Water and Land in Flux: Pedagogy for Design Innovations that Inhabit Water

Niloufar Emami
Louisiana State University

Abstract

The Float'n'rise Design Studio encourages a paradigm shift in design by speculating how a partially submerged building can be designed along the Southern Louisiana coast. As the erosion and submersion of terra firma continues, what might the future of a community's existence look like? If the fact that once-inhabitable ground slowly submerges is assumed, why not construct buildings designed to float on water in the first place? Instead of holding firm to past ground/water conditions, and only raising buildings according to the hundred-year flood level principle, why not embrace a relationship with water as a new design opportunity? Located at the intersection of architecture, ecology, and advanced technology, this studio is a step forward in navigating the fraught/complex relationship between terra-firma/aqua-firma and its environmental settings, using advanced computational and fabrication techniques to rethink modes of habitation in the coastal areas of Southern Louisiana.

This paper first provides an overview of the environmental conditions of the Southern Louisiana region in general and New Orleans in particular. Then, a review of the existing research and practice in the field of floating architecture is presented. Next, the specifics of the Float'n'rise Design Studio are introduced, followed by an overview of the CAD/CAM techniques employed throughout the process. Finally, students' projects are presented with a discussion of how they aligned with the pedagogical goals.

Employing CAD/CAM methods was found to be an inspiring source for design thinking that offers innovative design solutions to multi-faceted complex problems. It can also act as an aid in prototyping and to verify the feasibility of proposed design scenarios. In fact, an interesting improvement to the studio, if repeated, will involve using CAD/CAM techniques paired with material explorations to fabricate small-scale prototypes that can actually be tested on water. The iterative nature of prototyping and testing can synergize the iterative nature of design towards better contextualizing it.

Keywords: Materials + Construction Techniques, Floating buildings, Buoyancy, Digital fabrication, Technology Pedagogy

Introduction

Human settlement is an aggregation of properties grounded in the static character of terra firma. Humans have developed a false sense of ownership and authority over land and its associated ecological networks, including water. The space between land and water, however, is best considered amphibious. The word amphibian derives from a Greek root meaning 'to live a double life.' As a result, a dynamic reading of a potential amphibious space can be related to both land and water, while implying a tenuous relationship between the two: "An amphibian is a transitional figure inhabiting a space not just where land and water meet, but where they overlap and claim each other" [1].

According to Barker and Coutts, "Approximately, 40% of the world's population currently live within 100 km of the coast and 20% of the Earth's population live in river basin areas at risk of frequent flooding" [2]. The duality of water, at times our friend, at others a threat, must be examined in order to redefine our relationship with water. In fact, how we respond to the thread of flooding will shape our cities as much as our need for water. Many past civilizations have demonstrated ingenuity in designing with water, such as floating housing in Tonle' Sap in Cambodia. Barker & Coutts (2016) introduce and define *aquatecture* as a "water centric approach to design in which flood-risk management, development pressure, and adaptation to climate change are simultaneously reconciled to allow buildings and cities live and work with water."[2]

Humans' sense of authority over land is shaken after a flood. The relationship between land and water is particularly complicated in lower Louisiana, where the coastline is in a constant state of change as the site shifts between terra firma and aqua firma: this occurs both slowly, over time, and also abruptly, during natural disasters such as hurricanes or rising floodwaters. The lands along the Louisiana Gulf Coast are subject to the risks of fluctuating environmental conditions, which can be as harsh as 2005's Hurricane Katrina in New Orleans, or the 2016 flood in Baton Rouge.

Focusing on flooding as a threat, it can occur from various natural sources including rivers (fluvial), coastal and tidal sources, and surface water (pluvial) flooding. Other possible sources of flood include sewer, groundwater, or artificial structures. As flood risk increases, traditional approaches to defending land from flooding become more costly and less effective. A paradigm shift is needed to embrace the natural water cycle and to begin designing *with* water, rather than against it. Considering these approaches to tackle flood risk on a building site, how can designers get past a focus on design strategies of flood avoidance, flood resistance, and flood resilience, moving toward strategies where a building floats on water or, more dramatically, where the building is amphibious?

