Living With Water：

How Flexible Structure Types Build Resilience in a Dynamic Landscape？

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Abstract

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Coastal cities of the United States have suffered and will suffer great loss from flood-related hazards. Governments and organizations have taken many strategies to prevent, mitigate, and recover from their impact. When the episodic hazards, however, are accompanied with chronological threat—namely sea level rise—together they will generate more challenges than what traditional treatments can resolve. Widely adopted mitigation methods, such as stronger structures and higher elevations, are showing limitations given land loss due to sea level rise.

This research explores alternative strategies in the land use planning and architectural realm to enhance hazard resilience in Mexico Beach. The research aims at identifying some unconventional architectural techniques other than elevating foundations-- such as floating homes, amphibious homes and disposable homes-- that may enhance resilience to coastal hazards in a dynamic landscape, and determining under what environmental, regulatory and economic conditions they may most appropriately be employed. Mexico Beach in Florida is such a site threatened by both episodic hazards like flood and hurricanes, and slow but ever-present sea level rise. In 2018, Hurricane Michael brought devastation to Mexico Beach, but it also opened a window to redevelopment as well as an opportunity to experiment

with revolutionary methods of handling coastal threats. In the course of researching this thesis, Mexico Beach adopted a plan which excluded the application of these techniques. In response, this thesis presents Sanibel, Florida, as a counterfactual case to illustrate how a conservationist strategy might encourage development with a resilient suite of housing types.

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Acknowledgments

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1.Introduction

The recent hurricane Michael surged into Mexico beach and caused vast destruction. Among the ruins it left behind stands a house whose owner is well prepared for the event and invested much more on structure strength than the local building standard required. This view inspired a lot of people to request FEMA funds to improve building standards for the area's reconstruction to increase local resilience.

Figure1: An image of Sand Palace, Mexico Beach, after Hurricane Michael, reprinted from CNN news

Flood-related hazards have increasingly captured the attention of scholars and planners. As mentioned by researchers, "One of the most dangerous and frequent challenges to human settlements comes from the flow of water into areas that are not designed for such inundations—in other words, flooding."(Lamond et al., 2011). Nowadays, flood risk measurements and building regulations have become routines in urban planning. Coastal flooding caught more eyes after hurricane Katrina. Institutions like FEMA have been more active than ever to ensure the resistance and resilience in coastal areas. People in high risk areas have to comply with the regulations including adopting stronger material and elevating their houses to have access to flood insurance.

Advocates suggest that FEMA also tighten the construction requirement in Mexico beach to increase its resistance to flood impact. There raises some questions: Is elevating and strengthening the most suitable mitigation in Mexico Beach towards floods? Or at least, is it the most proper solution for all properties in the city? Does elevating and strengthening buildings provide Mexico Beach with most resilience to all kinds of hazards? Will the mitigation induce other problems to the community?

To address the questions, reviewers of this regulation first need to know that episodic hazards are not the only threat that coastal areas like Mexico Beach are facing. Chronological changes like sea level rise and coastal erosion are claiming the land the properties stand on. There are as many, if not more, studies showing that Sea-level rise (SLR) poses a particularly ominous threat because 10% of the world's population (634 million people) lives in low-lying coastal regions within 10 m elevation of sea level (McGranahan et al. 2007) (Fitzgerald, Fenster, Argow, & Buynevich, 2008) . There are an increasing number of researches and plans on this issue.

In the recent years, the number of studies addressing the two threats Mexico beach--Sea level rise and coastal floods increases. However, most of them are either focusing on one of the issues rather than the combination of them. When the two threats are put together, nevertheless, the situation becomes more complicated. Among the mitigation to these two threats there are two trends that contradicts each other—One seeks longer occupation of the land, the other looks for preparation withdraw.

Sand Palace, the lonely survivor in Mexico Beach Hurricane Michael, proved the determination, capacity and of course capital of its owner to overcome "the big one". But is ultra-standard construction the perfect solution for the whole area? As sea level rises, the shoreline will eventually migrate behind the strengthened building. Could every family afford to invest all their money in reinforcing the house and have the property gone forever, together with the lot? If FEMA urges residents to spend money elevating their house and build it as strong as a bunker, people will lose more when they inevitably retreat from the area decades later. And as the standard rises, developers tend to increase density to compensate for the increased cost, which ends up in anchoring more value in the area destined to be consumed. Another problem is the large investment to stick to tight regulation today may obstacle the communities' capacity to adapt to future change. The shoreline is an environmentally unstable area compared with inner land. Adjustment in building codes and regulations are more likely to take place. Even if we don't think that far towards the retreat time, the increased cost and toughness of the properties make it harder for new interventions.

This study explores how to increase coastal flood resilience on a dynamic landscape with a combined architectural and land use planning approach. Land use planning and regulation presupposes the morphology (formal types) of structures and infrastructures as well as other non-architectural factors, such as property rights, that support different land uses. Changing the suite of available architectural types also changes the way land can be used and regulated. In this case, alternative strategies including disposable structures, portable structures, and amphibious structures may enable a land use plan to build both resilience to episodic hazards and flexibility to adapt as sea level rises. A qualitative research will be conducted, for the pros and cons of each strategy is relative and hard to quantify. And potential impact is yet to be explored and new findings may emerge with additional data. Comparisons will be made between alternative strategies and those existing in Mexico Beach coastal area treatments like elevating buildings and merely strengthening structures. Geo-spatial data of the site, including the NOAA sea level rise forecasting will be examined to determine where these strategies could be applied. The article will include case studies of these interventions that achieve best results in implementation to see whether they could succeed in places facing similar challenges.

Beyond just answering the research question, the research intended to serve as a preliminary, counterfactual study for the redesign of Mexico Beach. And furthermore, it could provide guidance for the design of other sites with similar conditions to Mexico Beach and facing a similar combination of threats. Mexico Beach faces threat from a combination of floods, hurricanes and sea level rise and it has an opportunity to redevelop. These two factors make it an ideal site to study the potential of unconventional architectural methods. There however lies a difficulty that Mexico Beach has made in its redevelopment plan which prefers exploitation over conservation thus leaving little room for the practice of these methods. As a solution, the thesis studies Sanibel, another city for a more eco-friendly coastal development strategy. The thesis then makes an assumption that Mexico Beach chose a similar strategy as Sanibel does and delves into that scenario to experiment with the tools.

2.Review of literature

As mentioned by researchers, “Humankind’s need and desire to control natural forces to preserve life and improve their lifestyles has a long history. One of the most dangerous and frequent challenges to human settlements comes from the flow of water into areas that are not designed for such inundations—in other words, flooding”(Lamond et al., 2011). Flood related hazards have captured attention of scholars and planners since long ago and the study on the nature and impact of floods has will ever continue.

2.1. Impact of coastal hazards and Sea level rise

Compared with riverine and storm water floods, coastal flooding is usually more destructive because they are driven by waves and transport much more energy. Apart from wetting the house like storm water floods often does, coastal floods deal massive impact damage to buildings. Besides, coastal areas are most likely to be the first victims on the path of hurricanes and face the strongest power they bring. Sea level rise, though not fierce and dangerous as episodic hazards, could take land with properties on top slowly and irreversibly. The impact of coastal hazards and sea level rise on the economy and society is a hot topic among researchers. Many studies focus on either of the two, or explore the relationship between them. Mexico beach is facing both threats, better understanding of their nature help with strategies to relieve from the damage they cause.

(Luc et al., 2010) conducted a quantitative study aiming at assessing the impact of natural disasters on the economy and social life in Vietnam. Spatial analysis on disasters over the country is done at the beginning. Then the author adopted existing models to measure the influence of the disasters on socioeconomic. The study covers different types of hazards. The conclusion on flood is that households can adapt to riverine floods, but it's hard to prepare for severe coastal floods.

In hazard resilience related research, natural disasters, even flooding alone could be subdivided to different types and analyzed respectively. Those areas far from dense urban regions could suffer less from disasters even if exposed more regularly to disasters.

In a quantitative study on sea level rise prediction (Fitzgerald et al., 2008), the research topic went in two directions. One research question is how sea level rise impacts shoreline landscape, the other is what is the model predicting future changes. Author uses a combination of data from documents and first hand data. Data includes spatial data, chronological data.

The prediction of sea level rise may be useful to help evaluate the importance and urgeness of dealing with SLR in Mexico Beach. The form of salt marshlands, barrier isles and retreat of plants prior to tideline's arrival means land value may be lost quicker than the real sea level comes.

(Blalock, 2017) did a qualitative case study aimed at predicting sea level rise in Gray Harbor, Washington and accessing its impacts to local nature and built environment. It also studies the adaptation approaches of concerning areas and explores potential strategies. documents and analytical graphics are included. Case studies of New Orleans, Washington and New York are made to explain how adaptations reflect the socio-ecological relationship. Conclusions are suggestions with strategy proposals.

A wide range of adaptations are presented and summarized into three categories: protection, commodate and retreat. Introductions to each specific strategy and comparison between them are presented, which may help determine the adaptation in Mexico Beach.

(Boettle, Rybski, & Kropp, 2013) did a quantitative study on how sea level rise changes the frequency and damage of episodical coastal floods. The focus is on annual, monetary damage caused by coastal flooding of a specific magnitude. Models are built to examine the relationship between the Extreme value of sea level and annual flood damage cost. Case studies of Copenhagen and Denmark are also used to support the theory. A function describing the relationship is made as the conclusion.

Case studies on existing places of similar characters with the research site can support the strategies promoted in the site. Chronological change such as sea level rise has a relationship with episodic change. As sea level rises the frequency and damage of chronology will also increase.

2.2. Planning & Disaster recovery

One individual has too limited power to retain the value of his properties in face of natural disasters, and is too vulnerable to take the risk alone. The government and organizations play important roles in hazard prevention and mitigation. To apply alternative building types to Mexico Beach, planning will function as a tool. There are many studies on how planning and regulations alleviates the damage cost by hazards.

A study of Aerts el al on LA beaches(Aerts et al., 2018) illustrates the importance of dynamic planning when dealing with SLR issues. In this study, suggestions were made to the local organizations that multiple adaptations could be set, to allow one change gradually into another overtime. FEMA is criticized for its plan for Mexico beach to ignore change. The cost of a wide range of implementations are presented. Although I'm not doing quantitative research, general relative cost is useful in comparison between strategies.

(Bernstein & Rand Gulf States Policy Institute., 2006)Another report focuses on presenting the conclusion and suggestions rather than the process of the research. But from the outcome it's not hard to interpret that it’s a case study aiming at Mississippi on the condition and availability, both prior to and after hurricane Katrina, of affordable housing, and related policies.

In this official research aimed directly at developing strategies for another southeast area that suffers great loss due to a super hurricane like Mexico beach, both higher building standards and alternative types of structures are recommended. In proposing Mexico beach, maybe it's better to think of stronger elevated houses and flexible houses as alternative solutions to the same problem rather than splitting them as opposites.

(Comerio, 2014)In a qualitative research lead by Comerio et al, the researchers aimed at revealing the importance of the housing approach in disaster recovery, and makes comparisons between different types of housing approaches in the world. Data incorporated are mostly narrative statistics from documents. Two case studies of housing approaches in Chile and New Zealand are made to help explore the effectiveness of different approaches. Conclusion is that housing is a priority in recovery, and more should be taken into consideration than physical replacement.

The power of government and participation level of community in planning affairs greatly influence the strategy of rehousing in the aftermath of disasters. An effective strategy in one place may not work as well in another. When applying a successful treatment from a place to elsewhere, differences in culture, demographic attributes and planning procedure should be considered.

2.3. Response of built environment

Various approaches could be used to mitigate coastal hazards. The goal could be achieved through nature, building, or engineer intervention. Most of the articles on coastal hazard proof design focus on nature and engineer approaches like barriers or buffers. Among those focusing on how architectural treatment could help with the problem, most stick to the conventional “strengthen and elevate” strategy. Few literatures take a deep look into alternative building types.

(Jeroen et al.) A quantitative research comparing the performance of two types of resilience strategy. Target site is the metropolitan area near Hudson River. Models of flood risk are made, and construction cost is anticipated to evaluate two models: barrier protection and reducing risk with building codes. Transferability of the strategies to other regions is also measured after the conclusion.

A combination of multiple strategies should be employed to best enhance local hazard resilience. Certain strategies serve best for certain sites. When adopting hazard mitigation strategies considerations should be taken on whether the strategy successful in another place could succeed here.

(Song, Fu, Wang, Peng, & Gu, 2018)Another quantitative study aimed at creating models predicting future impacts of SLR and induced flooding on Bay county coastal area, Florida. Approaches adopted include multi linear perceptron neural network, Similar weighted instance based learning and binary logistic regression. Data used are land cover maps from Florida Geographic Data Library (FGDL) and sea level rise scenarios. Variables are selected based on lit review and data availability. Predictions on the possibility of hazards as well as urbanization practices are made. In the final conclusion "soft" strategies in high density areas and planned retreat of coastal areas are highly recommended.

With detailed data analysis processes but the prediction models, the outcome and conclusion are of value to coastal mitigation. In these scenarios, "soft" strategies are also preferred over sheer strength of structures. Attempts to defeat rising water tend to increase the exposure of communities to SLR, which backs up the theories in Mexico beach research.

