ADAPTATION STRATEGIES FOR SEA LEVEL RISE: CASE STUDIES AND APPLICATION TO COASTAL TOWN OF CEDAR KEY, FLORIDA

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN URBAN AND REGIONAL PLANNING

UNIVERSITY OF FLORIDA

2014

To my lovely daughter and my whole family

ACKNOWLEDGMENTS

I truly appreciate the instruction and encouragement from my committee chair Professor Ilir Bejleri and co-chair Professor Kathryn Frank. Professor Ilir Bejleri helped me a lot on GIS and design skills on coastal urban design in my thesis. Professor Kathryn Frank helped me on the analysis parts of my thesis, especially in the eco-system part. Without their help, I would not have accomplished this thesis.

Additionally, I thank Professor Zhong-Ren Peng. He gave me some very important guidance on the transportation part of my thesis. I also would like to express my appreciation to my classmate Sean Reiss and Rong Zeng. Sean helped me a lot on getting the materials which I needed for my thesis, because I'm not familiar with the government websites in USA. Rong always helped me when I had a problem. Since I stayed in Connecticut and California the whole time when I wrote my thesis, she helped me a lot to deal with lots of paper work which had to be done at the University. She is so warm-hearted and I really appreciate her a lot for her kindness. At last, I deeply thank my family and my friends for their support and caring for me all the time.

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LIST OF ABBREVIATIONS

BCDC	Bay Conservation and Development Commission
FGDL	Florida Geographic Data Library
GIS	Geographical Information System
IPCC	Intergovernmental Panel on Climate Change
PDRP	Post Disaster Redevelopment Plan
SLR	Sea Level Rise

Abstract of Thesis Presented to the Graduate School
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December 2014

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Major: Urban and Regional Planning

Global climate change contributes a lot to the sea level rise. The issues caused by sea level rise are becoming more and more serious for the coastal residents. Coastal areas are extremely vulnerable to flooding and storm surges, both of which have the ability to damage the delicate coastal ecosystem, properties, and the economic opportunities of the area. Science has demonstrated that sea levels are rising and the effects of this phenomenon will impact the vitality of our coasts. The effects of sea level rise will increase salt-water intrusion into freshwater and groundwater, increase the power of storm surge and associated flooding, and other important impacts.

This thesis is focused on exploring adaptation strategies to address the potential problems that will be caused by sea level rise in Cedar Key. The goal of this thesis is to develop sustainability mechanisms in the coastal communities through planning. The methodology of this thesis is organized in three steps: first, to learn different adaptation strategies through literature review. Then analyze a series of case studies to understand how to apply these adaptation strategies into practice. Second, analyze the conditions of the study area - Cedar Key in Levy County of Florida - to fully understand

the kind of problems that may occur in the future by the sea level rise. Third, develop suitable adaptation strategies for the study area.

It's important to note that there is another research at University of Florida doing a sea level rise study for Cedar Key. The author joined Dr. Lewis' studio in 2012 Spring semester, which was the first studio focused on that project. Additionally, Dr. Frank - the co-chair of this thesis - conducted another studio on that same study in the 2013 Spring semester. This thesis work was conducted independently of the above studios. The author has included in this work a comparison of findings and recommendation as another opportunity to highlight options to deal with the challenges of sea level rise.

CHAPTER 1
INTRODUCTION

Problem Statement/ Justification

Over the last 35 years, global temperatures have been steadily increasing, causing land-based ice caps and glaciers to melt, and thermal expansion of the oceans (NOAA). The result is a predicted rise of sea level between 7 and 23 feet within the next century (IPCC). This places a large vulnerability on the coastal places that humans rely on, not only as a place to call home, but also a place of economic opportunity and ecological importance. Rising sea levels will erode beaches; drown marshes and wetlands; damage barrier islands, habitat, and ecological processes; and cause saline intrusion into freshwater ecosystems and groundwater, flooding or inundation of low-lying areas, and damage to private and public property and infrastructure.

Human beings are drawn to coastal environments: for their economic opportunities, as well as their sense of beauty, mystery, and wonder. As the dangers of a changing climate threaten our coastlines, a more forward-thinking coastal management strategy is needed to guide future growth and infrastructure decisions in these vulnerable areas (Beatley, xi).

Coastal habitats, which are significant connections between the land and water, especially for rural coastal communities, are expected to be degraded by human exploitation and will be further stressed by rising sea levels (Snow and Snow, 2009; Costanza, et al., 2008). For instance, in the economy aspect, many coastal areas have beautiful views and these areas are developed as traveling places and the local economy relays on the tourism. Because of the sea level rise, some natural resources will be hurt more or less. Some coastal infrastructures will also be submerged by sea

water or flood. Storm surge will be intensified. These outcomes by sea level rise will lead to the decreasing of tourism which will finally affect the local economic development.

There are many adaptation strategies for the coastal cities to deal with these outcomes caused by SLR, such as building sea wall, increasing coastal armoring and retreat from the coastal areas. This thesis aims to identify the hazards caused by sea level rise and proposes urban design solutions to deal with these potential hazards in the city of Cedar Key, Florida.

Research Question and Objectives

Research Question

Nowadays, more and more people care about the effects of sea level rise. The SLR will have effects in many aspects which will impede the future development of the coastal society. A large number of SLR projects incorporate sustainability as the paramount goal. To realize the goal, planners have to integrate the built environment and other aspects, such as economic development, transportation and etc.

How could the SLR influence the economic development? What are the appropriate solutions to deal with such bad influences? How can the ecosystem be hurt and what strategies will be helpful? The planners are facing many challenges. Sustainability assessment is one of the most crucial challenges. The outcomes of SLR are complicated. Planners should explore the most appropriate solutions to build a sustainable developing society. Because of the limitation of the current scientific and financial resources, and time period, the research is mainly focused on the eco-system, transportation and economic development. How to guide a sustainable development in the coastal area is the main question for this thesis.

Research Objectives

- The main objectives for this thesis are:
- To analyze the effects of SLR on eco-system, transportation system and economic development.
- To explore solutions towards the problems identified caused by SLR.
- To create the most suitable strategies for the study area (Cedar Key) for its future development dealing with the SLR.

CHAPTER 2
LITERATURE REVIEW

Sea Level Rise

This Global warming now is one of the greatest issues in the whole world. The carbon emission is continuing to increase and the climate change is also proceeding in a faster speed. In the past 10 years, the mean temperature of about over 85% continent has risen 1 degree centigrade (Figure 2-1). In the next fifty years, the mean temperature of the earth's surface will rise 5 degree centigrade (Figure 2-2). In the past century (1900-2000), the sea level has risen 20 cm and the mean rate of global sea level rise is about 2mm/yr (Figure 2-3). Figure 2-4 shows the comparison of maximum and minimum projections of the global sea level rise by the year 2010 from diverse authors or publications (U.S. Amy Corps of Engineers [USACE], 2011)

Estimates developed by Florida State University (FSU) suggest Florida's coasts will experience sea level rise in the range of 0.23–0.29 feet by 2030 and 0.83–1.13 feet by 2080. These estimates are lower than the estimates of global sea level rise generated by the Intergovernmental Panel on Climate Change (IPCC) in 2001. The IPCC's 2001 estimates for global sea level rise are in the range of 0.16-0.49 feet by 2030 and 0.33–2.13 feet by 2080.

Outcomes of Sea Level Rise

The impacts of SLR have been investigated in a range of policy-driven sub-national, national and regional/global case studies, as well as many science-oriented studies. A large amount of socio-economic analyses have also been undertaken in the assessment.

Most significant bio geophysical effects of SLR are listed in the Table2-1. The natural-system effects of SLR in the table have a range of potential socio-economic impacts (Nicholls, 2002a), including the following identified by McLean et al. (2001):

- Increased loss of property and coastal habitats
- Increased flood risk and potential loss of life
- Damage to coastal protection works and other infrastructure
- Loss of renewable and subsistence resources
- Loss of non-monetary cultural resources and values
- Impacts on agriculture and aquaculture through decline in soil and water quality

In the Table 2-2, it shows almost 180 million people would be affected by a one meter SLR and assuming no human response in terms of adaptation.

In the United States, the researchers have done continuing analysis towards the impacts of SLR. Table 2-3 shows a one meter SLR scenario.

As in Levy County, the impacts of SLR are mainly considered in storm surge, salt water intrusion, coastal wetlands decline and coastal habitat reduction and so on.

Sea level rise will increase the storm surge which will finally cause the flooding. According to Table 2-4, only May and June the monthly precipitation of Levy County is less than the whole Florida. All the other months, the precipitation of Levy County is more than the whole Florida. Lots of problems will come out with the flooding, such as the fresh water contamination, fresh water supply, transportation issue, and so on.

The City of Cedar Key

In the study area, Cedar Key of Levy County in Florida, the mean sea level has risen about 10cm from 1938-2001 (Figure 2-6). According to the Florida Long-Term

Tide-Gage Records, the sea level rise in Cedar Key is 1.8mm/yr (Figure 2-6). In the future, with the rising sea level, the shoreline of Florida will change as the Figure 2-7 shows and lots of continents will be submerged. The whole Cedar Key is in the dangerous area (Figure2-8).

Importance of Cedar Key

According to the 2010 US Census data, there are 702 people living in Cedar Key. According to Florida Agriculture Statistics Service, aquaculture is a significant part of Florida economy. The contribution of cultured clam sales was assessed to be $34 million to the state's economy in 1999 increasing to $53 million in 2007, making clam farming an important agribusiness. Clam farming takes 83% of the Florida economy, and Levy County contributes to a major portion of the clam farming in total. What's more, the clam farming is very famous in Cedar Key. It holds seafood festival every year and the festival attracts many tourists to come. Table 2-5 and Figure 2-9 show the changing sea level of Cedar Key.

Current Solution and Limitations

To build barrier, barrier in this strategy is acting like a wall or fence to protect the inland of the coastal area. Usually, they are large dam, gate or lock or a series of them which manages tidal flows in and out the Bay.

The barrier is really effective to some extent. It can protect a large area of land in single sweep. However, it does have some limitations. Firstly, barriers are very expensive to build. The famous Three Gorges Dam in China is expected to cost $25 billion when completed. Secondly, the barriers will damage the ecological system. The BCDC's study shows that the barrier would affect the Bay's salinity, sedimentation, wetlands, wildlife and endangered species. Additionally, with the rising sea level, the

barrier is less and less workable. For instance, according to historical data supplied by the Environmental Agency of the Government of Great Britain, the height of the containing wall along the Thames River has to be increased by about 2 meters between 1879 and 1970 to protect the city from river surge (Figure 2-10). Examples of building such barriers are Maeslant Barrier, Thames Barrier, Venice MOSE and Bay Arc.

Linear protection, to build levees ad seawalls to fix the shoreline in its current place. Nowadays, linear protection is the most widely used way to protect the inland development. It is different from the building barrier strategy. It is built continuously and it can protect the shore from strong wave action.

We can combine linear protection with other strategies to protect the developing inland from the rising water caused by storm surge and sea level rise. What's more, the linear protection can also get along well with the new development along the levees. On the other side, it also has some limitations. First of all, it can only protect some usual storm size or rise in sea level. The unusual large storm can damage the levees, such as the levees in New Orleans were damaged during the Hurricane Katrina. Secondly, the maintenance will cost lots of money. Thirdly, the artificial shoreline is more vulnerable to erosion. However, many people don't know it and build some development along the shoreline. As a result of this, such area is very vulnerable to flooding.

Floating Development, using structure which can float on the surface of water. There are many cities already had there floating development. In Sausalito, the first houseboat communities were built in 1960s. Dubai has many floating hotels and restaurants which have attracted many tourists to visit here. The high tides and earthquakes are uncertain. But the floating development is so resilient to accommodate

with the changing sea level and seismic activities. Though the floating development has many advantages, it also has many limitations. The effective zones are limited to protected areas which have been built floating development. And the floating structures also don't work well in the places which use to suffer wind and wave action from storms. The ocean coastline is such kind of place. Additionally, whether such type of development is suitable in high density cities hasn't been demonstrated.

Elevated Development, raising the height of land or existing development and protecting it with coastal armoring. Filling the Bay for new development now is used in Netherlands to expand and elevate land for settlement. Japan and Dubai also have filled a large area for new development. The world-wide famous Palm Island in Dubai is built on the filled ground in the sea. Such strategy may be an effective way for protecting low-lying infrastructure, such as airport. However, the elevated development is a short-term strategy and now it's still not clear whether this strategy is workable in the high-density areas or not. Additionally, if the development along the shoreline is started, it will increase global warming emissions which will finally affect the sea level rise.

Living shorelines, using wetlands as natural shoreline to protect the inland. The natural living shorelines are very effective for protecting shorelines from floods and erosion by absorbing waves. Living shorelines have many benefits to the society. Such as they can purify the water, provide great habitat for fish, and other wild lives which is essential to the aquatic food chains. In a word, the natural living shorelines are not only good for the protection of inland but also good for the ecological balance. However, the limitation is that it will cost lots of time and space to build the effective living shorelines.

Firstly, we should find the appropriate area to build the living shorelines. Not all the soil is perfect for their growing. What's more, we also need use a continuous land. Only if the living shoreline is continuously built, it can work effectively. Additionally, they also need good management which calls for much time and money. What's more, not all the land can be built as natural living shorelines. It requires enough space to migrate landward and sufficient sediment. Some places even have to move development inland from urbanized areas at the water's edge which is very costly.

Managed retreat, abandoning the threatened areas near the shoreline. The managed retreat is used when other protection methods are very expensive or considered to be not effective. Such strategy can minimize people from suffering a catastrophic flood by relocating development to a safer place. The abandoned area can be used to build wetlands and natural living shoreline which can provide protection to the inland development. However, it can be very expensive for the developed areas to move and many coastal property values will be lost. There is another limitation that many property owners are not will to move. No one can force them to move to another place. What's more, it's not easy for the shoreline communities to relocate in a new place with good development. Some shoreline communities lack the ability to adapt to the new environment.

According to what just have been discussed, an evaluation table is built to compare these adaptation strategies. Table 2-6 is the evaluation table.

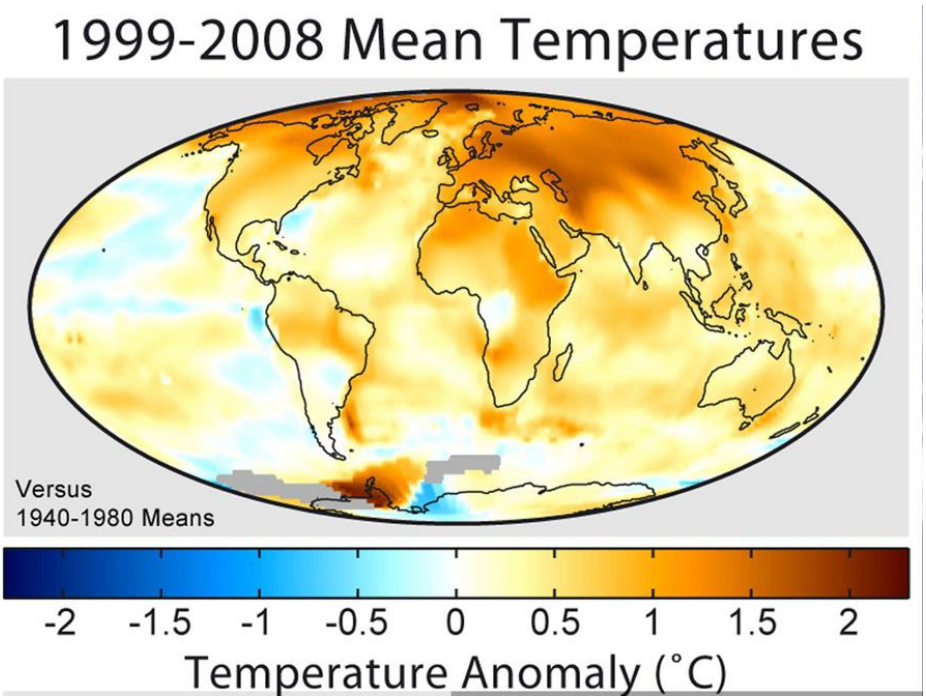


Figure 2-1. 1999-2008 Mean Temperatures Source: Figure courtesy of Robert Rohde, www.globalwarmingart.com.

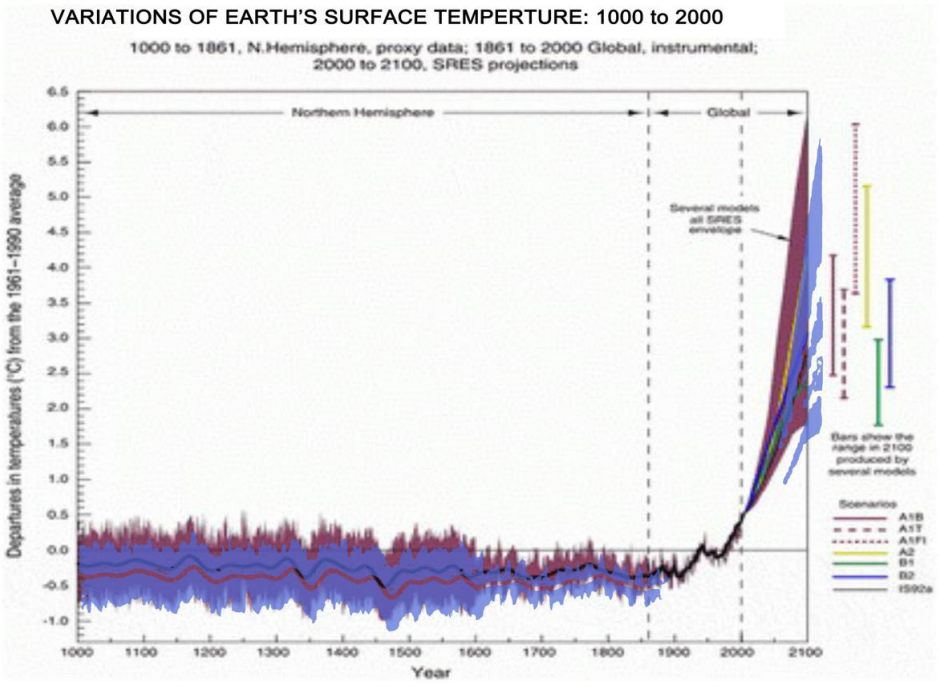


Figure 2-2. Variations of Earth Surface Temperature Source: IPCC, Synthesis Report, figure SPM-10b

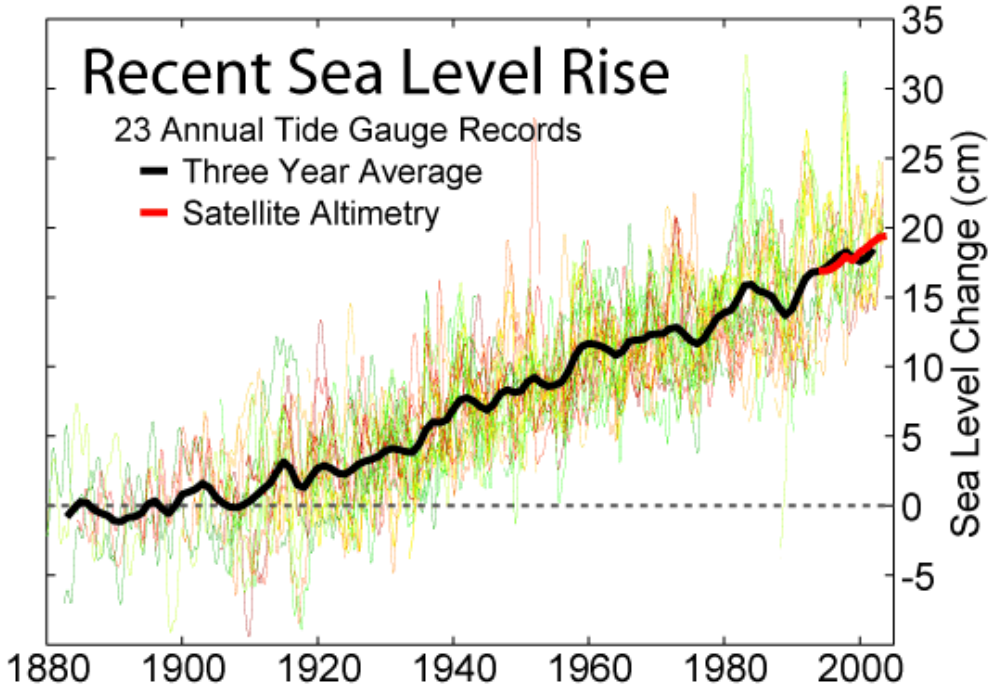


Figure 2-3. Recent Sea Level Rise Source: Courtesy of Robert A. Rohde/Global Warming Art Project

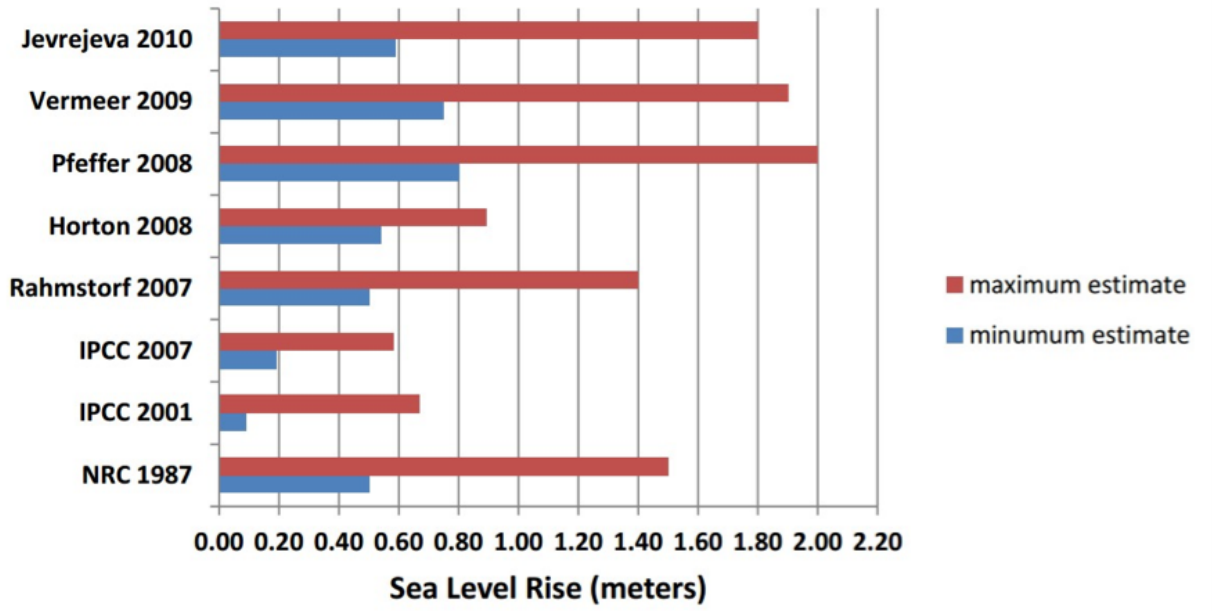


Figure 2-4. Comparison of maximum and minimum projections of global SLR by the year 2100. Source: U.S. Army Corps of Engineers, 2011.

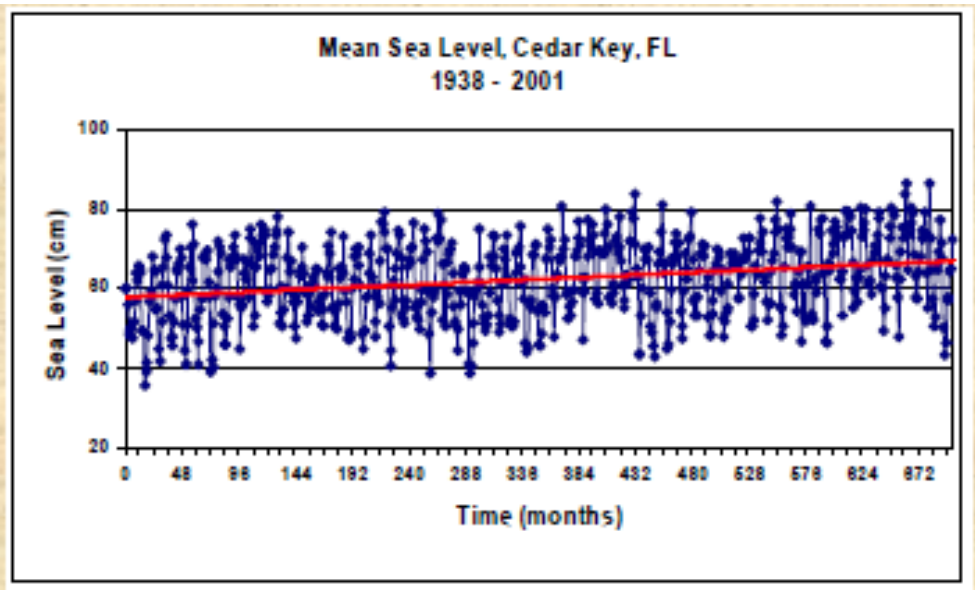


Figure 2-5. Mean Sea Level, Cedar Key, FL**.** Source: Douglas, B.C. and Peltier. W.R. 2002. The puzzle of global sea level rise: Physics Today. V. 55 (March 2002). P.35-40.

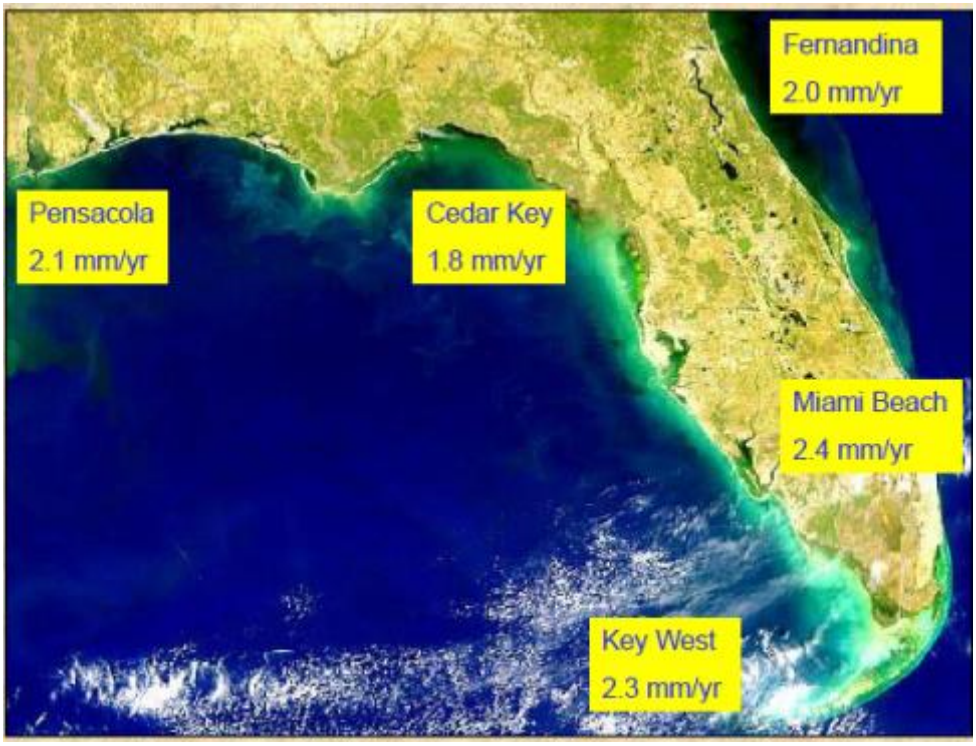


Figure 2-6. Florida Long-Term Tide-Gage Records**.** Source: NOAA long-term tide gage data; image from SeaWiFS, NASA/Godard Space Flight Center, 1999

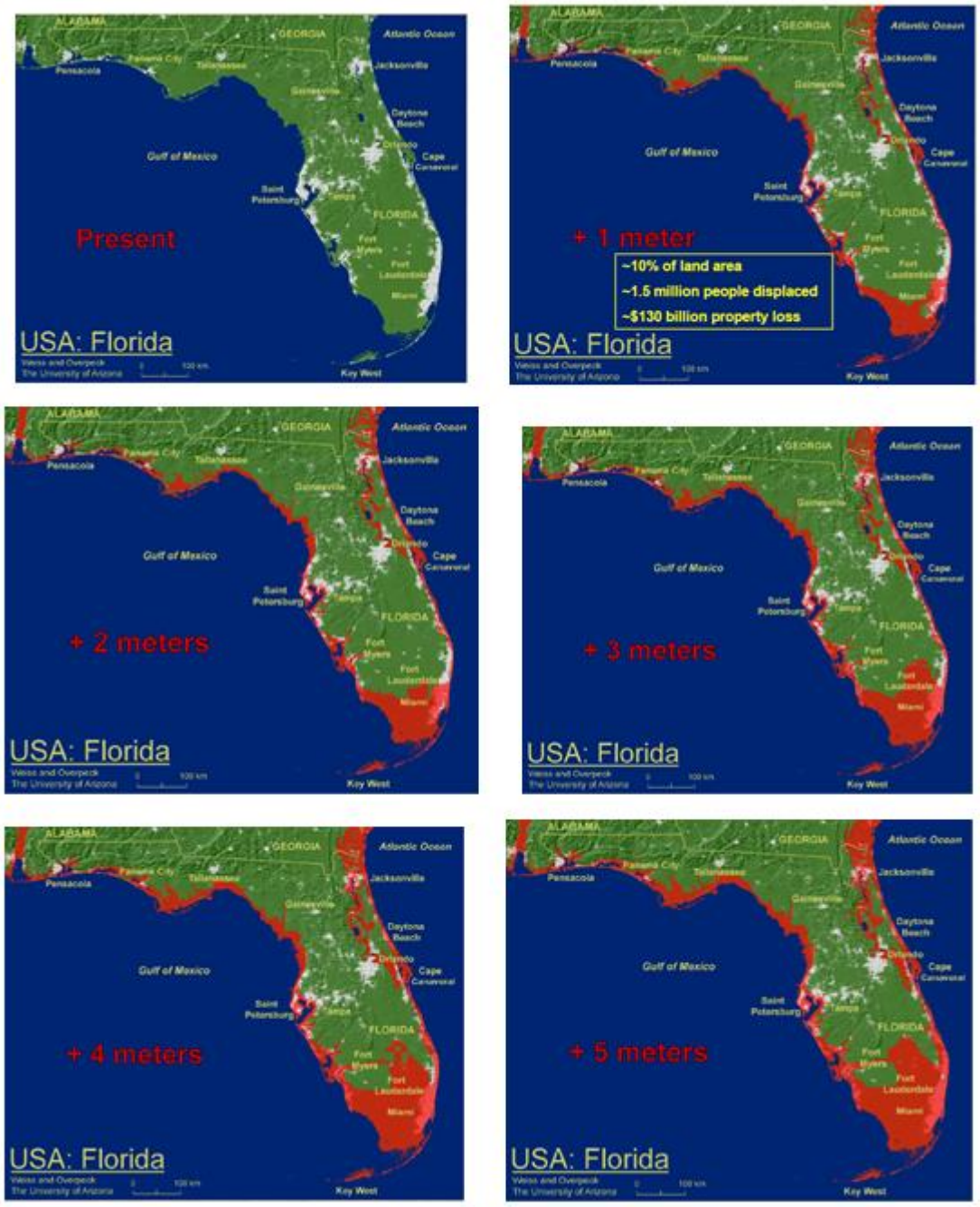


Figure 2-7. Florida Shoreline change with the sea level rise**.** Source: Weiss and Overpeck, Environmental Studies Lab. Univ. Arizona.

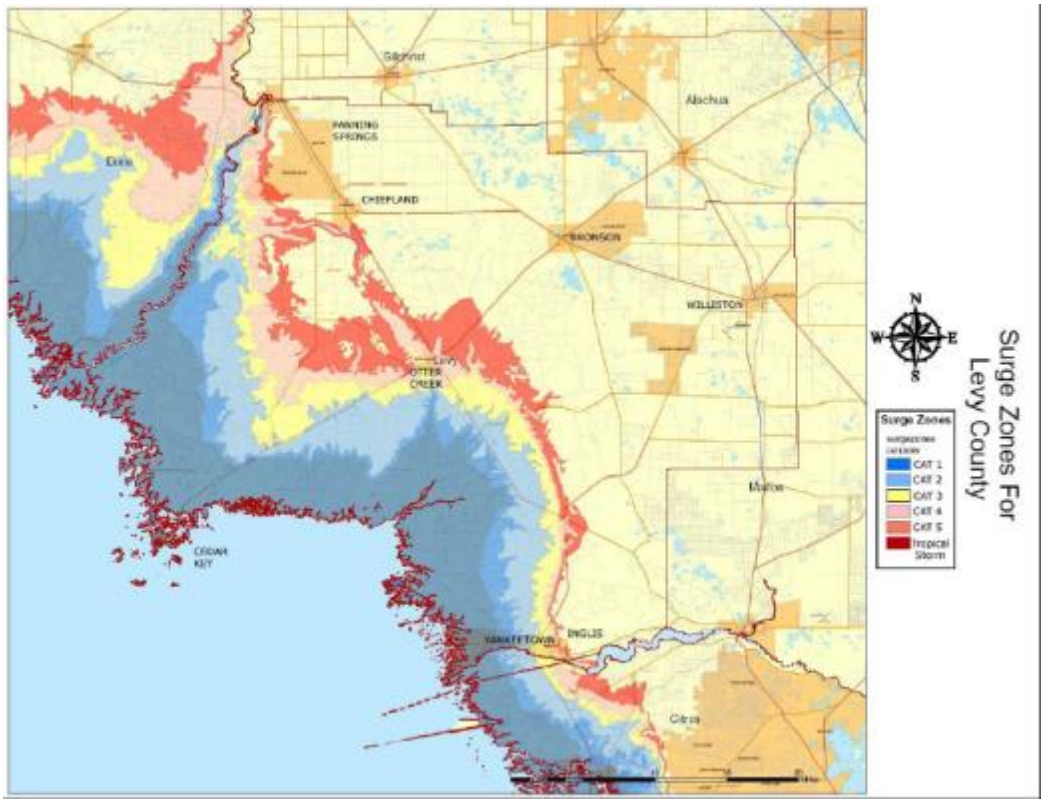


Figure 2-8. Surge Zone of Levy County Source: Google map

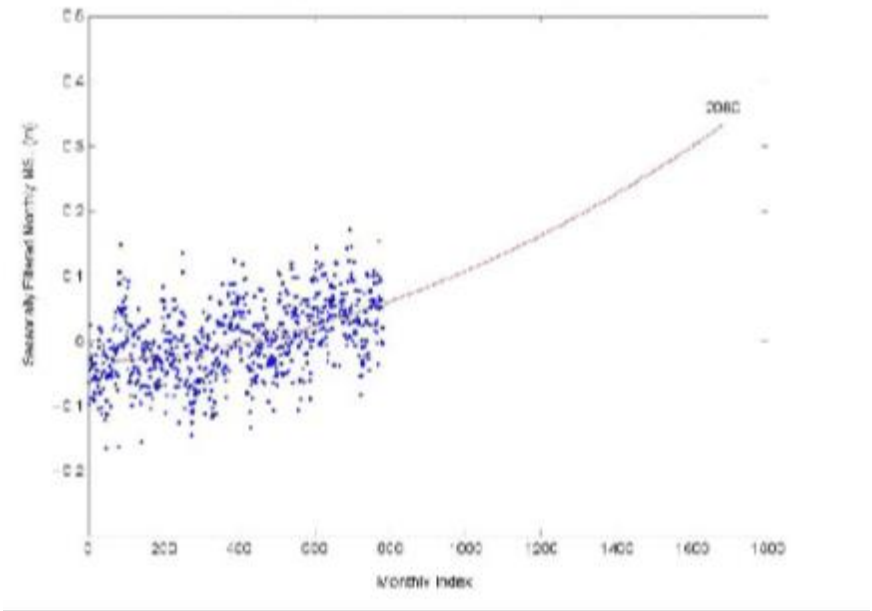


Figure 2-9. Cedar Key Gage Station Forecast Filtered Sea Level Rise. Source: Climate Change in Coastal Areas in Florida: Sea Level Rise Estimation and Economic Analysis to Year 2080

Figure 2-10. The Thames Barrier is located downstream of central London. Resource: Flickr user Miscal Photo Man

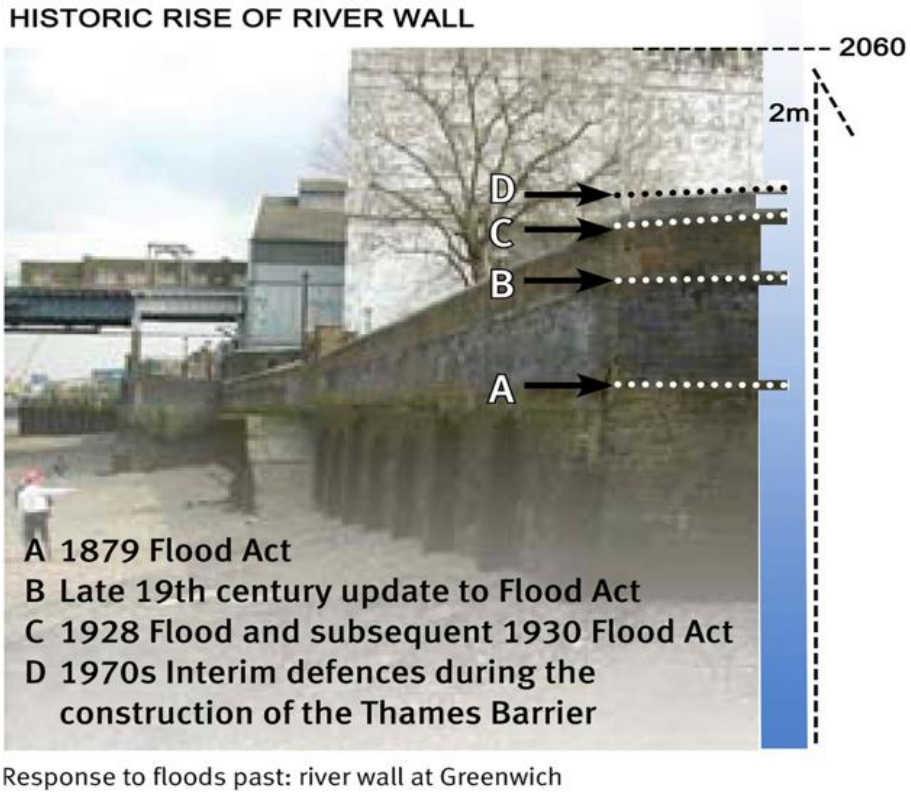


Figure 2-11. Historic Rise of River Wall. Source: Environment Agency of the Government of Great Britain

Figure 2-12. Motorway Dike in The Netherlands. Resource: Picasa user Wilfrid

Figure 2-13. Multi-family floating canal houses. Resource: Flickr user Stevecadman

Figure 2-14. Old and New. At right, an elevated house in New Orleans by Kieran Timberlake for the Make it Right Foundation. Resource: Flickr user werdsnave

Figure 2-15. Suisun Marsh wetlands in the north of San Francisco Bay. Resource: Matt Knoth

Figure 2-16. An abandoned beach house awaits demolition. Resource: Flickr user Swirlspace

Table 2-1. The main effects of relative Sea Level Rise. Source: Robert J. