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Salty Urbanism: Towards an Adaptive Coastal Design Framework to Address Sea Level Rise

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ABSTRACT - *Utilizing the North Beach Village neighborhood in Fort Lauderdale, Florida, as case study, "Salty Urbanism" establishes an interdisciplinary team to develop a coupled research methodology and pedagogical approach that envisions and quantifies the experiential and ecological outcomes of alternative ways forward for the neighborhood in response to climate instability, disruption and rising sea levels. These outcomes consider an inevitable future of saturated landscapes and, as a result, integrate research models that accommodate a variety of best management practices (BMP), low impact development (LID), green infrastructure (GI) and other alternative concepts to be implemented over time in the neighborhood adaptation plan.*

Keywords: flood-adaptive design, resilient design, urban design, sea level rise, coastal resilience

Coastal areas face a wide range of environmental threats that span across spatial and temporal scales and involve the collaboration among many relevant disciplines. The disciplines range from practicing architects and engineers negotiating site, infrastructure and architectural issues, to researchers involved in modeling climate, sea level rise and urban development patterns along coastal corridors. However, the complexity of environmental issues as well as the diversity of disciplines and methodologies employed presents substantial barriers to establishing common ground and integrated solutions that might be possible within a more collaborative and comprehensive framework. Utilizing the North Beach Village neighborhood in Fort Lauderdale FL as case study, "Salty Urbanism" establishes a team of engineers, architects, planners, city officials and neighborhood stakeholders to develop a coupled research methodology and pedagogical approach that envisions and quantifies the experiential and ecological outcomes of alternative ways forward in response to so-called "king tides," where infrastructure intended to drain runoff works in reverse during extreme high tides, a result of rising sea levels. These outcomes consider an inevitable future of saturated landscapes and integrate research models that accommodate a variety of best management practices (BMP), low impact development (LID), green infrastructure (GI) and other alternative concepts to be implemented over time in the neighborhood adaptation plan. Though these solutions were not originally proposed to address rising seas, they do provide a framework that can be transferred in effective ways. Furthermore, the approach fosters urban solutions at the scales of individual lots (what a property owner can do), public rights-of-way (what the municipality can do), and neighborhood (what coordinated public/private collaborations can do). Urban design proved an appropriate point of departure to manage the potentially awkward intersections of knowledge and to more effectively cross-reference the multiple scales and challenges of urban systems. The integration of design practice, speculative studio environments and interdisciplinary research provides a robust model for designing adaptive coastal communities in the wake of natural disasters and rising sea levels.

A WICKED PROBLEM: SEA LEVEL RISE AND COASTAL URBANISM

Sea level rise is an ongoing climatic phenomenon that continues to put coastal populations at risk for increased flooding in the long-term. However, short-term flooding following extreme storms and during king tide events where sea water inundates low-lying streets and properties, and serves as a basis of future flooding that will become permanent due to sea level rise. This is a critical concern since nearly half the US population lives within 50 miles [80 km] of the coast and involves most major commercial, leisure and import/export enterprises. Hence, much of the economic activity of the nation is tied to coastal communities. Various researchers have already noted impacts on coastal and island environments and most coastal communities are cognizant of the ongoing discussion about a threefold threat: sea level rise, the associated loss of soil storage capacity and more intense storms overwhelming the current "stormwater" infrastructure. As a result of these environmental threats, critical infrastructure, both horizontal and vertical is at immediate risk. Unlike the extreme periodic flood events, the phenomena of sea level rise is a slow, steady flood, allowing communities to take the appropriate time to evaluate and plan for the impacts to ensure that stranded infrastructure and neighborhood inaction can be exceptions to the norm.

As mentioned above, Southeast Florida is particularly vulnerable to future inundation from sea level rise and further flooding from more frequent and intense storms due to its low-lying topography.[1] The potential effects are further exacerbated by continued diversion of "stormwater" runoff into canals and surrounding waterbodies.[2] Research and vulnerability mapping have shown that, depending on coastal geomorphology, the sea level rise may affect not only the areas immediately adjacent to the coast but also inland areas due to the effect of the rising sea on hydrogeology.[3] Due to Southeast Florida's porous geology, as saltwater infiltrates inland and raises the relative height of the water table, soil conditions will be less able to absorb large amounts of seasonal rainfall. In addition, along the coastline, it is now commonly understood that for every one foot of sea level rise, two hundred feet of inland impact will occur in some areas.

In the aftermath of super storm Sandy, Southeast Florida and Fort Lauderdale in particular, recognized its ill-preparedness and vulnerability to such events, where man-made and natural armoring was weakened along a section of the beach just north of North Beach Village (the research focus area). One month later, high seasonal tides washed away State Road A1A and the seawall infrastructure and the replacement cost exceeded over US$80 million for less than one mile [1,6 km] of beachfront. In the years since, the region has understood that the current protections are merely short-term mitigation strategies that only address the symptoms of flooding and storm surge, and do not capitalize on the long-term solutions that adaptation strategies that bridge ecological infrastructure and urban design can deliver to address the added dimension of sea level rise. Interesting, the recent Hurricane Irma showed that the new infrastructure investments still failed as a foot of sand covered A1A and caused its closure for over a week (Fig.1).

Figure 1. Fort Lauderdale Beach Boulevard after Hurricane Irma. Lack of ecological infrastructure allowed over one foot [30 cm] of sand to inundate street.

Historically, water and the efforts to control it have driven Florida's development patterns. From the earliest settlements and trading posts established by late nineteenth and early twentieth century to the luxurious resorts and urban landscapes of today, Florida's history is interwoven with water management, or more specifically, flood management. Ever present threats from the fluctuating water table (driven by a wet subtropical climate) and regular tropical storm patterns resulted in these efforts to reclaim wetlands for agricultural and human development projects. The year-round growing season and warm humid temperatures afforded by Southeast Florida's subtropical climate made it an attractive candidate for further development, but the watery landscape posed numerous challenges to inhabiting the land.

The 1943 Davis Vegetation Map shows South Florida as it existed pre-development. This map provides insight into the hydrology of the region and illustrates why Southeast Florida and in particular Fort Lauderdale is vulnerable to subtle fluctuations in rising seas. Rainfall from the center of the state flowed into a series of lakes north of Lake Okeechobee and then into the lake itself where water overflowed its southern edge into saw grass marshes and tree islands of the Everglades bioregion. Water would filter through the regions vast "river of grass" ultimately ending up in the massive underground reservoir of the Biscayne Aquifer or carried east and south to the coastal estuaries of Florida Bay, Biscayne Bay and the Atlantic Ocean. In Fort Lauderdale, the New River linked the Everglades to the Atlantic Ocean through a riverine landscape of interconnected salt and freshwater marsh habitats. This riparian system included pine ridge islands distributed within essentially a large wet prairie complex. The lack of a strong coastal pine ridge, as those found north in West Palm Beach or south in Miami made Fort Lauderdale far more vulnerable to flooding historically and poses new risks from climate change. In fact, Broward County, where Fort Lauderdale is situated, averages just three feet in elevation compared to the rest of Southeast Florida at four. Historically, this produced architecture that was flood-adaptive, where first floors were designed to flood and small hamlets were built on the pine islands connected via river transportation routes. In the early twentieth century, Napoleon Bonaparte Broward began construction efforts to dredge, create canals, build levees and alter the flow of water across the landscape. Broward County, in particular, owes its very existence to the system of canals and levees that were built (Fig. 2).

The results of more than a century effort to shape, drain and develop the landscape and promote economic growth has left a severely degraded environment (above and below water), compounded by the fact that Southeast Florida is the fasted growing region in the United States. Urban waterfronts have developed according to local social context - economics, recreation, and land use needs, which often denude coastal areas of native landscapes and exceed ecological functioning. In Florida, coastal development is occurring at unprecedented rates. Since the economic pressures to continue to build in these areas indicate the trend will continue into the foreseeable future, (despite the strong likelihood that Southeast Florida will experience as much as 26 in. [66 cm] of sea-level rise by 2060), the need for a consensus on a neighborhood scale approach is increasingly urgent.[4] Currently, within tidal zones of the region, twentyfour occurrences, or twelve days of nuisance flooding are experienced per year. It is projected that nuisance flooding will occur twice a day every day, across the region at 24 in. [60 cm] of sea level rise or 730 times a year.[5] Therefore, the real challenge for developing resilient communities is ensuring ecosystem integrity within urban contexts.

Current sea level rise projection models forecast between 6-10 in. [15-25 cm] by 2030 and 14-26 in. [35-66 cm] by 2060, and the region will have to adapt or raise public infrastructure and private property, with ominous financial implications. This is already happening in areas of Miami Beach, where a half billion dollars is being spent to raise roads and install pumps. However, these efforts have caused unintended environmental degradation of Biscayne Bay and only solve flooding issues for the next ten-twenty years. Just one foot [30 cm] of sea level rise is estimated to put $4 billion of taxable property at risk in the region, and $31 billion by the time there is three feet [91 cm] of rise.[6] Significant increases in insurance costs due to risk exposure will be required to cover the inescapable risks on the horizon. Already the government-sponsored insurance company is facing challenges due to high rates of subsidization currently being underwritten for flood insurance, which is only further complicated by other insurance rates related to wind and storm events. The state must reduce

Figure 2. Dredging canals west of downtown Fort Lauderdale.

its risk exposure by either raising rates or forcing policy holders back into the private market, which is far more costly for flood insurance and in some areas non-existent. Florida's most valuable property assets are at risk of flooding and long-term inundation as a result of future sea level rise. In Fort Lauderdale, homeowners without mortgages have chosen in most cases not to carry flood insurance due to cost increases. Florida's economy is tied to water as real estate and boating industries are major economic drivers. A study published by Florida Oceans and Coastal Council states:

> Three-fourths of Florida's population resides in coastal counties that generate 79 percent of the state's total economy. These counties represent a built environment and infrastructure whose replacement value in 2010 is $2.0 trillion and which by 2030 is estimated to be $3.0 trillion.[7]

ADAPTATION PLANNING AND THE CITY OF FORT LAUDERDALE

Over the next 100 years, nothing will radically change the built environment of Southeast Florida more than climate change and sea level rise. Hence, the need for developing a long-term design and planning framework that adapts to the effects of climate change and sea level rise is critical. More specifically, there is a need for a "systems" approach that utilizes urban design and takes into consideration infrastructure impacts, future investments, and insurability of risk as long-term objectives to address potential impacts from both coastal flooding and a rising water table, while at the same time guiding communities' future land use and investment plans. Considering the Brookings Institute's statistic that 50% of the built environment projected to exist by 2050 currently does not exist, there is an enormous opportunity to create an innovative coastal-hazard adaptation design approach and urban place-building framework to protect economic, engineering, environmental, and quality of life issues from potential impacts of sea level rise, storm surge, rainfall and runoff on the coastal zone in Southeast Florida. One could define the current phase of Southeast Florida building development as robust yet transitional. Once the development is built, it will be more difficult to retrofit due to the deleterious economic and environmental conditions mounting in the region. This transitional phase poses the greatest opportunity to implement new policies that mandate adaptive design technologies and techniques.

The city of Fort Lauderdale (pop. 170,747) is leading in the area of sustainability, resiliency and adaptation planning regionally to become the first major municipality in Florida to approve the use of "Adaptation Action Areas," which enables Florida cities to prioritize infrastructure improvements within areas vulnerable to climate change and sea level rise. However, these tools are mostly policy-driven applications to flood mitigation and climate adaptation, and have yet to fully absorb long-term engineering and design frameworks that could significantly reduce infrastructure costs and embed ecological infrastructure for added protection and eventual adaptation. Design frameworks and tools that serve the seven miles of coastline and 165 mi. [265 km] of inland waterways (330 mi. [531 km] of shoreline "edge"), as well as the relatively flat topography and dense urban development of Fort Lauderdale are desperately needed by the City. Concurrent to these challenges and efforts, the so-called "king tides" phenomenon has emerged as the city's most apparent evidence of sea level rise and the coming coastal crises.

Reconciliation ecology, a branch of ecology, which studies methods and approaches to increase biodiversity in human-dominated ecosystems is an emerging concept first proposed by Michael Rosenzweig in his book *Win-Win Ecology* (2003). Based on his theory that there is an inadequate quantity of land area designated as natural preserves and conservation, the built environment must increase biodiversity within urban areas in order to address ecosystem services, as well as offset and adapt to new challenges caused by urban development and rising sea levels. This approach for an integrated coastal adaptation design strategy poses interdisciplinary questions, such as how can soft infrastructure technologies that come out of the ecological sciences and engineering fields be appropriated by architects, urban designers and planners in development of new design strategies and tools for innovative coastal adaptation while simultaneously achieving, through smart design, greater urban livability? As an emerging urbanism framework for coastal adaptation, "Salty Urbanism" could be a form of new urban paradigm that aims to accomplish this integrated approach. In this regard, it strives to couple ecological processes within urban infrastructure and public space networks to develop urban solutions at the scales of individual lots (what a property owner can do), public rights-of-way (what the municipality can do), and neighborhood (what coordinated public/private collaborations can do).

ADAPTATION DESIGN CHALLENGE

Coupling ecosystem services with urban development are at obvious odds with current planning and zoning regulations and the lifestyles of residents in the region. The situation summons creative approaches on how to retrofit traditional architecture, planning and urban design to address storm surge, sea level rise, and changing rainfall and runoff patterns on the heavily-developed coastal zone. Defending against water from all directions is a particularly unique challenge of Southeast Florida, making it a good candidate for pilot study and development of an adaptation framework that can be appropriated by other coastal communities.

The proposed approaches to adaptation also support new and creative urban development capable of solving the complex and multi-faceted issues of urban place making - approaches to the design, planning, and management of public space and quality of life. This has surely sparked debate on the extent to which the region must reconcile with the environment and quality of life concerns to become truly resilient. While application of soft infrastructure outside of urban contexts is not difficult, the challenge remains to formulate adaptation measures using soft engineering technologies. For example, living shorelines, sand engines, breakwaters, bioswales, rain gardens, infiltration and exfiltration trenches, and constructed wetlands among many others, can be tested within urban land development and especially in coastal communities. However, the greatest obstacles preventing acceptance of urban soft engineering are standardized municipal codes, zoning ordinances, development industry conventions, and cross-agency permitting processes, which prescribe civil-engineered water management solutions. In addition, the risk-averse land development industry is uncomfortable with untested urban adaptation techniques that have not been locally mainstreamed. Thus, developers and governmental agencies prefer known civil-engineered water management solutions, which maximize property development potential, leaving little open space for ecological infrastructure implementation.

Place-building models, such as “Salty Urbanism,” will engage socio-environmental development and collectively yield a new ecology of the city necessary to address the greatest ongoing challenge to planning and design: ecological design within human-dominated ecosystems. By adopting ecological terms, architecture and urban design can achieve greater resilience and retool itself with the ability to adapt to changing conditions. It is at this juncture that reconciliation ecology, as previously discussed, provides a framework for innovation. Beyond composition, ecological thinking requires logics of assembly where timing, interactivity, sequencing, componentization, and recombination constitute another aesthetic and utilitarian intelligence. Urban design projects bring problems involving community-scaled systems related to energy, food production, water, waste, and transit. Only urbanism gives the architectural and planning professions a holistic framework through which these systems can be engaged, and urban design is often the missing piece in discussions on resilience and smart growth planning.
Novel architecture with a new vision of adaptive urbanism lends itself to embracing historic and emerging technologies. Flood-adaptive architecture can provide a robust catalog of building typologies from flood-proofing to amphibious techniques, the latter being fairly unrecognized in Southeast Florida (Fig.3). The region has many examples, from Stiltsville in Biscayne Bay to new projects like the Perez Art Museum Miami, where the building are raised above parking area that acts as a sponge to capture rainwater and prevents flooding from storm surges.

As alternatives to conventional development, green infrastructure and low impact development is considered soft-engineered infrastructures predicated on replicating ecosystems, which requires an ecosystem services approach. Ecosystem services are those goods and services derived directly or indirectly from processes within ecosystems.[8] Additionally, the accepted seventeen ecosystem services can be grouped into four classes: Regulation, Carrier, Production, and Information.[9] Sustainable management of ecosystem services can be defined as those practices that result in no net loss of renewable capital from each of the four classes, essentially defined as "carrying capacity." [10] Ecosystem services, therefore, represent a form of capital, an asset of some quantifiable value. Regardless of this fact, ecosystems are currently modified with little or no estimation of the cost in loss of ecosystem services or effect on local or regional sustainability. It is at this tangency between the production of scientific methodology (through testing and falsification) and the symmetrical activity of design models (making and prototyping) that a new design framework and tool emerges coupling urban development and ecological sciences.

SALTY URBANISM: TOWARDS AN ADAPTIVE COASTAL DESIGN FRAMEWORK

In development of a resilient coastal urbanism tool, the "Salty Urbanism" framework calls for embedding ecological processes within urban infrastructure and public space networks to develop urban solutions at

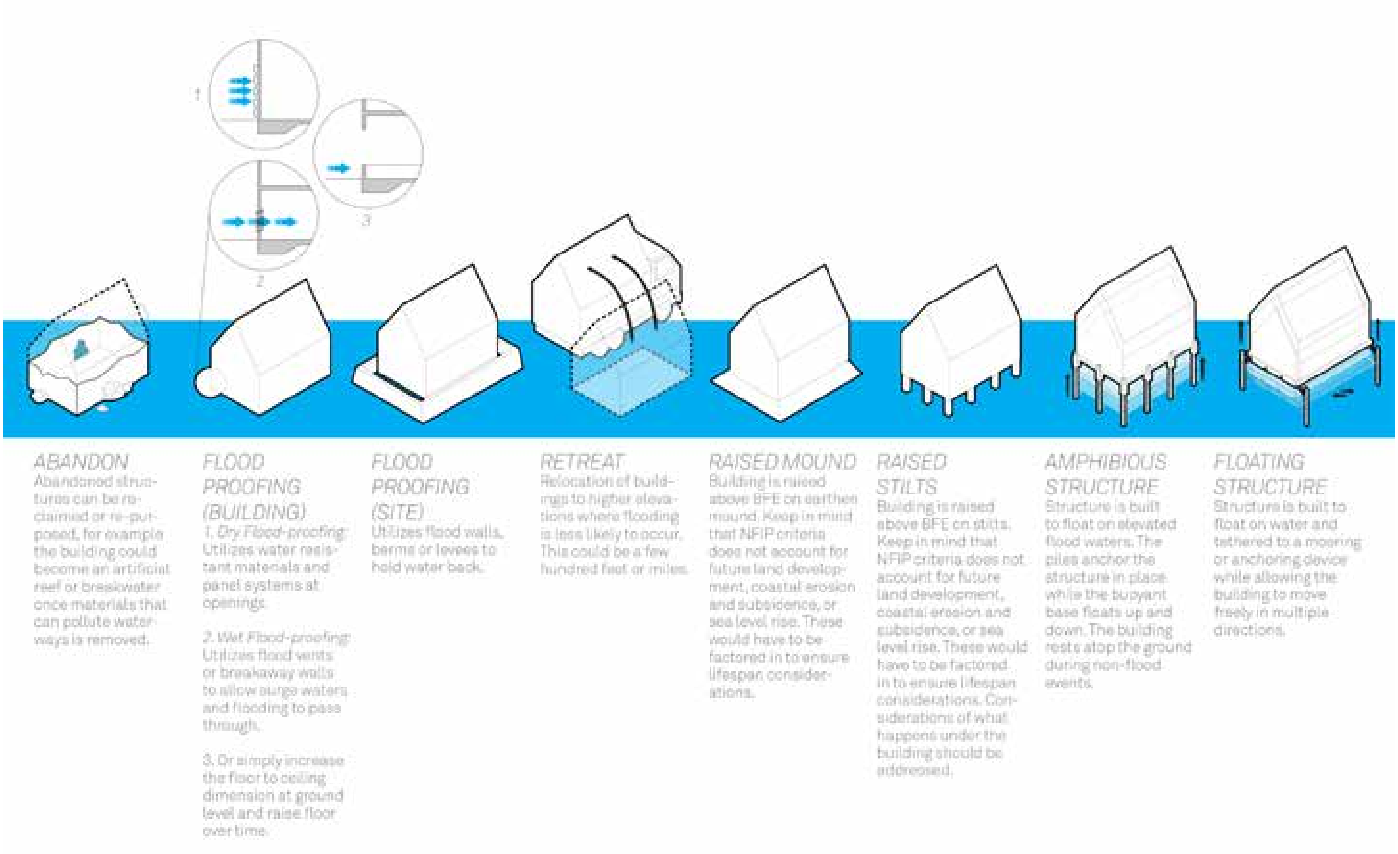


Figure 3. Flood-adaptive menu of building types that could be deployed within the Southeast Florida context.

neighborhood scales. Through a grant from the Florida Sea Grant program entitled, ADaPT: Adaptation Design and Planning Tool for Urban Areas in the Coastal Zone, a design framework will be developed using the coastal context of Southeast Florida where approach and design methodologies can be transferred to other coastal communities globally.

Multi-Scale and Multi-Disciplinary Approach

In order to change the prevailing land-development models to favor integration of ecosystem functioning in urban development, this project proposes implementation of soft-engineering technologies within niche scales of the building, lot, public rights-of-way (streets, easements, parks, etc.), and neighborhood, to generate feedback between bottom-up design thinking and top-down policy and planning production. Best management practices (BMPs) alone may address issues of urban stormwater quality and quantity, however, they will not lessen flood potential as environmental engineering and urban planning disciplines are practiced as separate fields. New tools and design methodologies that help connect segregated disciplines are needed to meet the complex challenges in Southeast Florida and the rest of the country over the next 100 years. Our multi-scale approach (building, lot, public rights-of-way, and neighborhood) will provide a link between the large-scale policy-driven approach and bottom-up design thinking and scientific modeling to provide niche adaptation solutions.
Four core objectives form the action items within the framework: "understand," "assess," "imagine," and "sustain."

Objective 1 - "Understand"

The understand objective establishes asset based mapping and hydrological modeling that provides a baseline for design and planning issues and frames discussions between the project team, municipality and community stakeholders.

Objective 2 - "Assess"

The assess objective surveys existing soft-infrastructure technologies for site appropriateness and integration within design scenarios. Moreover, this objective reviews area codes and regulations that may become barriers to certain design solutions - an important activity given the need to change prevailing development regulations and challenge them if necessary.

Objective 3 - "Imagine"

The major objective is to develop a community design visioning framework that will consider all design and planning options, and consolidate a preferred set of solutions - subject to further community input - toward one refined strategic planning solution. Four scenarios should be investigated:

"business-as-usual" (if nothing was implemented), "soft defense," "strategic retreat," and "land adjustment." These scenarios are then compared and discussed to determine political will, costs, and acceptance from community stakeholders.

Objective 4 - "Sustain"

This objective ensures design efforts and public outreach is operationalized and overarching research questions are solutions-oriented rather than curiosity-driven. In practice, producing such questions means that stakeholders - at all levels - must be engaged not only at the end of the project (the classic "outreach" model) but also at the beginning and intermediate stages. In this way project results have the greatest likelihood of emerging as salient (relevant), credible (scientifically sound), and legitimate (fair).[11]

APPLICATION OF FRAMEWORK TO NORTH BEACH VILLAGE

The primary objective of "Salty Urbanism" is to produce an adaptation plan for North Beach Village that addresses sea level rise and coastal livability concerns and serves as a decision-making tool in which public buy-in and political will can be thoroughly vetted to determine feasibility of a particular scenario application.

Objective 1 - "Understand:" Hydrological Assessment and Modeling of North Beach Village

The understand objective establishes asset-based mapping and hydrological modeling with historical research that illuminates the planning issues and frames discussions between project team and city and community stakeholders. The purpose of this objective is to clearly illustrate sea level rise and stormwater flooding vulnerability within North beach Village to a lay audience.

The barrier island of Fort Lauderdale Beach, in which North Beach Village resides, began development in the 1920s with a series of land reclamation activities and construction of the Intracoastal Waterway. Large areas of mangrove forests were cleared and dredged to form "finger isles" along Las Olas Boulevard, which provided access to the beach, and the first resorts were constructed. North Beach Village began development in 1946 from the maritime hardwood hammock, dunes and saltwater tidal marsh. The entire western half of the neighborhood was a mangrove forest that was raised three feet with muck and fill to make it suitable for further development. This accounts for vulnerability maps indicating the entire western half of the neighborhood is extremely vulnerable to flooding.
By 1955, the entire area was built out with beach resorts and vacation homes for winter tourists. Air conditioning was in its infancy and buildings

were designed for passive cooling. Like the early buildings along the rivers, first floors were either raised or allowed for occasional flooding from tropical storms. It was an early example of resilient planning and architecture of courtyard, single-loaded slab, and tower buildings.

The "Salty Urbanism" team research began by identifying, through "forensic ecology," how the natural system of barrier island ecologies worked and were interrelated (Fig. 4). This analysis includes the flora and fauna of the barrier island and provides a foundation for design thinking that does not mimic natural systems, but rather can implement potential solutions to