2.4. Alternative Building Types

Some researchers seek flexible building types as a way to increase resilience in coastal areas. There is research on the characteristic, economic efficiency, and implementation of new structure types. However, most of the researchers are in west Europe or southeast Asia. While new approaches such as amphibious structures are occupying the market in the Netherlands, they draw little attention in North America.

(Kusenbach, Simms, & Tobin, 2010)A qualitative study is designed to find out the mobile house owners' readiness for mobile house owners in Ruskin, Florida. The data is from a survey to 75 residents living in mobile houses. The outcome suggests that on average, mobile home owners (think they) are more vulnerable to hazards than permanent dwellers. The readiness towards hazards vary greatly from person to person. The lack of guidance and related plans are thought to account for the vulnerability.

A qualitative research by organizations(UNESCO-IHP and COST Action C22, n.d.) aims at finding whether Amphibious houses could be a better strategy than fixed elevated houses. It's not a formal qualitative research for it mostly uses case study to reach its conclusion. It sets up grounded theories but just talks them out instead of using experiments.

In a research material published by Buoyant Foundation, the author addresses the advantages of amphibious houses, meanwhile exposing a lot of relative weakness of the strategy FEMA promotes.

(Nilubon, Veerbeek, & Zevenbergen, 2016)Another study intends to explore the role amphibians could play in transforming the city of Bangkok into a flood resilient city. Research question, I guess, is how amphibious houses can raise the flood resilience of Bangkok, and when and where are the ideal to adopt them. It uses a mixed method approach. It uses qualitative mapping analysis, a case study about the adoption of how amphibious structures work well in Lad Krabang, and set up quantified standards. It uses spatial data (they produced the graphics but didn't say how they get information)With each step as a filter, they finally decide the ideal place for amphibious structures and present it as a plan.

This study is not only a research but also a practice. These shows that spatial analysis is particularly helpful in addressing coastal hazards since sea level rise is not occurring evenly all over the beach. From many design approaches like adding ponds and seasonal sunken parks the author suggests that increasing "hard resistance" is not the only physical solution to increase hazard resilience, flexibility to future changes should also be addressed in mitigation and prevention.

(Prosun, 2011)A study done by Prosun has a research question that is whether and how can amphibious housing be an affordable method to increase resilience in Bangladesh Flood area. This documentary study is accompanied by projects in which the author designed and built amphibious house in Dehaka, Bangladesh. The most intriguing contribution of this practice lies in that it’s an unusual practice to adopt amphibious house in areas as a tool to provide affordable mitigation to floods. It is a rare practice to relate amphibious buildings with affordability to the poor. Moreover, the project successfully attempted to implement amphibious retrofitting on existing buildings. However, the success is based on the unique character of buildings in Dehaka. It still remain to be seen if American City’s can learn from that experience.

In summary, there are literates paying attention to the threat of sea level rise and discuss how the methods to alleviate the problems. There are also studies on architectural methods such as amphibious house as tools to mitigate riverine flood. However, there is a lack of studies on how to use Architectural mitigation methods to overcome threats posed by sea level rise. This thesis intends to look into that direction and analyze how architecture can help coastal settlements build resilience to the combined threats of sea level rise and floods.

3.Site Analysis

3.1. Geography & Nature

The city of Mexico sits in the northwest part of Florida, to the south east of Panama City. It’s a small city built along US highway 98, which goes along the shoreline facing Mexico Gulf. On the southern edge of the city is its famous white sand beach along the shore, which is a major tourist site of the city.

Figure 2: Aerial map of Mexico Beach, adapted from Google Map

Exposed directly to the Gulf of Mexico, the state of Florida has a history of extreme weather events from the sea, among which most frequent and hazardous are hurricanes. Most recorded local hurricanes originate from the south and meet Florida as their first encounter. With no buffer lands between the city and the sea, Mexico Beach is also vulnerable to the damage of the hurricanes. When a hurricane arrives from the south, the city is subject to a combination of three types of damage----the raw force of the wind, the inland flood caused by rainfall, and the direct impact of waves from the sea. In 2018, such a combination caused severe damage to Mexico Beach, ruining most of its buildings, almost wiping out the city.

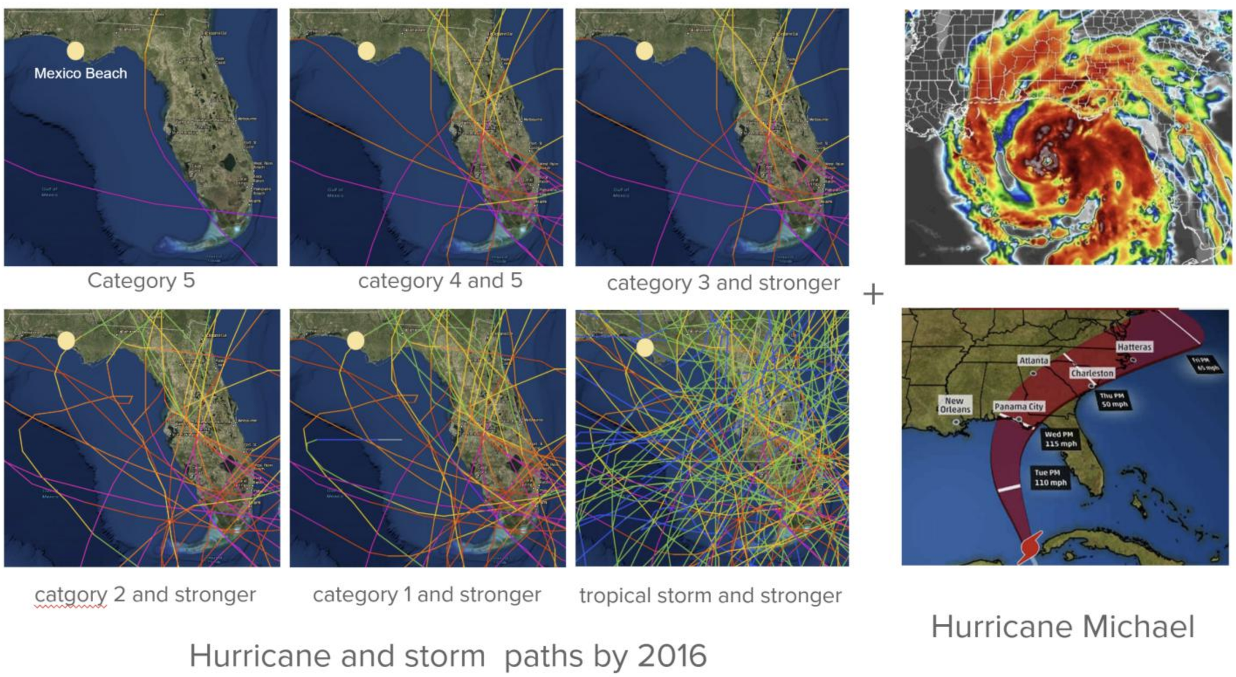


Figure 3 : Historic hurricane and storm Paths near Mexico Beach, adapted from NOAA

As climate changes, the ocean soaks more heat and expands in its volume. In addition, the rapidly melting ice in the poles and glaciers further accelerates the expansion. To make preparations for sea level rise, it is important to know how fast the process is. Different associations provided different predictions, based on the observation site and scenarios they chose. In 2019, The Intergovernmental Panel on Climate Change(IPCC) predicted a 2-4 feet rise in global sea level by the end of this century, based on an assumption that global carbon emissions keep at a high rate. The National Oceanic and Atmospheric Administration(NOAA) estimates a higher increase in sea level in the local scenario of its observation site in Panama City, the closest one to Mexico Beach. NOAA predicts a 6 feet rise by 2100 in its intermediate high scenario, and a 8 feet rise in its high scenario .

Regardless of which model of sea level prediction is more accurate, Mexico beach is going to suffer great losses as the advancing shoreline claims land. With a sea level rise of 3 feet, the city will lose most of its beautiful white sand beach. According to the conservative estimates, this will happen by the end of this century. While the High scenario by NOAA predicts a 3 feet rise to occur in the 2050s. Before completely falling below sea level, the usually pristine, white, expansive beaches in Mexico Beach are also subject to the threats of coastal erosion. As sea level rises, the increasingly severe storm surges can also threaten the existence of the sand beach. Severe storms can remove wide beaches and dunes in a single event, and this issue is of particular concern to Mexico Beach residents who live right by the water where one or two feet of erosion can have catastrophic consequences. With the combination of future sea level rise and increases in storm frequency and intensity, coastal erosion will also increase. Thus, the reduction in tourism due to loss of the beach is an issue to consider in the reconstruction process of the city.

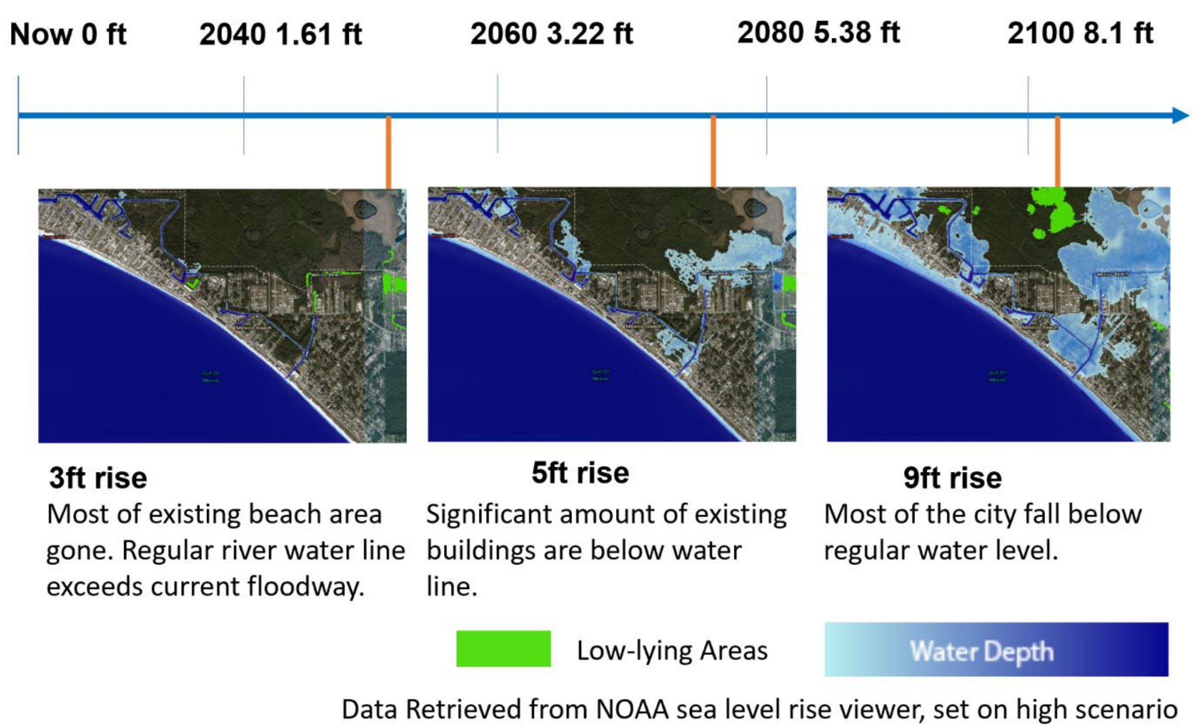


Figure 4 : Effects of Sea level rise on the City of Mexico Beach, Florida. Data Retrieved from NOAA sea level rise viewer

Table 1 : Mexico Beach, projected loss in a 500 year event, data retrieved from Mexico Beach Resilience Redevelopment plan

Occupancy	Number of Parcels	Number of Structures	Value of Structures	Value of Contents
Residential	692	700	$129,676,492	$64,839,746
Commercial	17	24	$12,165,975	$12,165,975
Industrial	6	9	$1,629,544	$2,444,316
Institutional	8	9	$920,148	$920,148
Government	3	3	$3,108,093	$3,108,093
Total	726	745	$147,503,252	$83,478,278

Compared with the long term sea level rise, wind is a more urgent and destructive threat to consider at the time being. In a temporal hazard case, wind also causes more devastation than flood. The city pointed out in its post hazard analysis report that 40% of buildings in the city fall in the special flood hazard area (SFHA), which means an area that becomes a flood zone when a 100-year flood occurs. On the other hand, almost the entire city sits in the storm surge zone and is vulnerable to storm surges. The city concluded in a simulation that storm surges cause almost twice the loss as what a 500-year flood will do. This comparison indicates that the capacity to reduce damage caused by wind is an important point to consider when retrofitting local buildings.

Table 2 : Mexico Beach, property value within storm surge zone,data retrieved from Mexico Beach Resilience Redevelopment plan

Occupancy	Number of Parcels	Number of Structures	Value of Structures	Value of Contents
Residential	1655	1674	$266,760,842	$133,380,421
Commercial	57	66	$20,900,287	$20,900,287
Industrial	7	10	$1,766,539	$2,649,809
Institutional	14	15	$1,397,701	$1,397,701
Government	8	8	$4,051,378	$4,051,378
Total	1741	1773	$294,876,747	$162,379,596

3.2.Demography & Ownership

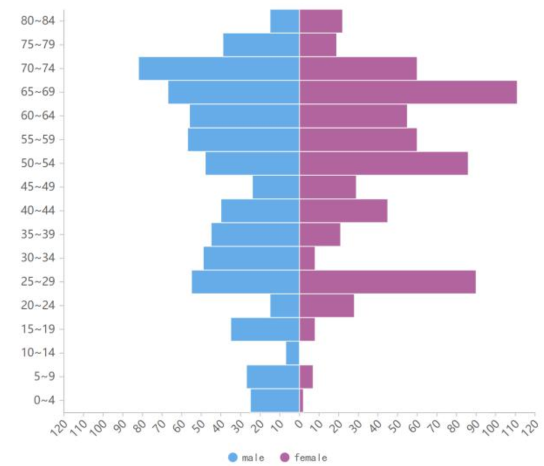
3.2.1.Population

According to the 5-year community survey by the United States Census Bureau, Mexico Beach has a population of 1386 in 2019. Despite a reduction in dwellers in 2018 when Hurricane Michael forced many families to move out of the city, the dwellers came back and rebuilt their homes next year. COVID-19 cast some shadow on local tourism in 2010, but the municipal government claims that the city is accepting a lot of tourists in 2021 and the renter market had a bloom this year.

Age

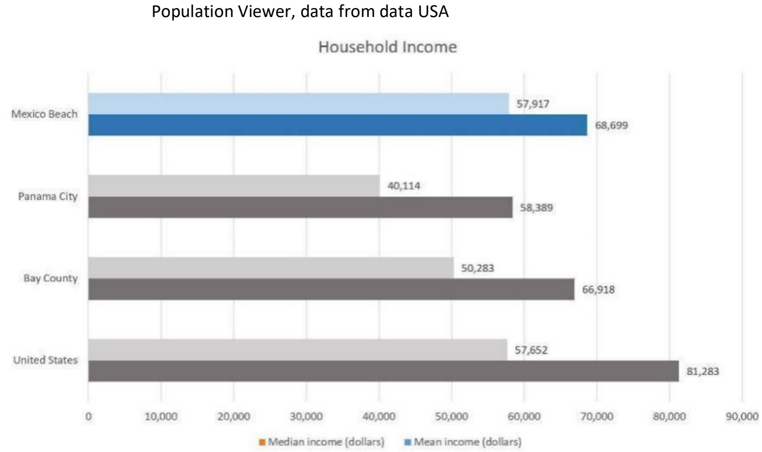
The city's residents have an average age of 58 years. Roughly 1/3 of the dwellers are over 65 years old. This age structure presents a need for enhanced accessibility. People after retiring age are less likely to enjoy climbing stairs every time they enter or leave home. The traditional method of elevated homes may come in handy and save residents' properties during a flood, but the extra effort wasted on stairs dragging grain on every normal day is a burden to the residents when accumulated.

Table 3 : Mexico Beach population pyramid 2021, data retrieved from World Population Viewer



Additionally, retired old people tend to spend more time within the community, for there are no more to spend in the workplace and on commuting. More people staying in the community usually means more communication. Designers also have to take into consideration the impact on

Table 4 : Mexico Beach household income,retrieved from World Population Viewer, data from data USA



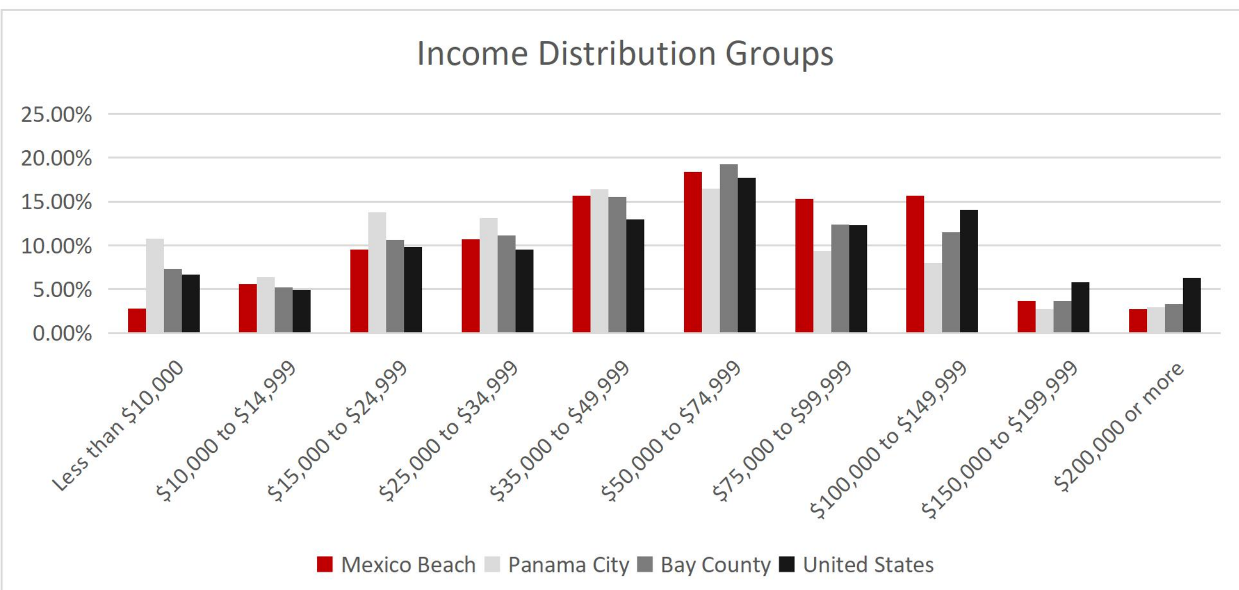
sense of community when determining which type of house to adopt..

Income

Mexico Beach is much richer compared with its surroundings. Families in Mexico Beach have 44% higher median income than those in Panama City, the city's close neighbor. The city also holds a median household income that is about $8000 higher than that of the Bay County region. Although Mexico Beach has a slightly higher median income than the National median, its average income is much lower—A gap of around $13000 dollars lies between. This statistic suggests that a common family in Mexico beach has good economic status, but the richest group doesn't hold as much of the value of the city's total as those in other places.

Another difference in data provides further support to the skew of income distribution in Mexico compared to its neighboring areas. Surrounding cities usually have low income or middle-income population as the primary group and high-income population as the minority. The trend however reverses in Mexico Beach. According to census data, there are 168 households, which account for over 20% percent of the city's residents, have an annual income of over $100,000 –which is about twice the city's median income.

Table 5 : Comparison of Income distribution between Mexico Beach and other regions, date retrieved from U.S. Census Bureau, 2013-2017



Census data in the chart above suggests that Mexico Beach has a low proportion of households with extreme low or high income while it has an outstanding share of families with an income between 75,000 and 150,000 dollars compared with both Panama City and National average. This data indicates that income distribution in Mexico Beach is more balanced and a bit skewed to the higher end. Such income structure calls for extra consideration for upper middle class who care about cost and notch of the buildings. Utmost affordability for the poorest and luxurious demand from the wealthiest is less of a problem when choosing housing types to apply here.

3.2.2.Expenditure

Although having an almost identical household income to the national median, Mexico Beach has a significantly higher household expenditure. The median household expenditure even exceeds the median income. Amongst all the items, grocery and transportation add much less burden to households in Mexico Beach compared to other areas, while housing makes up a notably higher proportion of expenditure than the U.S. Average. But it's unsafe to deduce that housing affordability is a top issue in Mexico Beach from the fact that dwellers spend a great proportion of their income on housing. The median home value in Mexico Beach is not higher than surrounding regions while residents have higher income. The tourism industry may explain the uncommon high percentage of housing expenditure in the city.

Table 6 : Comparison of median annual cost distribution in Mexico beach and other regions,data retrieved from data USA

cost type \ region	Mexico Beach	Florida	USA
Overall	114.5%	110.9%	100%
Grocery	91.9%	101.5%	100%
Health	99.4%	97.80%	100%
Housing	142%	118.7%	100%
Utilities	109%	101.3%	100%
Tranportation	114%	130%	100%
Miscellaneous	98.5%	96.9%	100%

(percentage shown is the ratio of median cost in each region compared to the median cost in the USA)

Unlike what happens in most other cities of the country, the renters in Mexico Beach have higher income compared to those who live in the house owned by themselves. The Average income of renter-occupied households is 27% higher than that of owner-occupied households, while median household income of renters in the country is only half as much as the median income of owners' households. Apart from having more budget, tourists are also more willing to spend on housing. Renting houses in

attractions is a short-term expenditure compared with covering the cost of one's own house. The median rent in Mexico beach is thus 20% percent higher than the national median. Consequently, the interest of transient dwellers who support the city's economy by renting houses here is also an aspect to consider when deciding the building techs to apply in Mexico Beach.

Table 7 : Income and housing cost of owner/renter occupied households, data retrieved from world population viewer, 2018

Although the extra cost spent on housing doesn't necessarily suggest that affordability is a main issue, reduction in expenditure is always an aspect to consider when choosing housing types. If new housing types could lower either the construction or maintenance cost of the buildings in hazard prone areas, the savings could relieve the residents of the pressure from excessive cost from purchasing flood insurance as well as adding to the city's attractiveness to tourists.

3.3.Zoning & Land use

Before Hurricane Michael, the city was designated into two parts. The north-west corner of the city, together with a stripe along the coast is for tourism use while the east part of the city is for local residents. US Highway 98 separates the tourist residential zone one its south from the residential uses on its north, preventing the two kinds of uses from interfering with each other.

In 2018, while Hurricane Michael devastated a large portion of buildings in Mexico Beach, it also opened a window for the city to change its zoning. In the 2019 development plan made by Mexico Beach, the city changed a demolished residential zone on the north side of the highway into tourist mixed use. With this change of zoning, the highway is no longer a border between the two uses. As tourist zones now engulf

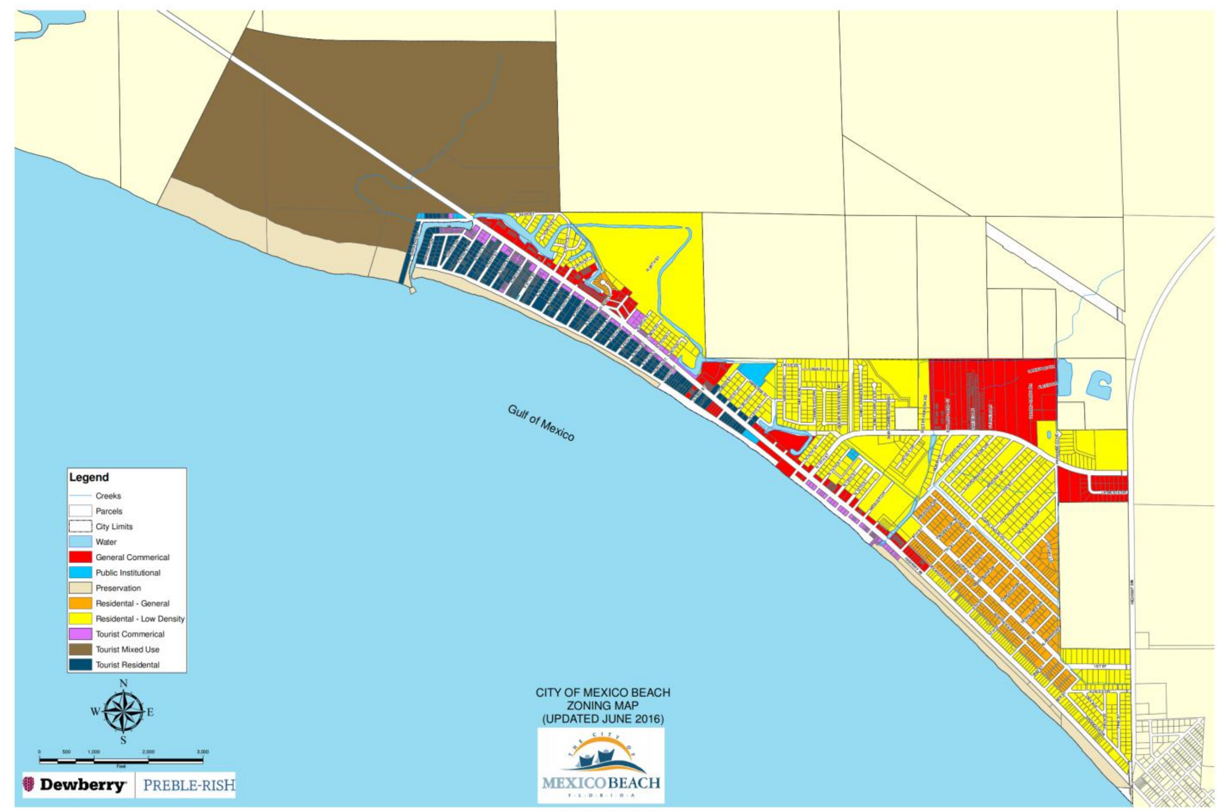


Figure 5: 2016 zoning map of Mexico Beach, reprinted from city of Mexico Beach

the residential district in the west half of the city, the separation between the two zones blurs. This change will enhance the city’s capacity of providing more tourist recreational activities and may lead to more interaction between tourists and local dwellers.

Another major change is the city changed its original tourist-residential zone into a high density residential zone. The name change from tourist zone into residential zone doesn’t imply the city’s anticipation of reduction in tourism. On the contrary, the aim of this change is to attract and shelter more tourists. Although the name changed into residential zone, the original permits on building types of tourist-residential use still apply. The master plan explains that increase in density will allow the city to keep up with the growing need of renters. It is also worth mentioning that the city figured out in its post disaster analysis that apartment buildings suffered less damage than detached houses. They are increasing

Figure 6: 2019 zoning map of Mexico Beach, reprinted from City of Mexico Beach

the density of the tourist zone near the shoreline with the expectation to increase resistance against future storm surges.

3.3.1.Massive Future Expansion

Apart from the change in the zoning codes within the existing city boundary, Mexico Beach is seeking an aggressive expansion in its recent plans. The shortage of housing units in the aftermath of Hurricane Michael, combined with the new housing demand from surrounding development are the two main reasons for such mass construction in the plan. During the hurricane, 760 out of the 1690 structures in Mexico Beach took substantially damage(over 40% damage), while only 166 escaped the damage without suffering any damage. The immediate shortage of housing and the lack of funds to rebuild them force the city to rebuild without hesitation and collect revenue quickly to compensate for the loss .

Table 8: Projected population composition of Tyndall Air Force Base, data retrieved from Military Installations

Population

- 3,421 active duty
- 5,356 Active Duty Military Dependents
- 798 civilians employees
- 9,403 retirees from all branches; 5,560 Air Force; 1,927 Army; 226 Marine Corps; and 1,690 Navy

Panama City metro: 171,322

Median Age: 40.1

Population Type	Number
Active Duty	3,043
Family Members	5,356
Retirees/Retiree Dependants	9,403/11,597
Civilian Employees	798
ANG/Reserve Component	245
Traditional Guard/Reserve	99
International Active Duty	31
Total Population	30,572

Besides, Tyndall Air force Base, a new military base to the south of Panama City and 10 miles northwest of Mexico Beach will finish its construction by 2023. The Base aims at holding over 30,000 people, which is over 20 times that of Mexico Beach. The addition of such a large population in the area will

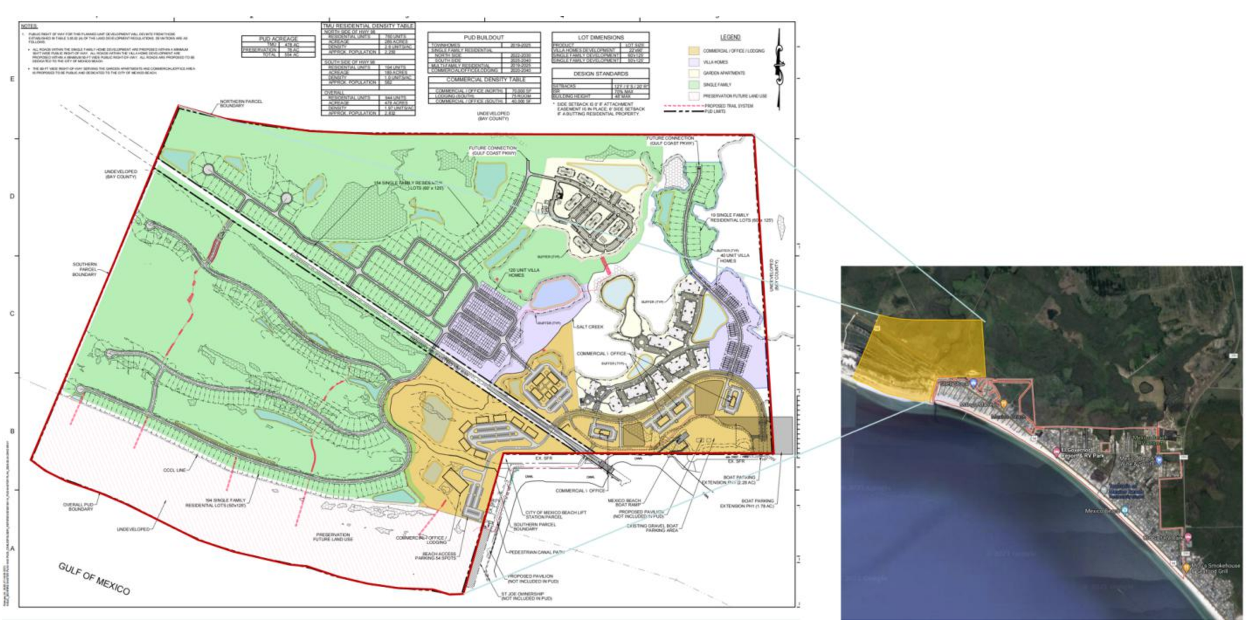


Figure 7 Mexico Beach town house community plan by St. Joe company, data retrieved from City of Mexico Beach

stimulate the needs of housing in Mexico Beach.

4. Alternative Housing types

4.1 Types of Architectural mitigation

Apart from a change in the perspective towards coast and interaction between society and nature, Mexico Beach could also benefit from a larger variety of architectural form in its hazard prone regions. The wide gap between the aspiration of fast expansion and the grievous depression due to the disaster leave Mexico Beach with hardness to overcome but also opportunity to evolve. The mass reconstruction of demolished properties and establishment of new communities opens up a window to experiment new techniques to help build resilience. Strengthening the material and elevating the foundation of the houses is a universal architectural strategy that FEMA recommends. This solution has proven its capacity in alleviating financial losses in disasters, but it is not the only access to resilience. There have been many other practices in the United States and all over the world of using unconventional architectural methods to help communities prosper in regions prone to coastal or inland flood hazards. Depending on the natural feature of the site, as well as the social character of the community, each type of the building technique could perform drastically. If planners and property owners can learn the advantages and flaws of each type, they can adopt these building forms accordingly and let them each shine in their most advantageous site.

4.1.1.Floating homes & houseboats

There are a lot of practices of houseboats and floating homes in the United states. People often confuse these two terms with each other, but they are actually different types of dwellings. Houseboat is by nature a boat while floating homes are buildings on water. The latter has a floating foundation connected to urban utilities on land, and is meant to stay in place, while houseboats have limited mobility by allowing itself to quickly disconnect from utilities on the dock and be towed away through water. These two types of houses both have the capacity to adapt to rise or descend as the level of water shifts, since they don't have a foundation of fixed height and always float on the surface of the water.

4.1.2.Amphibious houses

An amphibious house is a relatively novel concept to most parts of the world. The Europeans are the first to adopt it into designs. Designers in the Netherlands, where people have a long and hard history coping with water, first implemented amphibious houses as a way to deal with flooding. Then, in the UK, Baca Architects designed the project Amphibious House in Buckinghamshire, London.

Like floating homes, amphibious houses employ the same strategy to negate the influence of changes in water level. Instead of trying to resist water flow and seal water outside the building, it floats upwards in a flood or sea level rise case. The major difference between a floating house and amphibious house is that an amphibious house is built on land rather than on a permanent water body. The house has a foundation that is light and not fixed to the ground. During a flood, the house floats as if it's a boat. Surrounding the house is however a frame that locks the house horizontally, preventing water from washing it away.

The design of amphibious houses' buoyancy varies drastically as site condition as well as the personal preference of the owner differs. Depending on the massing and density of the foam-based foundation, the portion of the amphibious house falling below water while afloat varies. Some buildings have their basement partially underwater during a flood. These basements are usually storages and don't have water-vulnerable features like power sockets below the designed water line. While some other designs include a larger foam foundation, allowing all the living areas to remain dry during floods. The height of the frame, on the other hand, determines the extent to which the building can float up. The frame often also functions as an outer wall of the building. Its height usually doesn't exceed the height of the building excluding roof height. This principle is both for aesthetic and safety concern. For a regular two floor house, the rise limit is up to 18 feet. A major limit of amphibious houses is that the vertical movement of its foundation requires detachment from neighboring structures, so townhouse communities like St. Joe company's project in Mexico Beach cannot adopt this strategy.

4.1.3.Disposable houses

"Disposable house" is not the name of a building type. Here, it simply refers to properties which are built with low investment. Unlike what FEMA recommends, they do not have the strength to resist the impact of waves. But they are built with cheap material so that investor's will not lose too much in the case of a disaster. Property owners can easily rebuild the house after their destruction. The light material making up the structure will reduce the secondary damage when the debris of the house flows through waves and collides with other buildings. The new construction of a disposable house is easy, but an owner can't retrofit an existing house into a disposable one. As a result, this method only works in sites that need redevelopment.

4.2.Comparison

Such a variety of flexible building types presents numerous possibilities in coping with coastal hazards. But the performance of each type varies greatly under different circumstances. To determine where and when to implement each type of the buildings, is to answer the following questions: Against what threat does each type outperform or underperform the others? Where and when does each of these threats occur? What existing values do they undermine? Which region has and nurtures these values?

Apart from the building types researched above, this section will also include the traditional elevated house, which is now the dominant treatment at the site. By comparing the performance of this existing building type and the flexible buildings, this test aims at revealing whether and to what degree these buildings can make improvements to resilience of coastal communities. Then, it explores where and under what circumstance these building types can have best performance.

4.2.1.Shifting water level

The height of the water surface is shifting at every moment. Predictable reciprocating change like tides doesn't present as much difficulty into coastal life and planning. The sudden irregular rise and fall of water in floods and the slow yet irreversible ascension of mean sea level are the two factors threatening dwelling along the shore. The effectiveness to respond to the steady or sudden, temporary or permanent change in water level, is a key concern in choosing housing types in waterfronts.

Houseboats and the floating houses, as their names suggest, are buoyant and able to adjust with water level. No matter how much water level rises, they remain on the surface. These two building types outperform the rest in their unlimited adaptability to water level. Their buoyancy, on the other hand, sets limitations on the implementation of these building types—they can only be installed on water. Considering that sea level rise is the major trend in Mexico Beach, the likelihood of a total removal of the water in a floating home community is neglectable. So, their incapacity to withstand the situation where water drops far below the baseline doesn't become a drawback here.

Though coastal dwellers have been using elevation as a method to counter the influence of sea level rise and flood for a long time, elevating a house only provides limited resilience to the change of water level. The first reason lies in that a constant elevation of houses can't adapt to the changing demand presented by sea level rise in the long term. A house with a 4 feet elevation can survive a flood bringing 4 feet of water depth. But as sea level rises by 1 feet later, that elevation can only protect the house from a 3-feet-deep flood. Every foot of sea level rise can lead to a new FEMA standard of resilience in elevating new constructions, not to mention the 6-10 feet sea level rise Mexico Beach is likely to experience by the end of the century. If a house owner plans to lift his house in an already flood prone area to make it capable of withstanding major flood until next century, elevating the foundation will be a less practical option because it's not economically efficient to build a house with two-story-high elevation for future events, and nor will it be worthwhile to start with a low elevation and constantly readjust the structure of the house to changing standards. As a result, elevating a house to FEMA's standard only provide it with immunity to regular floods in the near future. The house owners still need other supplementary reinforcements to ready the house for severe flood events and long term sea level rise.

Amphibious houses solve these two dilemmas well. This type of building floats up as water rises, while it also holds the ability to descend after the water retreats. An amphibious house also beats a traditional elevated house in that it can adapt to a larger change in water level. Varying depending on the specific design, an amphibious house can have a floating limit of up to 18 feet, which can help it hold ground in Mexico Beach in the long run.

4.2.2.Wave Impact

In addition to wetting properties, coastal floods also carry devastating energy that destroy buildings. The resistance to physical impact of waves determines whether a building can stand in the front line facing direct impact of water.

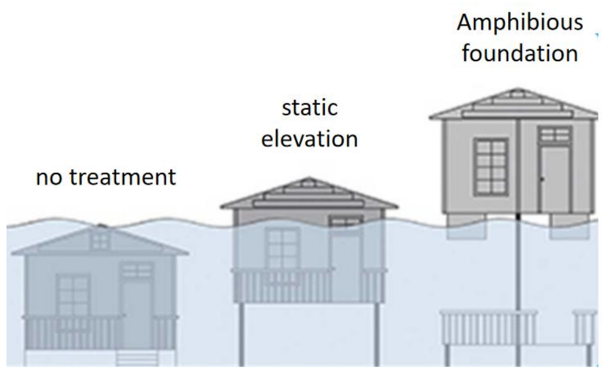


Figure 8: Comparison between amphibious house and elevated house in extreme floods, adapted from Anthropocene Magazine

Houseboats are smaller and lighter than regular buildings. They are not anchored to the ground. This feature make it resistant to wave impact. The ability to move and sway mitigates the force of the impact. And the vertical movement along with the waves reduced the direct horizontal impacts on the facade of the building. Extreme floods are predictable, in these cases, houseboats can pull away and guide to safer places in advance.

Floating houses share the capacity of mitigating impact forces with slight sways, but can't escape an anticipated major flood as easily as houseboats do. Owners can move a floating home, but only with the help of an owned or rented slip and tugboat. The cost of such movement is very high, ranging from $25000 to $200,000, based on the size of the building and the distance of movement.(https://portlandfloatinghomes.com/moving-a-floating-house/) In addition to the high cost, the movement is a slow process. Beyond that, it becomes more difficult for residents to make contacts and deals with tugboat service providers upon the arrival of extremely bad weather. As a result, a floating home protects itself well in milder floods but suffers from severe floods.

Figure 9: Moving a floating home with tugboat consume large amount of time and money, adapted from Portland Floating Homes

Amphibious houses can float upwards in floods as houseboats do but can't move horizontally to redirect the energy in impacts for a frame constrain the position of the house. The frame can have a length as the building's height but isn't as large and solid as the building's facade. During a flood, the building redirects all the force received by the facade facing the wave, to the connection point between the frame and the building. The side with smaller size undergoes higher pressure. Waves with high fluid velocity break the frame and cause the house to displace or collapse.

Disposable houses have little resistance to impact. They can crumple easily in a hurricane. But the owners don't intend to have them resist impact in the first place. They can rebuild these buildings quickly after a disaster. The main loss comes from the appliances and property inside the buildings. How much loss the owner suffers depends mainly on how much belonging they put in the building and how much they can evacuate before the disaster arrives. For permanent residents, hauling everything away from home to a safe place when they receive the alarm is impractical. Homeowners tend to have most of their properties at their house. Should the house be washed away, the owner suffers a great deal of loss, both economical and emotional. But for resort housing units, the owners will not hide all of their belongings inside. There are only limited appliances for the renters to use. The owner could come and take the most valuable items to safety. For tourist service structures like souvenir shops and restaurants, the situation is basically the same. The loss of disposable houses in disasters depends highly on the reaction time between the alarm and the occurrence of the disaster.

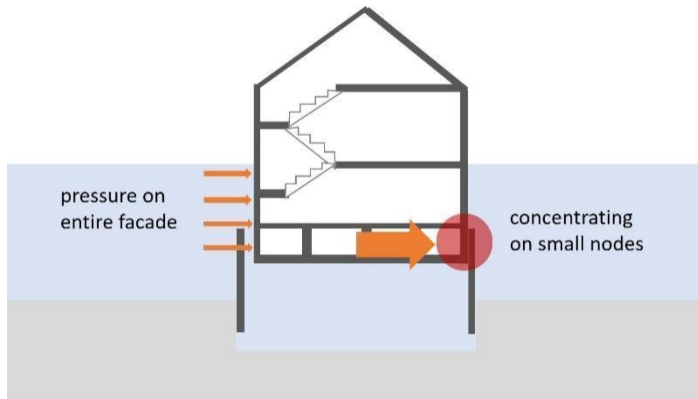


Figure 10: Amphibious house is vulnerable to impact of water with high velocity, for having no fixation to ground and rely on frames to keep in place.

Traditional elevated houses have their foundations facing the impact of waves. The foundation is stronger than the facade of superstructure, so it can withstand the impacting force. For those elevated houses built on pillars, water can simply flow through the space below, leaving the building intact. Though all the above happens only in scenarios where wave height doesn't exceed the elevation.

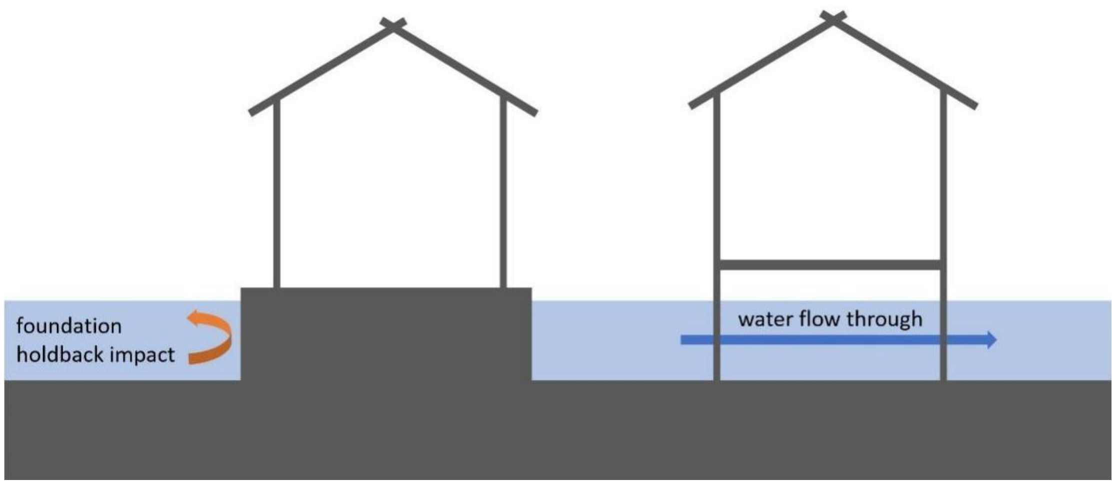


Figure 11: Traditional elevated house, either letting water through first floor or not resist water impact well.

4.2.3.Wind

In addition to the wave it carries, the storm itself can damage and even blow apart structures. For the flexible building types, capacity to stand against storms determines whether their stand on the northern shore of Mexico Gulf can last long. The most vulnerable part of a building to wind is its roof, especially when there are openings on the facade including windows, doors or broken holes letting wind into the house. Mitigation methods include sealing all holes on the facade adjusting the overhang distance of the roof, adopting a hip roof design where the roof has four slopes descending to each wall of the house. Apart from these universal causal and solutions to wind damage, this section will discuss the difference in performance of each flexible housing type to wind.

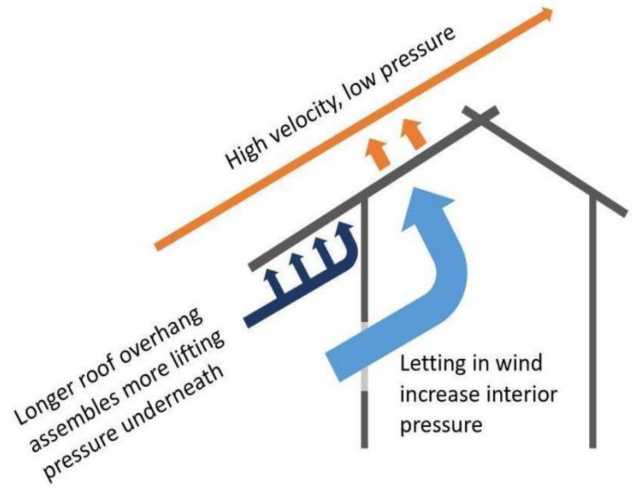


Figure 12: Reasons causing roof especially vulnerable to wind damage.

Houseboats can adapt to the movement of water but wind with high velocity can cause them great loss. The small friction between them and the water surface makes it easy for the wind to blow the houseboats away. As most storms in the area originate from the sea, they tend to drive houseboats toward the shore, making them strand. The houseboats can anchor themselves in the docks. But the density in which residents dock houseboats in the docks makes it a more dangerous place to stay during high category hurricanes—The houseboats collide into each other and receive damage on both shells and interior properties. An important feature that helps houseboats escape major floods is that they can sail away to milder waters. However, compared with flood, the wind part of the storm influences a larger area. The energy that air carries reduces slower than that water does. The impact region of wind damage can cover inner land and rivers that waves from sea cannot reach. Even if houseboats can move away, they'll find it more difficult to dodge wind than flood.

Floating homes also share some of the weaknesses like little friction. But they can anchor themselves to either the bottom or the shore. Unlike houseboats, floating homes are real estate properties and have parcels rather than a docking lot. Their larger mass also reduces their involuntary movement by wind, preventing them from bumping into each other.

Elevating a house functions well in negating the impact of water flow, but such competence doesn't extend to resisting the damage of blowing wind. If an owner elevates his house and makes use of the extra height to create a waterproof basement, the house will have a larger facade catching the wind. The total force the facade withstand is the product of average wind pressure multiplying the area of ind-catching surface. An increase in the facade area leads to an proportionate increase in the amount of force wind applies on the building.

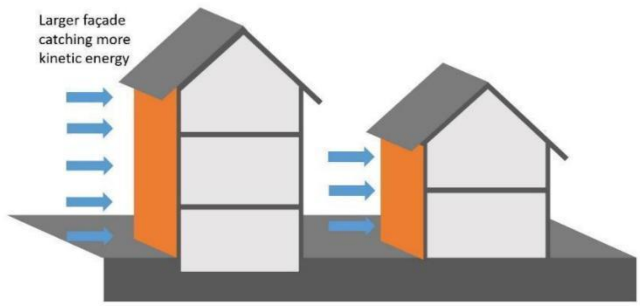


Figure 13: Large facade causing vulnerability to wind

In another case, if the owner elevates the house, but instead on top of pillars so that wind can go through the hollow first floor, just like how water flow through in a flood. However, neither does that prevent adding to the building's vulnerability to wind. Although the area of wind catching facade doesn't increase compared with a regular building, the position where the wind applies forces on the building changes. When a building stands against wind, it's the connection between the building and the ground that keeps it from falling over. The wind is applying a torque whose point of rotation is the bottom of the building and whose stress point (the point where force is applied) is at the center of the catching facade. The variable describing the effectiveness of the twisting force is torque. It is measured by the product of the strength of force and lever arm length. In this case, the two buildings receive the same amount of force, while the stress point of the elevated house is higher, thus more distant to the point of rotation, resulting in a larger torque. That means winds of same strength are more likely to push the elevated house over.

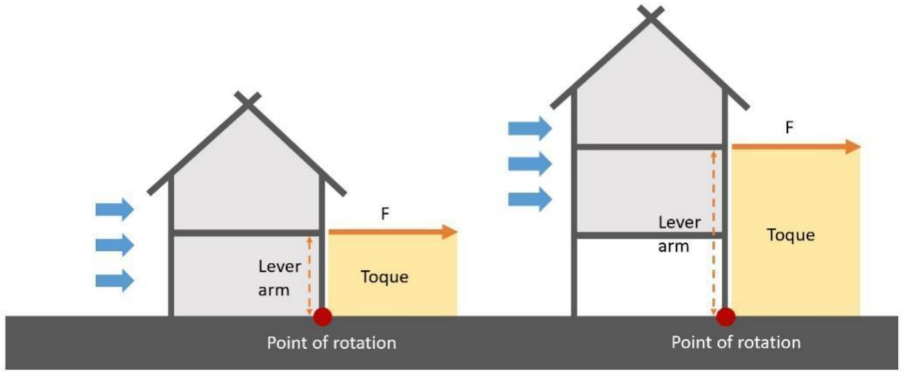


Figure 14: Elevation on pillars causing vulnerability to winds

In contrast, an amphibious house only rises in cases of raised water surface. It appears the same as a regular house when not afloat. An amphibious implementation subsequently neither adds to nor detract from a building's resistance to wind damage.

4.2.4.Influence on Living

Before functioning as a bastion securing the safety and guarding the valuable property of the owners, a house is first a place for people to settle in and carry on with their daily activities. Although a lot of coastal settlements like Mexico Beach face the dual pressure from sea level rise and floods, the residents still put the majority of their time in leading normal lives. Apart from the retrofits' capacity to reduce the loss people suffer from extreme events, planners have to consider their impact on the quality of routine life, from the perspective of both individual and community.

From the point of a homeowner, one drawback of conventional elevation is obstructing the access between the home and its surrounding environment. People have to climb extra floors every time they enter or leave the house. Considering the significantly older median age in Mexico Beach than other part of the country, this inconvenience will become a nuisance to the residents in the city.

Besides adding obstacles to the physical link between a house and the environment, elevating a house also turns down visual connectivity. This lack of connectivity however could sometimes be beneficial for dwellers to whom interference from outside the house is not welcome, typically for renters who have no local acquaintances and appreciate safety and privacy over communication with their stranger neighbors.

An amphibious home, on the other hand, stays on the ground when there is no flood. People inside and outside the building stand on the same level, thus visual contact and connectivity are as easy as regular detached houses. Neighbors can share food or borrow items without the need to climb up and down dozens of stairs, people can sit on the sofa while seeing and talk to another family member in the yard. Amphibious houses do not deprive owners of these interactions as an elevation will do.

Visual connection between a dweller inside a floating home and the water as well as the moorage is clear. But it is hard to have close connections to the land for these properties that need to moor at designated locations. They have limited interaction with buildings or roads on land since the zone between is the beach without construction per the public trust doctrine. The connection with other nearby houses is also less direct than that between those neighboring buildings on land, because of the looping trail on moorage and the hindrance of water.

Whether disposable houses interfere with accessibility depends on how and where the construction takes place. If they are elevated tourist bungalows on top of pillars on the shore, they do reduce contact between their dwellers and passers by. On the other hand, a ground level shop or restaurant can encourage access and contact from the road. The expendable nature of the building doesn't set a limit on accessibility, whether to open or close towards the outer world depends on the need of the owner.

From the perspective of the community, massive application of retrofits on houses can drastically change the character of the neighborhood. Elevating all buildings in an area alters the experience of pedestrians. Although the density and floor area ratio in the region remain the same, a change in the ratio between road width and building height will change the sense the streets convey.

Amphibious houses preserve the existing style and features of the neighborhood, for they keep the same appearance with other buildings without retrofitting. Only in a flood event will they ascend with water level in response, in which case they still retain the original height above water level. In a place with a large amount of redevelopment like Mexico Beach, an amphibious house is the tool to enhance flood resilience without exceeding the original height and mass of existing buildings.

A change in urban form will not bring direct losses to the social value in the area, but as a small city featuring tourism, the uniqueness in the character the city presents adds to its attractiveness. Mexico Beach is known for the character of a small city with loose development and association with nature. Alternative building types that build in a way responsive to local resources and preserve that character can add to the competence of local tourism.

4.3.Appropriate sites of application

Each treatment method, including the conventional lifting method required by FEMA, possesses its advantages and drawbacks. Depending on the natural character of the site and the land use of the structure, the performance of each building type varies significantly.

Table 9: capacity of different housing types handling threats

Type of building(rows)/ Performance(columns)	Adjust to sudden change of water level	Adjust to long term sea level rise	Resist water impact	Resist wind	Keep Physical accessibility	Keep Visual connnectivity	application on existing building
elevated house	√	×	√	×	×	×	√
houseboats	√	√	?	×	×	√	×
floating house	√	√	×	√	×	√	×
amphibious house	√	√	×	√	√	√	×
disposable building	×	√	×	×	√	√	×

? : performance depends on support

The traditional elevated houses stand well against the impact of waves. They also have strong resistance to regular flooding until sea level rises above their designed threshold. Their extra height leaves them weak against extreme winds, which is a severe drawback in Mexico Beach. But elevating is the only retrofit that does not require the total reconstruction of the property. Hence, elevation works best in sites that have a relatively higher attitude where sea level rise is not an immediate threat. However, elevated buildings on these high grounds will catch more kinetic energy from winds. Environmental Tools such as vegetation barriers can help mitigate the potential damage. In Mexico Beach, those blocks that survived Hurricane Michael but do not plan to undergo full reconstruction can continue tp use elevation as a strategy to increase resilience.

At the time being, researchers still depict houseboats and floating homes vulnerable to hazards like hurricanes and tsunamis. They however adapt well to the change of water level resulting from the interweave of sea level rise and floods. Houseboats are weak against the impact of both waves and wind, but with the support of advanced warning and evacuation systems, they can mitigate the loss by relocating to safety. Currently such support systems in Mexico Beach are inadequate. But should the city address this issue in its plan and take effort to assist their evacuation, the cost and difficulty of relocation can drop significantly. At that point, houseboats can emerge as an effective way to mitigate coastal hazards and boost the tourism of the city.

Amphibious houses have the strongest performance among all the housing types in resisting wind, which is a dominant threat in almost the entire city. It also helps preserve the character of a loose, small town style development by maintaining the original height and accessibility of the buildings in the area. But the requirement of detachment together with the limit on building mass to install amphibious foundations leads to low density. As a result, it can’t fit in areas where the city demands higher strength of development. Besides, the lack of resistance to direct impact of water determines that amphibious houses perform better in the inland areas rather than near the beach. Installments of tools that slows down the flow of tides in a flood, such as levies, water gates, barriers, and vegetation buffer belts can help alleviate the weakness and improve the performance of amphibious homes.

Although disposable buildings themselves are vulnerable to almost any coastal hazard, they reduce loss with lower reconstruction cost. The building itself cannot adapt as the sea level rises, but it mitigates the problem with its short designed lifespan. When a flood destroys the building, the owner can just build a new one. When sea level changes to a level that interferes with the use of a disposable building, the owner can just rebuild it into another type that better fits the situation. As sea level rises, the increase in the severity frequency of disaster events will raise the cost of reconstruction of disposable houses. The cost-efficiency of disposable houses will diminish over time and other housing types will eventually outperform it. Consequently, it is a temporary strategy, which fills in the blank before the condition on the site matches the needs of other building types. Disposable housing needs sufficient support from the city to function well. The first requirement is in time warnings of disasters to leave owners enough time to remove valuables from the buildings. An advantage compared to houseboats is disposable houses don't require the city to provide a relocation site. The owner just needs time to collect belongings and load their vehicles. This strategy also needs the support from regulations to allow them to redevelop into other types of buildings in the future. Disposable houses work better on rental homes and shops rather than permanent dwellings.

5.Another Approach

The alternative building types each possess unique strength in dealing with the threats that sea level that sea level rise poses. Adopting them in the proper site can help coastal communities build resilience to hazards and shape their neighborhood character. However, to function well, all those building types need support from the plans of the city -- Not only codes acknowledging their existence, but also regulatory supports that help them to perform to their best.

The current planning in Mexico Beach emphasize adherence to the site. It encourages higher density and more investment on the beach. The city also seeks expansion along the shoreline, and intends to alter its loose urban form with the introduction of a townhouse community. These changes obstructs the adoption of these building types. In order to explore the ideal environment for the success of these retrofits, this section studies Sanibel -- A case that faces a similar situation as Mexico Beach does, but treats the relationship with the beach in a different manner.

5.1.Sanibel - A Conservationist path

Sanibel Island is another coastal city in South Florida. It shares many similar features with Mexico Beach. The city of Sanibel faces Mexico Gulf directly. Its southern shoreline towards the Gulf, combined with the nature reserve in the north of the city, make the city an appealing tourist site. The city, like

Figure 15:Sanibel when sea level rises by 3 feet,adapted from NOAA

Mexico Beach, faces an urgent threat presented by sea level rise. Sanibel island has a low general elevation of only 3 feet. A 3 feet rise in sea level which deprives Mexico Beach of its white sand beach, will on the other hand claim most of the lands in Sanibel, ruining almost all the existing ecology system in the northern wetlands, eradicating the value of tourism on the island.

In such a case, making most use of the land's value before retreating, as what Mexico Beach's new plan suggests, appears to be a very practical strategy. However, the city chose another path. At its foundation in 1974 as a municipality, the establishing act declares that "... planning for the orderly future development of an Island community known far and wide for its unique atmosphere and unusual natural environment and to ensure compliance with such planning so that these unique and natural characteristics of the Island shall be preserved ...". The original Land Development Regulation Act also addressed the necessity of avoiding overcrowding and over concentration of population. The city has stuck to these guidelines all over the years. Sanibel clarifies in its plan that it will resist the pressure to comply with excessive development that contrasts the vision of the original plan and will defend against the economical or social activities that may undermine the Ecosystem in the city, both on land and in the surrounding sea.

Although tourism makes up much revenue of the city, the city declared in its plan that its quality as a Sanctuary as well as a community is what makes Sanibel Island appealing to tourists. It welcomes visitors to share and enjoy, while also requests visitors to respect the quality. The city will reject if developments and activities to allure the need of tourists bring harm to this quality. The city put a lot of effort into the protection of its natural resources, community features and coastal access.

Contrasted with Mexico Beach's development plan after Hurricane Michael, Sanibel focuses more on the conservation of the natural resources of the island and original character of the community, rather than the exploitation of tourist revenue.

In face of the increasingly frequent and severe coastal hazards, Mexico Beach chose to add density to the shoreline to make most use of the attraction and expand tourist capacity. In contrast, the city of Sanibel aims in the opposite direction. In its master plan, Sanibel declares a goal to reduce and limit the exposure of social assets like people or properties to the threats of hazards. The plan ensures this goal by enacting a series of regulations including: limiting public investment in hazardous coastal areas; directing dwellers to concentrate population away from zones vulnerable to floods; limiting the development density on shoreline below existing level; controlling the total population growth in the city to ensure adequate evacuation in case of disasters; binding new construction on the island together with the development of evacuation system within and beyond the city boundary.

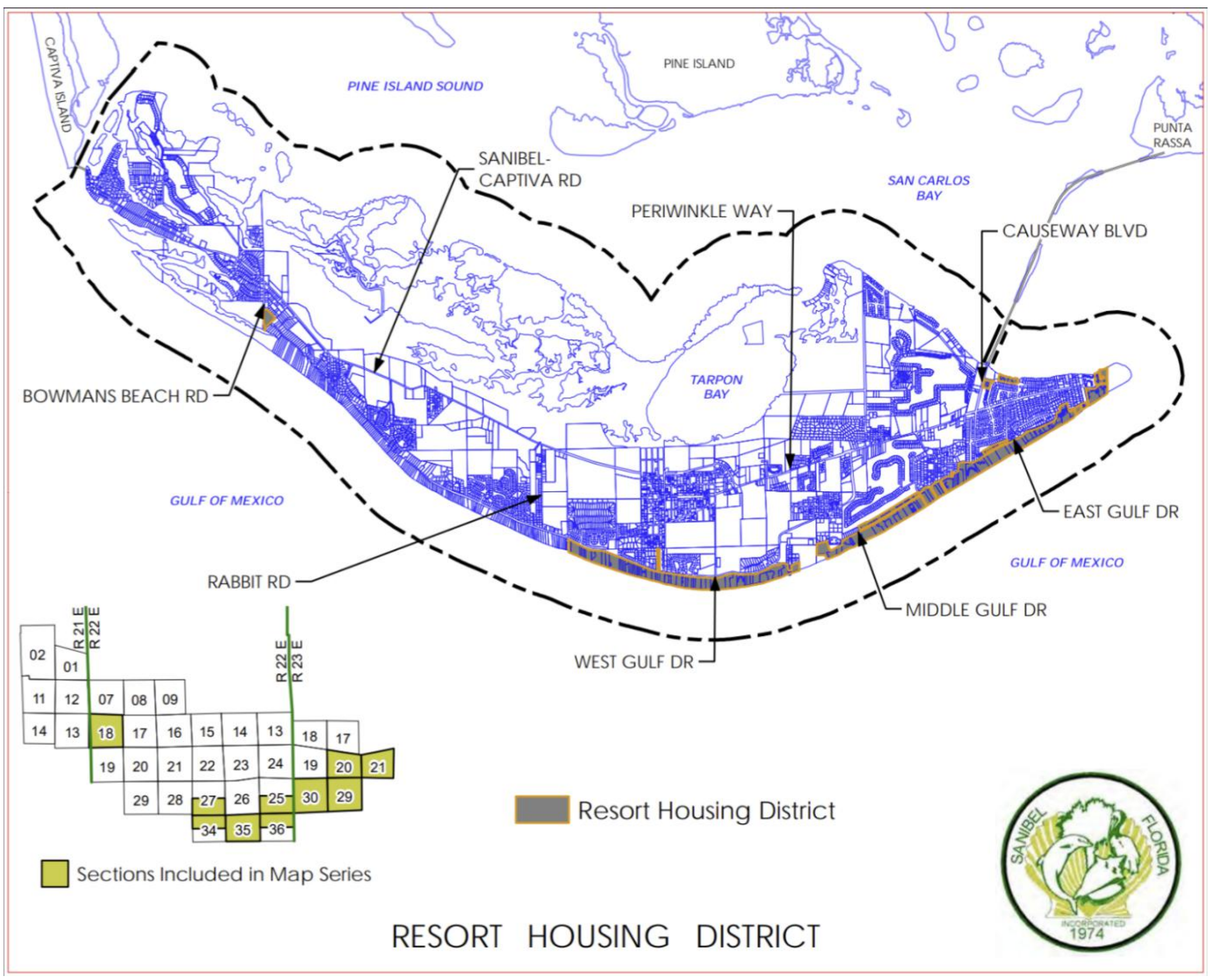


Figure 16 Resort housing district in Sanibel, reprinted from Sanibel Master Plan 2013

In order to concentrate permanent dwelling units away from flood prone areas near the beach, Sanibel designated a belt featuring short-term rental buildings on its southeast shoreline as a resort housing district. In its guide to the redevelopment of the resort housing district, Sanibel encourages the retention of tourism-related land use as the properties in the area redevelop. The guidance sticks to the city's master plan to control density, allowing redevelopment to retain the number of units, should the redeveloped property keep its short term rental character. Those redevelopments in resort housing zones that change to other uses will be subject to tighter limits on size and density. With these acts ongoing, long term occupancy homes which have more to lose in disasters will be gradually discouraged away from the most flood prone area. More than that, the strength of investment on the shoreline will remain static, if not drop, over time. The combination of these two factors reduces the city's vulnerability towards both coastal floods and sea level rise.

Apart from growth management and development control, Sanibel pays effort to preserve nature as a way to strengthen the city's resilience towards floods. The city requires waterfront properties to build and maintain vegetation buffers between their site and the beach. These buffers can reduce the velocity of waves and wind from the sea and filter out debris from the beach while a disaster such as hurricane occurs. The regulation, however, also demands those properties to keep clear access to the beach. So, the buffer belt will not impede people in the city from enjoying the amenities of the sea.

Figure 17: Green buffer between beach and resort zone in Sanibel

In addition to the buffer on the southern shoreline, the city also pays attention to the maintenance of wetlands in the center of the city as well as the reservation area in the north of the island. These wetlands are valuable as aesthetic attractions for tourism and an important component of neighborhood character. Moreover, they are vital natural pools that can respond to the change of water level in the city. In cases of flood events, these low lying wetlands function as sponges to take an edge off the sudden influx of vast volume of water.