Previous studios at the Louisiana State University (LSU) School of Architecture have examined and speculated on this fragile relationship, including Ursula McClure's amphibious constructions for LUMCON [3] and Shelby Doyle's Losing Ground Studio [4].

This paper summarizes research and speculations conducted in the Float'n'rise Studio on the design of floating buildings in Southern Louisiana, New Orleans. This options studio was offered at LSU during Fall 2018. The studio takes *architecture* as its first focal point by considering a program that works both with and on the water. The second focal point of the studio, *ecology*, explores/interrogates habitation and settlement patterns that are isolated from ecological systems in an unsustainable manner. In other words, when a building shares the space of the water's edge with the native inhabitants of the water, ecology becomes a key concern. Thus, design and construction features that encourage cohabitation with marine and avian life were considered. The third and final focus is on *technology*, which shapes the means and methods of investigating a complex problem. Computational design and simulation tools are employed to explore the center of gravity and of buoyancy of a submerged object. Composite materials, as well as ship design technologies, add to the collective studio's examining of the materiality of a buoyant object. In addition, digital fabrication techniques, such as 3D printing and CNC cutting/routing are employed for prototyping complex, non-Euclidian surfaces, all in service of tackling a complex multi-faceted problem. This paper includes explanations of the context, the educational methodologies employed, and the final design projects interventions developed by students.

Context: Southern Louisiana and New Orleans

For better or worse, the history and livelihood of New Orleans are inextricably associated with the city's relationship to water. Water has been a boon for New Orleans, as the Mississippi River and Lake Pontchartrain provided ample support during the fledgling years of the city. Transport, recreation, scientific exploration, and sustenance have all been a part of this critical relationship. However, the city also has faced an eternal struggle against water, as the very forces that keep the city alive also threaten its existence. In addition to the ceaseless job of pumping water out of the city, New Orleans is faced with catastrophic weather and climatic events that could potentially inundate the entire city.

To better understand the context, site analysis is conducted considering the *physical* (and material), *political* (and managerial), and *cultural* (and symbolic) aspects of the site at the architectural, urban, and regional scales. The results of site studies at the regional scale, commercial and recreational fishing describe an important part of Southern Louisiana's political aspects (Fig. 1).

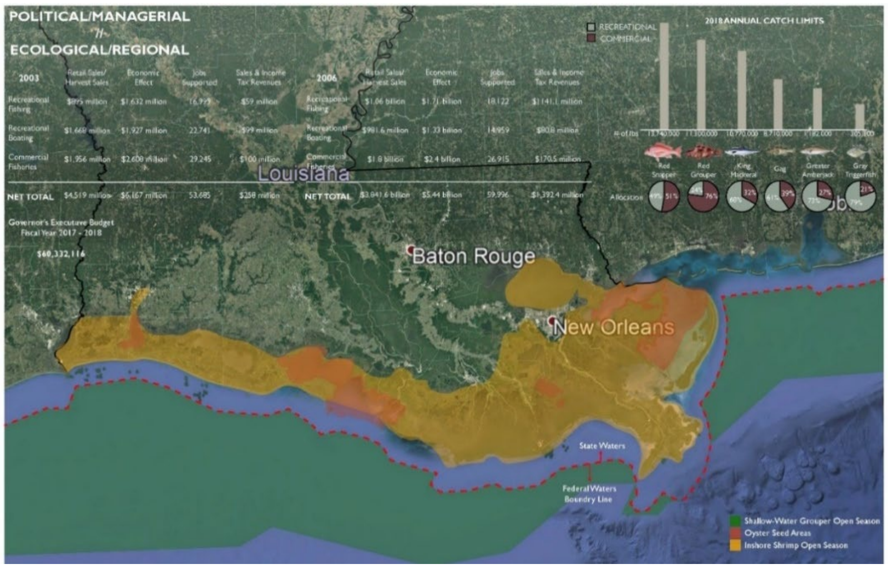

Fig. 1. Analysis of political aspects at the regional scale developed by a student (developed by Annan Wang)