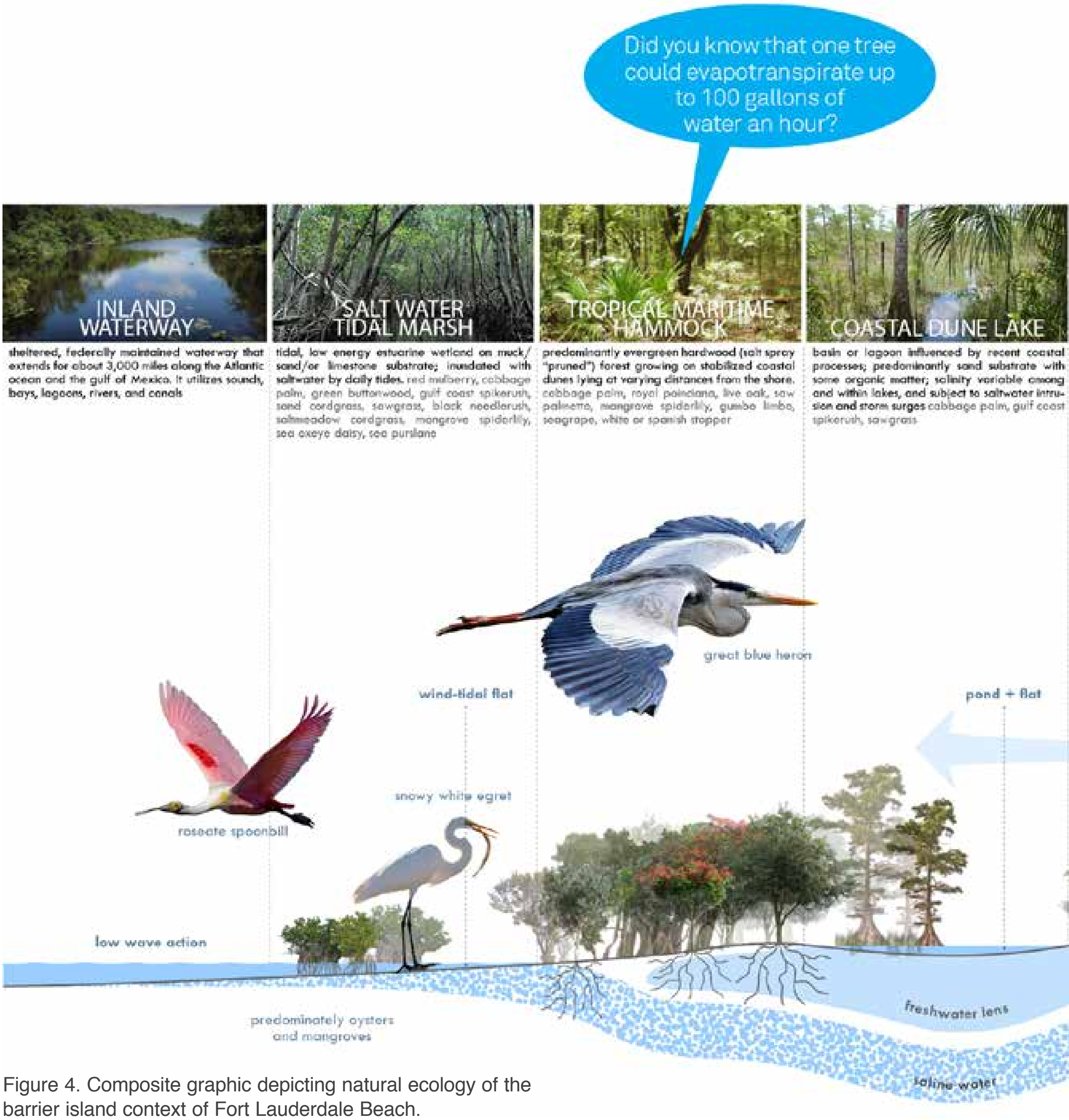
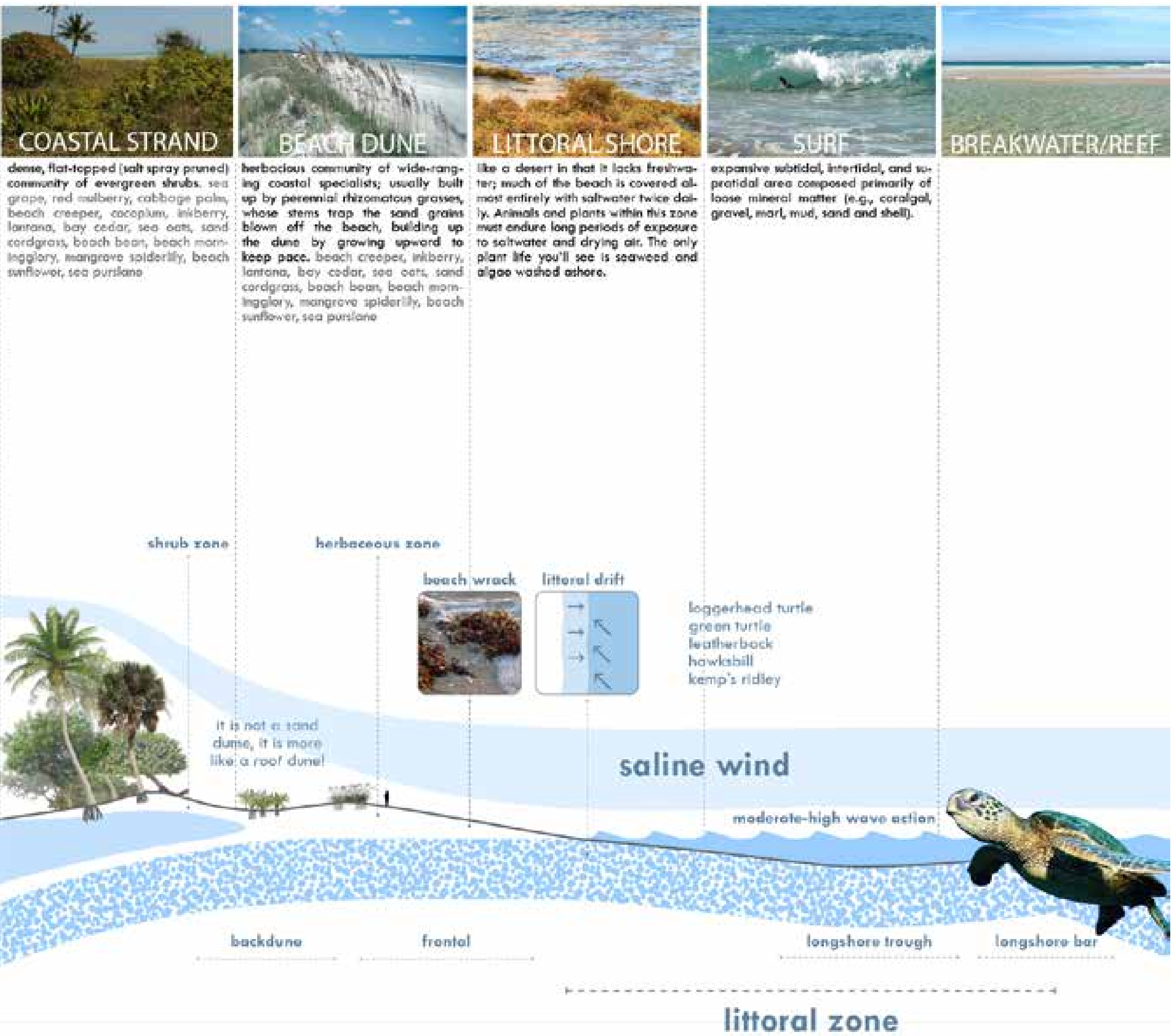


Figure 4. Composite graphic depicting natural ecology of the barrier island context of Fort Lauderdale Beach.

work within the hydrogeological dynamics of place. This research into the historic ecology also provides valuable insight into vegetation types and ecosystems that could be reinterpreted in design of reconciliation ecology principles for North Beach Village Adaptation Plan design for private property and public space planning.

Sea level rise and stormwater modeling can predict future vulnerabilities of infrastructure and property within areas of low elevations that may be affected by inundation from the ocean directly, from rising groundwater levels, and inundation caused from the inability to drain certain areas.



Defining vulnerability requires the research team to define the critical or "acceptable" level of service (frequency of flooding). Several means to assess vulnerability are employed. The first is good topographic data, and readily available LiDAR data for the coastal community is utilized. Prior vulnerability assessment modeling used a bathtub model for inundation across the region.[12] The bathtub approach assumes that groundwater levels will be flat and match the elevation of the ocean (typically the average) to determine vulnerability. This method is used by many governmental organizations due to the ease of data acquisition and model creation. The main disadvantages of this type of model is that it does not consider urban water control infrastructure such as levees and canals that lead to overestimation of inundation, nor the fact that groundwater levels cannot be "flat" and generally correlate with high tide, not mean tide. The results can lead to underestimation of inundation because they do not identify the higher groundwater tables in low-lying inland areas that might flood versus areas along the coast. A modified bathtub model is a model that considers more than just static elevation to determine sea level rise vulnerability. The modified bathtub model is used here for vulnerability assessment maps of North Beach Village. This approach assumes that groundwater levels increase as one moves away from the coast, an assumption that is easily justified with groundwater monitoring data in many communities within Southeast Florida. The importance of the groundwater table in the model is that it is responsible for determining the soil storage capacity.[13] In these cases, the difference between the topographic surface and the groundwater surface was used to determine the potential vulnerability of infrastructure and land areas. Projecting groundwater levels indicated a greater risk for flooding, and more rapid failure of roadway bases and buried infrastructure in North Beach Village. As a result, water, sewer, stormwater and transportation infrastructure in low-lying areas was compromised. Once these vulnerable areas were identified, solutions and cost can be identified.

To compound the sea level rise issue, North Beach Village, like all of Southeast Florida, has distinct wet and dry seasons and a very flat topography. Seventy percent of the annual precipitation typically falls from June to September, just before the king tides in late September and October. As discussed above, the soil capacity to store water is limited because the aquifer levels are often just below the surface in the wet season; it is this limited soil storage that leads to flooding, necessitating the extensive drainage facilities that discharge large volumes of water during the wet season. As a result, there is a nexus that drives the public demand for future development in North Beach Village, while protecting infrastructure and property from flood damage. Such impetus requires short and long-term planning and assessment of vulnerable areas. Long-term decision-making becomes critical because infrastructure and development is not temporal - it is expected to last 50 years or more. Hence, it is in the community's interests to develop a stormwater planning framework to adapt to sea level rise and protect vulnerable infrastructure through a long-term plan. While uncertainties in the scale, timing and location of climate change impacts can make decision-making difficult, response strategies can be effective if planning is initiated early.

