was formed from three acrylic surfaces and two steel arches. The steel arches strengthened the structure. Each surface is created from 125mm thick 5m wide and 3m long from acrylic. The acrylic surfaces were sealed and the steel structure with a special underwater silicone sealant and the steel structure is protected by a special high quality marine paint system and a series of zinc anodes. The structure is supported on four 750mm diameter steel piles (concrete filled), which were driven into the seabed. This method was selected to minimize the damage to the already existing reef. The material, idea and construction technique of transparent tunnels in public aquarium was used in the design of this undersea restaurant. There are many applications of acrylic tunnels around the world in various lengths and thickness according to the requirements. The idea, material and construction technique of transparent tunnels in public aquarium was used in the design of this undersea restaurant. There are many applications of acrylic tunnels around the world in various lengths and thickness according to the requirements. Wooden jetty connect the entrance of the restaurant to the shore. The underwater structure can be accessed via a spiral staircase.

5.1.4 Red Star Restaurant

Left: Figure 5.1.1.L Interior of the Red Sea Restaurant

Source: http://elegantliving.ceconline.com/ART_6000016572_340700_EL_01.HTM

Right: Figure 5.1.1.M Entry chamber from the top

Source: http://www.atlasobscura.com/places/red-sea-star

The third structure, the Red Star restaurant sits submerged 20 feet (6.10 m) under water off the coast of Eilat in Israel. The design and construction of steel tank was developed by architect Josef Kiriaty. Interior designer, Ayala Serfaty, turned this space into a restaurant, inspired from aquatic world. The use of color balance the bluish aquatic light. The architectural concept of the project consists of two sections which are above and below the sea. The upper part consists of houses lounge, coffee bar and kitchen while the dining area and bar are located underwater.

The lower body was a steel tank which was built in a shape of a cross, that is, a combination of pentagonal alcoves. The form of the structure allows underwater view through windows to each seat. Underwater views were provided by 62 acrylic windows on steel walls and ceiling. Framed views were achieved by this view ports as in the case of Otter Inn hotel. Visitors reach the entrance space of the restaurant above sea level by means of a bridge Diners descend two levels to the underwater part through the spiral staircase. The underwater structure was constructed from steel plates which were welded together on land and weighted down. Subsequently it was anchored by concrete to the sea bed.

5.2 Analysis and findings

5.2.1 Floating city

The floating city conceptualised by the Seasteading institute provides valuable insight into the parameters needed to be considered during the design of such a large scale ambition and endeavour. The main design considerations were found in the analysis of the development of the floating platform where the programs would be supported on. As such, the firm Deltasync has coined the design consideration factors for the city (to be more specific, the platforms) by the terms movability, dynamic geography, water experience, and sea keeping. The firm has also paid attention to growth development of the city.

Firstly however, the idea to determine the size of the floating platforms were discussed on. The area or in particular, the length of the platform comes from the average wavelength of the waves, whereby it was suggested to limit the platform length to at least double the wavelength on the seas. Any lower than that would sea increasingly aggressive swaying and rocking of the platforms. If the size had got any bigger than twice the wavelength, it would experience high tension and would require tension cables to keep the structure rigid. Since the habitat proposed for this thesis concerns a futuristic time scale, there is a scope to avail the option of technological advancement of the future.

The options for movability of the floating city or the individual floating platforms which the city proposed were shown taking into account current technology only. The options came in the form of towing with ships, the platform being contained in semi-submersible ships and the platforms having the capacity to self-propel themselves. Although the firm would prefer the first option over the others, the capacity for self-propulsion of the platforms seemed the most realistic since in times of emergency, the whole city will be subject to the arrival of a flotilla of tugboats or ships to tow them away from the danger zone. If structures can be made hydrodynamic to a minimal extent at least, it will be possible for somewhat convenient for the towing of the platforms.
The individual platforms have the ability to rearrange themselves and enjoy what the firm terms 'dynamic geography'. This comes from the understanding that the platforms which may exist in different shapes can coexist in different layouts giving it users a certain freedom of changing the landscape and the 'aquatic fabric' of the entire city. This will be worked on in detail in the project. Water experience, or the physiological and psychological connection to the aqueous environment is primarily linked to the above as well. Experience of water depends on the horizontal and vertical proximity to water, and will be focused on as well in the design phase. Protection from the sea, in particular to the action of waves in times of natural disasters is suggested in the form of a sea wall encompassing the entire area of the city.

Apart from the major design decisions, an insight into the incremental expansion and the economic feasibility of the proposed city was discussed. The incremental expansion or the growth development concerned the scale of the city at different stages and concerned different scales of and number of programs at different times.

5.2.2 Underwater habitats

Before evaluating the comparison between contemporary examples, differences between contemporary examples and underwater habitats should be mentioned from architectural point of view since both of them were mainly proposed for the betterment of people. Underwater habitats meant mere shelters, comfort and space. Quality were not considered. Providing separate living, sleeping and bathroom quarters, cooking facility and systems for communication and television indicated the degree of comfort and habitability for these structures. Therefore underwater habitats cannot be stated as architectural examples.

As mentioned earlier, underwater design is an engineering standpoint. The main objective of the studies of engineers was to create structures which can resist higher hydrostatic pressure. Although depth is not important for contemporary examples as for engineering projects; form and geometry of engineering structures were utilized in the examples of hotels and restaurants. In particular, Poseidon Undersea Resort consisted of various spaces with different dimensions since it was proposed as a hotel. Therefore various forms combined according to the function it housed. For suits, form of submarine was used whereas for public functions curvilinear walls with domes were used. Ithaa Undersea Restaurant utilized the technology of transparent acrylic tunnels and Red Sea Star Underwater Restaurant were inspired from underwater tanks. As mentioned previously designing in different environments have their own characteristics, limitations and differences. From this perspective, the basic and most significant matter is form and geometry, since the perception of interior space is related to form and geometry and other design parameters. For the design of space colonies there are two important factors that limit the possible forms. Firstly, the habitat must contain an atmosphere in order to be habitable for human. Secondly, residents must experience an acceleration to provide gravity and this can be accomplished by rotating the colony. Thus, orbital colonies must be rotationally symmetric around at least one axis. This limits the practical shapes to the sphere, torus, dumbbell and cylinder.

Structures are facing wind force, effects of gravity, earthquake and dead and live loads on land. The pressure in the underwater structure should be equivalent to the pressure on land, one atmosphere. Therefore, structure should withstand the hydrostatic pressure greater than inner pressure. That limits the form and geometry of submerged structures. Evaluation relating to degree of enclosure is very important for architectural approaches to underwater design. As noted before, maximizing transparency increases the relation between occupants and environment. This approach should be thought of as one of the main objectives of underwater design. The studies on submarines, transparent tunnels and the contemporary examples led to make an appraisal about the relationship between form and geometry; and the provided view to exterior. From this perspective, selected examples pointed out that transparency of underwater structure is directly related with its form and geometry. Namely, the selection of the form and geometry has an effect on the connection of occupants with the environment. In mentioned examples, materials which have been used in marine constructions were used. Steel and acrylic plastic were preferred for surfaces whereas concrete was used for anchoring and buoyancy. Transparency was achieved by acrylic plastic which had an extensive use in deep submersible and aquarium applications. New materials may be developed with collaborate study of architects with engineers by time to lead new opportunities which can meet the architectural approaches better. Examples were also compared in terms of required technology in order to indicate their practicability. As mentioned earlier using curvilinear forms over the cubic ones is advantageous in terms of underwater view. On the other hand in terms of technology it has disadvantages since it require more advanced technology. When two examples which house same function compared, to construct a design like Red Sea Star Underwater Restaurant is easier since the technology of manufacture of steel tanks can be utilized. On the other hand for a design like Poseidon Undersea Resort or Ithaa Undersea Restaurant that maximizes the underwater view require more advanced technology so it is more difficult to realize. Modular system can be required to design large scale projects which are composed of many units. According to the functions and space requirements different forms will be brought together to form the structure. The advantages of utilizing modular system in underwater design can be listed as: Variations of the project in different sizes can be built by adding or subtracting units. That leads to rise in the number underwater structures. Construction of underwater structures in modules will be functional in terms of emergency and maintenance. During a crack and leakage, there is a possibility that the entire structure will be collapse. To prevent this each module can be isolated in case of emergency. Ease of repair can be achieved by modular system. It will provide the units to be detachable and capable of being removed from the complex when required as achieved in Poseidon Undersea Resort.

In the restaurant, functions were provided in the entrance space and linked with the space housed by submerged structure. That provides integrity between over and lower part of the project. On the other hand Ithaa Undersea Restaurant was unsuccessful from this perspective since only entrance was provided over water and linked by a staircase. There should be additional functions above and staircase links two functions to each other. Therefore, as long as the entrance space of submerged structure is provided over water level, functions should be housed in this space and linked functionally with the lower part. In terms of safety Poseidon Underwater Resort was found successful since it safety dome and emergency entrance for each unit was proposed. In addition small submarines were suggested in critical areas. In other examples, for safety of occupants the strength of the structure and material was designed accordingly. Architectural solutions should be thought together with rescue submarines and divers for these examples. Poseidon Underwater Resort was designed and constructed with modular system which can be stated as successful. Because modular system provide the construction of units on land and subsequently attach to each other or separate under water which lead to advantageous in safety and ease for repair.

Chapter 06

Program and development

6.1 Rationale of the Programme

The proposed design concerns a future habitat built during the timeframe of the 22nd century. However, for lack of technological predictions/accurate foresight, the thesis proposal is built up on existing technology or technology that is still in the research phase. The scenario for economic and social makeup of the future city is subject to the same problem: lack of prediction of the future. As such, existing social and economic systems are taken as a constant factor for the future timeline. Since the development of program depends on all the above, it is imperative that the reasons for the considerations behind proposing the suggested programs are understood.

The futuristic city will house all the zones and functions needed in any mega polis of the current global context. Namely, but not limited to, commercial and residential zones, industrial, recreational, governmental or administrative zones, etc. While the proposed city will contain different degrees of and expand on the above zones in future, for the duration of this thesis, only a particular zone will be designed: the part that produces energy. As mentioned earlier, colonisation of any new places involves three basic steps: military control over the area to secure it, establishment of a communication network and production of resources or energy to sustain the city in the long term. The first step is irrelevant for this proposal, and the second and third stages happen almost with close timing of one another; these are very basic start up components of a city. Hence the energy producing hub. The hub is also alternatively proposed to be able to be built in the current timeframe to produce and supply energy to the existing national grid, as much as technology would allow.

To make the city functionally self-sustaining, the energy producing zone or the energy hub will need to provide accommodation for its employees or workers in the form of housing. Therefore, housing of different scales are being proposed for this energy producing hub since it is expected that employees with varying family sizes and coming from a range of social stratas will occupy this city. Therefore, housing of three different scales have been proposed: namely in the form of a 2 family house, 4 family house and a 6 family house. These are subject to further design development.

In order to support this populace, food and other items will be available at the local stores also proposed. However, food will not be grown in the hub at this stage since it is the primary stage for the growth of the city. As the city expands, other zones will come into being that engage in food production; up till that time, food supply will have to depend on external sources such as existing cities – namely

Chittagong since it is situated right next to it. As such, the program for the stores will mainly consist of storage areas, exhibition areas and administrative zones apart from the main store.

A transportation hub incorporating future transport technology, in particular – flying cars and buses, improves hovercrafts, submerged personal vehicles as well as floating vehicles will be taken into considerations. As mentioned in the start of this section, only those vehicles will be considered that are already exist as prototypes or those that are successful in the primary design phases. This is to bar the program entering the realm of science fiction. Spaces for docking, maintenance, passenger arrival and departure halls, administration and other programs will be taken into account.

A minimum security infrastructure will have to be taken into consideration for this entire hub since will involve at least a few hundred people. As such, a base for an amphibious police force that can operate both on land and water is being considered. This base will host both land and sea vehicles, maintenance zones for them, training and administrative zones and housing for the security personnel.

Religious infrastructure is also incorporated into the energy hub in the form of mosques, churches, temples and pagodas. The scale of the religious infrastructure is subject to consideration.

A health facility will exist on the hub primarily to act as an emergency and primarily health facility. Programs that support advanced treatment will have to be relied on with existing facilities at existing cities, or until such facilities become available in the future stages of the city.

The main program concerning energy production is wholly subject to technological advancements in future. The proposed power cells will seek to produce tidal, wave, solar, ocean thermal energy and wind power from this habitat. It is expected that spaces for equipment needed to operate such power production facility will decrease largely in a hundred years timeframe, and as such, a proposal based on existing technology will surely not apply a century for now. However, program for the power cells based on existing technology will be proposed keeping in mind a certain flexibility of reconfiguring the spaces or enable an adaptive use of such spaces in future. Since this is subject to the design development of the thesis, such visions cannot be discussed currently.

CHAPTER 07

Thesis Development

This thesis progressed in two major phases: the first phase involved study into the different aspects of the final proposal, and the eventual development and establishment of parameters or principles for the thesis. The second phase involved designing a habitat for a particular context, under limitations of a thesis design studio.

7.1 Development I: Establishing the thesis process

The first phase of this thesis concerned setting up the development process besides working on/studying on the different design aspects. It began by a bulk of literature collection relating to major areas such as hydrology, water engineering, material science, renewable energy systems, climate change, water architecture, community of people who live on/at the threshold of land and water, social sciences, and lastly, site conditions. After these areas were initially agreed to be studied upon, it was possible for a basic thesis development process to be established.

The basic process involved understanding how the future habitat will eventually grow out of.
Generally, changes in habitat occur due to a complex combination of environment, human psychology and lifestyle, each affecting the next in a logical progression. This can occur in two distinct ways: if the habitat evolves, then it is seen that the natural and the man-made environment affects human psychology, which brings about changes in our lifestyle, that ultimately goes on to affect our habitats. In an alternate setting, if the habitat is the result of a sudden change, then it is seen that the impact of the natural and man-made environment is too direct on the development/change of the habitat itself, with which human psychology and lifestyle tries to cope with.

In both the cases, this multidisciplinary thesis requires the involvement of scientists, architects, psychologists and social scientists among others for a holistic construction of the year 2100 scenario. As this is an architectural thesis however, only the role of the architect has been explored in constructing the built environment of that time. As such, studies of the natural & manmade environment has been done at first, beginning with the people, or the future residents of the envisioned habitat. At one stage, the Bangladeshi nation has been attempted to be understood from an architect's perspective.

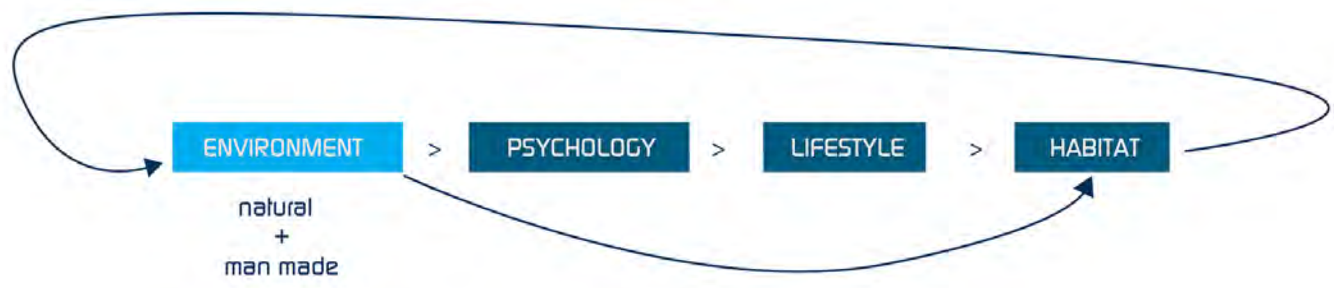


Figure 7.1.A General thesis process

As mentioned earlier, study of the natural and the man-made environment involved looking into existing and proposed habitats, water engineering, social sciences and site conditions. The rationale was established upon climate science, which involved looking into issues of land inundation, overpopulation, food shortage, climate refugees, intense weather condition. Studies of existing and proposed habitats/architectures, some of which have already been discussed, involved studying different categories of structures such as undersea research facilities, undersea habitats, submerged hotels, submerged museums, floating cities, floating high-rises, traditional habitats, power plants, research centres, multimodal transport terminals, passenger sea ports.

Studied areas of water engineering includes hydrology – more specifically – chemical hydrology, surface hydrology, water quality, oceanography, ocean engineering factors such as buoyancy, water & air pressure, stability & anchorage, volume consideration, density of building material, etc. Life support systems for the submerged portion, including, physical environment, chemical environment, biological environment and utility systems. Building materials were studied on, and so were renewable energy possibilities, aiming to incorporate different forms of renewable energy such as solar and wind power etc. Since this will be a habitat on water, a huge emphasis was given to tie the programmatic functioning in general and the ecology of the habitat with the water, and thus wave energy, tidal energy, ocean thermal conversion energy (OTEC) was given high priority in incorporation within the design. Technology that are not yet in commercial use, but are in the process of being developed such as harnessing electricity from the trees, or using a water habitat comprising of flora and fauna to recycle black water. These have been done so from the understanding that such emerging technology have the potential to be in common use in the next century. Also, incorporating of technology into this habitat that already exists in the laboratories was agreed on as being a cautious approach to designing this highly technology based architecture/habitat, otherwise the design might risk falling into the realm of science fiction. The use of technology will be discussed with more detail in future.

At one point, a habitat was decided to be designed on a specific area that is either submerged in the 22nd century, or is in the open sea. Factors of consideration of site forces included depth, seabed topography, water pressure, proximity to coast (urban areas), proximity to marine resources, water quality, existing marine habitats, current and tide flow, etc. Communication and transportation technology were the main areas of technology that was looked into for designing the habitat. As far as future technology is concerned, a debate results on the extent of incorporation of technology into future visions of living on a water habitat, due to our incapability to project future technology. Such debates that often stirred up during design reviews almost always presented two extremes: the incorporation of existing technology only, as a result of which the entire habitat will inherently and intrinsically be something more of the present than the future. The other extreme involved designing the future habitat with technology that does not result from the evolution of any existing technology, and as such, risks turning the design into mere science fiction. A balancing act was therefore required, for one incorporated a certain amount of rationality needed to be present in all design parameters, while entirely compromising on the other devoid the project of the realm of thought and creative thinking, not to mention the very notion that this design is meant for a hundred years into the future. As such, existing communication and transportation technology gave projections on the future scenarios of these two fields, which will discussed in the 3rd chapter.

Human sciences study included looking into the scenario of future education, future family structure, the stance of organized (and unorganized) religion in the next century, and the economic and political standing a hundred years from now. As like before, the past and existing scenarios of such cases were studied to derive hypothesis and projections on the future.

The following diagram assists in a better overview of the first phase of the thesis development process:

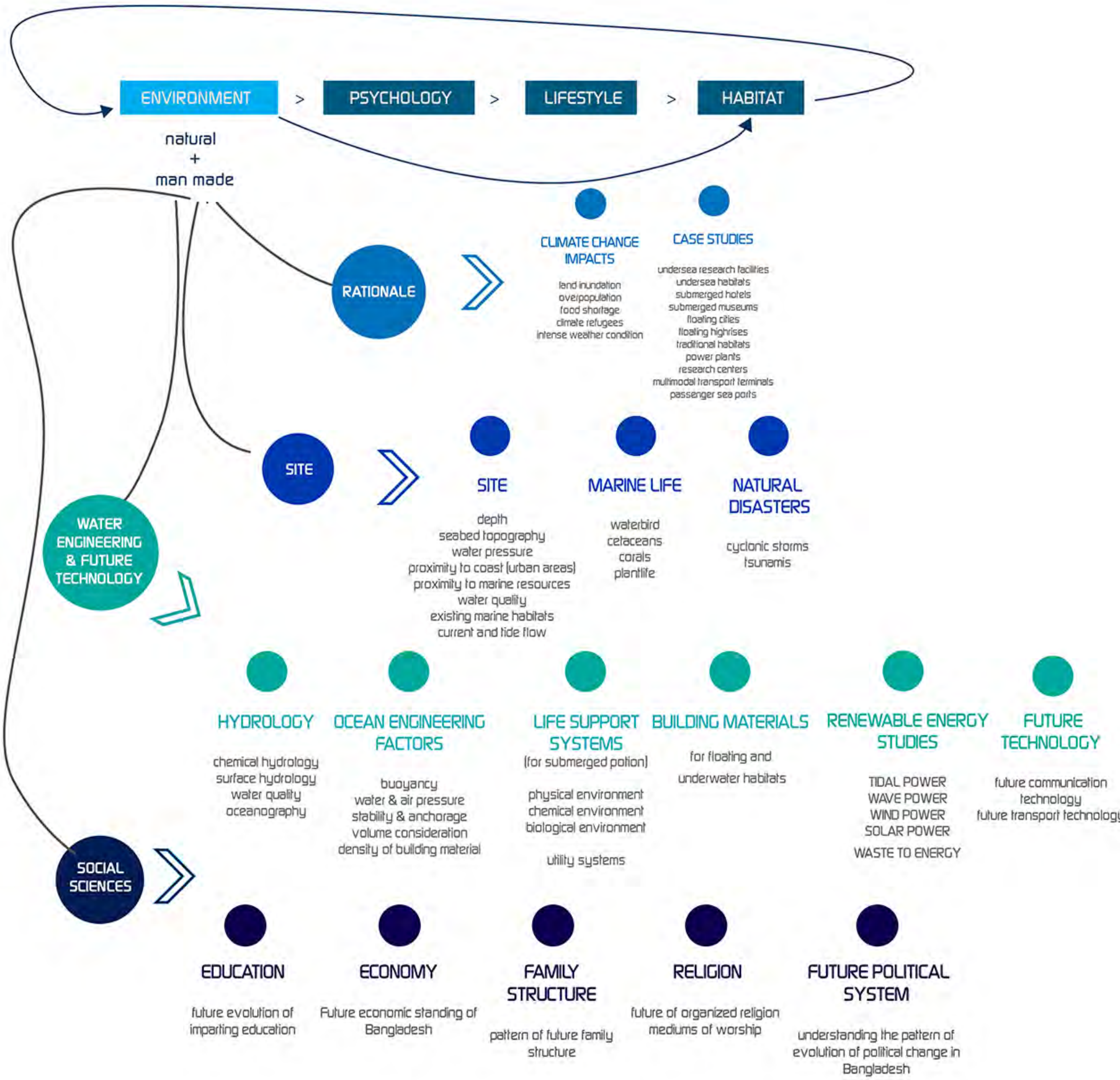


Figure 7.1.B Detailed thesis process

7.2 Development II: Major design factors

The second phase involved studying in more detail, more important areas of the design in order to establish basic design parameters. These mainly included design aspects of underwater and floating habitats, materials and the design of an ecology. Human health and life support systems were also looked into.

7.2.1 Underwater structure design

Major factors relating to underwater design includes water pressure and ambient pressure, stability, anchorage, maintenance of vertical equilibrium, and the aspect of a decompression chamber. Water pressure is a major factor of concern for any underwater structure, and this increases linearly with the depth. The chart below shows how water pressure increases with depth.

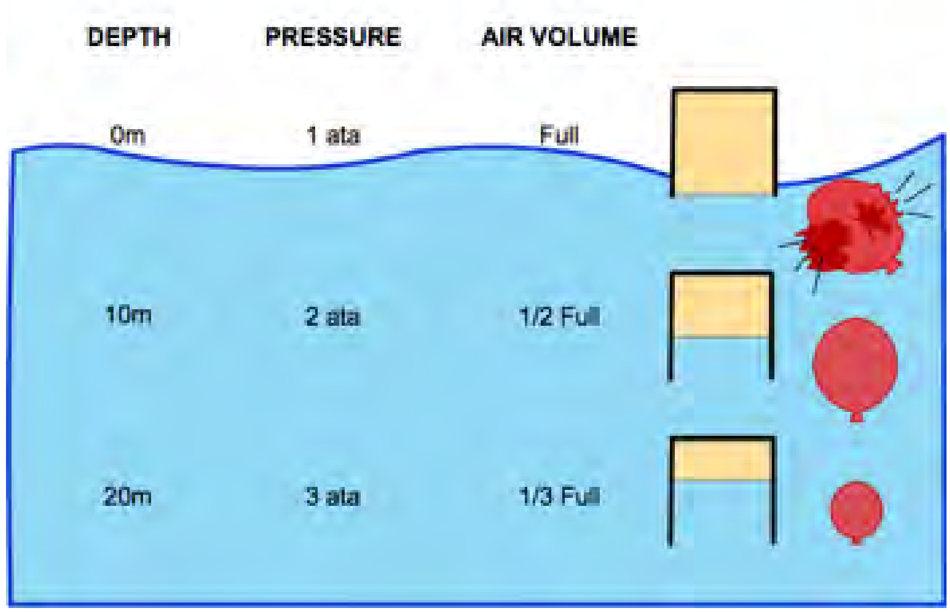


Figure 7.2.1.A Variation of water pressure with depth

Source: explorecuriocity.org

To design for such changes, technology gives us the scope to design for an ambient pressure, whereby the local pressure at a particular depth can be used as the interior pressure as well, thereby reducing the hydrostatic forces on the shell or outer casing of the building. Designing with ambient pressure also gives the scope to design for direct interaction with water, for example, the floor of an underwater space can be an open to the water itself, enabling a programmatic scope of anything between an underwater vehicular docking station to a swimming pool. In such a case, the interior air pressure has to be kept greater than the pressure of the water at the bottom to keep the water out. Designing with ambient pressure however, presents hazards to human health since humans would be breathing an altered composition of air when under the ambient pressure of water. As such, they will need to undergo decompression procedure in a decompression chamber/space before returning to the surface.

Stability is another major issue, and a stable submersible structure will have a center of gravity below the center of bouyancy. Also, stability due to the resistance to rolling is directly proportional to the increasing distance between the center of bouyancy and center of gravity. Such princinples help construct a stable object that minimised vertical and horizontal movement. This is closely related to the idea of buoyancy (which in this particular case involves achieving vertical equilibrium for the whole habitat). It is a state of equilibrium between the uplift, the weight of the structure and the anchorage to resist the current forces and resist the uplift in positively bouyant structures, better represented by the following equation:

Weight + Vertical component of the anchorage force = water

Anchorage is the other major issue that determines the health of an underwater structure. The submerged structure needs anchorage to achieve horizontal and vertical stablity. Horizontal forces from waves and sea currents are called drag. They are of two types: frictional drag and pressure drag. Frictional drag is minimised with smooth surface finishes. It is best to distribute the anchorage points along the perimeter of a stable dwelling, again based on current technological developments.

A diagrammatic summary of the above would be as such:

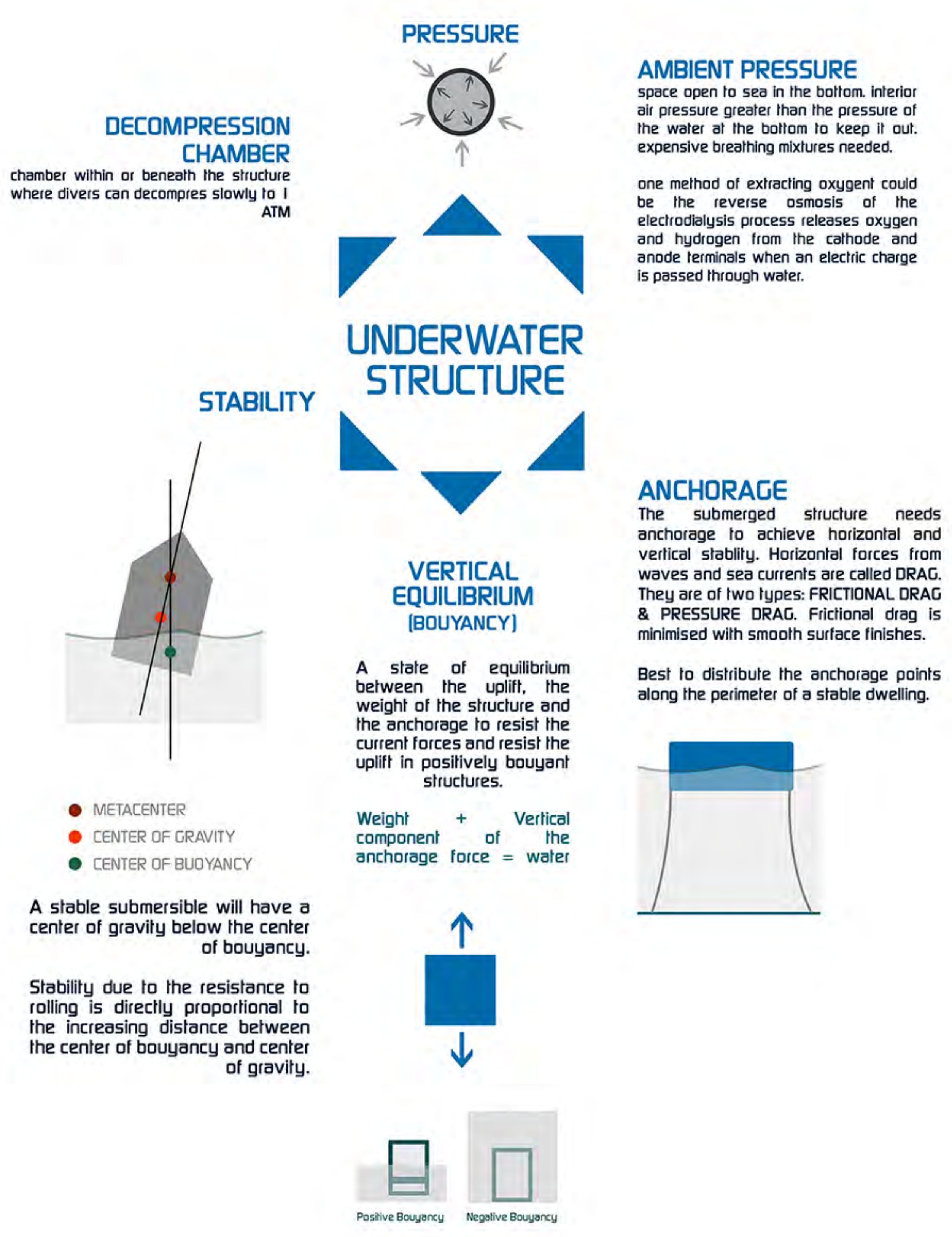


Figure 7.2.1.B Major determinants of underwater structure design

Compiled

When considering possible underwater shapes, ocean engineers suggested that either a sphere be employed for the dwelling form, or a tear or blimp shape with a length to diameter ratio of from 5 to 7. The former because of its superior structural capacity and the latter to minimize frictional drag.

The merits of a circular structure in terms of access, circulation and internal arrangements led to its selection. An alternative, for reducing drag in a circular, ellipsoidal structure, is to link a number of them together in groups along a line parallel to the current flow by tethering.

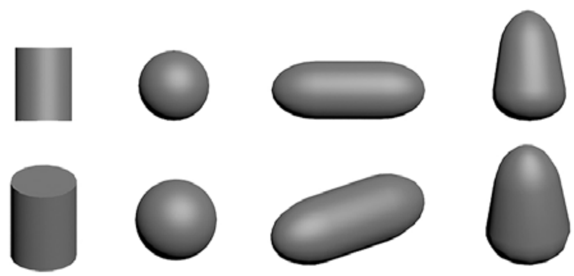


Figure 7.2.1.C Possible shapes of underwater structures

Looking a bit more closely into the sections of underwater marine life, it is seen that the most common thriving species conform to either circular or elliptical cross sections, as seen below:

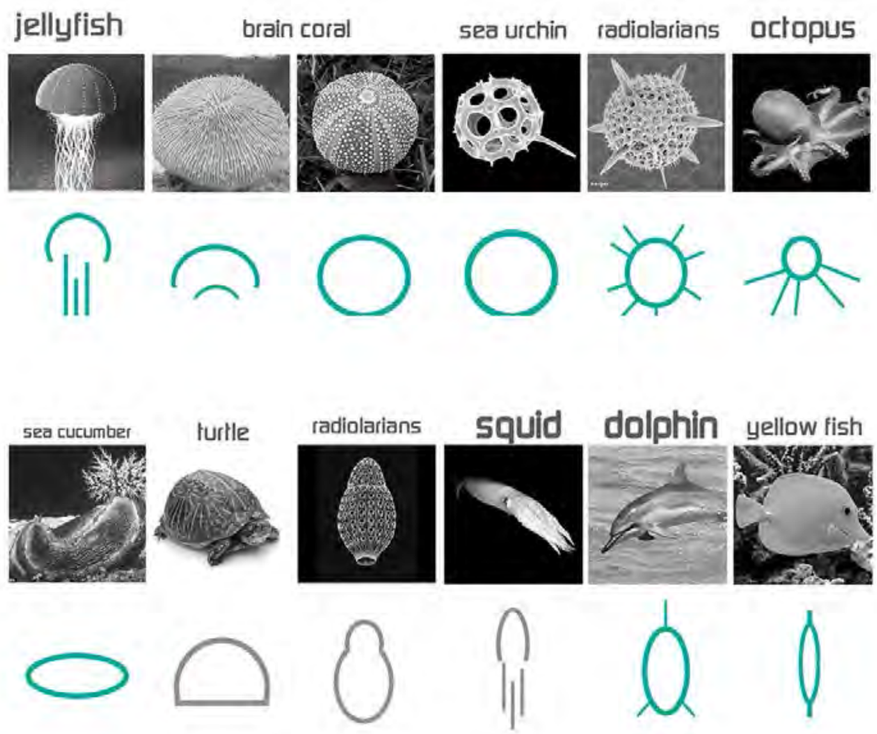


Figure 7.2.1.D Study of shapes of marine species

7.2.2 Floating structure design

Major considerations for a floating structure design includes designing for the spatial layout, designing for mobility, stability, buoyancy and of course, structural optimisation.

As far as the mobility of the water structure is concerned, the type and number of mooring connections and interconnections between platforms; connections, both to the ocean floor and in between different platforms are vital to the feasibility of a floating habitat. Mooring connections will keep the habitat stationary. In between the platforms there will be several types of connections: structural connections, utility connections and bridges. In order to enable emergency relocation, these connections not only need to be strong and flexible, but also easily disconnected.

The hull resistance to water during transportation is another important issue. Whether movability is feasible will also depend on the amount of resistance in the water. When platforms are towed during relocation, the shape of the hull will affect the amount of resistance and thus the amount of power that is required for propulsion. A larger platform requires greater structural height and a larger part of this height will be submerged, resulting in increased draft. This means that increasing the size of the platform will exponentially increase the resistance.

Lastly, the mechanism of movement is a concern, for the reason that the floating structure should be able to move away quickly and the mode of transportation should be one that is available at any given time. Considering technological advancements in the 22nd century, a self-propulsion system is proposed.

Stability along with buoyancy and strength are precursors to safety. Stability is a measure of the platform's resistance to tilting. When waves or other forces tilt the platform, the center of buoyancy moves to the direction of the tilt, because this side now displaces more water. The upward buoyant force will counteract the tilting motion and in combination with the downward weight of the platform, it rotates back to its equilibrium. The distance between the forces of buoyancy and gravity is referred to as the righting arm. A larger platform has more resistance to tilting, because more water needs to be displaced in order to tilt the platform. A structure that is less than half a wavelength in size will tend to mostly follow that wave; if the structure is more than twice the wavelength, its response will tend toward zero.

As in the case of an underwater structure, buoyancy presents itself as huge factor. Bouyancy is an upward force exerted by a fluid that opposes the weight of an immersed object. In a column of fluid, pressure increases with depth as a result of the weight of the overlying fluid. Thus a column of fluid, or an object submerged in the fluid, experiences greater pressure at the bottom of the column than at the top. This difference in pressure results in a net force that tends to accelerate an object upwards. The magnitude of that force is proportional to the difference in the pressure between the top and the bottom of the column, and (as explained by Archimedes' principle) is also equivalent to the weight of the fluid that would otherwise occupy the column, i.e. the displaced fluid. For this reason, an object whose density is greater than that of the fluid in which it is submerged tends to sink. If the object is either less dense than the liquid or is shaped appropriately (as in a boat), the force can keep the object afloat. The following diagrammatic representation summarises the above:

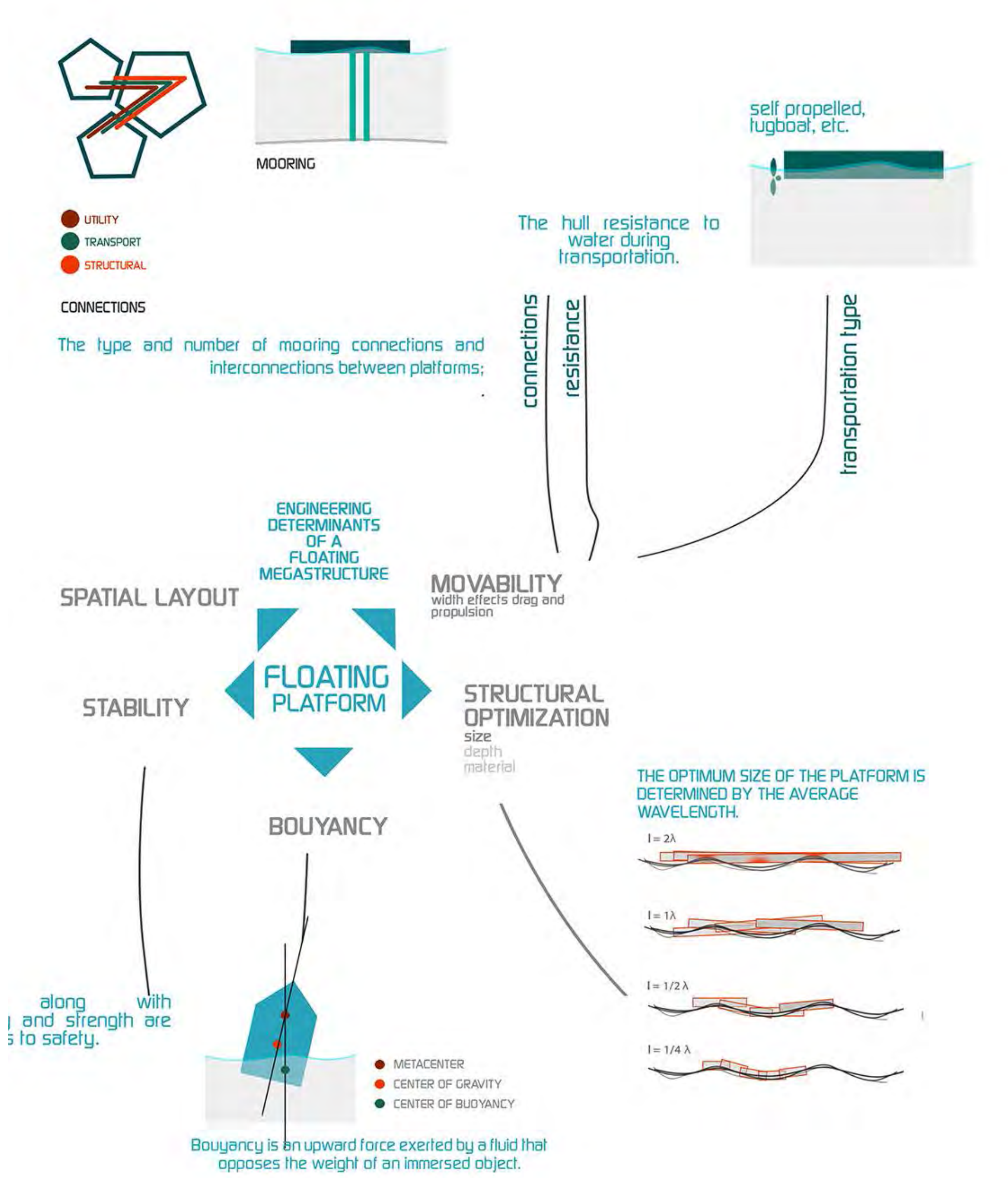


Figure 7.2.2.A Major determinants of floating structure design

Compiled

7.2.3 Other design aspects

Apart from the core engineering considerations discussed about above, more human experiences of the habitat and the water, and the development of the architecture and the urban spaces of such a habitat remains the primary area of concern for such habitats. Such studies were dealt with by the Seasteading institute, an organization with similar aims of building and establishing floating cities on the seas. These factors are described in the following sections - based on different urban arrangement scenarios - presenting advantages and disadvantages for each:

DYNAMIC GEOGRAPHY: A floating habitat can enable greater freedom at a city level, on the community level, or individual level. This can be achieved by possibilities for moving inside the habitat with one's own house as an individual, or even moving away from the community with a group of inhabitants.

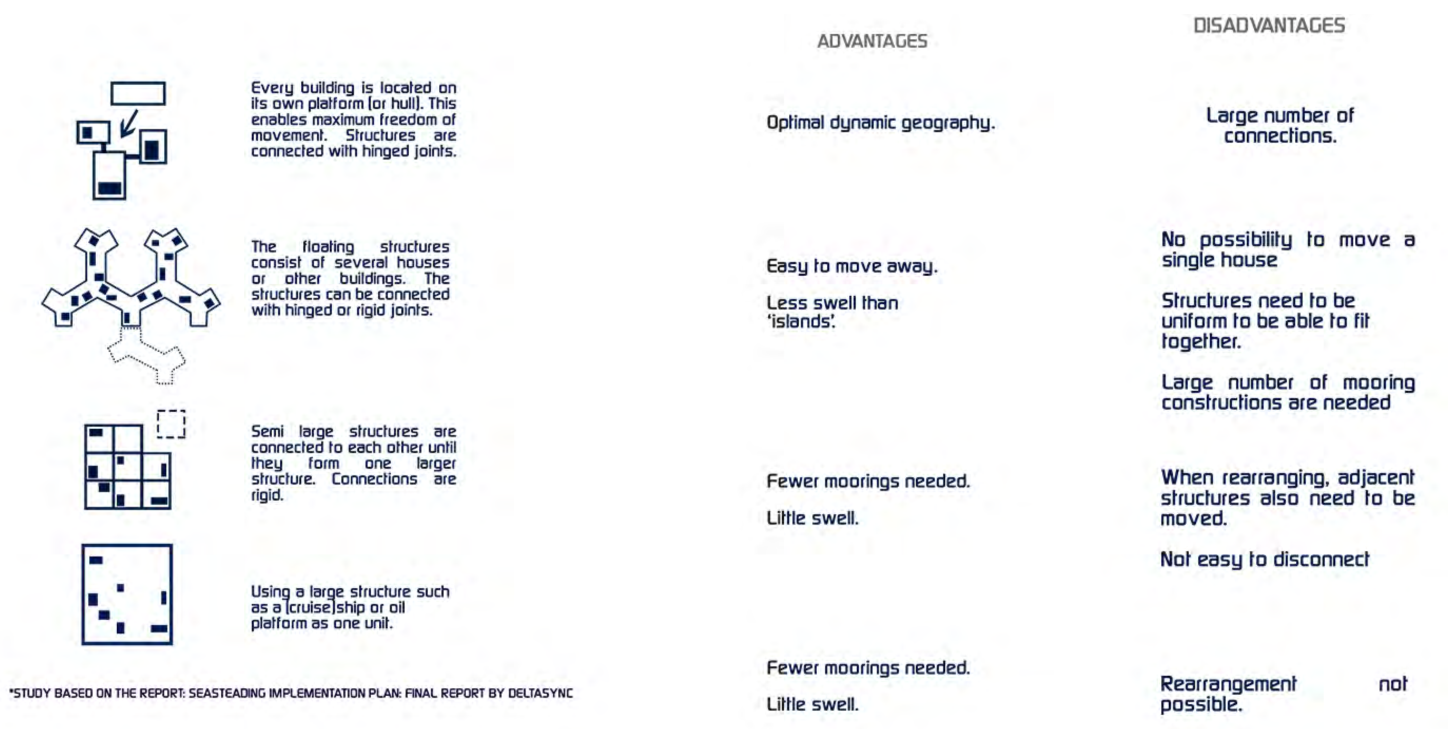


Figure 7.2.3.A Advantages & Disadvantages of Dynamic Geography

Source: DeltaSync

WATER EXPERIENCE concerns the visual and physical experience of water and the inhabitants, namely, but not limited to swimming, 'future boating', diving, fishing, etc.