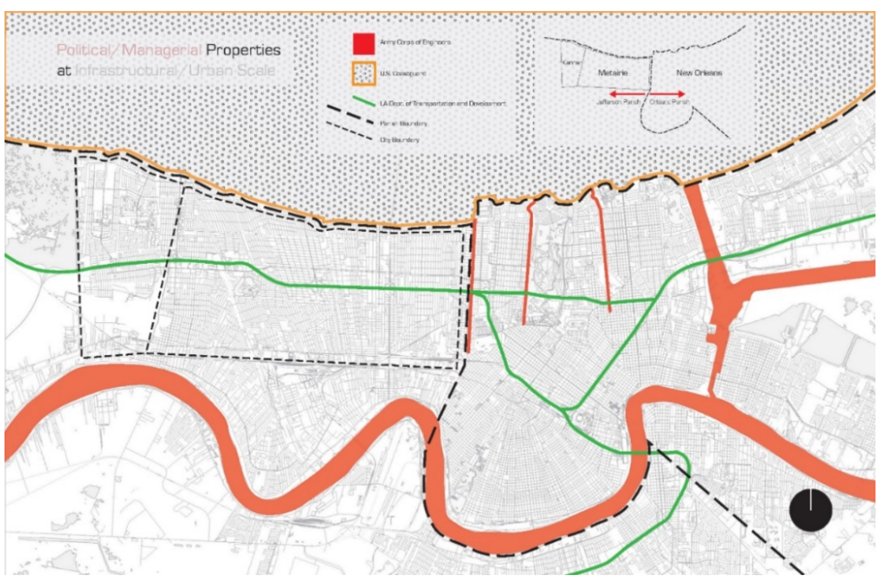

Fig. 2. Political (and managerial) aspects at the urban scale, showing the New Orleans–Metairie divide, as well as the areas overseen by the Army Corps of Engineers versus the U.S. Coast Guard developed by a student (developed by Jordan Farho).

Looking at Fig. 2, water sources that affect flooding and flood management in New Orleans, namely Lake Pontchartrain and the city canals, are overseen by two different institutions. The Army Corps of Engineers oversees the Mississippi River and canals within the two cities, whereas Lake Pontchartrain is overseen by the U.S. Coast Guard. Despite the differences in oversight, these two systems are interconnected; the water in the canals is pumped into Lake Pontchartrain to control canals' water levels and prevent the city from flooding. Therefore, the water level of the lake is subject to constant fluctuations. Among these canals, the 17th street canal functions not only as a water management system, but also as a dividing line between New Orleans and Metairie, two cities with social and economic differences. This region of the lake was chosen as the studio's site for designing a floating building due to its many interesting dimensions. The next section briefly overviews precedents of floating architecture and prototypes before reviewing the details of the studio in the following section.

Floating architecture

In architecture, "a floating building is usually a lightweight structure that rests on a buoyant base or foundation designed to rise and fall with the level of the water" [2] . Thus, for it to float, the buoyancy of the platform must exceed the weight of the building. The floating building is usually tethered to mooring posts that allow it to move up and down (with changes in water level) but prevent it from floating away.

As Barker & Coutts, (2016) explain, floating architecture is feasible where water depths exceed 1 meter (or about 3 feet) [2]. Taller floating buildings require greater water depths, or *draft* (a term used in naval architecture) to provide sufficient buoyancy for the weight. It should also be noted that floating buildings are best suited for static bodies of water, such as purpose-built docks and inland lakes, where water level variations are predictable, and flows are usually low. Therefore, for implementation, robust planning guidelines and building codes are required.