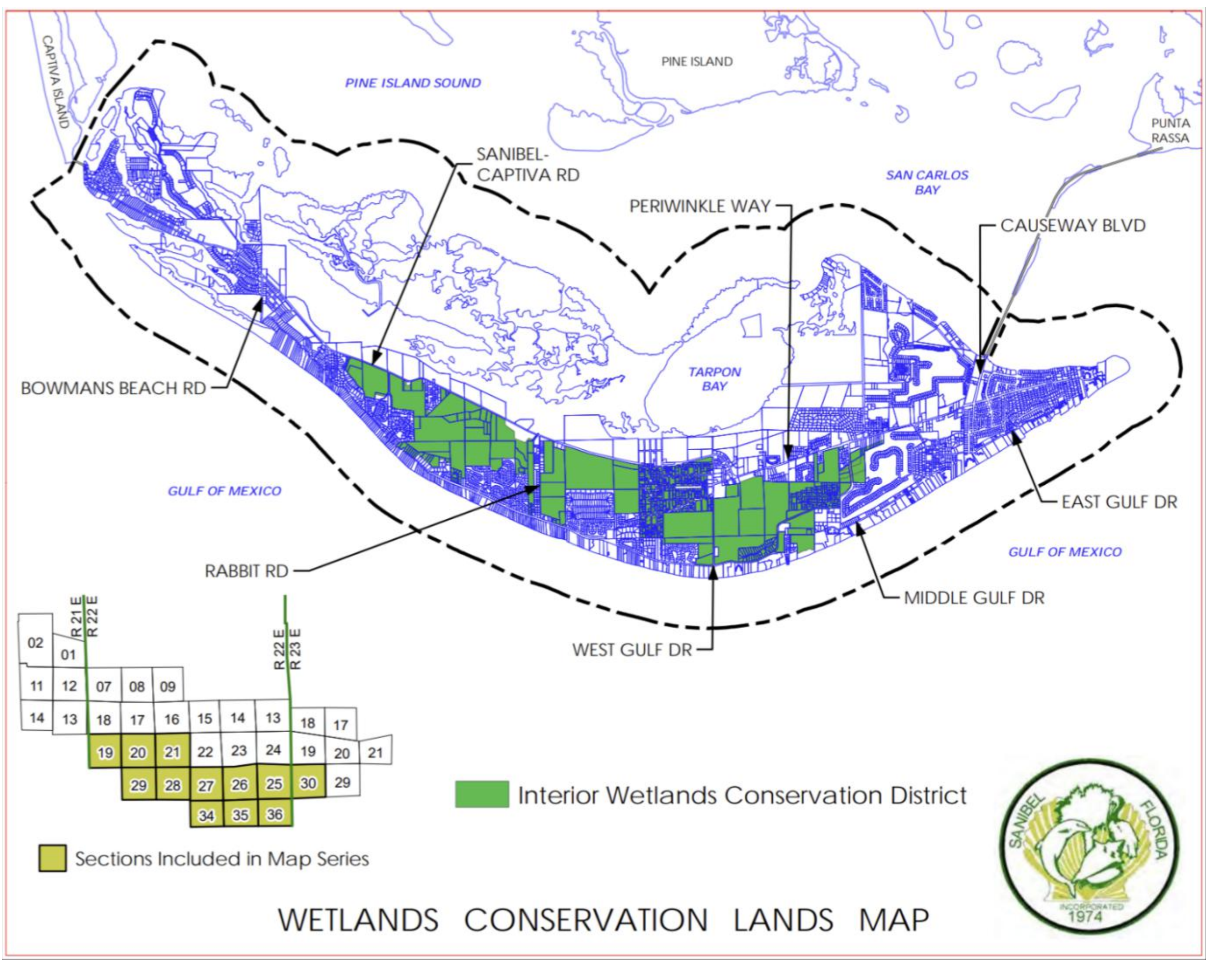


Figure 18: Interior wetlands conservation district in Sanibel, reprinted from Sanibel Master Plan 2013

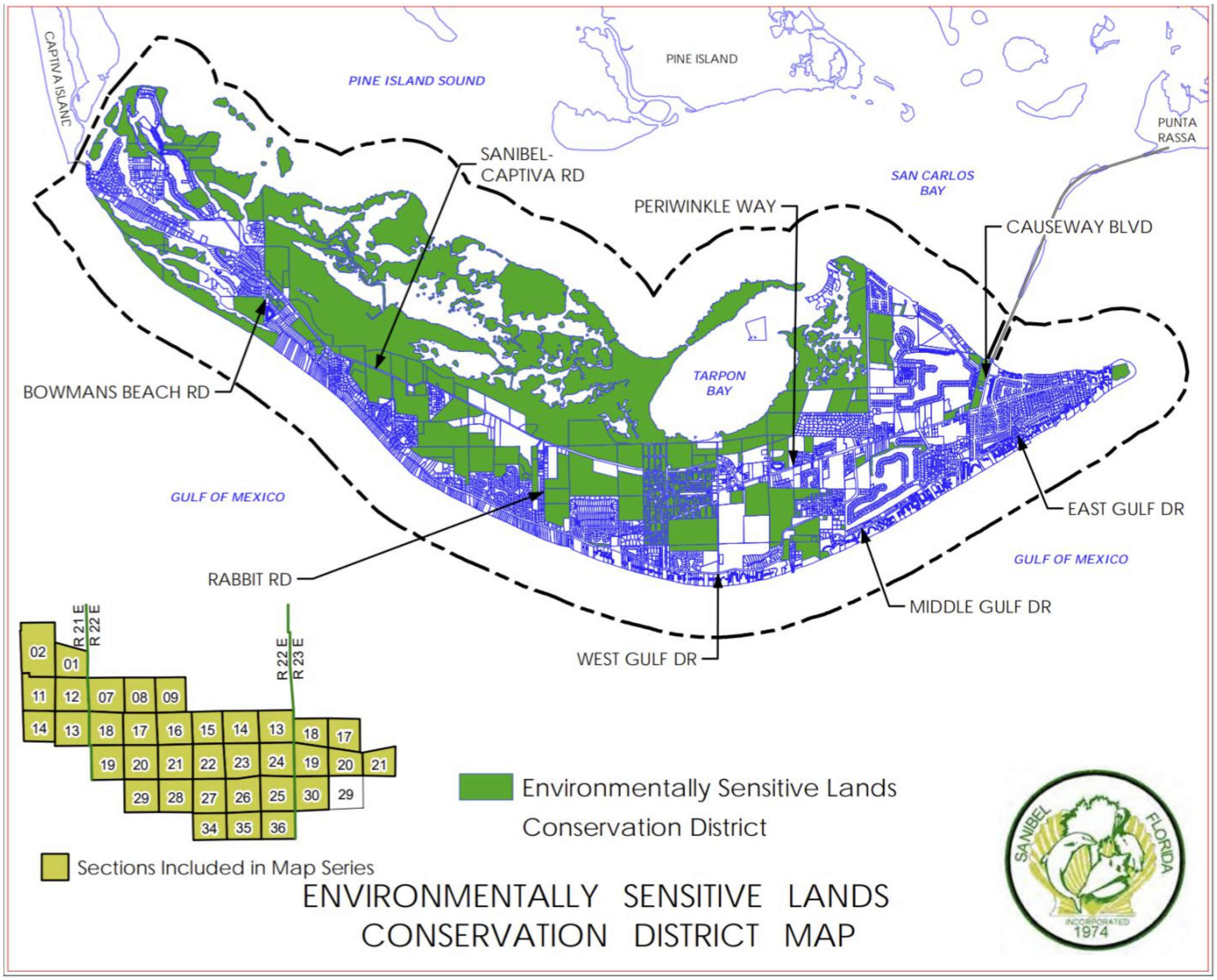


Figure 19 Environmentally sensitive lands conservation district map in Sanibel, reprinted from Sanibel Master Plan 2013

6.Counterfactual scenario in Mexico Beach

Mexico Beach has now designated its southwest shoreline as a high density residential zone and made plans to expand its territory toward its west. The city wants additional development along the shore to support more tourism, in order to make up for the grievous loss it suffered from Hurricane Michael. This strategy of fast expansion and highly concentration towards the beach obstructs the experimental application of alternative housing types. Although the redevelopment after Hurricane Michael opens up a window for testing the performance of unconventional architectural forms. The city has already made its detailed plan for future development and decided to adopt none of these techniques.

Despite the fact that Mexico Beach sticks to FEMA's recommendations without considering the possibility of these housing types, the situation Mexico Beach faces is still an ideal test ground for the new architectural methods, if only the city had a conservationist's perspective like Sanibel toward the interaction with the sea. When the city is back at the point after Hurricane Michael, as a window is open for new development after the mass destruction of structures, should the reconstruction plan gone on another path where local Ecosystem and flavor of the community be considered the first priority, it could become a test ground for techniques like amphibious house. This section presents what possibility lies in that counterfactual scenario and how alternative building types could help Mexico beach better preserve its sense of community.

6.1.Alternative tentative Plan

The core topic of this research is to discuss the capacity and application of unconventional housing types in Mexico Beach. In Mexico Beach there are many appealing sites for the applications of these architectural techniques, but without supportive regulations most of them cannot prosper. Learning from the experience of Sanibel, Mexico Beach can issue from some plans and guidelines in a conservationist's point to enhance its resilience and st up a ground for the introduction of the housing types. The following plans are not necessary suggestions for the city of Mexico Beach. Some of them contradict what is happening in the city. This part is using Mexico Beach as an example to illustrate what methods can planners do in a city with that combination of threats and opportunities. Again, this part is not about denying the correctness in the plan of Mexico Beach, nor is it about criticizing the choices the city makes, it's about discussing another possibility where regulations favor the building techniques.

Like Sanibel, Mexico Beach has a long shoreline that acts both as an appealing tourist attraction and a sensitive hazardous zone. Increasing investment in the area will stash more value in the zone. To protect these values from sinking in disasters, the city needs to add in extra money to strengthen the resistance of the properties and enable them to function well. The added investment makes the area more valuable and calls for further protection. To avoid the vicious circle, the city can in reserve set regulations to limit the development near the beach. Drastic decline of investment on the beach will impact the life quality of residents and bring unsentimental districts to the community. The city has to ensure that the retreat of value from the beach takes place gradually. The method Sanibel chose is a nice example. Mexico Beach can let existing buildings keep functioning without changing their use and density, but set the limit on those owners who want to redevelop. By preventing the density of redevelopment from exceeding existing buildings , the building density on the shoreline will gradually shrink over time. At present, the city has poor capacity of evacuation sites on water, the shoreline is still unfriendly to houseboats and floating homes. Amongst all types of buildings, the disposable housing suits the character of the shoreline best. This type of building is good for rapid redevelopment on the beach to revive tourism quickly so that the city can finance further reconstruction elsewhere. The shoreline has the most dynamic character in the city as sea level rise consumes land. Disposable housing shines in this region for it helps control the amount of investment on the beach, which allows flexible updates in strategies to catch up with the unpredictable changing environment. Besides, disposable houses serve best as short term rental uses, which also meet the need of tourism near the beach. To encourage more disposable housing on the shoreline, the city should publish regulations that discourage long term residence in this area and meanwhile build up a disaster warning system to help the owner of these buildings reduce losses.

According to the vulnerability assessment of Mexico Beach, wind damage is the largest threat for most of the buildings in the city. To mitigate that, the city can publish guidelines to encourage the use of amphibious houses in the residential zones, especially those in the north that are relatively far from the sea but are low lying. For houses in these areas, the likelihood of crushing by direct impact of a wave is low but water level can be high in a flood. To support the implementation of amphibious homes, the city should set higher height limits to buildings, while encouraging detached development in the city. To reduce the velocity of water that is the biggest threat of amphibious homes, Mexico Beach can demand in its regulation that properties in sensitive zones have to include and maintain vegetation buffers to slow down water flow. Mexico Beach can also support amphibious houses by building stone or concrete barriers between vulnerable communities and the sea. The city should as well encourage the construction of environmental mitigation tools like rain gardens.

Mexico beach lacks the supportive environment for the development of floating homes now. The city can start making an effort now to build up an alarm system, create pathways and support teams. It can also cooperate with nearby cities and municipalities to build evacuation moorages to meet the need of local houseboats.

Apart from these tentative guidelines and recommendations, Mexico Beach should designate its urban region into different zones based on the prevalent threat in the area. In each area, the city can encourage the application of certain types of buildings, as follows:

6.2.Division of Threat Zones

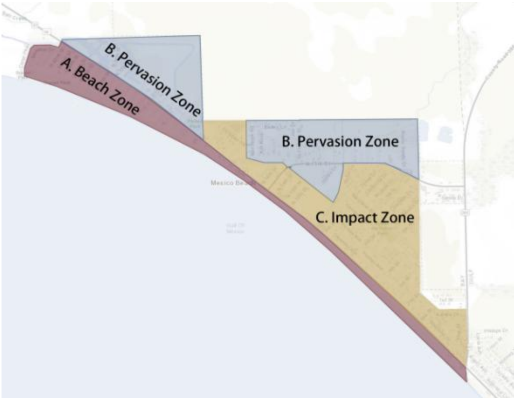


Figure 20: Three types of zones in Mexico Beach

Chronological hazards such as sea level rise and episodic ones like storm surges are the two dominant kinds of hazards threatening all communities in Mexico Beach. Different combinations and interweaving of the two hazards define the character and main concern of each community. With this discipline, the city consists of areas of three categories.

Figure 21: Beach Zone in Mexico Beach

The first types is the Beach Zone. These areas are where sea level rise and flooding are both fierce. The waterfront in the western half of the city faces direct impact, absorbing the full energy of traveling tides. Most of these unsanctified parts are also halfway up the beach slope. As a result, they have relatively lower elevation than the rest of the city. Direct tidal impact and imminent sea level rising together make them the most vulnerable. Constructions in such places have to take both physical resistance to sudden impact and long-term resilience against rising water level into serious consideration. In this area, the city will limit development and try to concentrate away long term residence. In the near future, the city will encourage disposable resort buildings in the area to prepare for future changes.