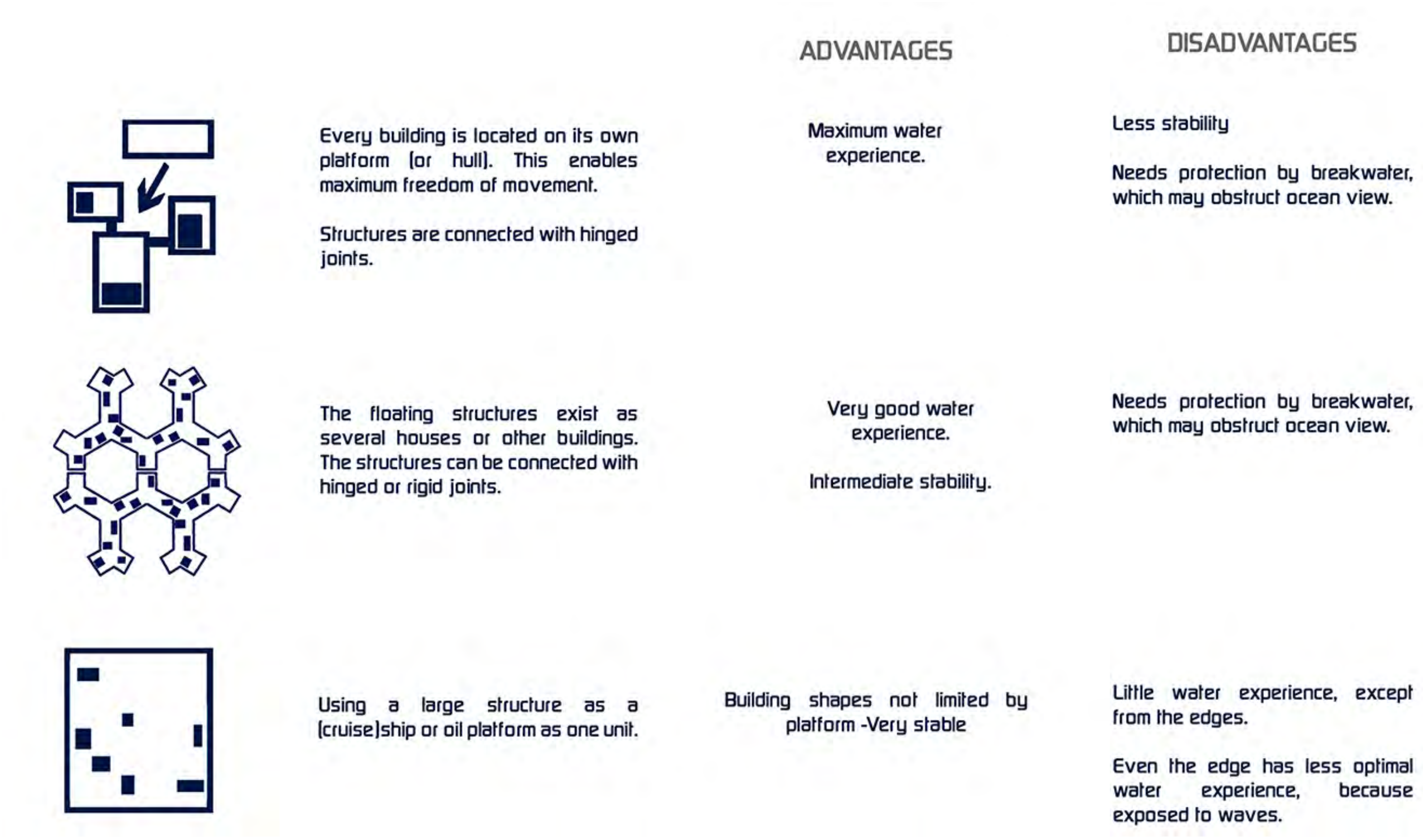
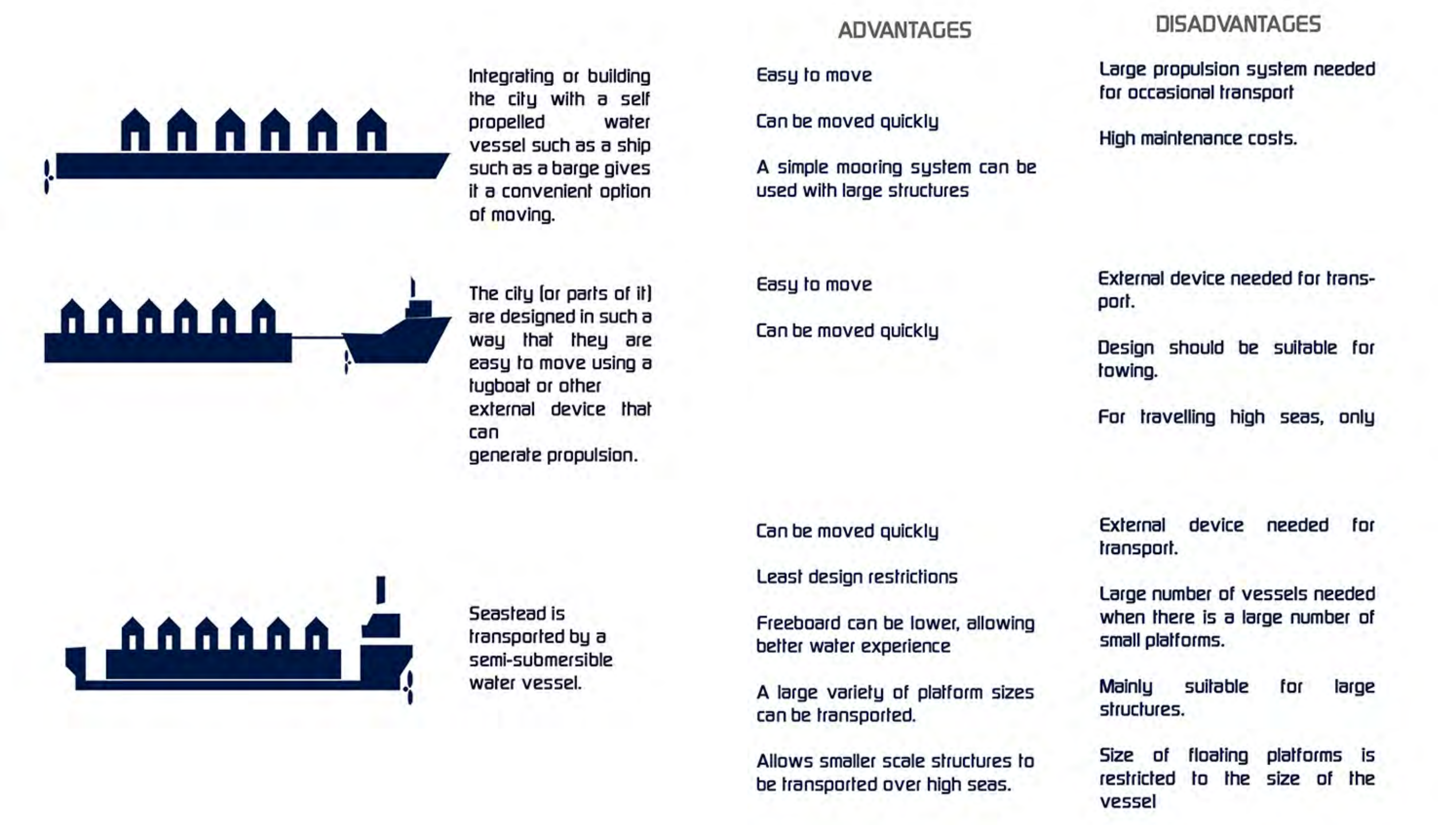


Figure 7.2.3.B Advantages & Disadvantages of Water Experience

Source: DeltaSync

MOBILITY is needed to avoid hazardous weather, or to move to areas with more potential for a greater yield of renewable energy, etc. The most important design qualities in terms of movability are the speed, safety, and convenience of the movement. Semi-submersible ship can also transport smaller structures over high seas. The Blue Marlin, for example, has a deck space of 63 m × 178.2 m (207 ft × 584.6 ft) and a deck area of 11,227 m2 (120,850 sq ft).1 The largest semi-submersible ship is the Dockwise Vanguard (Boskalis) which is 70 x 275 m and suitable for extremely heavy loads.



		ADVANTAGES	DISADVANTAGES
	Integrating or building the city with a self propelled water vessel such as a ship such as a barge gives it a convenient option of moving.	Easy to move Can be moved quickly A simple mooring system can be used with large structures	Large propulsion system needed for occasional transport High maintenance costs.
	The city (or parts of it) are designed in such a way that they are easy to move using a tugboat or other external device that can generate propulsion.	Easy to move Can be moved quickly	External device needed for trans-port. Design should be suitable for towing. For travelling high seas, only
	Seastead is transported by a semi-submersible water vessel.	Can be moved quickly Least design restrictions Freeboard can be lower, allowing better water experience A large variety of platform sizes can be transported. Allows smaller scale structures to be transported over high seas.	External device needed for transport. Large number of vessels needed when there is a large number of small platforms. Mainly suitable for large structures. Size of floating platforms is restricted to the size of the vessel

Figure 7.2.3.C Advantages & Disadvantages of Mobility

Source: DeltaSync

SEAKEEPING is a term exclusively used to describe the ability to survive severe sea conditions in a protected bay, or to be able to adapt for survival on the high seas. Major issues on the high seas are the depth, the large (rogue) waves and (tropical) storms. These factors present challenges for mooring, wave breaking and comfort.

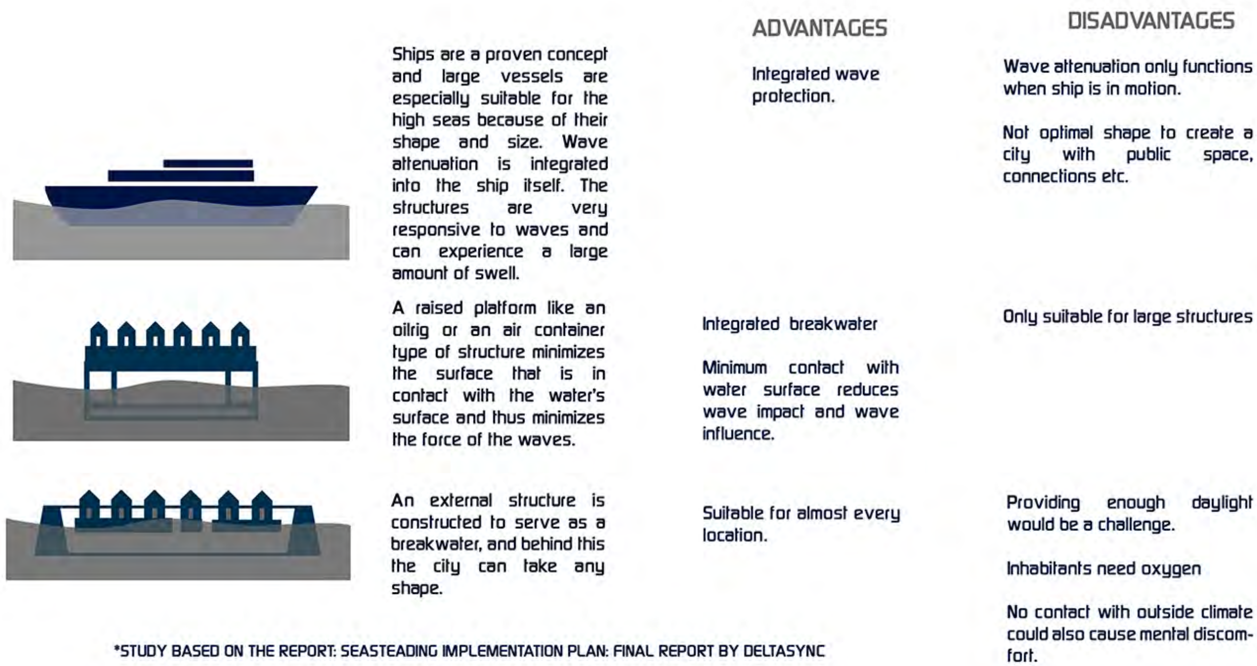


Figure 7.2.3.D Seakeeping

Source: DeltaSync

GROWTH DEVELOPMENT of the habitat is another major issue to be looked into. Looking at the previous sections, roughly two types of structures can be distinguished: large structures developed at once and modular structures that grow gradually. The 'ship' or 'raised platform' structures need to be constructed and financed at once and are difficult to expand. Smaller structures, which may be protected by a breakwater or combined to one large structure, allow for much more gradual growth. For a gradual strategy, a modular system consisting of smaller parts is more suitable than large structures that are constructed at once.

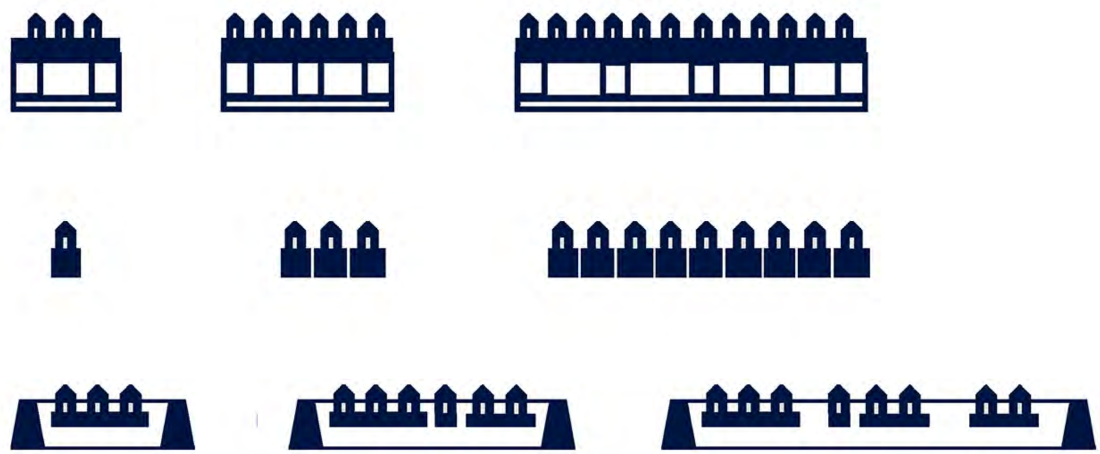


Figure 7.2.3.E Growth Development

Source: DeltaSync

Lastly, a series of anti-sinking mechanism was designed in favour of a safer habitat. The following diagrams not only outlines general safety features such habitats can be designed with, but the overall planning and steps to be taken to minimise human casualties in case of sinking. Increase in the depth of tiers represent a more serious level of emergency:

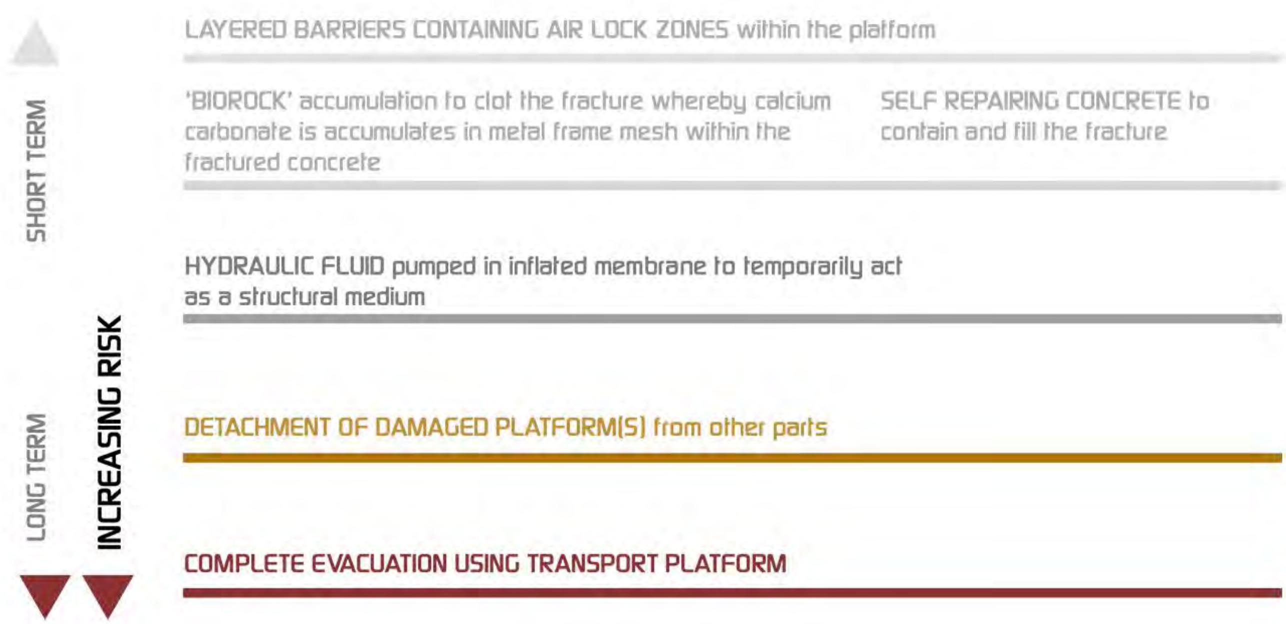


Figure 7.2.3.F Anti Sinking Mechanism

Possible scenarios affecting a structure due to soil failure underwater is also described in brief the following diagram:

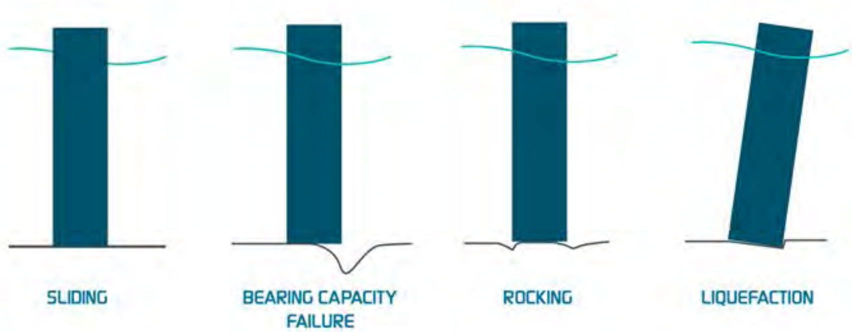
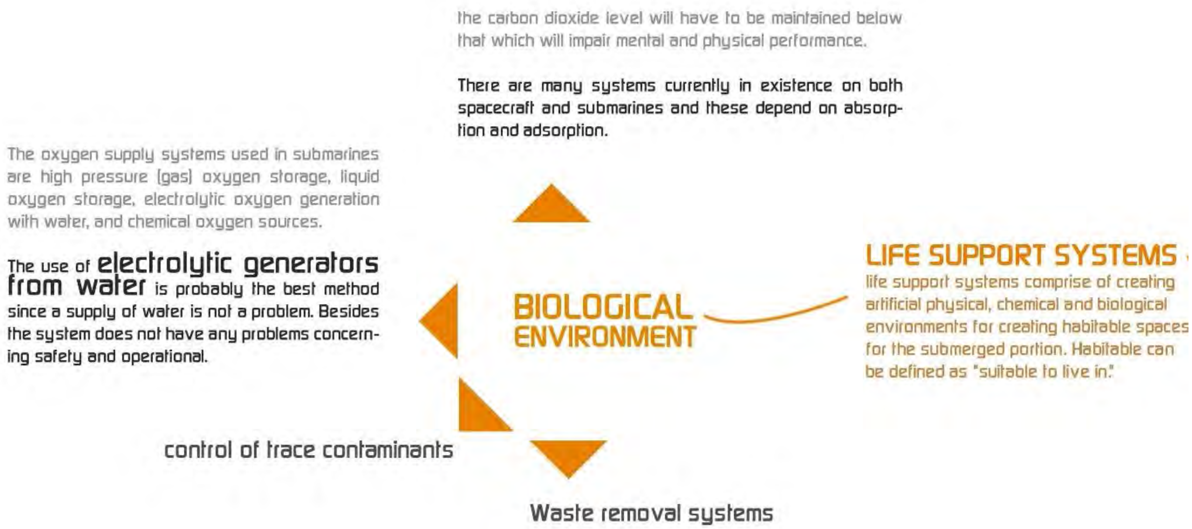


Figure 7.2.3.G Possible soil failure

7.2.4 Health concerns & life support systems

Replicating living systems underwater included replicating biological and the physical environments underwater.



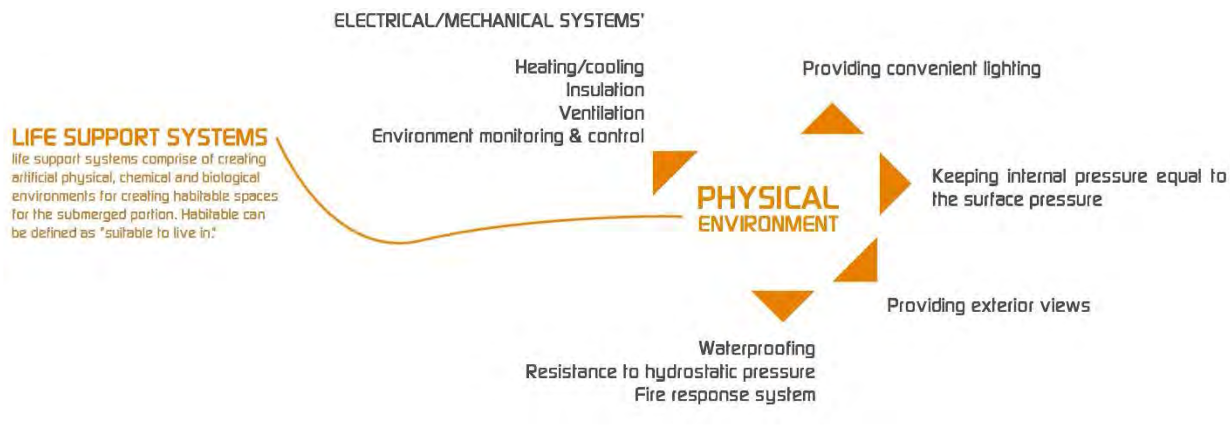


Figure 7.2.3.H Life support systems

7.2.5 Underwater structure design

Considering possible materials for water or underwater construction led to the following considerations based on which materials can be selected: High strength, good sound absorption quality, resistance to corrosion, fire protection, density, fabrication properties of the materials and lastly durability. A water habitat, be it over or under water needs to incorporate the above features. The materials in consideration below presents scopes for construction of the proposed design in the current time, however, it is expected that in the future timeline of a hundred years, material science will develop many folds to result in materials unforeseen in today's time that will present more possibilities for such types of construction. However, looking at today's time, possible materials, either in commercial use or undergoing testing in the laboratories with which such structures can be built with are namely acrylic, carbon based composites, concrete, hydraulic lime, metal and biorock. Each material comes with its own possibilities and disadvantages.

ACRYLIC: The extensive use of transparent acrylic plastic (polymethly methacrylate) in deep submersible and aquarium applications were seen during the last 20 years. Important characteristics of the material are being strong and transparent. Another plastic material which was stated as promising for future use is polycarbonate with its superior resistance to impact.