From a different perspective, some legal issues have proven to be complex and problematic. The traditional bureaucracy surrounding the construction industry and its financing are based on the assumption that the results of the construction is real estate property, which is inherently immobile. It is true that houses on the water are not intended to move to as great an extent as mobile homes, but towing them to another site or location, is certainly possible in principle [5].

Knowing that many types of floating structures are used in construction, natural materials such as straw, bamboo, and wood have been used historically by indigenous populations to make lightweight buildings designed to rest on raft structures. Timber, fiberglass, steel, and aluminum hulls are often found in houseboat design due to their structural and material efficiencies. More recently, alternative construction methods have been explored for higher levels of stability, durability, and minimal long-term maintenance. Modern materials employed in such construction include composites, such as polystyrene and concrete rafts.

The use of platforms to design floating buildings has many precedents. A well-known project is the Makoko school, a floating prototype. Its structure is built like a pontoon, on a series of plastic drums or barrels, making it less vulnerable than regular construction to flooding and extreme weather. It also harvests rainwater, recycle waste, and use renewable energy [6]. Its use of hollow plastic drums encourages questions related to material density and its relationship with buoyancy. Another example includes the floating pavilion in Rotterdam's city port, [7] with a total floor area of 1,104 square meters. The pontoon is made of expanded polystyrene (EPS) combined with a grid of concrete beams. Its geodesic domes are covered with lightweight ethylenetetrafluoroethylene (ETFE) foils [8]. Its combination of concrete and polystyrene creates buoyant platforms that offer greater durability and strength than the plastic barrels used in the Makoko school. Another example is Project Waterbuurt West, the largest floating house community in the Netherlands, consisting of houses constructed on piles and houses floating on the water [9]. The outline of each house is 70 m^2 (about 753 ft^2), with an immersion of 1.5 m (about 5 ft), while the maximum weight calculated for the house is just above 100 tons (about 200,000 pounds). The limitation on the depth of the water on which the apartments float encourages questions around not only material combinations but also on finding geometric configurations that can float in shallow waters. Finally, Seoul's floating islands are an example of very large floating structures (VLFS) consisting of three inter-connected islands [10]. The buoy on which the islands float is secured by 28 mooring chains to ensure it can withstand changing river levels and bad weather. This precedent encourages questions around how to prevent a buoyant artifact from floating away while allowing it to rise and fall with changes in water level.

Floating systems, artifacts, and ecosystems have also been explored by architects and researchers in an academic setting. Roger Hubeli and Julie Larsen of Aptum Architecture prototyped Isla Rhizolith, a floating concrete breakwater intended to revitalize Colombian shorelines [11]. Coleman Coker of the Gulf Coast DesignLab designed and built a floating camping site in Sea Rim State Park in Louisiana [12]. Moreover, Adam Marcus designed a prototype of a resilient coastal infrastructure [13]. The curved geometry of this prototype paired with the detailed curvilinear patterns on its surface encourages questions around how a designer can create freeform surfaces, and how to then realize these forms. Therefore, the CAD environment for creating these forms, followed by CAM methods for fabrication, is highlighted. There are many methods for implementing CAM, including 3D printing—an additive method—and CNC routing—a subtractive method.

Float'n'rise Studio

Float'n'rise is an Option Studio at the Louisiana State University (LSU) School of Architecture comprising fourth and fifth-year undergraduate students as well as third-year graduate students. The Bachelor of Architecture Program at LSU is a ten-studio sequence, while the Master of Architecture Program is a six-studio sequence. Rather than advocating for a traditional notion of building in South Louisiana, one that aims to protect buildings "against" water, this studio explores the concept of designing "with" water. Designing buildings that freely float on water to better respond to sea level changes, while attempting to enhance the natural ecosystem of the lake forms the core of this studio.