The modeling assumed 2.75 in. [7 cm] of rain in a 24-hour period which is consistent with the Florida Department of Transportation standards in the design of roadway infrastructure. When adding in projected sea level rise, the resulting flood stages were dire. When considering current conditions and projecting stormwater modeling over North Beach Village, anything under 4.5 ft. [137 cm] in elevation will flood at one foot of sea level rise, anything under 5.3 ft. [161 cm] floods at two feet, anything 6.3 ft. [192 cm] or lower floods at three feet. Considering 70% of the neighborhood lies below 6.3 ft. [192 cm], the challenge of managing flooding becomes extreme (Fig.5). These characteristics make North Beach Village a great context for exploration of innovative solutions that can draw from the area's past and embrace a flood-adaptive design framework.

Objective 2 - "Assess:" Green Infrastructure and Low Impact Development Technologies

Soft and hard infrastructure, from a long-range planning perspective, are needed for each scenario being considered in Objective 3. It is important to provide associated costs for each type of infrastructure, as this gives designers and stakeholders the ability to do cost-benefit analysis of a particular solution or series of solutions.

Figure 5. Vulnerability modeling from project partners Dr. Diana Mitsova and Dr. Fredrick Bloetscher at Florida Atlantic University.

A bevy of soft and hard infrastructure techniques and technologies related to both freshwater and saltwater systems were created within a matrix. The mix of fresh and saltwater technologies was of considerable importance given where installation within the scenarios could occur, i.e. freshwater systems would not be appropriate within western areas of the neighborhood since these areas would be inundated by sea water for the foreseeable future. Saltwater or coastal-based infrastructure systems included bulkheads, seawalls, levees, polders, living shorelines, constructed wetlands, surge barriers, breakwaters, groins, revetments, artificial reefs, dunes and sand engines as possible implementation products (Fig. 6). Freshwater or upland-based infrastructure systems included: pipes, underground and surface detention and retention areas, rainwater harvesting, bioswales, vegetated roofs and walls, pervious paving, infiltration and exfiltration trenches, rain gardens, constructed wetlands, and tree box filters. All of these potential technologies were arranged from mechanical to biological, appropriate location and increasing volume reduction. This matrix was utilized by the design team within

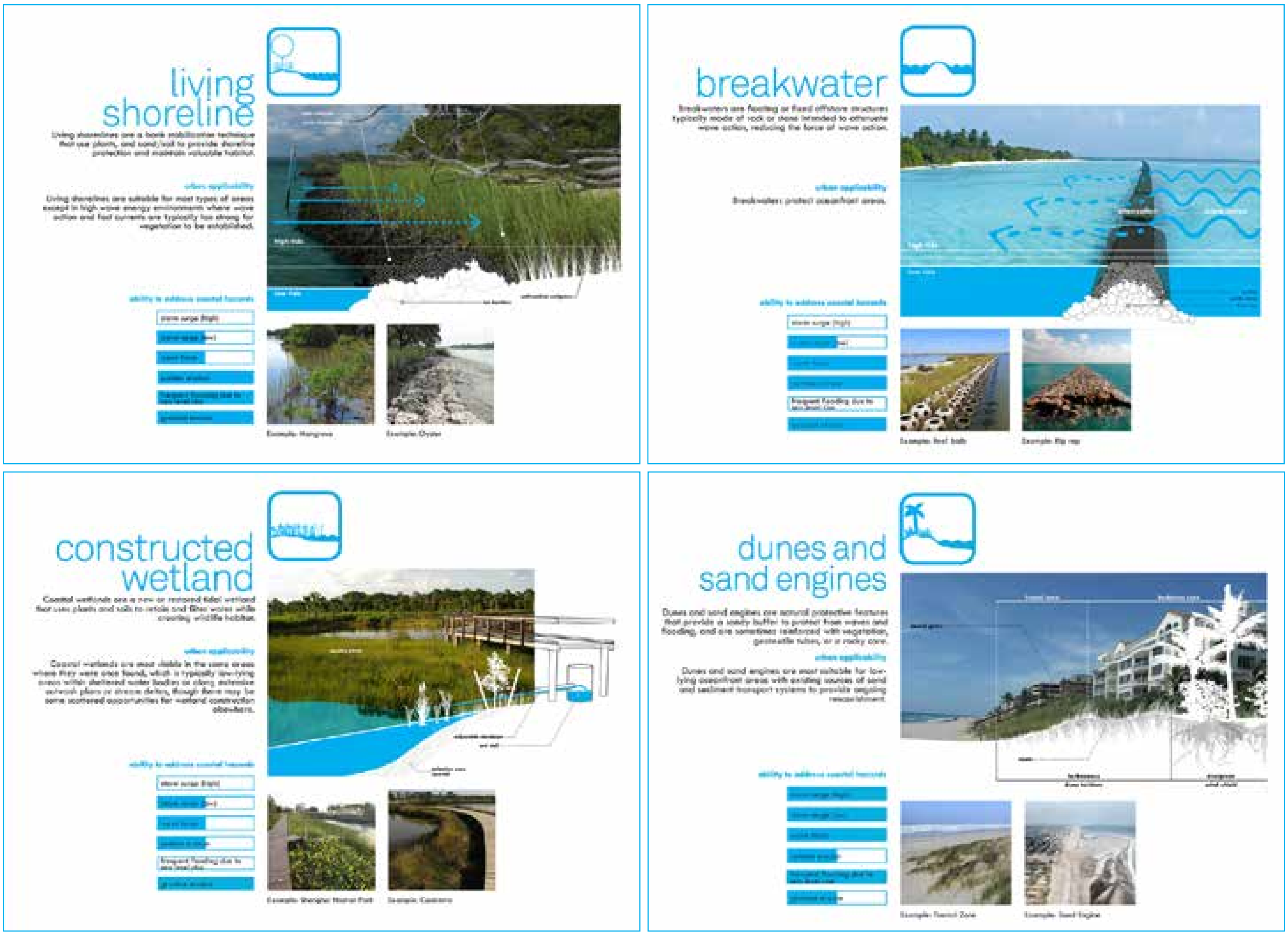


Figure 6. Examples of saltwater best management practices (BMPs).

scenario adaptation plans. Though comprehensive and all-inclusive in showing the range of BMPs, specific sizing of improvements must still be designed and tailored to specific scenarios to achieve optimum water quantity and quality requirements.

North Beach Village requires approvals from several regulatory agencies such as the Army Corps of Engineers, Florida Department of Environmental Protection, South Florida Water Management District and the City of Fort Lauderdale. This complex regulatory environment increases the challenges and is why building regulations and land development codes were vetted to expose potential obstacles or opportunities in implementation of a particular BMP in the design strategies and scenario visioning. Also of note, the project team created a plant palette of native, naturalized and salt-tolerant species to be deployed within GI and LID infrastructure. This is critical when proposing particular plant species in locations that will be saturated longer term by sea water over the next 50 years.

Objective 3 - "Imagine:" Adaptation Design Visioning for North Beach Village

Utilizing "Soft Defense," "Strategic Retreat," and "Land Adjustment" scenarios, asset modeling results and the matrix of soft and hard engineering technologies and techniques from above were explored through design visioning for North Beach Village. Four design studios at three schools of architecture collaborated to envision future adaptation scenarios for North Beach Village. A robust set of strategies emerged that link ecological and urban design thinking. The proposals re-think preconceptions about conventional infrastructure since most architecture students are unaware or have never designed for these complexities. Students generally feel uneasy about designing for things they are unfamiliar with, but the project, at times, positioned them in a state of unease. Although some radical proposals were produced, they were plausibly comprehended by stakeholders because students were able to embed datasets from the previous objectives. The following is a general assessment and description of design outcomes within scenario thinking compared to a "Business-As-Usual" scenario ("Business-As-Usual" is a fourth alternative that will also be modeled to show the effects of sea-level rise if nothing were implemented and will serve as basis to compare the other scenarios) (Fig. 7).

Scenario 1. "Soft Defense" can be defined as combining strategies of both hard and soft engineering employed to mitigate impacts of rising sea levels and non-point source pollution from urban runoff within development that is allowed to remain unaltered (Fig. 8). An example would be the installation of living shoreline along the Intracoastal Waterway and bioswales and rain gardens in the street rights-of-way (Fig. 9). Streets typically represent 35% of urban development - in North Beach Village, however, streets

Figure 7. “Business-as-Usual:” Three feet of projected sea level rise in North Beach Village if no further investments were implemented.

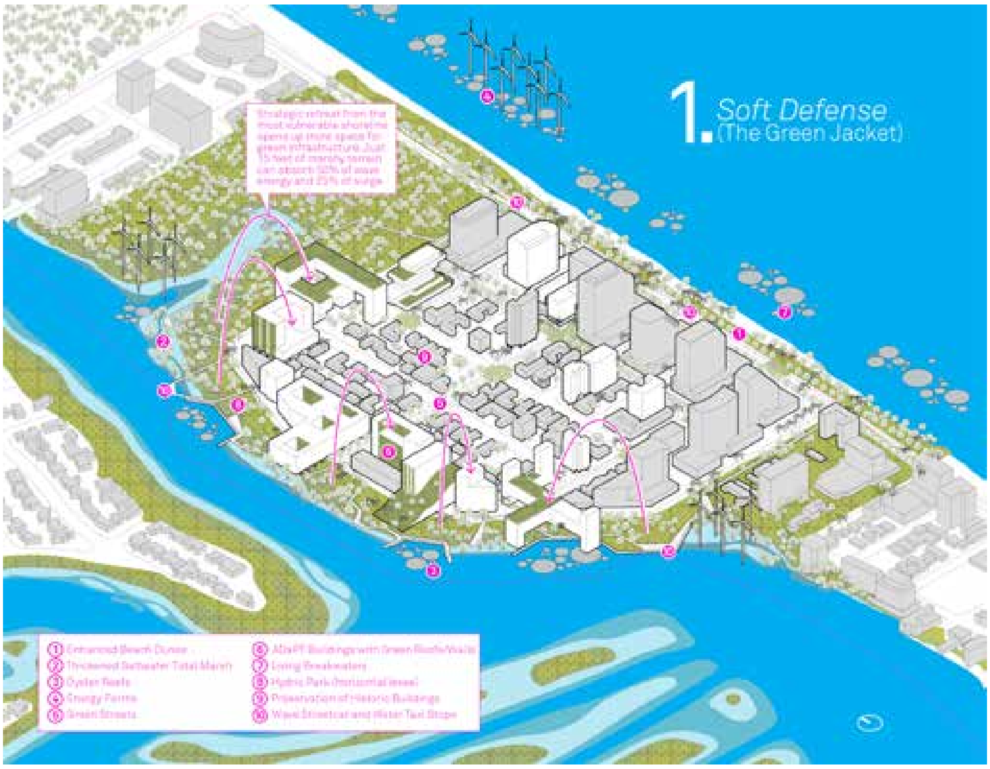


Figure 8. Axonometric of Soft Defense Scenario showing “Green Jacket,” and green and blue streets.

Figure 9. Perspective of living shoreline along Intracoastal Waterway with integrated ecological pest management system.

are oversized and make up about 40% of the urban development thus providing greater advantages in showcasing solutions. The defend strategy proposes a new green and blue street system combining high-tide gardens with salt-tolerant landscapes and pervious paving systems with new “complete street” roadway solutions (Fig. 10). These saltwater landscapes become “biopumps” with phreatophytic - long-rooted trees that transpire significant amounts of water for hydraulic control - to reduce the time saltwater inundates the streets during king-tide flooding. At the coastal ridge, landscapes mimic through reconciliation ecology principles, those of hardwood maritime hammocks where stormwater is allowed to seep back into the freshwater lens, recharging vulnerable groundwater. Essentially designed as a garden, streets become a productive ecological system rather than a net generator of pollution and exacerbated flooding. Streets as gardens also reduce heat island effects while providing new pedestrian amenities that leverage neighborhood and property value (important to developer acceptance). The design strategy will be to minimize encroachment on private property and alter only public land uses.

Scenario 2. “Strategic Retreat” can be defined as gradual removal of urban development through relocation to higher ground on the coastal ridge (Fig. 11). Thus naturalizing low-lying areas and intensifying urban

Figure 10. Before and after of street retrofit illustrating rain gardens and bioswales that act as "biopumps."

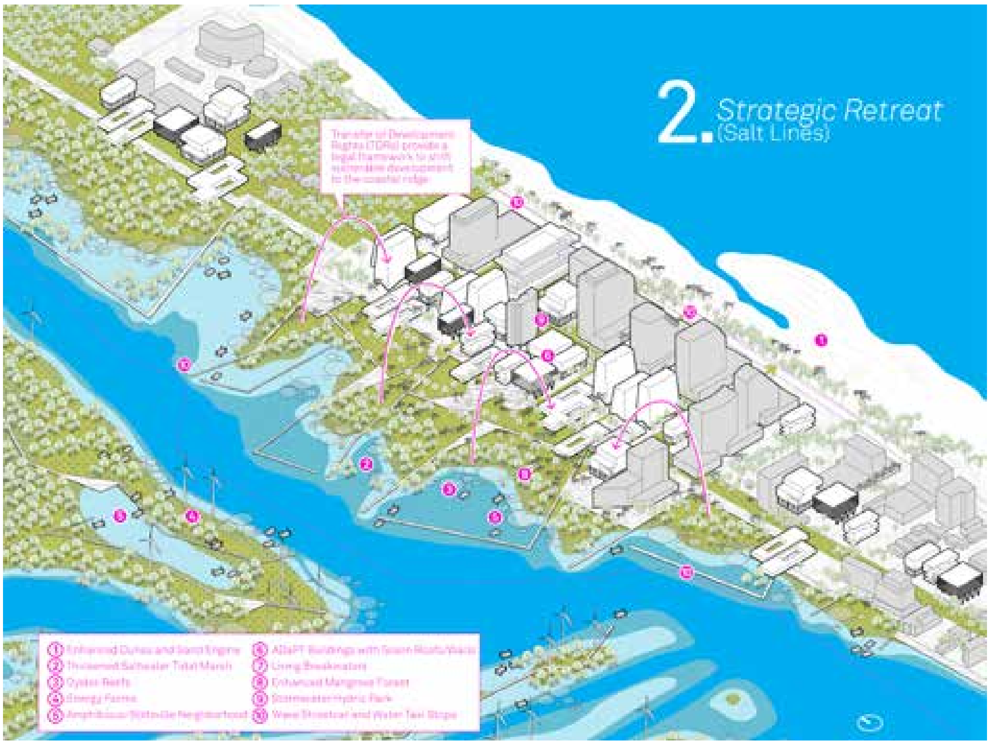


Figure 11. Axonometric of Strategic Retreat Scenario where re-development efforts and integration of green infrastructure are concentrated along highest elevation at coastal ridge and rewilding of lower elevation areas with natural landscapes.