COMPOSITES: Fibre-reinforced polymer composites are used in engineering structures such as aircrafts, spacecrafts, submarines, automobiles, trucks and rail vehicles, require more stiff and strong materials with less weight.

- the advantages for use in pressure hulls over the use of steel include reduced weight, superior corrosion resistance, improved hydrostatic strength, and reduced electrical and magnetic signatures.

- improvements in design, fabrication and mechanical performance of low-cost composites raise the use of composites for large naval craft and submarines.

CONCRETE: Reinforced concrete has had a long history of use in ocean structures. Most prominent are the North Sea platforms, Condeep, Ekofisk and Seatank. Barge type structures, cofferdams, bridge pontoons, sea walls and foundations are other structures which have employed available data for design and construction with concrete.

Floating drydocks, cargo vessels1 car ferries and pleasure craft have all been built of concrete. Not only as a cost cutting measure though, as reinforced concrete has other positive. The advantages of concrete include the fact that the compression due to the pressure of the sea is readily resisted by the concrete, it adapts readily to any shape; it also has rnoldability. It sas the greatest amount of strength and rigidity with the maximum amount of elasticity.

There is no more liability of failure in concrete than for any other structural material which is properly designed and constructed. By far, concrete's best asset in sea structures is its long life compared with either steel or wood. It is absolutely impervious to sea water action. It is resistant to corrosion and sea boring animal life.

HYDRAULIC LIME: Corrosive sea water can attack concrete in a number of ways. Free lime in cement combines with magnesium sulfate of the sea water forming. Calcium sulfate which, being larger in size than concrete, has a bursting effect on it. Puzzolane and other cements which are free from a surplus of lime and also contain a surplus of silicic acid, which is able to bind free lime, show high resistance to seawater—induced corrosion. Of the Portland cements, Type I and Type III serve well in the design of fresh water craft, the latter where high. early strengths are desired. Type II, modified Portland cement with its low percentage of tricalcium aluminate is resistant to the action of sulfates thus suitable for use in sea structures.

METAL: High tensile steel is mostly used in the constructions of submarine pressure hulls and the main problem is the increase of wall thickness among large diameters. As a result the weight of vessel rises and the vessel becomes to have no reserve buoyancy. Aluminum alloys are preferred as a construction material because of their availability, low cost and being easy to fabricate. The main disadvantage of this material is being vulnerable to corrosion when used in mixed structures because of their chemical properties.

BIOROCK: Biorock, also known as Seacrete or Seament, is a trademark name used by Biorock, Inc. to refer to the substance formed by electro-accumulation of minerals dissolved in seawater.

- Applying a low voltage electric current to a submerged conductive structure causes dissolved minerals in seawater, principally calcium, magnesium and bicarbonate to precipitate and adhere to that structure. The result is a composite with mechanical strength similar to concrete.

- Biorock structures can be built in any size or shape depending only on the physical makeup of the sea bottom, wave, current energies and construction materials.

-Grows cement-like engineering structures and marine ecosystems, often for mariculture of corals, oysters, clams, lobsters and fish in salt water.

- It works by passing a small electric current through electrodes in the water.

- The structure grows more or less without limit as long as current flows.

7.2.6 Proposed Ecology & integration with program

It was decided in principle to design a habitat that coexists with water and as a part of nature as a whole. As such, one of the main determinants of success set for this project was in its integration into the ecosystem of the context in which it will exist. For that, the habitat itself needed to be an important actor in the ecological cycle of the site, and for that, different forms of renewable energy in the form of wind, solar, tidal, wave, OTEC, electricity generation from trees were used as design elements for the habitat. They were not used as separate engineering mechanisms, rather were directly interpreted as architectural spaces. For example, the place of worship simultaneously acts as a solar powered electricity generator, with the concentrated solar light beams used as a center around which worshippers of different spiritual entities can gather. One such use of the light beam could be of a mihrab needed for an orthodox Muslim prayer congregation. Another such interpretation is the place of knowledge, which also simultaneously acts as a tidal lagoon. Knowledge is passed and nourished through virtual reality provided by future hologram technology that feeds all five senses. Individualised learning or virtual reality compartments tending to individual students can float on the water of the lagoon at high tide, and the mobility on water also allows for such cubicles or compartments to join together to form an incrementally growing learning space for group learning. At low tide, when the lagoon will be emptied of water, the cubicles will fall to the base of the lagoon, which will then act as a field. Also, wave energy producing elements have simultaneously been used as landscape elements along the water edges. Natural systems that use flora and fauna to recycle black water have been used to form recreational spaces such as parks. The community swimming pool has been designed as a rainwater harvesting pond.

The following diagram presents the proposed ecological cycle of the habitat, and is further subdivided into five distinct subcycles, namely cycle A: the cycle recycling black water, cycle B: the cycle producing biofuel from algae farming, wastewater and nutrients, and its conjunction with the water desalination plant, cycle C: the cycle of different non renewable energies producing electricity, cycle D: the cycle of rainwater harvesting, and lastly, cycle E: the cycle of accumulating carbon from water and dead marine species for biorock accumulation on the structure.

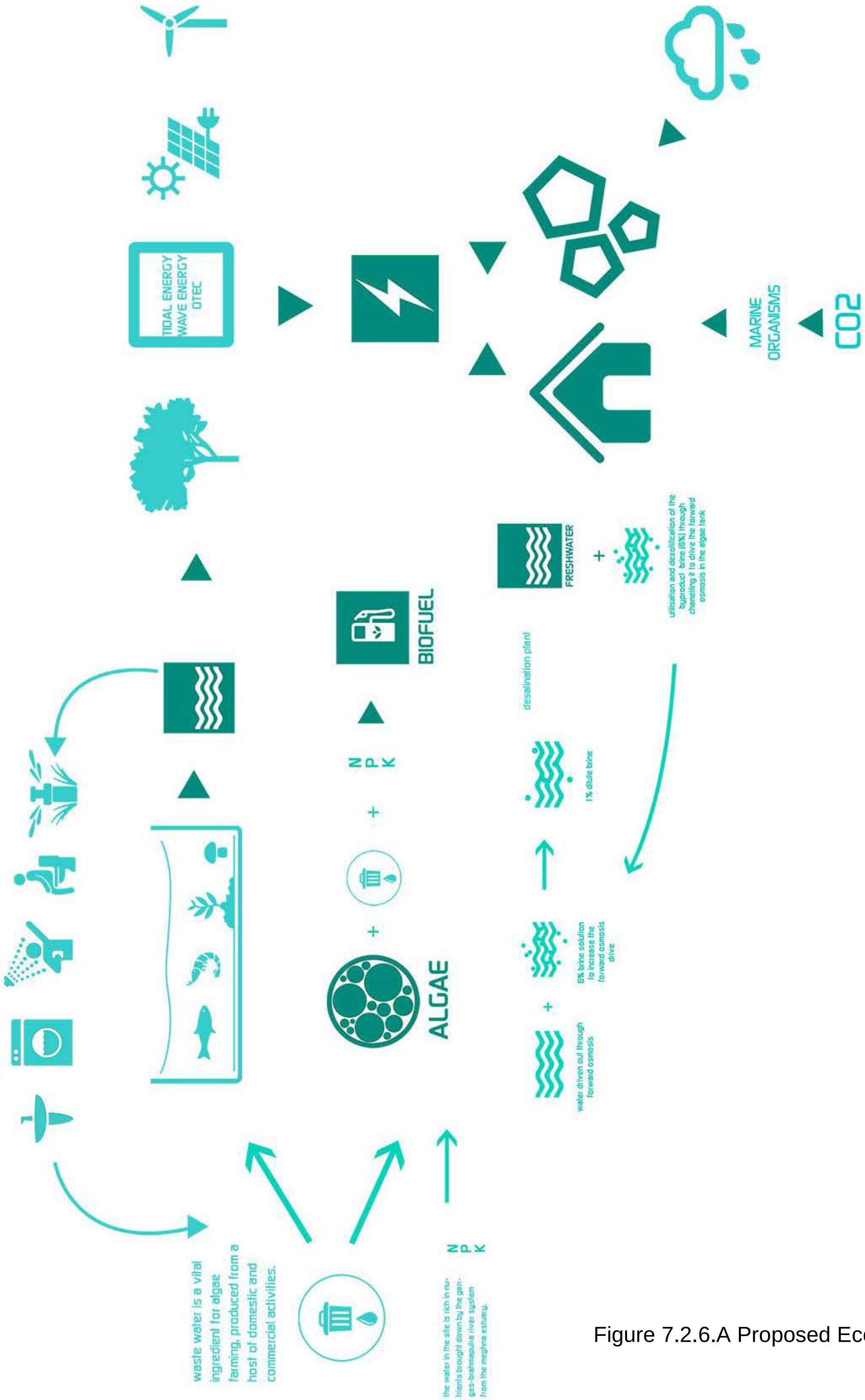


Figure 7.2.6.A Proposed Ecological Cycle

The individual ecological elements, their system of work and the scope of their potentials have been discussed below:

Cycle A (Living Machines): Greywater is wastewater from non-toilet plumbing fixtures such as showers, basins and taps. Blackwater is water that has been mixed with waste from the toilet. A person produces 121 Litres per day of waste water. Wetlands are water cleaning machines. Different ecosystems—such as those in streams, ponds, marshes, and tide pools—have remarkable capacities to self-clean and self-repair.

Living Machines comprise of a collection of tanks that hold different aquatic ecosystems. The tanks are teeming with grasses, algae, live plants, goldfish, freshwater shrimp, and snails, as well as a wide variety of microorganisms and bacteria. Living Machine System mimics the tidal estuary process

Wastewater progresses through the different tanks, which are linked through connector tubes. Wastes generated by the residents of one tank flow through the connector tubes and become food for the residents of another. After about a week of filtering, the waste is broken down into nutrients and food for algae, bugs, snails, and aquatic plants. The formerly mucky water is now considered gray water.

Cycle B (Biofuel production & Water desalination): The Bay of Bengal receives a huge influx of nutrients from the Ganges-Brahmaputra river system every year. Those nutrients could be used as inputs by floating cities to grow algae and produce food and biofuels.

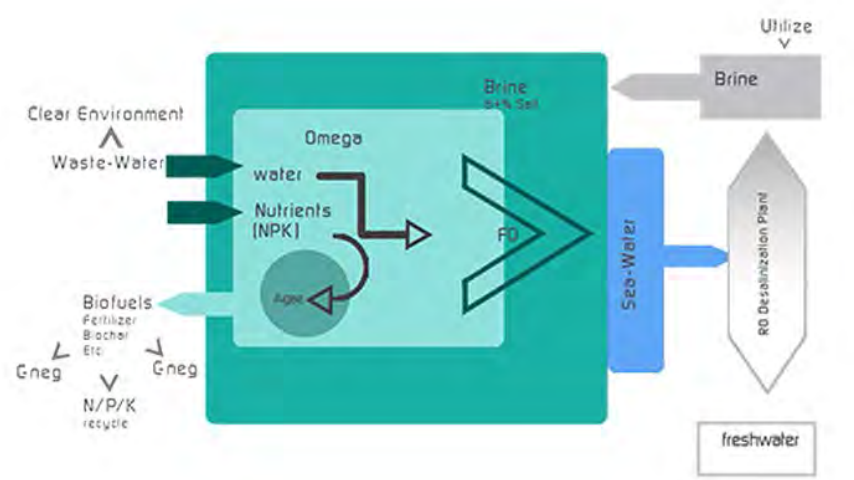


Figure 7.2.6.B OMEGA System

Source: NASA

Biofuel can be produced on the water, 10 to 20 times more efficiently than crops. Biofuel production from microalgae has a lipid content of around 40%, giving biodiesel yields of 40 to 50 tons per ha per year.. This means that a floating city could be able to produce energy through the reuse of waste products as wastewater and CO2.

Floating algae and seaweed farms could be constructed within the seastead. OMEGA(Offshore Membrane Enclosure for Growing Algae) is a collection of closed photo-bioreactors constructed of flexible plastic that can be filled with treated municipal or agricultural wastewater that would normally be discharged into the ocean. The modules float on the sea surface, maintaining the algae in ample sunlight. Forward osmosis membranes allow clean water to diffuse out of the bioreactors, leaving inside an algal paste, which can be easily harvested and processed into biofuels.

The water desalination plant produces a brine solution of 6% concentration that can be used to drive the forward osmosis of clean water in the OMEGA system. This mixing would dilute the brine, and filter out the clean water to a more drinkable state after which it can be chanelled to a desalination plant for fully turning it into a drinkable state. This system would work since the production of the 6% brine would take the same amount of energy as it would take to dilute the brine with the clean water from the OMEGA system.

Cycle C (Non renewable energy sources):

Tidal energy: The waters of the Bay of Bengal along Bangladesh’s coast have tides the semi-diurnal type of tides, ie two high and two low tides during the period of 24 hours and 52 minutes. The average height of tidal waves at the deltaic coast of the Ganges it 4.7 m. The average ocean current speed is 0.3m/s. This leaves a a huge potential for utilising tidal energy for production of electrical power. Tidal energy can be produced through mainly 2 distinct ways: Creation of a tidal barrage or lagoon, and the creation of underwater turbines known as tidal arrays, or similar systems that moves with the ocean current. Both can be integrated into the landscape of the floating habitat to create an engaging urban textures as well as to generate power.

Wind energy: The sea presents itself with a huge potential for wind power production. The Bay of Bengal receives an average of 2.2m/s. Wind technology in the 22nd century is expected to develop dramatically to produce a greater amount of electricity for the same amount of wind, although it is subject to future wind pattern. Wind turbines, if placed at higher altitudes will be able to generate more power than the ones operating at a lower height. Apart from turbines, wind can also be produced by piezoelectric poles that sway.

Solar energy: The site is situated entirely within the tropical belt and thus receives ample sunlight throughout the year, thus creating a huge potential for solar energy production. The average number of sunshine hours in neighbouring Chittagong city ranged from 5.1 to 6.9 hours since 2000 to present time.

Recent developments in solar energy integrates photovoltaics into fabric or even transparent glass, apart from the increasing efficiency of conventional solar cells. Development of cells that do not require direct sunlight have also been in progress.

Wave energy: Bangladesh has favorable conditions for wave energy especially during the period beginning from late March to early October. Waves generated in Bay of Bengal and a result of the southwestern wind is significant. Maximum wave height of over 2 meter with an absolute maximum of 2.4 meter were recorded.

Electricity generation from trees: Simply sticking electrodes into a tree can produce electricity, albeit insignificant at the current technology. A tree can gener ate anywhere betwen a few hundred milivolts to around one volt, however, if development of this technology in a hundred years timeline will immensely increase its potential

Cycle D (Rainwater harvesting): The area around the site received an average of 100mm rainfall for the last one and a half decade, with the maximum rainfall of over 200mm recorded in July and the lowest under 50mm in winter season. Rainwater harvesting has a promising potential for use in homes, offices and industry.

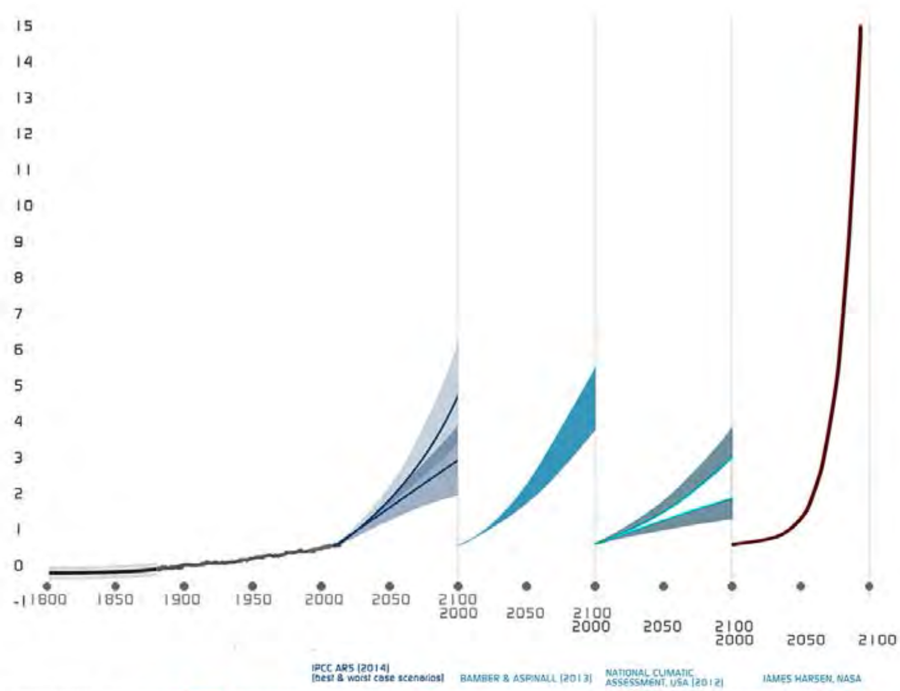
Cycle E (Biorock accumulation): The mechanism of this has been described in detail in section 7.2.5. Due to lack of data and scientific research in the particular topic, a projection of the scope or quantity of biorock within the chosen site could not be determined.

7.3 Development III: Hypothesis & Projections

Based on all the previous studies, existing projections of the concerned future time were used to deliberate on a few hypothesis, based on which the actual structure can be designed. Both these projections and hypothesis serve as design parameters. The most profound hypothesis is the one that asserts that the seas will continue to rise in future, with a 5m rise by 2100 being the worst possible scenario for Bangladesh. The following hypotheses ranging from multidisciplinary fields such as climate science, social sciences, technology, education, etc, has been backed up by researched facts.

HYPOTHESIS A: SEA LEVELS WILL RISE IN FUTURE.

The worst case scenario projection for Bangladesh is a 5m sea level rise within the end of the 21st century, submerging about 28 % of the existing landmass.



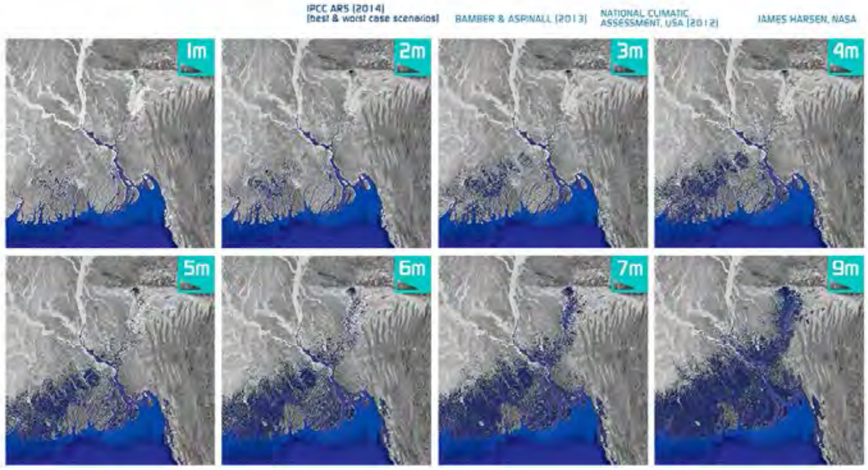


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Figure 7.3.A Sea level rise projections

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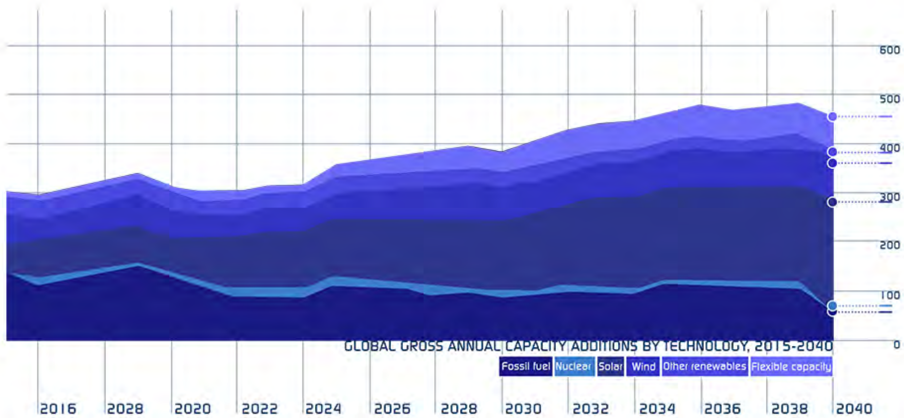
Figure 7.3.B Bangladesh land inundation due to sea level rise

Source: Google

HYPOTHESIS B: THE WORLD WILL RELY MORE ON RENEWABLE ENERGY FOR ELECTRICITY.