In the Fall 2018 studio, studying floating building precedents studio led students to consider two important design strategies that affect buoyancy: the geometric form and material of the buoyant platform. Investigating form and material in an abstract way was a key part of the studio even before the intervention design stage. Regarding form, students were taught the concept of buoyancy via exploration of the center of gravity and of buoyancy of different geometric shapes using CAD.

Following CAD, two methods of fabricating free forms, 3D printing and CNC routing, were explored. Students were encouraged to create patterns to enhance habitation by marine life. Creating the same surface using two different fabrication methods enabled students to compare the processes as well as the quality of the surfaces. From a different perspective, some students took an interest in exploring materials by conducting hands-on experiments with plaster, concrete, and foam to understand how composite materials with different densities can be employed to design a buoyant platform. The next three sections describe how each of these initial studies was implemented.

Computational studies: Center of buoyancy simulations

Understanding the concept of buoyancy is key for designing a floating building. Geometry and material choice both play a role in designing the buoyant surfaces. A small-scale project was defined to explore geometry's effect on buoyancy in floating structures. Rhinoceros, modeling software developed by McNeal, is capable of calculating center of gravity and center of buoyancy with an assumed water line elevation. Students were asked to explore how changing the geometry shifts these two centers in different geometrical shapes (Fig. 3). Students explored how the buoyancy in the z-axis decreases when the base thickness increases (Fig. 3- top row), how the center of buoyancy leans towards the bottom of the surface when a mass is added to a flat bottom surface (Fig. 3- middle row), and how creating a void or removing material pushes the center of buoyancy away (Fig. 3, bottom row).

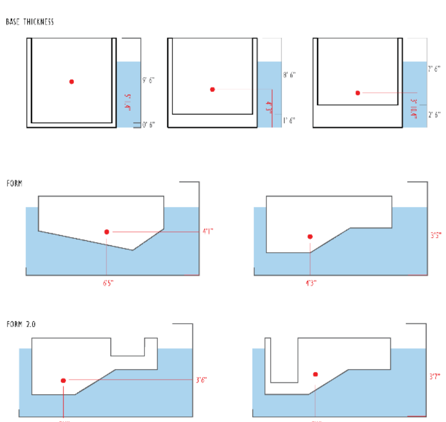

Fig. 3. center of gravity and center of buoyancy studies by Anne Kellerman, Julia Scheuermann.

Process studies: CNC milling and 3D printing

One of the technology education sections of the studio includes education on computer-aided design (CAD) and computer aided manufacturing (CAM) production. The additive and subtractive CAM methods—namely 3D printing and CNC routing, were introduced respectively. The students were asked to design forms, surfaces, and textures using CAD methods, and explored production using additive and subtractive techniques. Surface textures were a subject of study in employing different techniques, as the designed surfaces can be textured either through design or through CNC tool-pathing (Fig. 4). Learning to work with these methods while comparing the texture of the outcome was one of the learning goals.

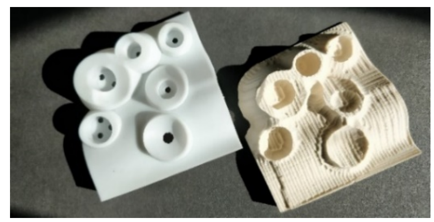

Fig. 4. Surface studies of 3D printing versus CNC milling developed by Amir Hussain, Bristie Smith & Jeremy Gremillion

Material studies: Composite buoyant materials

With respect to material investigations, students were asked to research the materials and construction techniques used in precedents of floating architecture. A group of students took an interest in hands-on material experimentation, building composites of foam and plaster and testing how these would float. The experiment was an exciting moment for them, as they experienced the feasibility of floating architecture, and how composite material comprised of two materials with different densities can float on water. Later, they used mold-making techniques to create a pattern for the floating portion of their structure (Fig. 5).

Fig. 5. Material studies conducted by Amir Hussain, Bristie Smith & Jeremy Gremillion

Design projects

Working in groups of two or three, students studied a section of Lake Pontchartrain's shoreline on the north side of New Orleans. They then identified a problem in the site and proposed a location for intervention to help ameliorate the identified problem. Finally, they imagined a possible future floating project based on this imagined intervention. As the instructor, I summarize some of my higher-level pedagogical findings:

<u>Program:</u> Students were free to develop the program of the design interventions. On one hand, this opportunity allowed them to focus on the CAD/CAM aspects of the studio. On the other hand, some were carried away in developing the program. Although there were square footage limitations, some proposed programs operated in two phases (normal vs. disaster). The increased complexity of these programs distracted students from the main thrust of the studio. The scale and complexity of the *program* must be controlled so that it does distract from the learning goals.

<u>Buoyancy:</u> Exploring center of buoyancy using CAD was effective. However, when students reached the point of designing an intervention, many students had difficulty implementing it, and used columns in their initial sketches. I believe making a floating object/geometry paired with CAD exploration could have enhanced CAD integration at the design phase.

<u>Access:</u> The section of Lake Pontchartrain chosen as the project site introduced more complexities (and design opportunities). One of the challenges of the project was the limited depth of the lake along the shoreline. Therefore, to design a floating building, students needed to move further into the lake to reach a minimum depth of eight feet. This condition challenged them to design (or to ignore) the access paths from New Orleans and Metairie shoreline to the entry point of their intervention. Therefore, *access* became critical and pushed some projects to have a landscape scale. Also, upon moving into the lake, I noticed that a *breakwater* needs to be designed for the design interventions. Therefore, a research project on infrastructures and breakwater structures was added to the curriculum to prepare students.

<u>Surface patterns:</u> Exploring design patterns using additive and manufacturing CAM techniques was fascinating to the students, and the scale and freedom of the defined project worked very well. However, not many of those patterns were carried forward to the design interventions. Perhaps scaling up the patterns understood as the building envelope would have a stronger pedagogical effect for later implementation in the design interventions.

<u>Material composite:</u> Exploration of composite materials was not part of the studio curriculum. However, after seeing its positive effect on students' learning when a group voluntarily conducted it, I believe it should form a key part of studio, enhancing both the design of the buoyant platform and surface patterns.

Here, the students' projects are analyzed regarding their proposed program, buoyancy, access, and surface patterns, to discuss how the learning methods led to their implementation in the design interventions.

<u>Weathervane (Jordan Farho, Chryshanna Williams)</u>:

As presented in Fig. 6-top-left, a floating amorphous form covered with glass and high-tech engineering plastics acts as a scientific and quantitative method of observing nature. This form is nested inside the vernacular decking, allowing for qualitative observation of the visually and physically changing environment. The proposed <u>*program*</u> had the right scale. The amorphous form created using CAD is a direct result of working with free-form surfaces and understanding how they can be fabricated. Designed as a <u>*buoyant*</u> blob, the compartments at the bottom of the intervention are designed to reduce density, while increasing the mass against the buoyant force of the water to make it float. The design intervention is *accessible* only by boat. *Surface patterns* were not translated to this design intervention, which fit the concept. This project met the studio's goals.

Bird Up: The Lake Pontchartrain Bird Haven (Henry Bein, Josh Nicols): This project (Fig. 6-top-right) provides habitat for migrating birds and a rehabilitation program for injured or oiled birds, while providing education and recreation for people. The *program* was the right size, aligning with the context. Regarding *buoyancy*, the principles of boat hull design were implemented to conceptualize a floating platform made of steel, hollow pockets, and wood. This design decision was based on students' understanding of materials and their effect on floating. The project resolved *access* by distancing itself from human society and becoming a floating island attached to the existing Breakwater park peninsula breakwater. *Surface patterns* were not translated to this design intervention, a missed opportunity, especially given the program focuses on birds. This project successfully met the studio's goals.