Figure 22: Lagoon Zone in Mexico Beach

The communities in the northern part of the city are further away from the shoreline than those in other zones. The waves carry less energy when they reach those “remote” communities. Moreover, the topographies as well as other buildings between these areas and the shore function as barriers to further weaken the tide. The floods still can penetrate and wet the interior of houses but don't cause immediate harm to structures of the buildings. As sea level rises, these areas quickly become low-lying below sea surface, but may not be subject to the tide line at once for there isn’t necessarily a route for saltwater to reach the region. That condition may last till sea level passes a certain threshold and sunken areas form connections between these parts and the sea. This area is designated as perversion zone, because the top priority ought to be keeping the interior of buildings dry in flooding and future sea level rise scenarios rather than protecting the structure from destructive force. In this zone, the city

Figure 23: Elevated Zone in Mexico Beach

should encourage amphibious structures, to enhance the resilience to constant change of water level, while keep the low-rise character of the community to conform with ecological areas within.

The last type consists of areas where flooding is a major headache while sea level rise hasn't become an urgent matter. Some neighborhoods to the north of the previous group stand on top of the natural slope. Some other communities in the middle part of the city have adopted grading work to raise the ground elevation of entire blocks. To these communities on high grounds, there is no worry of falling permanently under water before the arrival of a new century. But the short cliff on the beach doesn't save the buildings in high category storms. Communities in the eastern half of the city also benefit from the higher elevation of that area to keep the advancing mean sea level from reaching their property. However, the hydrology of the gulf puts them at a disadvantage. The eastern third of the city has a higher chance to endure more severe storm surges. There is a 1% annual likelihood for them to catch a 18-foot surge, which is way beyond the capacity of regular elevated foundation to handle with. For these areas, momentary protection or evacuation is more necessary than all-year round escape from the tidal line. In the elevated zone, homeowners should stick to the conventional elevation strategy, to brace their house against the potential waves surges.

6.3.Future Scenario

6.3.1.Near future

Figure 24: Mexico Beach, near future scenario, no flood

In the near future, permanent residence and investment strength in offshore beach zone will decrease, and reconstruction will focus on building cheap temporary resort buildings on the coast. Amphibious house will appear during the redevelopment after Hurricane Michael in the lagoon zone which faces a smaller threat from wave impacts. Those properties outside the low lying area will keep using elevation as a tool to increase resistance to impact.

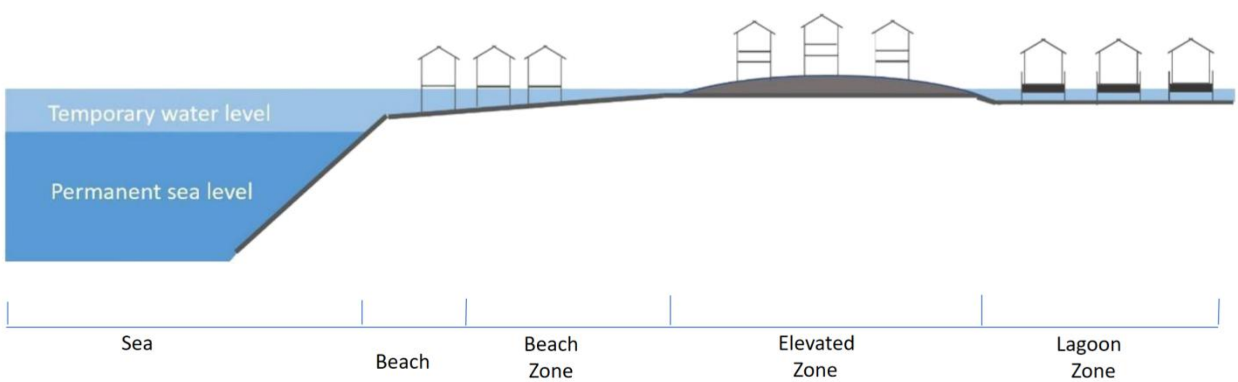


Figure 25: Mexico Beach, near future scenario, regular flooding

In a normal level of flood, the disposable bungalows on pillars could stay out of water damage while the elevated houses on the high ground remain intact.

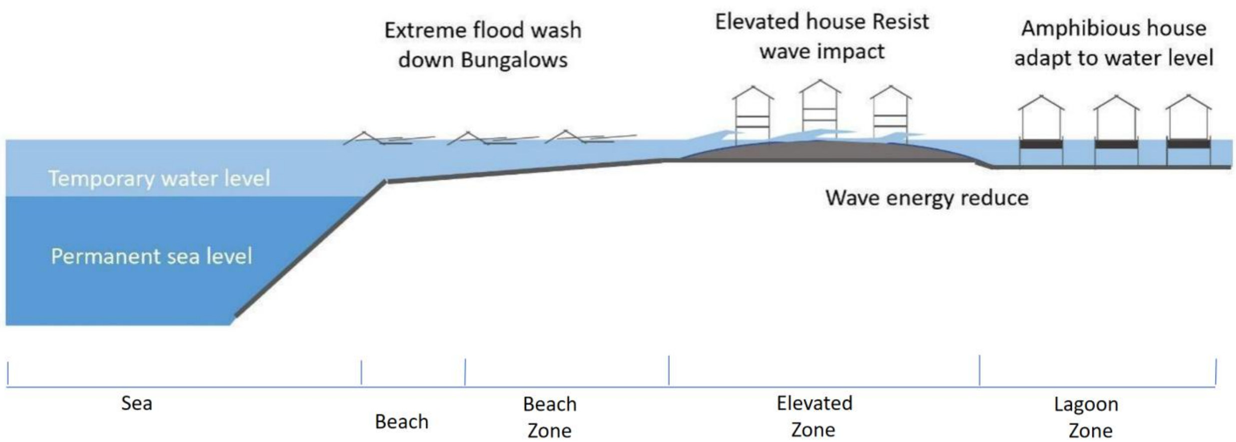


Figure 26: Mexico Beach, near future scenario, extreme flooding

When an extreme flood event occurs in the near future, owners of disposable houses take away their belongings and let the buildings collapse in the flood. They can rebuild occasionally and still profit as long as such levels of disasters do not frequently occur.

6.3.2.Distant future

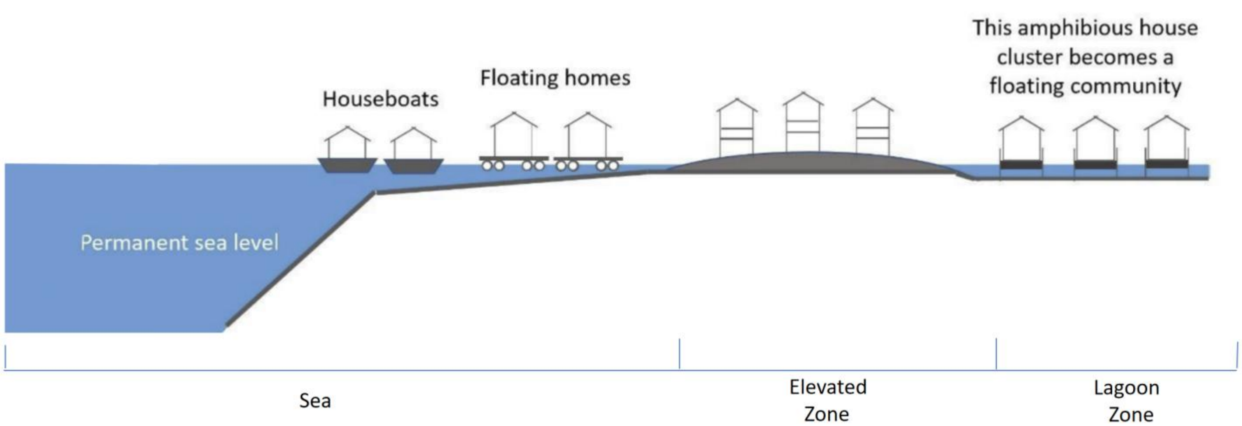


Figure 27: Mexico Beach, distant future scenario, no flood

As sea level rises, the frequency and severity of coastal hazard exceeds the threshold that disposable houses can withstand. The owners have to turn to other building types. At this point, the effort of Mexico Beach on building an alarm and evacuation system pays off, houseboats and floating homes can prosper in the city with sufficient support from the city. They take the place of disposable houses in the beach zone. When sea level rises by a significant height, it consumes the low lying land in the lagoon zone. Amphibious houses in these zones adapt to the change and permanently float.

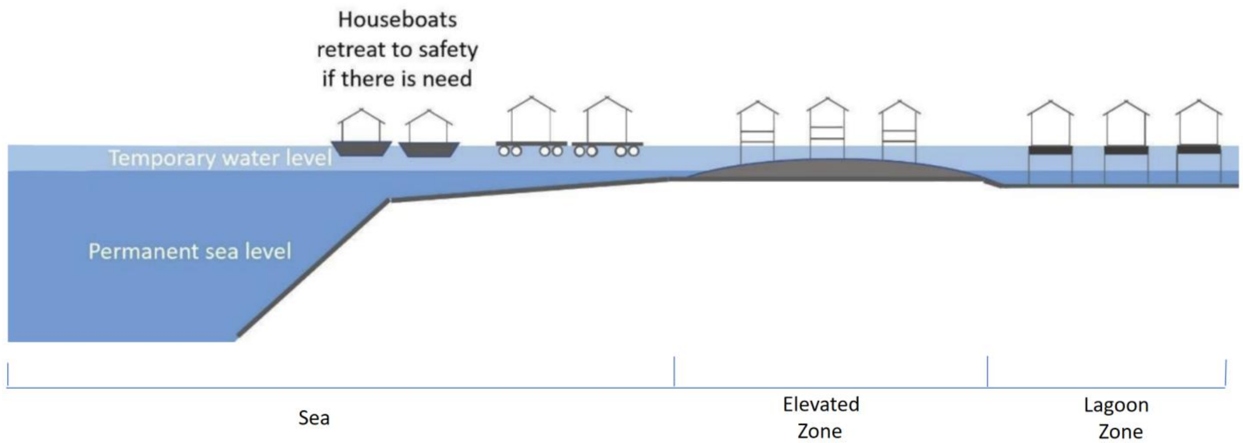


Figure 28: Mexico Beach, distant future scenario, flooding

7.Conclusion

Alternative building types, including floating homes, disposable homes and amphibious homes possess the capacity to mitigate hazard and address some problems beyond the capacity limit of conventional techniques such as elevating and strengthening the buildings. However, each of the building types has a unique set of advantages and shortcomings in dealing with these threats. As with elevated buildings, no building type is superior to other methods in all situations. When planning for the resilience of communities, instead of seeking a universal solution to all problems and all places, planners should look for the appropriate choice of retrofit type depending on the combination of threats and opportunities on the site. A proper combination of architectural techniques can significantly ameliorate the threat posed by complex of multiple hazards.

In addition to different capacities to deal with different combination of hazards, each building type also favor certain type of regulatory environment. Architecture mitigation can enhance the preparedness of coastal settlements toward hazards, but it cannot overcome the threat by working alone. The performance of floating homes and disposable structures varies with the homeowners' awareness of the incoming disaster and the cost and speed in which they can evacuate their belongings. Consequently, a system that anticipates the occurrence of disasters, warn residents of it, and provides routes and sites for homeowners to evacuate is the fundamental for these building types. Similarly, the application of amphibious house requires a loose development pattern as well as other mitigation measures that reduce water flow speed and filter out the debris the waves carry. Therefore, land use and zoning regulations that allow detached development and adopts natural buffer zone create a friendly environment for amphibious house.

The attitude towards the shoreline when planning the site determines the suitability of adopting these unconventional retrofits. The disposable house is a temporary treatment to fill in the intermediate stage between the current situation and the eventual state after sea level rises by a fair amount. A major ideology behind this approach is to reduce investment on the shore to make the waterfront more flexible in face of changes. Amphibious buildings also prefer low-density development for they can only apply to buildings disengaged to surrounding structures. Implementing these methods requires the city to lean towards a path of evacuating population and value from hazard prone areas. The way Mexico Beach rebuild after Hurricane Michael is on an adversary path, where the city add more development to the shoreline to increase the hard resistance towards floods. The natural and social character suggest requirements that can be met by adopting alternative building types, but the development approach eliminates the potential for experimenting with these new types in the city. Sanibel, on the other hand, is sticking to a path that gradually extract investment from the sensitive areas and limit the density in the city. That perspective in planning provides a good example for cities that want to experiment with alternative building types to learn from.

Apart from that, the new plan of Mexico Beach is also changing the original character of the city. The authentic taste of neighborhoods is a valuable heritage of this city. For small cities like Mexico Beach, the uniqueness of its urban form is also an valuable attraction for the local tourism industry. For these cities, mimicking the development pattern of larger cities can lead them to lose identity and become a lesser version of the latter. Instead of applying a standardized mitigation to all sites in the city, devising plans that encourage the adoption of alternative building types in response to the natural and social feature of the site helps the city retain its uniqueness and stay appealing.

In summary, with the support from regulatory, natural and engineering realm, alternative architecture retrofits such as amphibious houses, Floating homes and disposable homes can be an effective supplement to elevating and strengthening buildings, as tools to mitigate the complex hazard in coastal regions. Cases of such implementation in response to the combination of sea level rise and coastal hazards are still scarce in the United States. More experiments with these techniques need to be observed over time to justify the capacity of these building types in reality.

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