Although petroleum products are expected to last till the end of the century on a global scale, the world will switch to renewable energy sources much before that



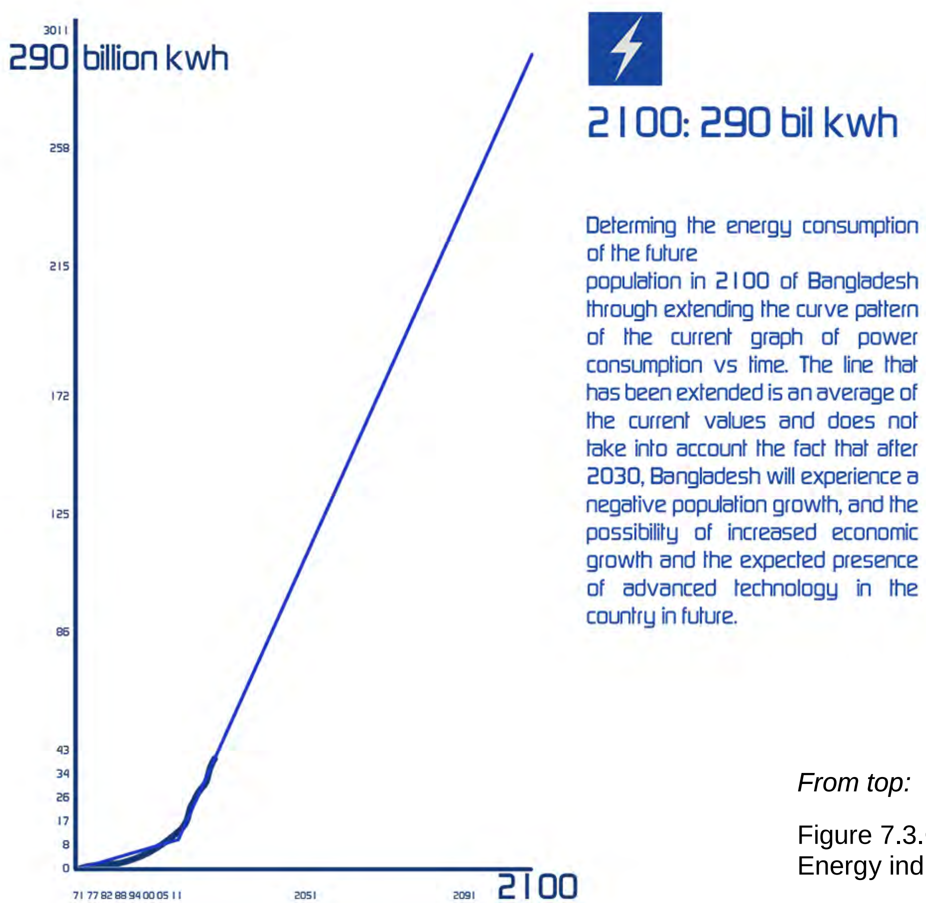


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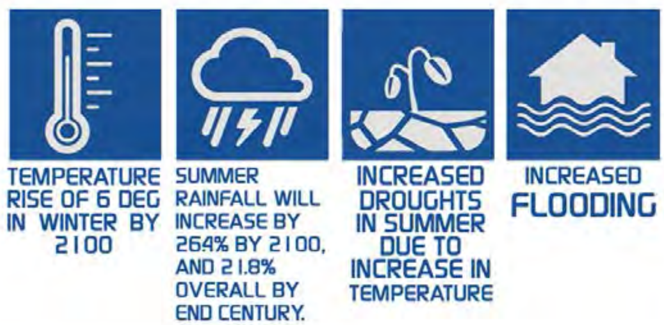
Figure 7.3.C Growth of Renewable Energy industry

Figure 7.3.D Projection of future power demand in Bangladesh

HYPOTHESIS C: CLIMATE CHANGE WILL CAUSE EXTREMITIES IN WEATHER.

The average temperature and humidity in Bangladesh will rise by 2-3 degrees by 2100. Precipitation will also increase by. The six seasons will be lessened to. Cyclones will increase in frequency and quantity.



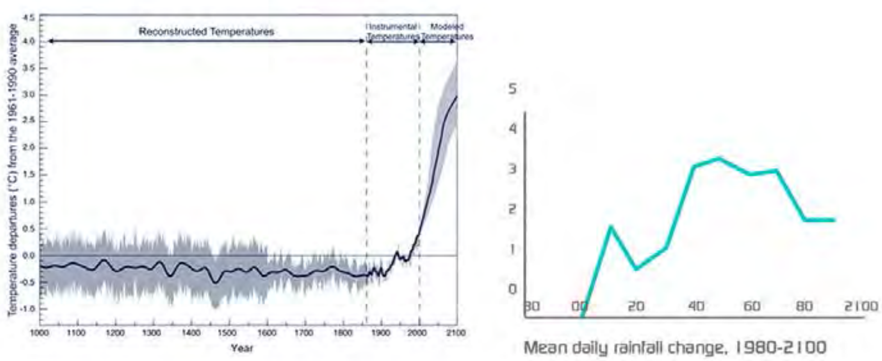


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Figure 7.3.E Future temperature projection in Bangladesh

Figure 7.3.F Projection of future rainfall in Bangladesh

Other major impacts of climate change includes a sharp increase in cyclonic storms. Climate change is expected to increase both the frequency & the severity of cyclones and the storm surges by 2050. When combined with an expected rise in sea level, cyclone-induced storm surges are projected to inundate an additional 15 percent of the coastal area.

Freshwater crisis will surface with the intruding salinity, creating a shortage of drinking water. Changes to water resources and hydrology will have a significant impact on the country’s economy, where people mostly depend on the surface water for irrigation, fishery, industrial production, vavigation and similar other activities.

Bangladesh's total forested area will decrease with the rise of sea level, especially in the south western regions where the Sunderbans are situated. The loss of forests will also threaten a loss of valuable ecology with land species particularly threatened.

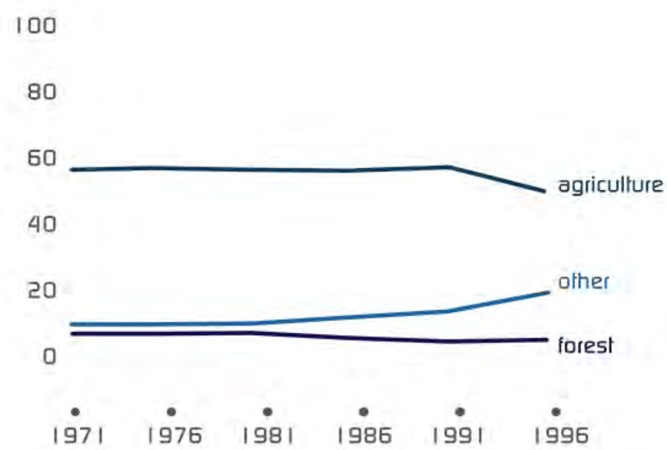

Figure 7.3.G Decline in land use for agriculture, forestry and other vegetation in Bangladesh

Rise in sea levels mean agricultural land will decrease, creating a crisis of food shortage.

The invasive salinity from the Bay of Bengal will further stress the nation's capacity to feed itself. Extreme Temperature, Drought, and Salinity Intrusion etc. are also responsible for the declining crop yields in Bangladesh. Temperature and Rainfall changes have already affected crop production in many parts of the country and the area of arable land has decreased to a great extent.

Figure 7.3.H Invasive salinity in Bangladesh

HYPOTHESIS D: TECHNOLOGY WILL DEVELOP MANY FOLDS.

Technology will increase many folds, and will accelerate non linearly. Vehicles pemitting three dimensional movement will be in wide use. Communication technology, in particular hologram technology will develop. So will health technology.

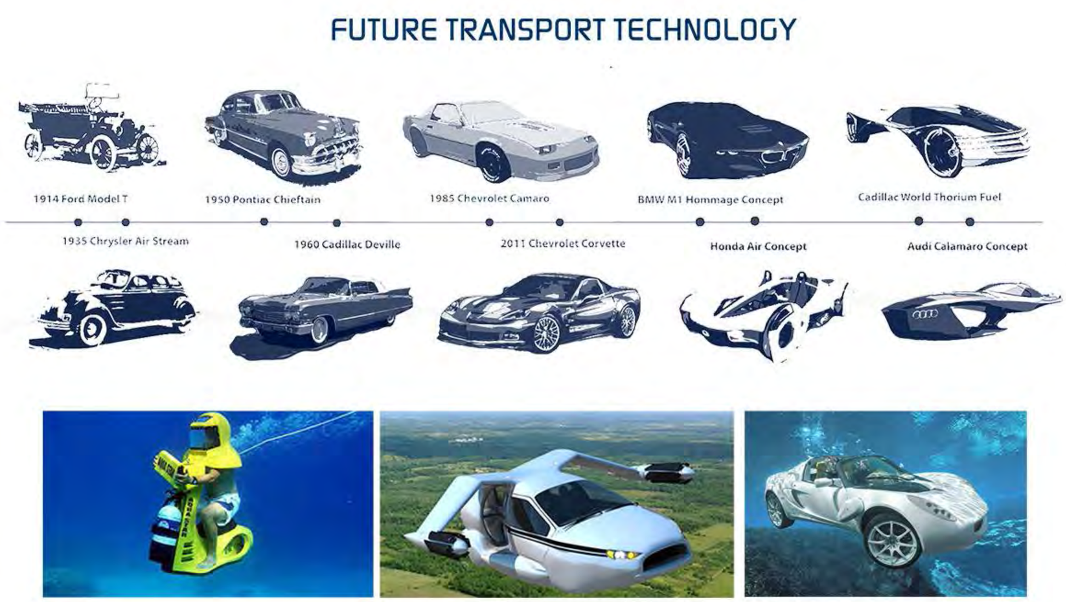

Figure 7.3.I Future transportation technology

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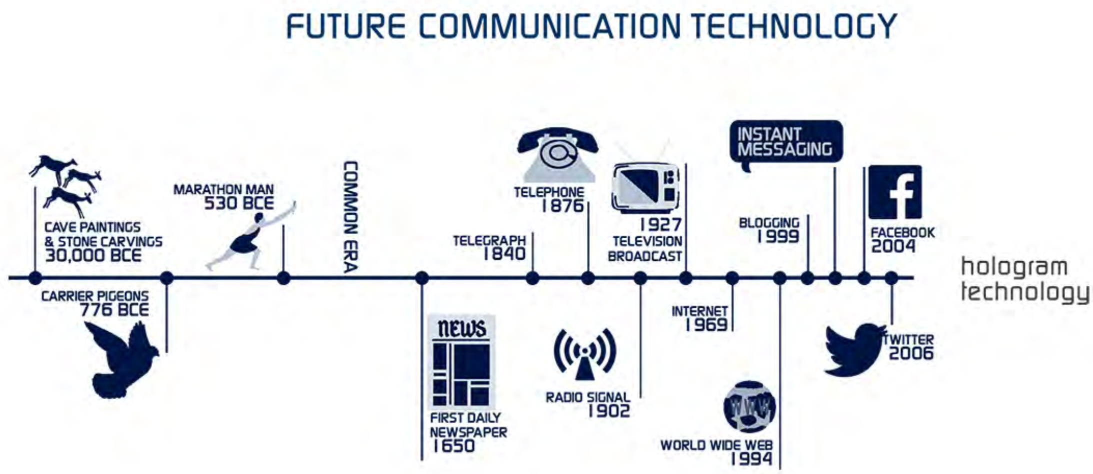

Figure 7.3.J Future communication technology

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HYPOTHESIS E: EDUCATION WILL BECOME MORE PERSONAL, COMMUNICATED VIRTUALLY.

Education will be more personalised with priority given on indiidual learning. Centers of learning will have closer association with industry. Knowledge will be communicated through virtual means.

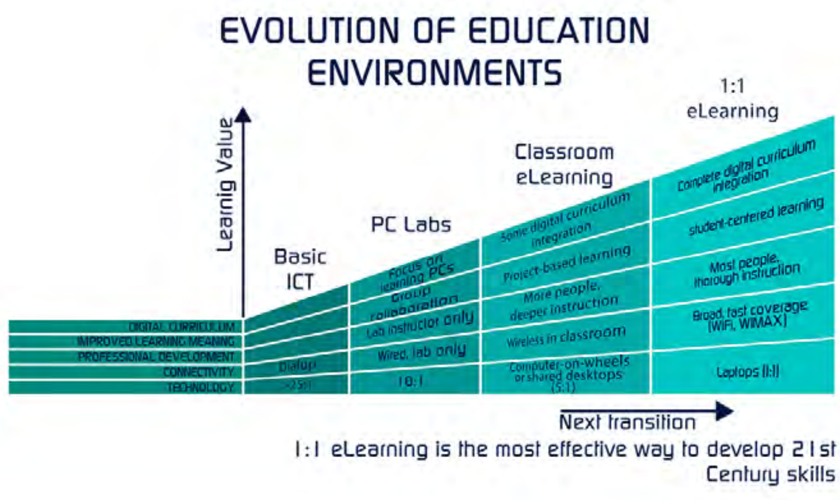

Figure 7.3.K Evolution of education environments

Source: Intel

HYPOTHESIS F: PER CAPITA INCOME WILL GROW, SOCIAL DISPARITIES WILL REMAIN.

Although climate change will cut Bangladesh's economic growth by around 4%, our GDP/capita will keep on rising. Set to become a middle income country by 2021, income levels will be higher in 2100. Social disparities will remain as long as capitalist economy prevails.

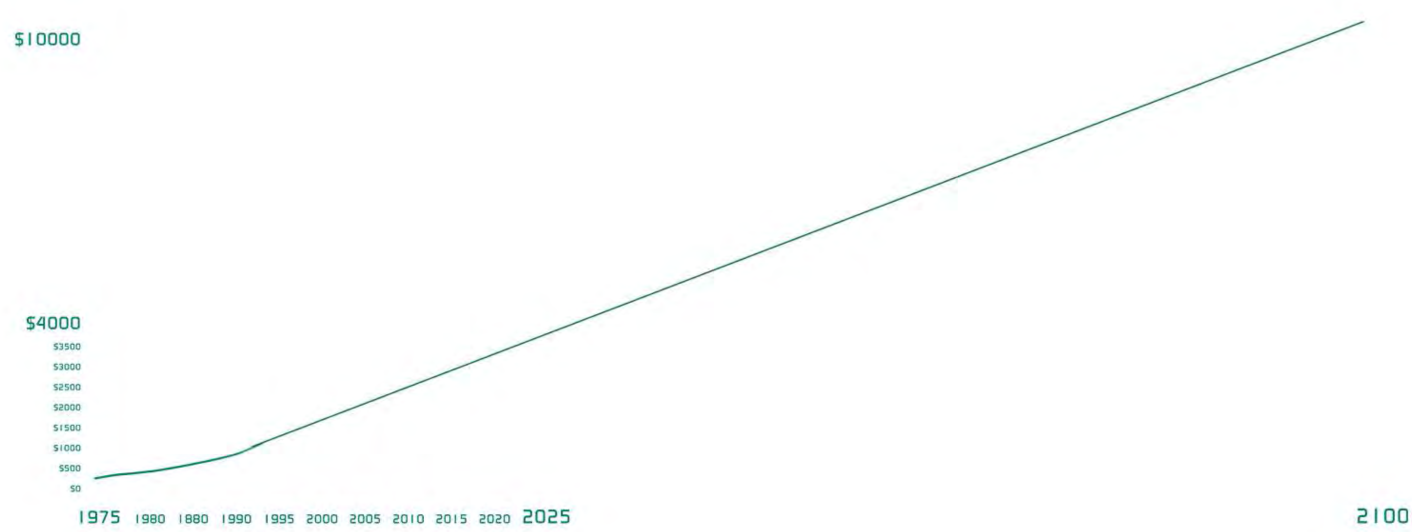

Figure 7.3.L Growth & Projection of per capita GDP in Bangladesh

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HYPOTHESIS G: FAMILIES WILL BE STRUCTURED BASED ON BIOLOGICAL AFFINITIES & SHARED VALUES.

Due to the growth of the economy and decline in overall religious values, families will tend to be structured based on social values, although biological families will persist. Due to the high cost of artificial land, families will tend to remain together in proximity as lesser people can afford otherwise.

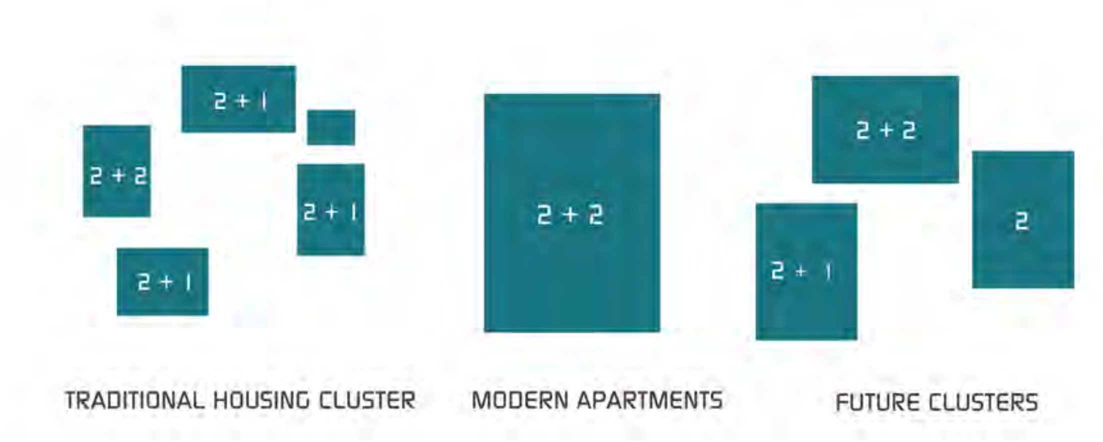

Figure 7.3.M Evolving family structure and future projection

HYPOTHESIS H: ORGANIZED RELIGION WILL PERSIST, BUT NUMBER OF ACTIVE FOLLOWERS WILL DECLINE.

Due to the growth of the economy and decline in overall religious values, families will tend to be structured based on social values, although biological families will persist. Due to the high cost of artificial land, families will tend to remain together in proximity as lesser people can afford otherwise. The following graph shows the growth and decline of certain religions since the 1950s into the first decade of the 21st century. The second graph, however proves the point that even a six decade change is a very insignificant change in the institution of the religion, which has only undergone major changes within the scale of atleast a century.

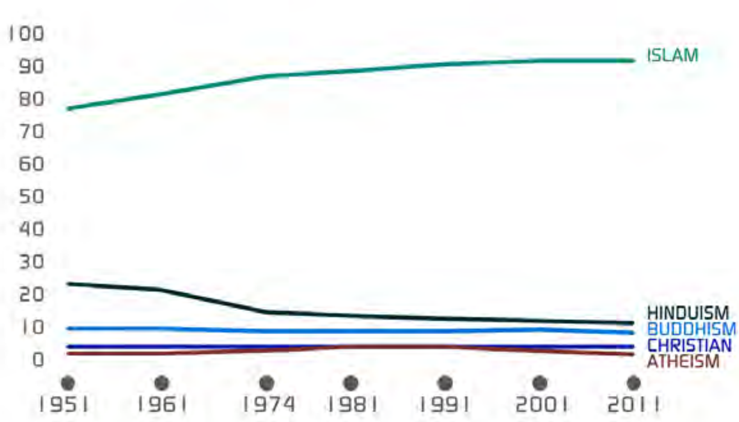

Figure 7.3.N Variation of different religious communities in Bangladesh

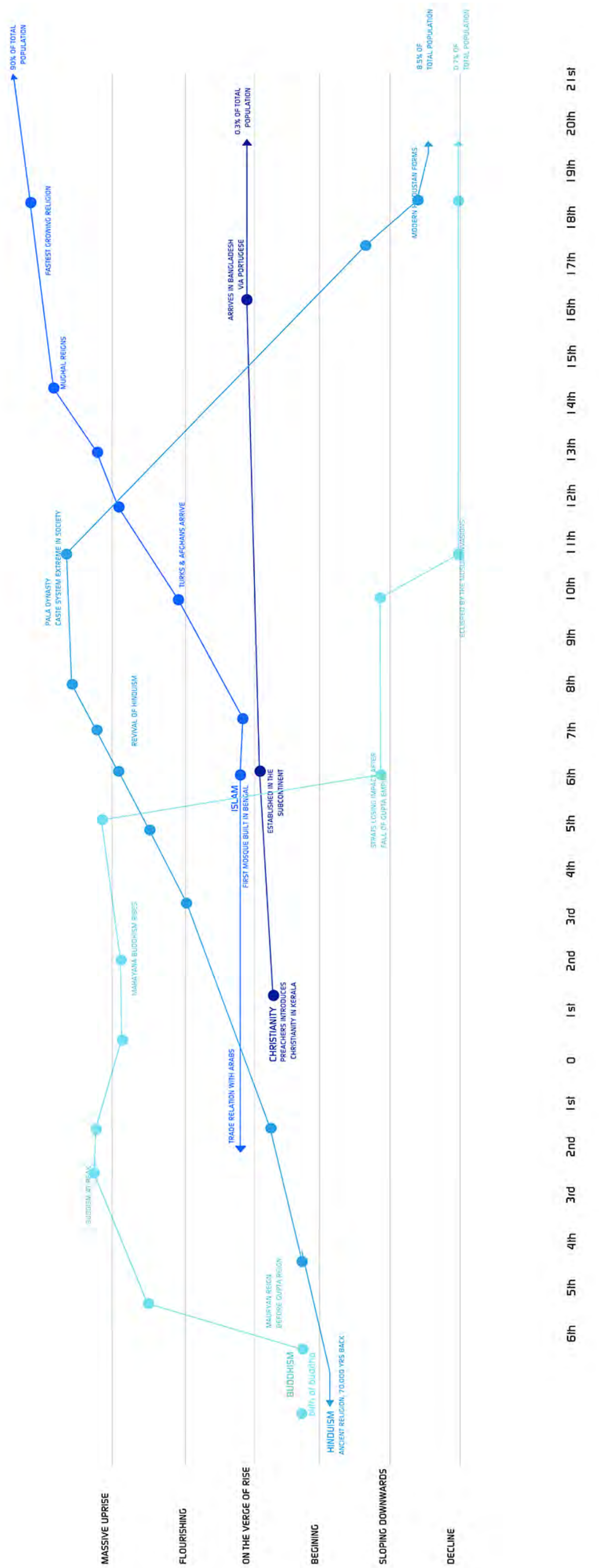

Figure 7.3.O Variation of different religious communities in Bangladesh throughout centuries

HYPOTHESIS I: POLITICAL SYSTEM IN 2100 WILL RESULT FROM MAJOR SOCIAL & POLITICAL CONFLICT.

Analysis of the Bangladeshi national psyche confirms that after prolonged years of growing unrest or minor conflicts in the social or national life, major political/social upheavals take place. Climate change will further accelerate the social conflicts.

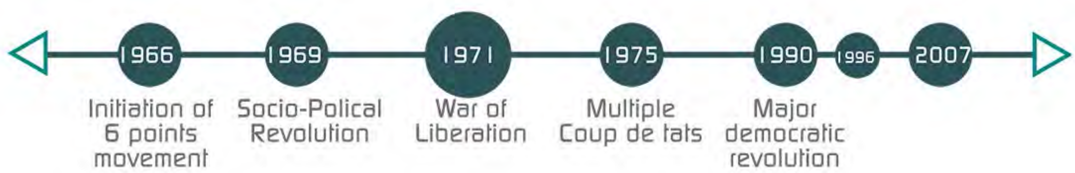

Figure 7.3.P Timeline of major political upheavals in Bangladesh, (1966-2007)

HYPOTHESIS J: POPULATION WILL BE AT A DECLINE.

The population will increase from the current 160 million to 203 million around 2030, and will start falling, reaching 180 million by 2100.

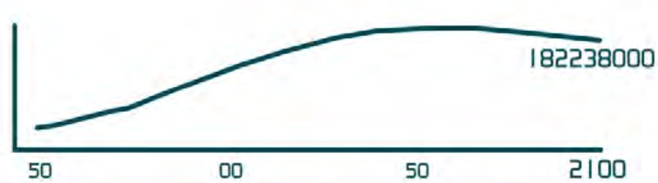

Figure 7.3.Q Projection of future Bangladesh population

Source: Population.com

Bangladesh's population in 2100- although experiencing negative growth- will shoot up to over 180 million people. Coupled with the invasive sea line, the population density of the country will rise further, for which new habitats for the increased populace will need to be pondered upon.

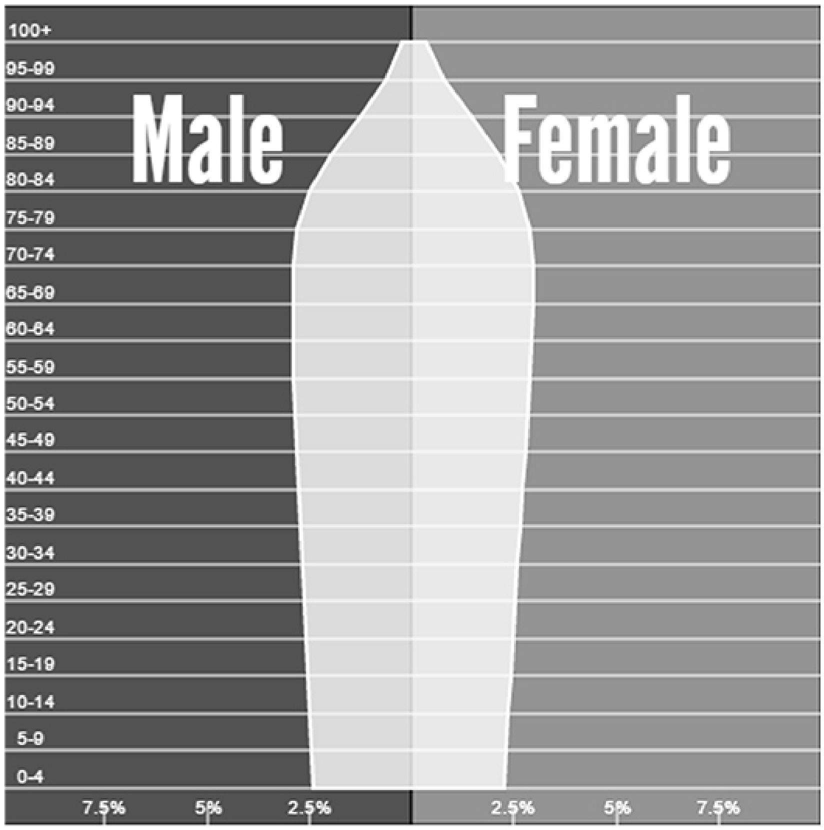

Figure 7.3.R Bangladesh population pyramid projection, 2100

Source: Population.com

7.4 Development IV: Study of the land & the people

Before designing a new form of habitat on the water, it was necessary to decipher the existing relationship of the people with the land as it is. As such, the Bengal delta (Ganges-Brahmaputra Delta) was analysed as were the people who have inhabited it for thousands of years. The following features of the land, and the similar features it shares with its people that were identified talks in general about the relationship between the land and the water in the Bengal delta. Such features gave cues for the design of the system of the future habitat. Attention was first given to the land itself, or more appropriately, the creation of the land.

It is acknowledged that the Bengal delta was created out of a process of continuous sedimentation by water currents from the Himalayas for over thousands of years. These currents- which today exist as massive river systems- namely the Padma and the Ganges river systems continue to sediment the delta, slowly increasing the landmass of the delta. In the case of Bengal, the water is responsible for giving birth to the land. Water therefore, is a creator of the land, which to oscillate between levels of fluidity throughout. This is the character of a delta, more specifically, the Bengal delta.

Afterwards, the river systems created habitats for flora and fauna, in the form of sustaining different marine species and plants. Such rivers, streams and other wetlands are home to many such species. Water, therefore, also acts as a life force for such species of living creatures.

The rivers also remould the land. Erosion and sedimentation on opposite sides keep on changing the geography of the land, inducing a very dynamic geography in the delta. In this case, the water is acting as a sculptor of the land it is creating.

As for the people who started living on this land, water directed, sometimes dictated their lifestyles. Water has remained one of the prime mediums of transportation for the people of Bengal, with primary access to many parts of the country still depending on waterways. Bangladesh is famous for its fishermen and the fishing community, which go on to define the country culturally. Many people make a living because of the existence of such rivers and water bodies. During the monsoon, the rivers swell causing the land to be reclaimed partially by water. This floods in much nutrients into the land for the growth of agricultural crops. Agriculture depends on the annual flooding of the lands, and the floods ironically ensure the livelihood and the food security of millions of people of the delta. Water therefore, acts as a sustainer of people and their lifestyle.

Lastly, water acts as destroyer of architecture, be it people's homes along the river shores or pieces of heritage that slowly breaks apart due to the penetration of water during floods, the presence of high moisture or erosion from the elements.

Water's physical characters of fluidity, transformation and mobility also mimics the relationship between water and the land, as well as its inhabitants. It is as though water's quality is genetically embedded within the land. The most profound of them being temporality. In Bengal, everything is temporal.

The second stage involved looking into the psyche of the people. Bengalis have known to possess a very fluid quality of emotions. Emotions in Bengalis vary within a good range within a short period of time, be it in the streets, in workplaces or homes, or inside classrooms, or during conversations. Bengalis have been generally recognized as being tempermental, with frequent jumps between different levels of excitement, anger, sadness and happiness among others. This emotional temperament is reflected in our body language, our composure, our voice modulation, etc. More so, it is strongly upheld in our paintings, songs, poetry, films among other forms of cultural expression.

Our opinions are also highly transformative. We differ widely on fundamental issues, be it war crimes or political processes, or basic principles of the state within a short span of one to three decades. Our opinions on the above, and much more have fluctuated greatly, with people taking different stances during particular times. This is indeed a rare quality in a nation that is not very common in other nations.

In Bangladesh, our memory is mobile. There has been a consistent failure on our part to hold on to major memories in our national lives, be it memories of achievement or tragedies. This has caused us to face the consequence of same or similar political disasters over the span of just a decade, particularly in the case of abolishment of the caretaker government system. At other times, the short span of public memory has led many major issues to fade in the past, such as seeking justice for extrajudicial killings, consistent tragedies in the garments industry or other sensitive issues.

Lastly, our organization is considerably fractal. Division is easily caused amongst us, be it in the scale of the family, an organization or even at a national level. We break off into small similar factions, whose particular character mimics the character of the whole. This arises as a result of explicit political manoeuvrings in workplaces and even home and communities.

All these stirs up the question: do Bengalis mimic the physical qualities of water? Or does this notion make it all too direct an interpretation of the involvement of water? Whatever the answer to these, it is for certain that temporality and fluidity are the most profound features in our national psyche. Because we are used to thinking in a fluid way, and are used to living in fluid environments (and for some of us, fluid spaces), similarly fluid, transformative spaces which will presumably be crafted by water for a future habitat can fit well with the Bengali.

As such, the proposed character of spaces for the 2100 habitat have been proposed as being transformative, fluid and dynamic. As needs & preferences are dependent on time, economic, natural & social constructs, they are fluid & transformative.

Changing preference for the design of and transformation of a space may range from homes, workspaces, etc. Forces of economics, society & nature present the need to add, subtract to, or reconfigure the three dimensional arrangement of spaces. These include increasing or decreasing the size of workspaces, homes, retail facilities, civic facilities, energy producing hubs, food producing cells, transport hubs, etc. Rooms may need to be added to accommodate guests, or subtracted due to children moving out. A larger social space may be needed to accommodate a family wedding or a gathering. Work spaces may need to be added or subtracted, depending on the volume of workers employed and performance of the firm. Mosques may need to be enlarged during larger congregations. Cultural performances may demand varieties of different space configuration. Increase in power demand may present the need for more power generating modules.

Another scope a water habitat presents, derived from the above study, is the use of mobile modular elements. The need for three dimensional mobility arises due to the need for spaces to protect itself or counter hazardous cyclones, storm surge, tsunamis, etc, or for responding to emergency situation (in case of a health facility), or the mobility of educational spaces into the underwater space.

Another important aspect of the study of people was to decipher an ideal state or environment of living for the Bengali. Since a negative phenomenon such as climate change is to be interpreted as a positive force in the evolution of our civilisation, it became imperative that the future habitat is designed on principles that promote an ideal living condition for the Bengali. As such, a probe began as to how Bengalis had lived for the past hundreds of years. From it, the ideal living environment of living of the Bengali was to be identified, and the future habitat accommodate the principles of that ideal living from the first steps of its design. As difficult as it sounds -due to the limitation of knowledge and resource and being in the capacity of an architecture student-it was possible to settle on an ideal scenario of living for Bengalis: the basic structure of the village.

As a generally assumed dystopian future presented by climate change is being attempted to be redrawn to present a hopeful coexistence with nature and water, search for ingredients for an ideal society was traced down to the traditional Bengali village structure, whereby clusters of homes belonging to a family where drawn towards three main forces of education, religion & political leadership. It became obvious at this stage that our current society's problems stem from a segregation of these three forces, and that there may be a scope for a more ideal society should these three forces: spirituality, knowledge & culture (replacing political leadership) feed on and support each other. It was thus decided that programmatic arrangement of these three functions therefore needs to be closely intertwined, or even shared in the same space(s).

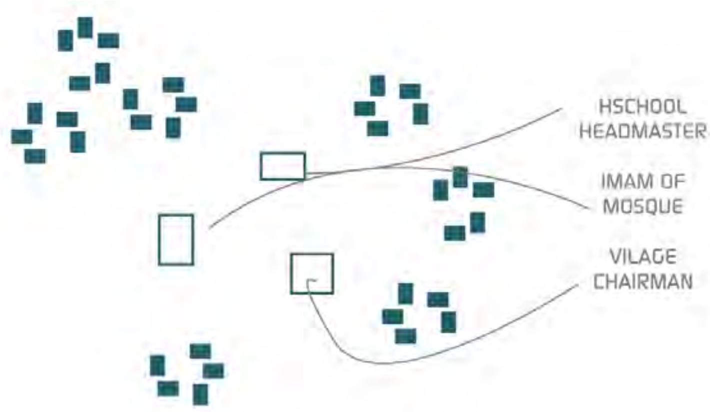

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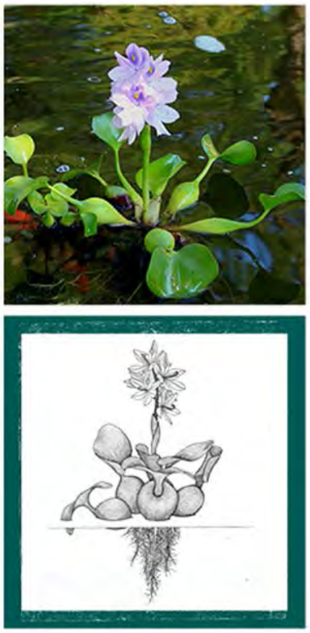
Figure 7.4.A Generic layout of a Bengali village,

Figure 7.4.B Conceptual rearrangement of the village layout for the future habitat

7.5 Development V: Conceptualisation & design evolution

Natural habitats that exist on water were looked upon for the future habitat to mimic. The intelligent principles of biomimicry was the prime factor behind studying mainly plant species on water that could direct the basic design of such future human habitats at different scales. As such, at least four different types of plants were studied, namely, emergent plants at the threshold of land and water, floating plants, free floating plants, and submerged plants. A chart showing their possibilities and potentials are displayed in the next page.

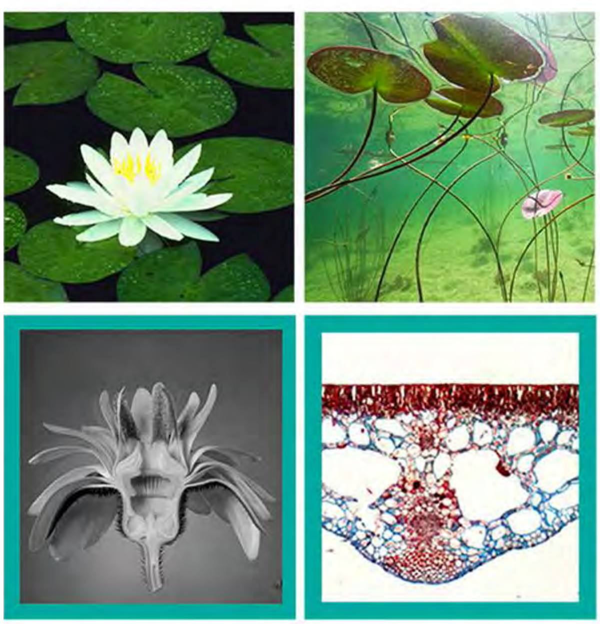
free floating



WATER HYACINTH
Eichhornia crassipes

> free floating
> broad leaves are held above the water by swollen, spongy leaf bases which surround the stem to form a float.
> Long, fibrous, branched rootstocks hang from the underside of the plant

floating



WATER LILY
Nymphaeaceae

> floating leaves and flowers attached to soil by stems
> rhizomes utilise water pressure for support
> The flat round leaves have a waxy water-repellent upper side. The underside, however, seems to cling to the water by surface tension.
> Flowers open and close daily
> Has huge variation of leaf area fragmentation by veins
> Flowers and leaves cluster around each other for support

From top:

Figure 7.5.A Study of free floating plants

Figure 7.5.B Study of floating plants

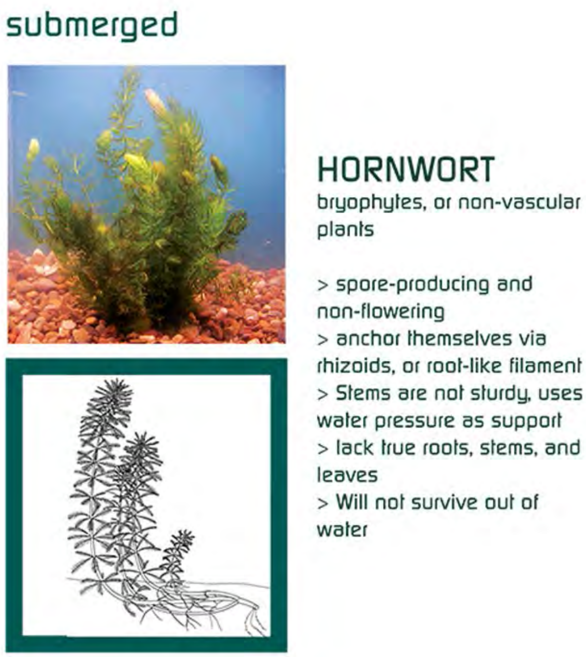


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Figure 7.5.C Study of submerged plants

Figure 7.5.D Study of emergent plants

Water plants were looked towards mimicking an already existing water habitat. After studying different plants, the water lily was identified as a potential plant that presents a strong potential behavioural and formation system to mimic. After photographing a series of water lily leaves, a common illustration of the water lily was able to be derived, identifying the basic pattern of the veins and their arrangement, in relation to the cells in between them. The veins and the cells were then separated, and represented separately as primary, secondary and tertiary elements. It was decided in principle to mimic the vein pattern and organization to design for vehicular and pedestrian circulation, with vehicular circulation mimicking primary vein arrangement and pedestrian mimicking secondary and tertiary organization. Also, utility connections and structural connection systems mimicked the primary circulation as well. The spaces in between conforming to different housing communities, health facilities, parks, forests etc mimicked the cells in between the leaves due to their incrementally growing arrangement focusing around the center. This hierarchy of size of the cells enable to accommodate program of different scale and extent. The cell arrangement was studied more closely in sections, identifying the main features such as the air cavity, the tapered arrangement, the sectional relationship in circulation, etc

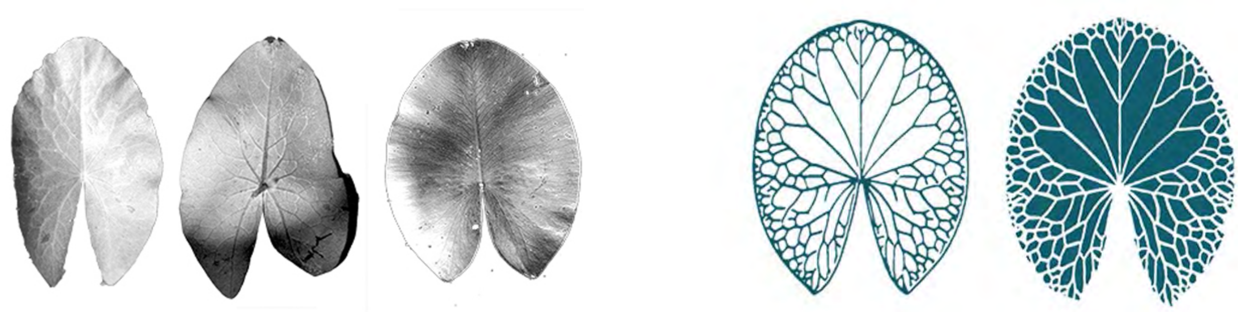


Figure 7.5.E Photographs & graphic interpretation of the basic component of water lily leaves

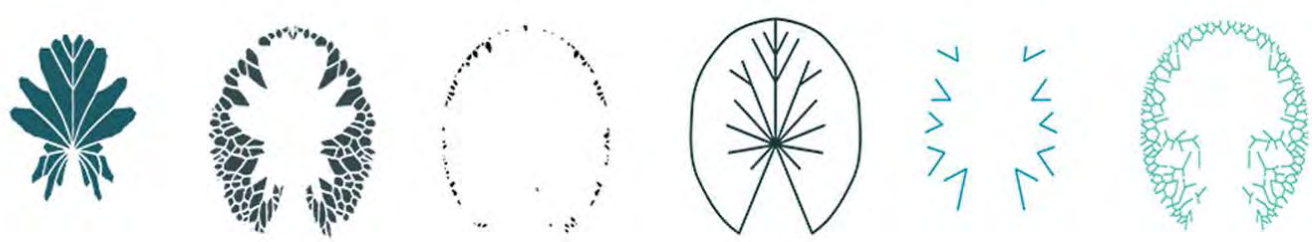


Figure 7.5.F Photographic analysis of the basic component of water lily leaves: Breakdown of cells & veins into primary, secondary and tertiary components.

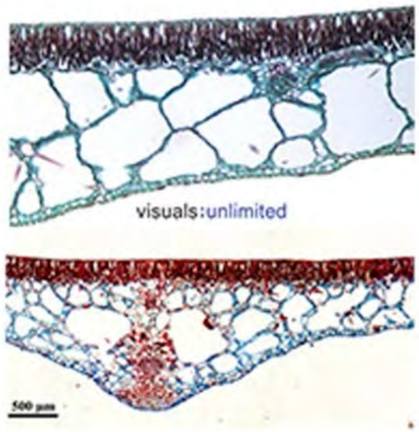


Figure 7.5.G Cross sectional imagery of water lily cells

The lily flower characterises layered concentric rings of petals in all three major axes that opens and closes. Thiis arrangement was mimicked to house the notion that places of faith, knowledge & culture should share intermingling, interconnected and common spaces so that one program feeds from, and supports the other. As such, faith was placed in the vertical axes z, while the worldly elements of knowledge & culture were housed in the x & y axes.

From left:

Figure 7.5.H Generic appearance of a water lily from top

Figure 7.5.I Generic appearance of a water lily

The configuration of a typical water lily elevational arrangement comprising some leaves, a flower and a bud goes on to reveal the conceptual arrangement of the elevation of a habitat it inspires.

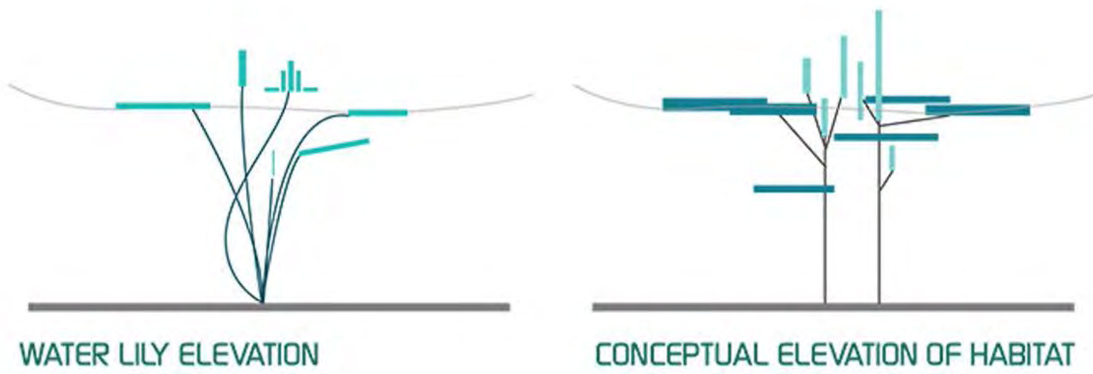


Figure 7.5.J Architectonic translation of a water lily elevation into the conceptual elevation of the semi submerged habitat

The habitat is designed at the scale of a neighbourhood, for 1000 people. It is regarded as the smallest unit of the entire city, and thus acts as a module.

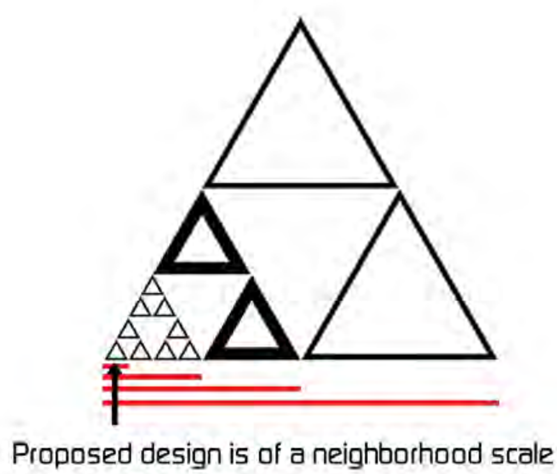


Figure 7.5.K Growth system of the habitat

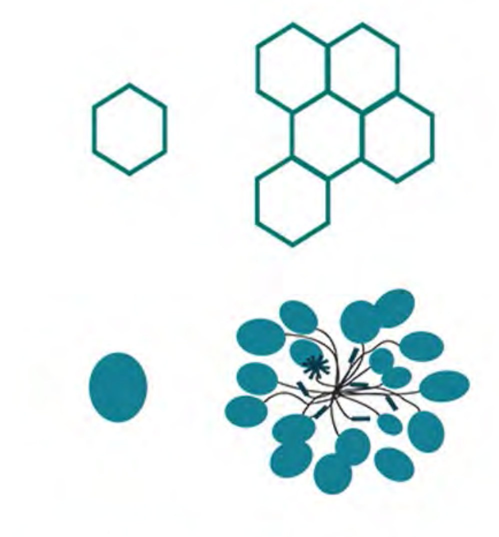


Figure 7.5.L Growth system of the habitat mimicking the growth of a water lily habitat

Placement of such similar modules side by side would result in the larger city. The module, also derived from the water lily leaf in profile also fits into the shape of a hexagon. This is due to the fact that a hexagon is one out of the three geometric shapes that ensures perfect tiling of a given amount of space, and is therefore the most efficient in arrangement and space utilisation. Just as a water lily colony grows, so will the habitat grow incrementally.

7.6 Development VI: Vision of 2100

Perhaps the most intriguing aspect of the thesis process: visualising 2100. Although much enshrouded with uncertainty due to the impossibility to predict the future time, it was possible to construct a vague scenario of the future from the studies explained till now. Most of the envisioned spaces- such as the intermingling spaces between the places of cultural expression (recreational landscape), places of knowledge and faith, or the apartment units or hospital -are a direct result of that thought process, and reflect a vigour that comes with the promise of technological progress in future. For most of the spaces, place making was done hand in hand with the spaces also acting as ecological elements directly contributing to generating power. Possibilities were dreamt of in first stages in collages, after which more specific sketches on the individual spaces were done.

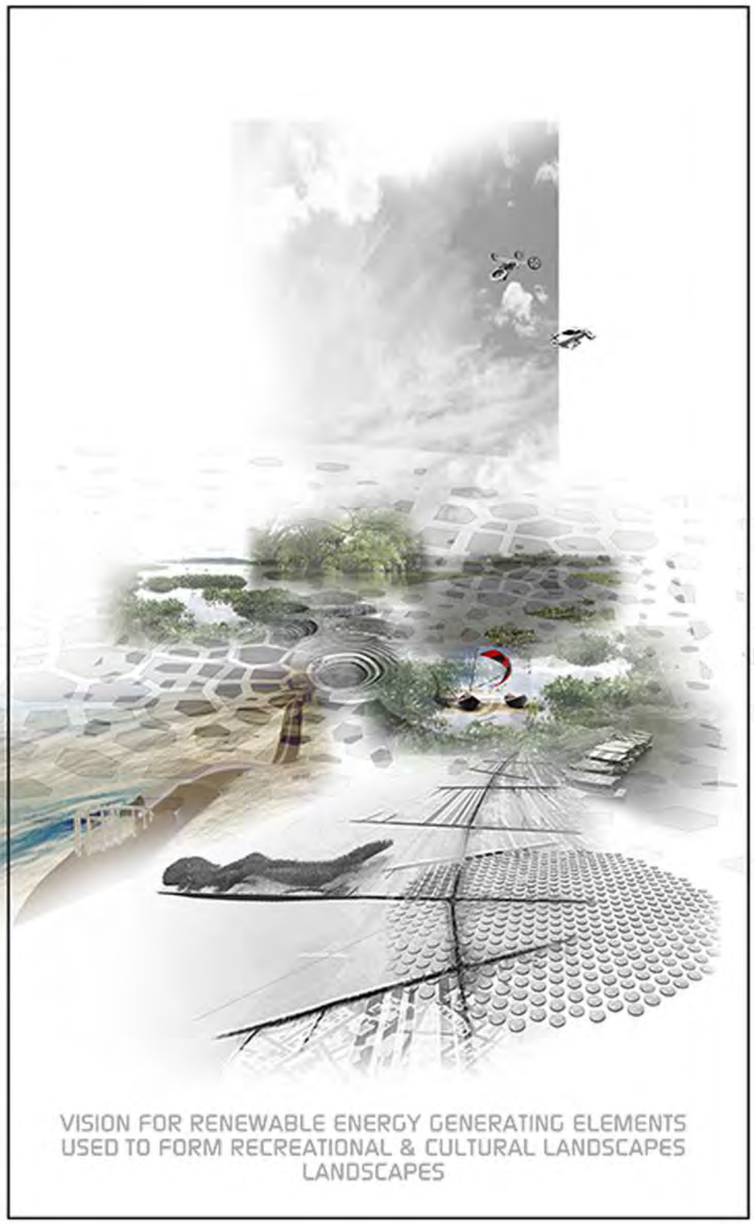


Figure 7.6.A Vision of a future recreation cum cultural landscape

Figure 7.6.B Vision of the future habitat in relation to engineering & technology

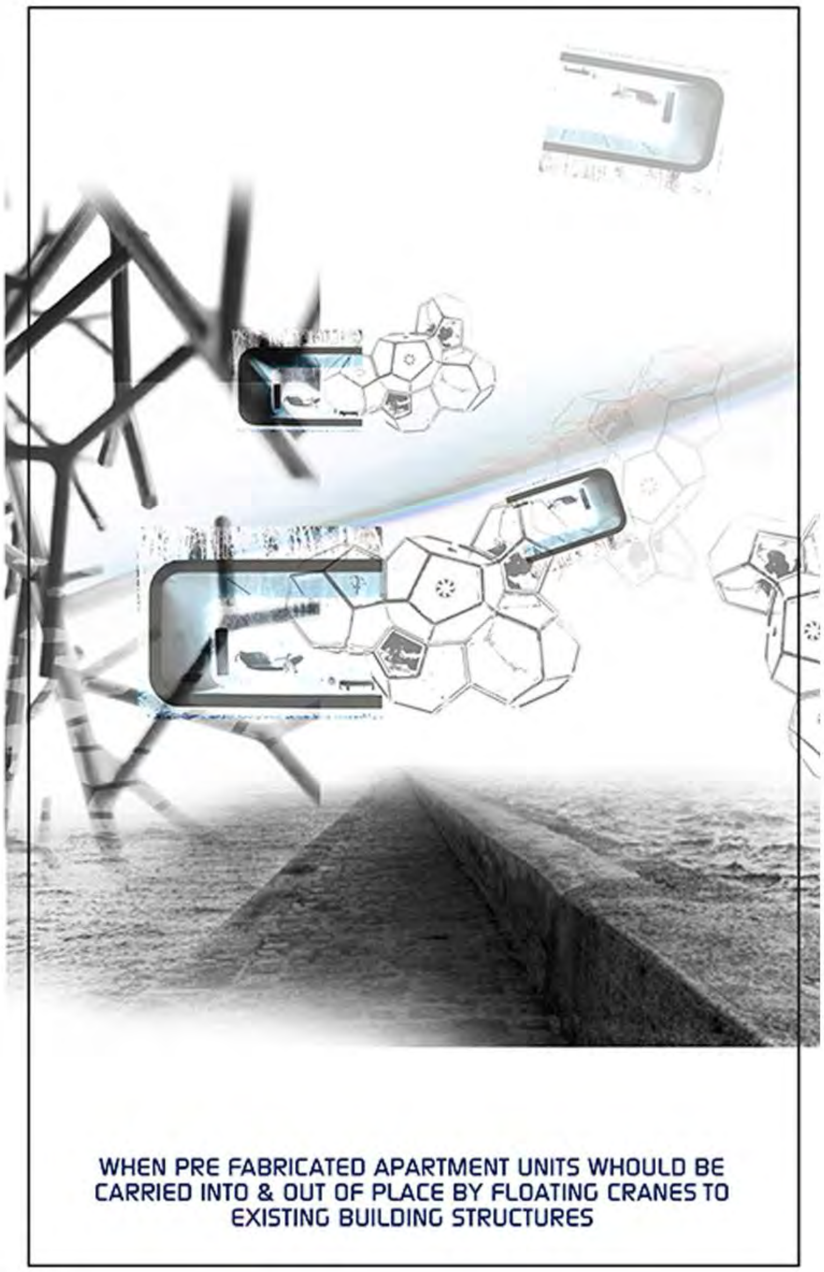


Figure 7.6.C Vision of the future flying spaces

Figure 7.6.D Interaction of the old city and the new in future

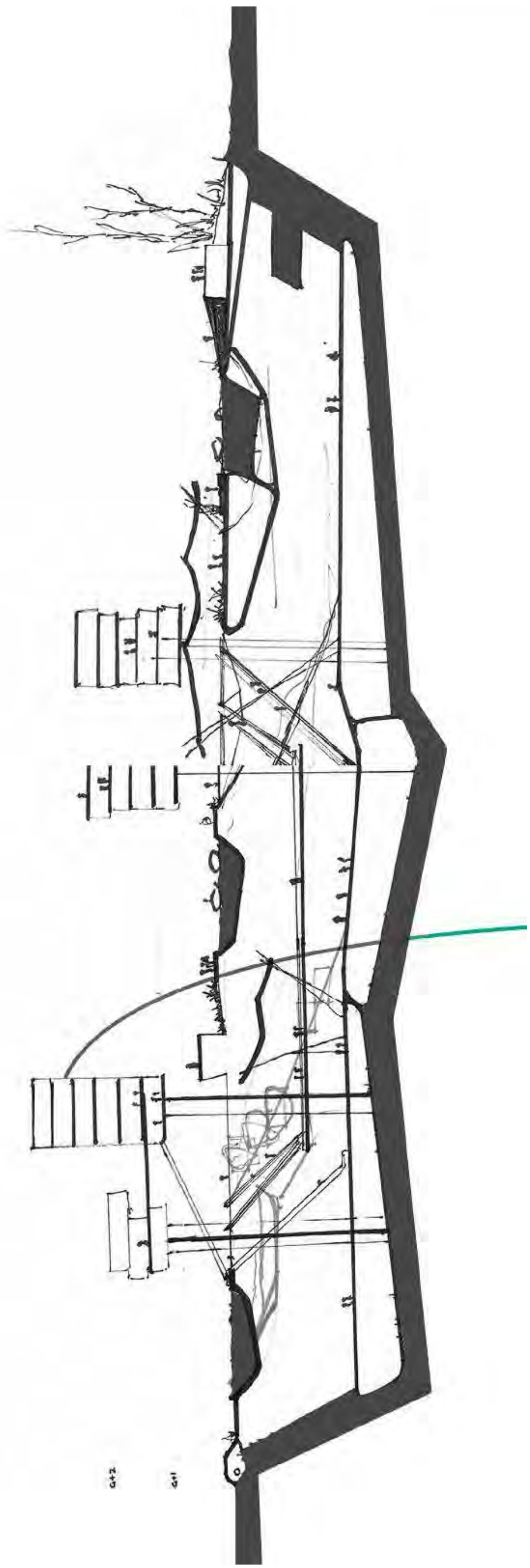


Figure 7.6.E Conceptual section of the semi submerged habitat

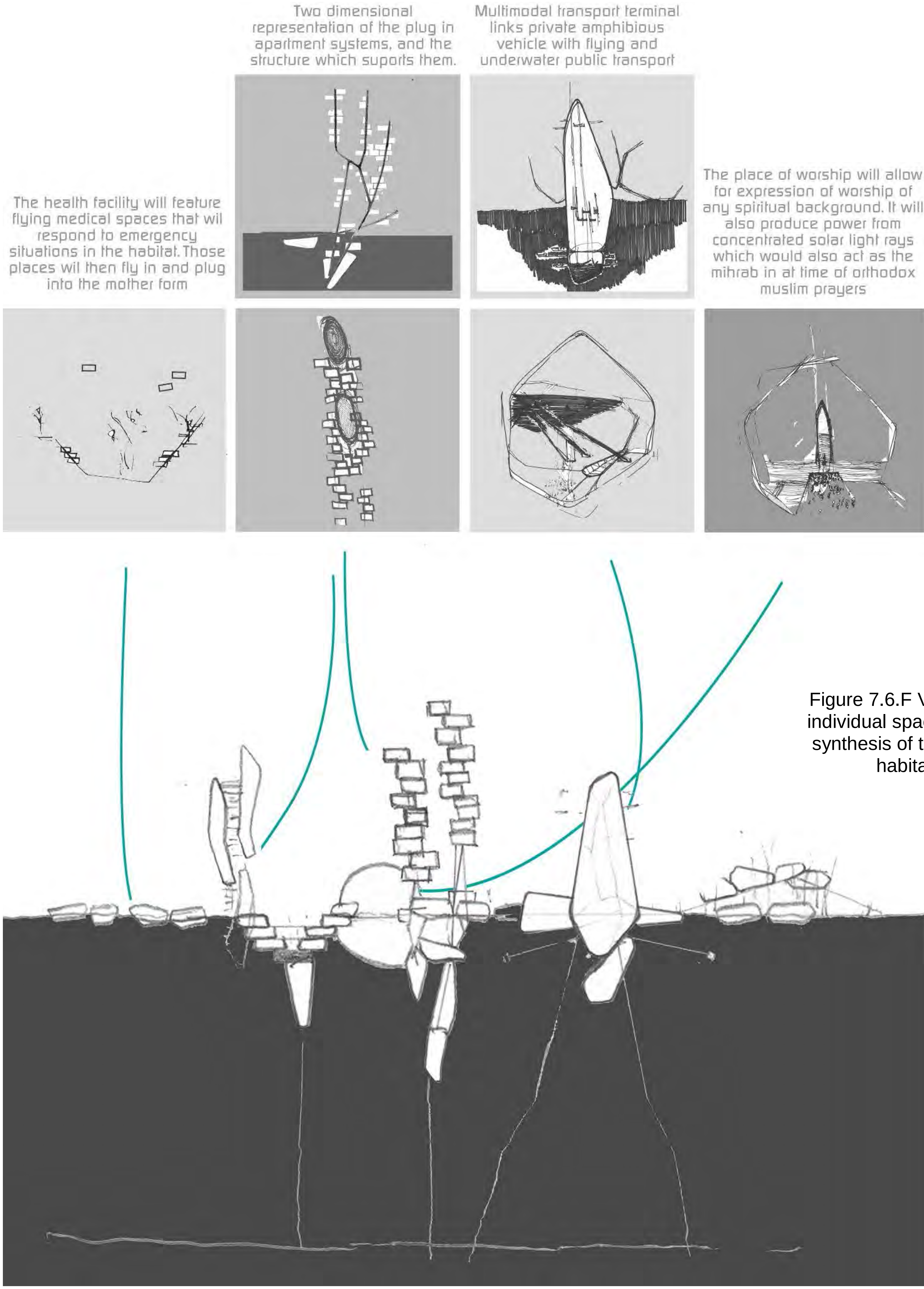


Figure 7.6.F Visions of individual spaces & the synthesis of the entire habitat

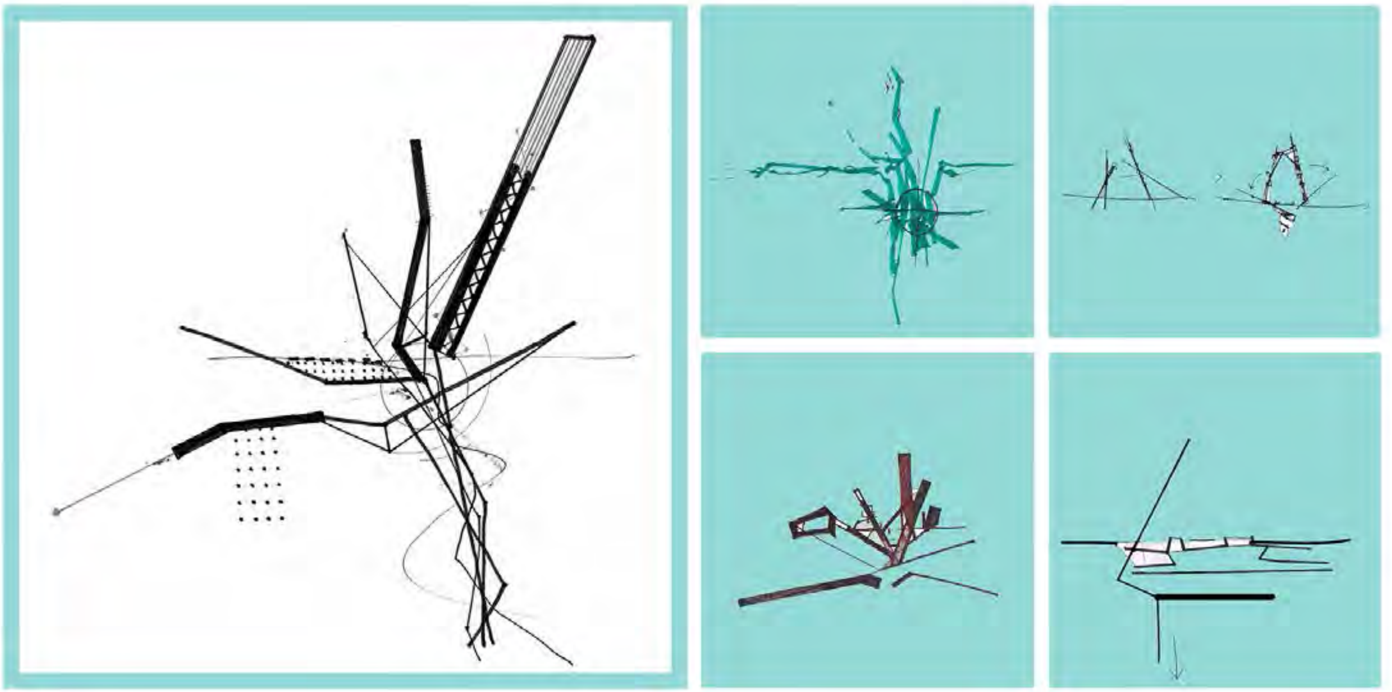
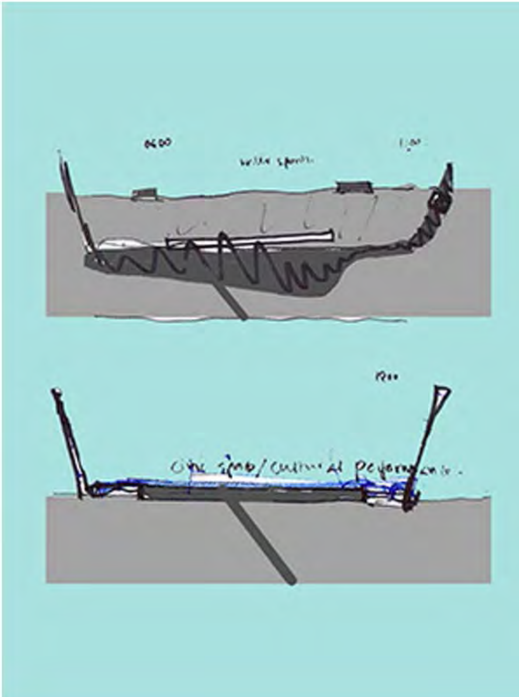


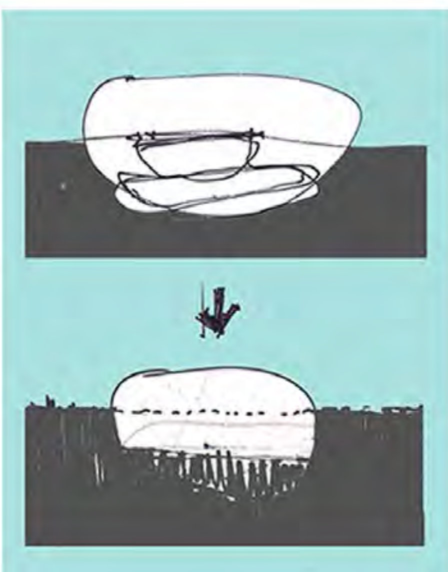
Figure 7.6.G Conceptual arrangement of places of faith, culture & knowledge from the mimicry of a lily flower.

Alternate layering (of petals & therefore, spaces) along three major axes, apart from variation of petal size & the cyclic opening & cl0sing of the petals are three of the major features of the water lily flower. These three qualities where used to create moving architectural spaces with the aim of allowing for intermingling of programs such as the place of worship, place of knowledge & the place of cultural expressions. As such, mechanisms were developed for turning the walled enclosure of the place of worship into an amphitheatre by tilting the walls which would also feature seating's on its surface. This will be possible by using submarine technology, & principles of buoyancy to raise or lower weights which would in turn raise or lower the walls.



Mechanism 1 involves using the tidal difference to design a changing landscape. At high tide, water would be contained inside, and floating programs such as educationals spaces could float above. At low tide, the water would drain out, allowing the previously floating spaces to settle down on a surface that could be used as a field for the educational facility. As the tidal cycle repeats, the flow of water would turn turbines that produce power.

Figure 7.6.H Functional mechanism of tidal lagoon & place of knowledge.



Mechanism II involves partial submergence of a space using water to fill air cavity spaces to change weight, and therefore the vertical level of the space.

Figure 7.6.I Mechanism of space submergence.

Figure 7.6.J Conceptual elevations.

The conceptual elevations revealed multi layered spaces in all three major axes, aiming to craft the two fluid elements of air & water. The layers on the horizontal axes organized spaces in sequence of their importance to the people and functioning of the habitat

Figure 7.6.K Conceptual plan layout (leaf)

Out of the three established types of biomimicry, the process and thereby the geometric growth and arrangement of the parts of the water lily was mimicked. As such, the architectonic expression of the habitat bears hints of the presence of the water lily in the origin of the design.

Figure 7.6.L Conceptual plan layout (flower)

The three dimensional arrangement of the flower petals of the water lily was identified as having strong potential to accomodate common programs that would unify all the people of the habitat. Just as the flower generally assume a central location on the leaves, which in turn support its, the programs growing out of the mimicry process will be surrounded and supported by the leaf elements.

interact more with water.

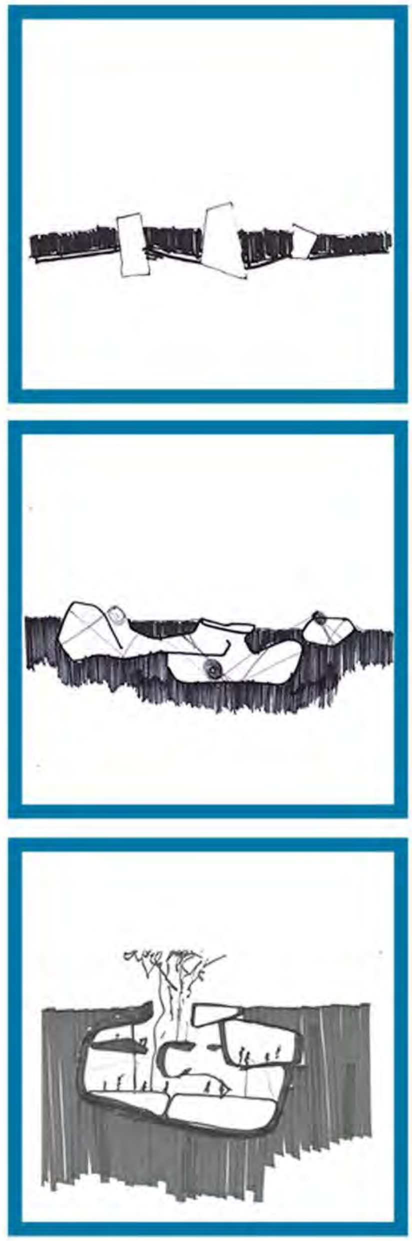


Figure 7.6.M Conceptual spaces in section

Working with two fluid mediums enabled scope for experimentation of spaces both over and under water. It was decided that programs important to human survival such as houses &health facilities would be placed on and over the surface, while programs such as workplaces, educational and recreational facilities could interact more with water.

7.7 Development VII: Drawings, perspectives & sectional perspectives

Figure 7.7.A Plan at high tide at 15’

1 HOUSING BLOCK A

2 UNDERSURFACE VEHICULAR PARK
(TREE ELECTRICITY FARM)

3 AMPHITHEATRE

4 RECREATIONAL/CULTURAL LANDSCAPE

5 MULTIMODAL TRANSPORT TERMINAL

6 HOUSING BLOCK B (RESTAURANTS)

7 LANDSCAPE (WAVE ENERGY GENERATOR)

8 PLACE OF SPIRITUALITY
(SOLAR ENERGY GENERATOR)

9 HOUSING BLOCK C (PLAYING FIELD)

10 HOUSING BLOCK D (SWIMMING POOL)
(RAINWATER HARVESTING POND)

11 PLACE OF KNOWLEDGE
(TIDAL LAGOON)

12 LIVING MACHINES RECYCLING SYSTEM

13 HEALTH FACILITY

14 HOUSING BLOCK E

Figure 7.7.B Plan at high tide at -12’

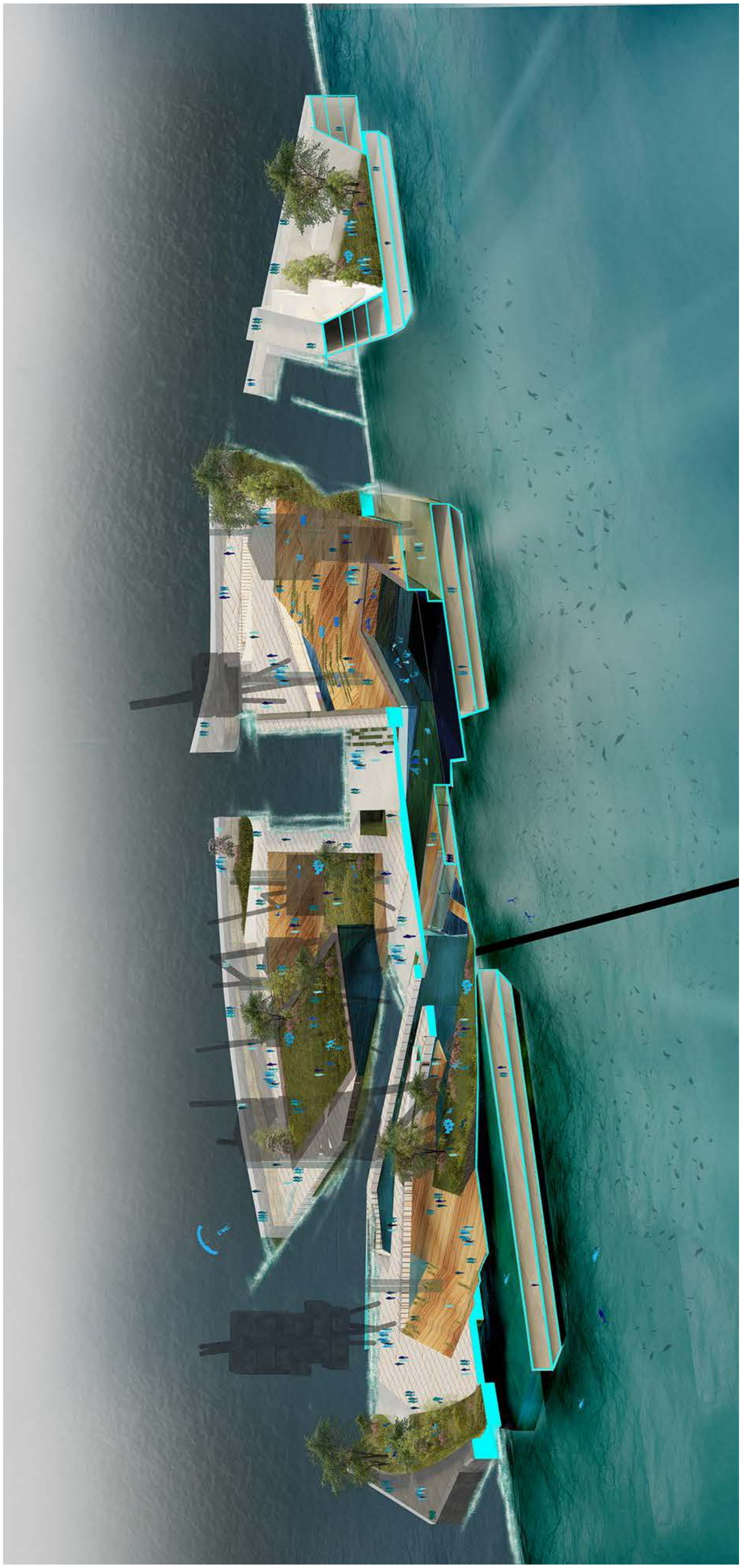


Figure 7.7.C Section A

From left: Housing community above the food court, underwater shopping plaza, swimming pond (rainwater harvesting pond) & hospital.

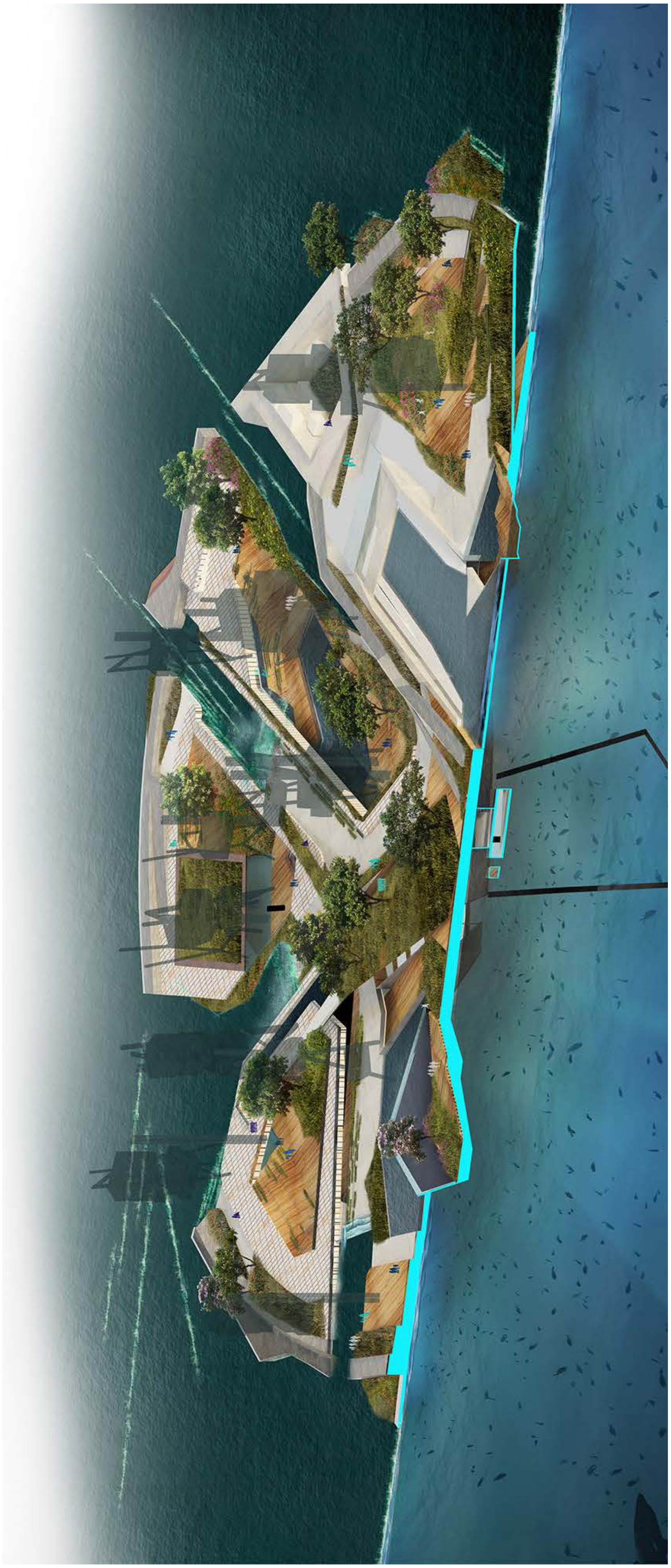


Figure 7.7.D Section B

From left: A housing community, amphitheatre, place of knowledge (and tidal lagoon), housing community)

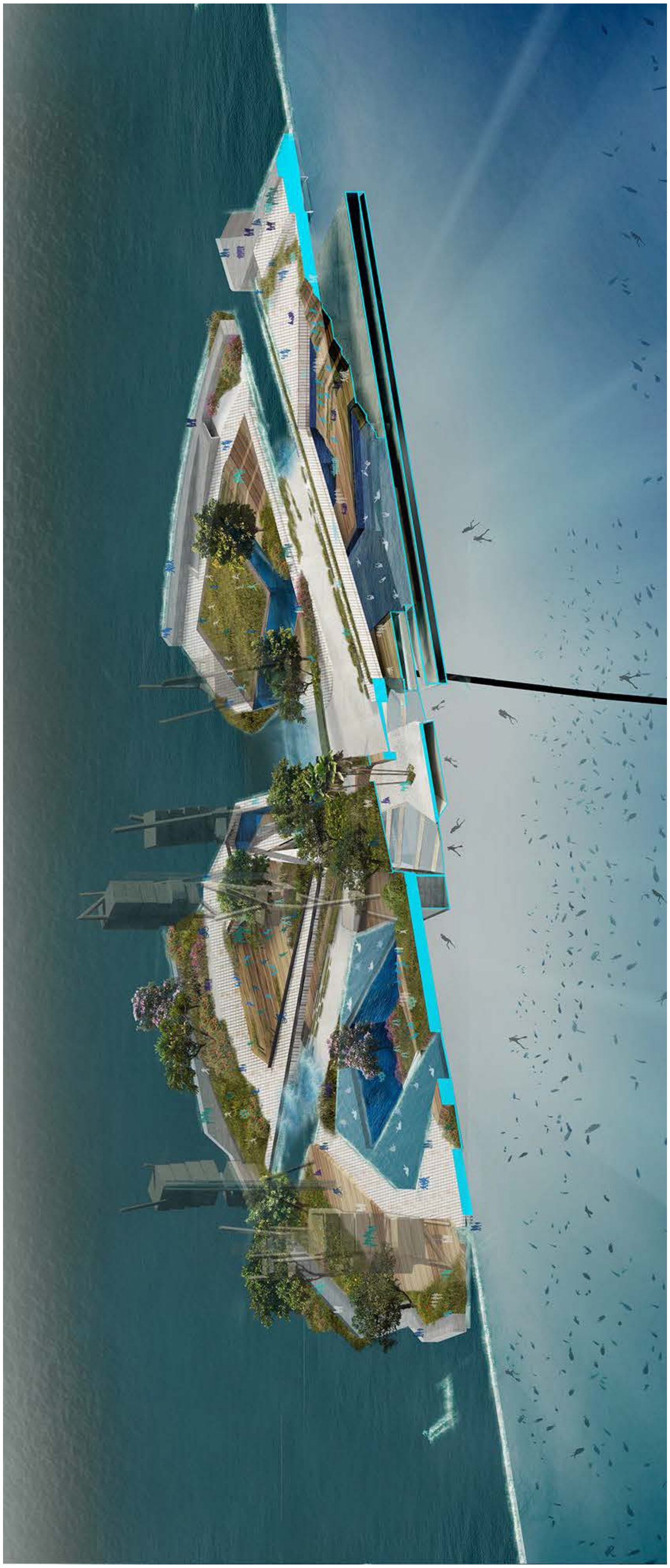


Figure 7.7.E Section C.

From left: A housing community, amphitheatre, the underground shopping district, waterway circulation and the rainwater harvesting pond (swimming pond)

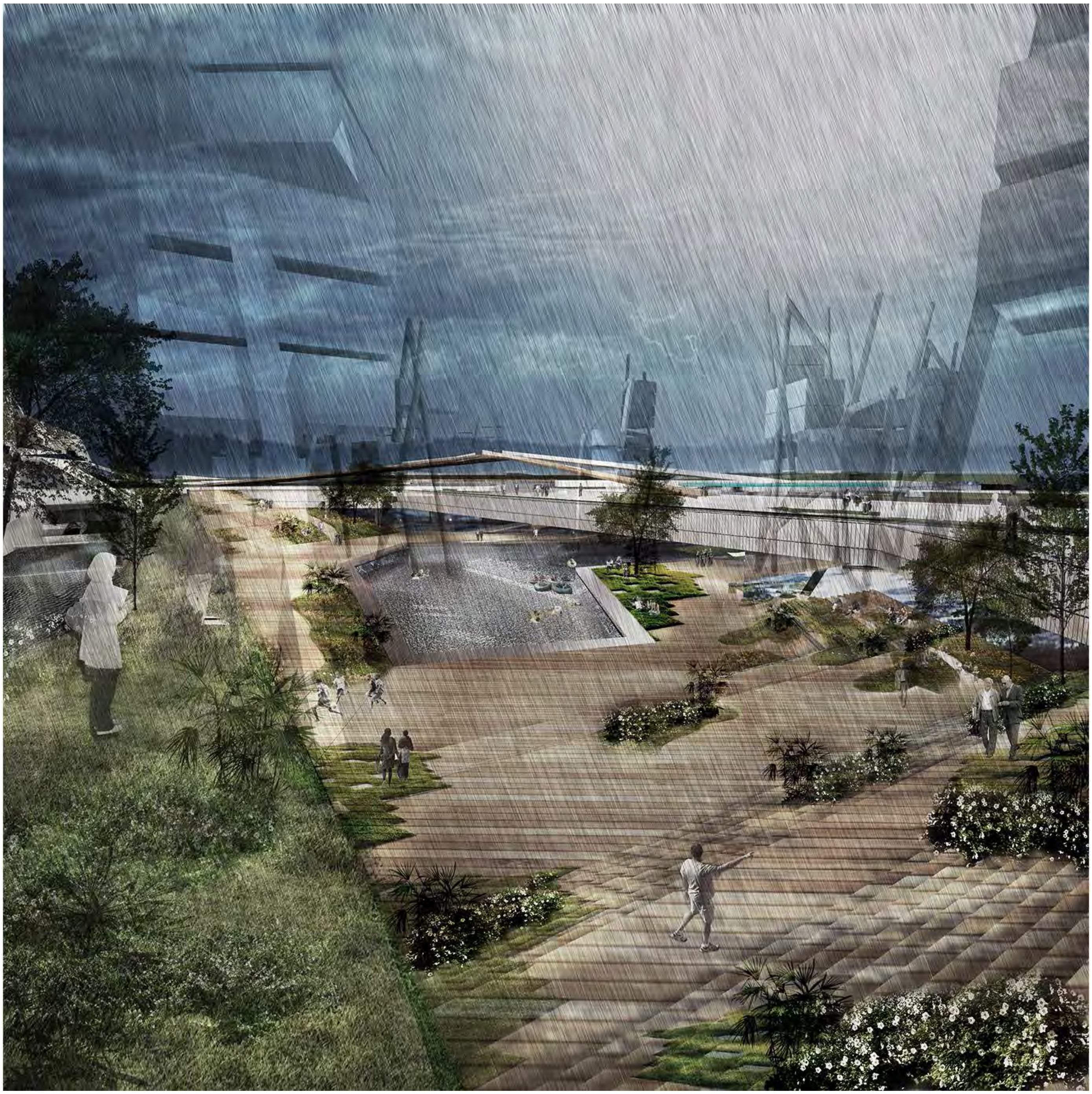


Figure 7.7.F Housing community in the habitat

Figure 7.7.G Submerged shopping plaza in the habitat

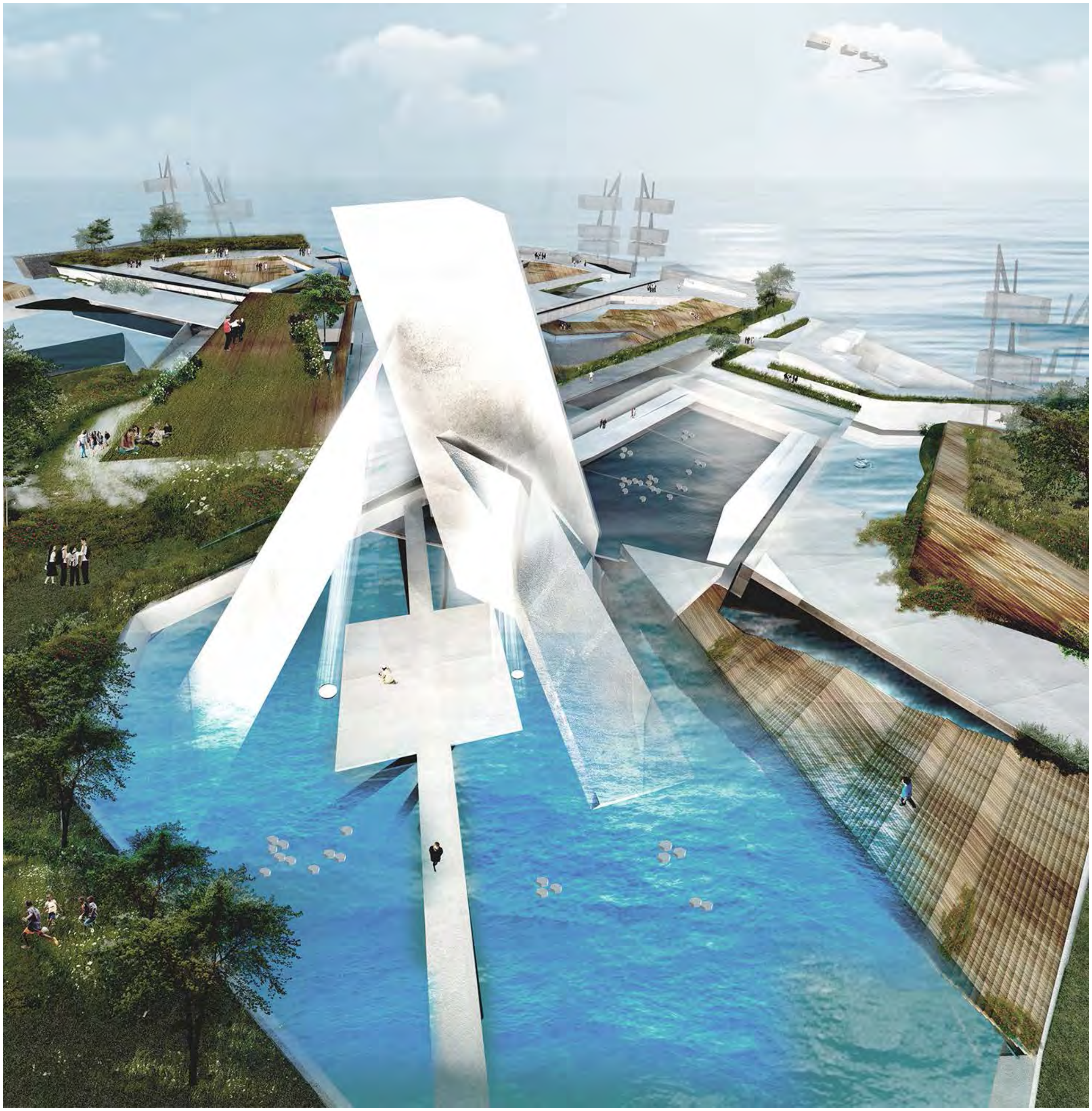


Figure 7.7.H Place of worship, flanked by the place of knowledge and cultural expressions

Figure 7.7.I Final Model

CHAPTER 08

Conclusion

Perhaps the most important learning for me was the fact that first and foremost, dreams have brought human civilisation to where we currently stand, and are therefore most important above all. Should our dream of crafting a more 'humane' future be done faithfully, honestly and profoundly, it will require only rationality to build them.

This project was initially inspired from two notions: that architecture leaves a benchmark of mankind's evolution, vis-à-vis, his progress and therefore ensures the possibility of giving solutions to problems we might be terrified of today. That the power of human will- will to imagine and will to innovate has sustained through architectural expressions through the millenias, and continue to do so will prevail in future as well. This meagre attempt is meant to only reinforce the above notions- more like beliefs- in the strength of architecture.

The second notion that inspired this effort was the diehard resilience of the Bengali people. Probably since our inception on this delta, we have lived hand in hand with water, coexisted creatively with nature and interacted with the natural elements of land, water, wind, vegetation and animal life as if they were members of our households. They have indeed been components of our lifestyles for centuries, and this future habitat only reasserts that feature once more. Most of the cues for coexistence with nature already lies in our habitats and in our lifestyles – definitely more in the countryside than in the urban realms- which begs the question: are we already not the people of the water?

The answer to this question will be very intriguing, and will appear in different forms and shapes from different individuals. This diversity in opinions and the ensuing debate is what make this thesis effort more interesting and worthwhile; it acts as a reflection on our way of life till now.

This thesis excites me for another reason: from the experience of the last eight months, it has pushed the boundaries of the existing architecture education system to the edge. This has manifested in the form of different work processes suggested by different faculties, the experienced and the new, through different opinions, debates (and even conflicts) between faculties, alumni, professionals and the student, and pulls the veil off previously covered realms of our thoughts, and beams a light powerful enough to ignite notions that remained in subtle or complete hibernation till now. My own experience as a student is personally immensely enriching, and I trust it has been the same for my guides. In the end of the day, all debates, opinions, conflicts, and appreciation have been acknowledged as positive contributions to the different dimensions that was needed to craft this floating, semi submerged habitat for the people of the water.

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