Communal Archetype (Anne Kellerman, Julia Scheuermann): The Communal Archetype aims to provide a location for cross-disciplinary education, communication, and decision-making open to all people. The vision is that it will host leading officials from the neighboring parishes of Orleans and Jefferson (otherwise separated by the 17th Street Canal). The main meeting room is responsive to the occupation of the center by the public, descending in the water as more people are present in the center, demonstrating people's power to affect the decision and make a change (Fig. 6-center). The *program* had the right scale and was well-contextualized. The students successfully combined the concept of *buoyancy*, by designing the hollow compartments and using materials with low density such as wood, as well as by integrating the concept of buoyancy to their core design concept: designing a room for policy makers that sinks in water as more people attend. From a different perspective, designing a freeform shell surface to cover the space was affected by their understanding of CAD/CAM exercises conducted at the beginning of the studio. *Surface patterns* were not translated to this design intervention. To resolve *access*, they used an existing breakwater along the lake with appropriate water depth for their site. This project successfully met the studio's goals.

Floating Nexus (Annan Wang, Cory Natal): Defining the *program* as a center for circulating knowledge and people, the structure is a passageway that meshes both architectural and landscape design to make the floating building connected to the city. Implementing *buoyancy* was a challenge in this project. However, *surface patterns* were successfully integrated into the design intervention; the surface curvatures on the top and bottom of were designed to attract birds and marine creators, respectively. The curvatures were combined with the access pathways to the intervention, starting from the shoreline, then going underneath the intervention, before wrapping around the intervention. *Access* was designed through the same pathway. The effect of CAD/CAM exercises was obvious in the development of this project, which met the studio goals to a good degree.

Bucktown Reef (Amir Hussain, Bristie Smith, Jeremy Gremillion): The *program* of this project revolved around fishing, boating, and cuisine, features vital to the cultural identity and traditions of Lake Pontchartrain. It is a floating fish market that allows the fishermen to sell fish off of their boats, combined with a restaurant that is sourced by the market's vendors (Fig. 6-bottom). The *buoyant* platform was combined with *surface curvatures* investigated earlier using CAD/CAM techniques. A breakwater attached to an existing breakwater was designed to provide *access* for pedestrians while also providing boat access for fishermen. This project exceeded the studio's goals.

H.E.R.C. Hurricane Education + Response Center (David Oliver, Brendan Bailey): The *program* was defined as educating about the dangers that hurricanes pose, while functioning as a search and rescue center following storms. The program was complex, as it needed to be designed for two phases of operation. This project employed the concept of *buoyancy* for designing the hull of the intervention—inspired by buoyancy studies—however, it did not implement *surface patterns*. *Access* was not also fully resolved. This project met some of the studio's goals.

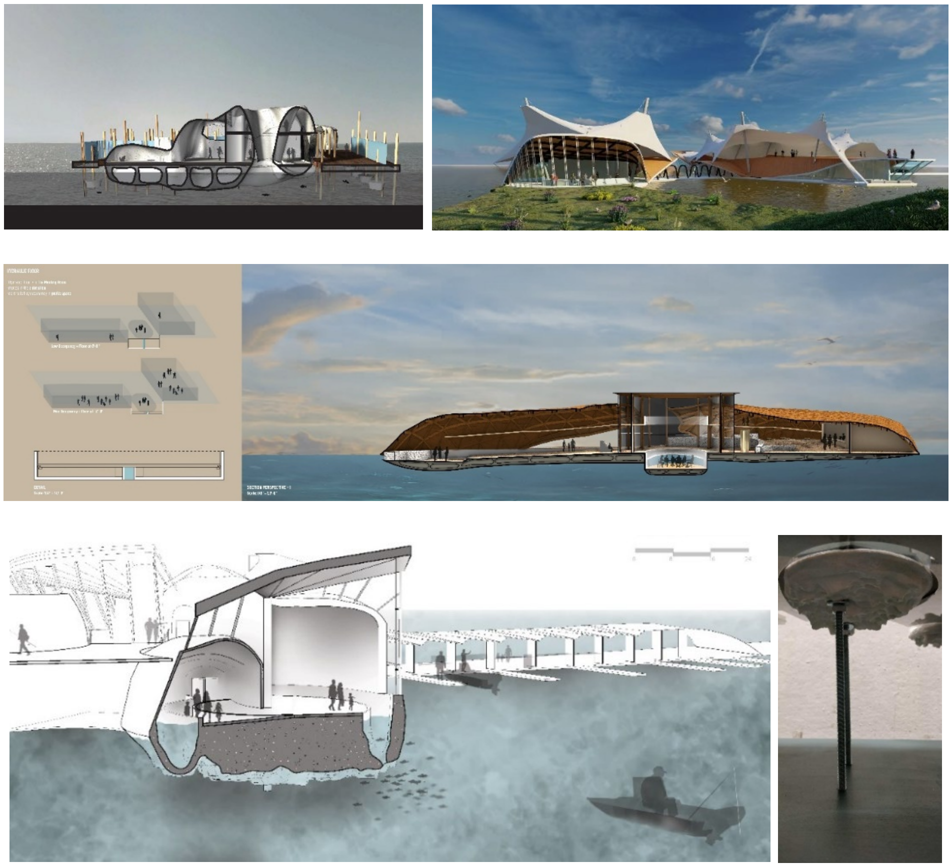

Fig. 6. Weathervane (top-left); Bird Up (top-right); Communal Archetype (center); Bucktown Reef (bottom)

Discussion

This studio took a non-traditional approach in speculating on design possibilities in Southern Louisiana. When levees, canals, and pump stations fail to protect already elevated buildings from the water inundation, it might be time to consider what else can be done to mitigate this problem. Students conducted in-depth site analysis, identified a site, and formulated a program around the identified problem. Afterward, they experimented with CAD and CAM processes and materials before designing a floating intervention.

The course evaluations indicate that the subject of the studio was challenging but interesting for the students. One student stated "I highly appreciate the professor's enthusiasm and interest in exposing the students to new programs and pushing our abilities. The challenge was both exciting and rewarding." Another student spoke more to the ambiguity and struggles in the studio by stating: "Overall, I am pleased with the results, but it was a definite struggle to wrap my talents and mind around something so big and undefined." From a different perspective, the education process seems to have been effective, as a student stated: "the process of this class has been very successful. I believe the teacher held students to a high level."

Upon reading the course evaluations I noticed that many students who took this "option studio" were interested in its material exploration and fabrication aspect. They believed the scope was wide, and some of them viewed the extensive site investigations as an element that could have been minimized. As the instructor, I believe the extensive site analysis resulted in rich and diverse problem identification followed by interesting program proposals. However, fitting an extensive site investigation and material/fabrication process investigation into one semester does not seems feasible, and I would seek to modify the studio in future semesters

Conclusion

This studio explored innovative design practice for designing with water in Southern Louisiana using advanced CAD/CAM techniques and composite material studies. The use of CAD/CAM methods facilitated exploration of complex problems, as well as validation of the feasibility of proposed solutions. However, mastering many of these techniques has a deep learning curve, meaning that for students to flourish, they should either have some level of understanding of the methods before enrolling in the studio; experiment further with these techniques in a parallel course; or focus more on the material exploration and digital design and fabrication aspect of the studio rather than conducting extensive site investigations or working with complex programs. By focusing on material explorations using CAD/CAM techniques, and by reducing the scale of the design intervention, small-scale prototypes can be made that can actually be tested on water. This will be an interesting improvement in future studios. This approach can also highlight how experiments translate into a prototype through an iterative design process.

Acknowledgments

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