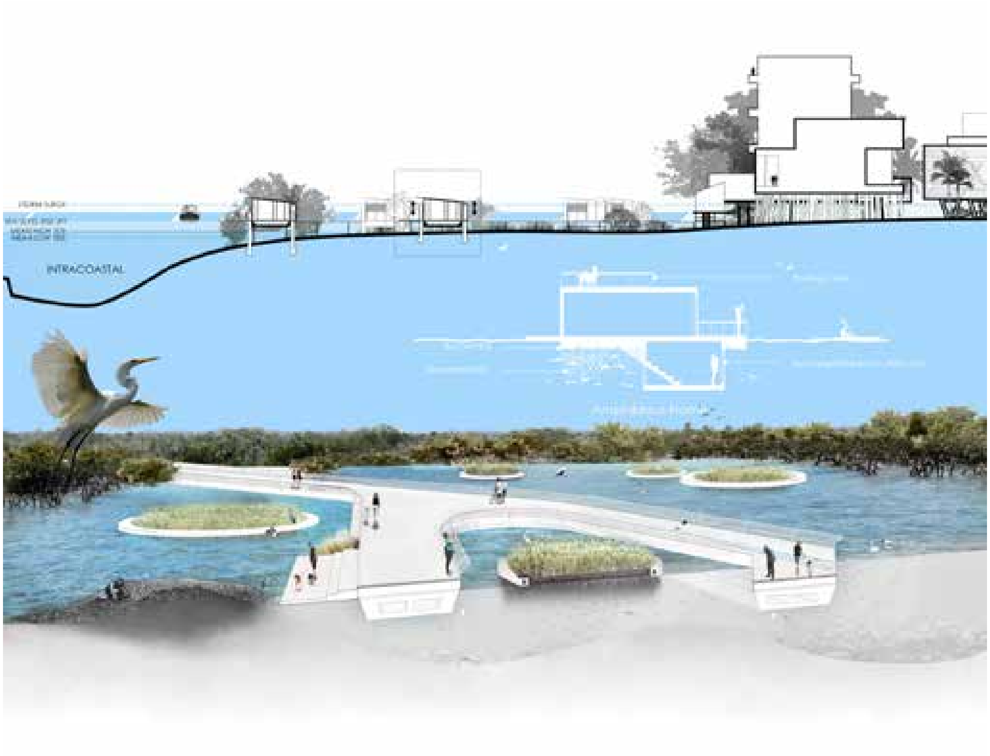


Figure 12. Amphibious buildings and breakwater/walkways with floating "biomats" and living shoreline elements consisting of mangroves and oyster reefs.

development on higher ground. This includes soft-engineered solutions that can be implemented over time as a "rewilding" design approach in both public and private property to the western areas of North Beach Village (Fig. 12). The design strategy may be that removal occurs after natural disasters or when a structure has reached its lifecycle or amortization rate. The coastal ridge is further densified with known legal frameworks like "transfer of development rights" through the implementation of a potential resilience easement or utility. Furthermore, enhanced dunes and sand engines are implemented along the beach as a way to further build robust ecological edges along both shorelines of the neighborhood (Fig. 13).

Figure 13. Enhanced beach dunes and sand engine along coastal segment.

Scenario 3. “Land Adjustment” can be defined as the reformatting of urban buildings, blocks, and streets to integrate soft and hard engineering solutions in an idealized design approach (Fig. 14). Unconventional and perhaps somewhat radical redesign of infrastructure, streetscapes and buildings would be undertaken and speculate on a range of adaptation options. New building types that showcase raised platforms for habitation as well as submerged living units with a transition to more water-based transportation systems were explored (Fig. 15). The approach engaged a number of design and planning challenges, such as property rights, historic architectural styles, and the integration of unconventional infrastructures that challenge existing zoning. Additionally, the scenario suggested food and energy production, waste and water recovery and pollution remediation as essential systems to be integrated in living formats. This scenario provides radical thinking and addresses issues beyond just sea level rise.

The scenarios are being further refined and modeled within ecosystem assessment tools to analyze their capacity and quantify ecological services outcomes. This will be essential in providing the City of Fort Lauderdale the data and proof of concept to establish implementation of one of the scenario visions within the neighborhood. Furthermore, analysis will give cost-benefit information to serve continued community engagement and eventual implementation.

Figure 14. Axonometric of Land Adjustment Scenario, which shifts development into atolls and islands for greater flood protection.

Figure 15. Amphibious structures and living shoreline that remediate pollution and produce food and energy.

Objective 4 - "Sustain:" Community Engagement through Shared Visioning and Education

"Salty Urbanism" will be formalized into a design manual for dissemination of project outcomes and will serve as a transferrable model for implementation regionally. Several workshops educating the public and neighborhood stakeholders have already occurred. A public gallery exhibit of design visioning from student and faculty adaptation plans was opened in North Beach Village to promote dialogue on the issues facing the neighborhood. Continued outreach is critical in transferring novel and complex solution-based strategies.

CONCLUSION

The complexity of interacting issues and methodologies establishes urban design and architects as the primary vehicle to navigate substantial barriers and establish common ground within a more collaborative framework - one that places architecture and planning as relevant fields in solution-based approaches to environmental challenges related to climate change. The design-based research highlights the potential integration of GI and LID to address climate and environmental threats, while considering the social fabric of the neighborhood relative to economic, recreational and cultural factors. The research goes beyond simple stormwater management infrastructure engineering and design to create a unique comprehensive strategy that links isolated research into a meta-disciplinary platform - one which leverages feedback from stakeholders, engineering, ecological and social sciences, and urban design to reward greater resilient planning while enhancing livability.

The City is poised to utilize project design visioning as it begins intensive investment of adaptation infrastructure in North Beach Village over the next decade. The City is encouraged by its partnership, valuing the team's expertise in living infrastructure research, reconciliation ecology design, and community design visioning and engagement. The City also acknowledges the added benefit of working with the institution within politically neutral research and visioning activities that avoid current NIMBYism that can impede implementation. "Salty Urbanism" will be disseminated regionally to stakeholders, municipalities, county metropolitan planning organizations and councils, and application of results will be synthesized into a design manual for national audiences to demystify the concepts of climate adaptation design and planning.

The North Beach Village demonstration project will serve as a platform for reforming municipal codes and permitting regulations to be more hospitable to urban adaptation models. The framework and design projects presented herein remain part of an overarching research effort to quantify the design decisions made within the collaborative project. The goal is that the project becomes a model for other "Adaptation Action Area" pilots around the City and region. The City sees the University, having two campuses located in greater Fort Lauderdale, and specifically the School of Architecture, as a politically neutral entity able to convene productive conversations on politically-charged topics. Phasing strategies will be developed that articulate schedules of recommended public and private investment, beginning with the easiest to implement. Ultimately, this project serves to enable the envisioning of alternative urban models to accommodate changing environments and engage the potentially taboo topics of current political discourse - something for which the architectural studio is particularly primed.

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Credits

Figure 1: Image provided by Joan Murray.
Figure 2: Image courtesy of Fort Lauderdale Historical Society.
Figures 3, 4, 6-15: Images provided by Jeffrey E. Huber.
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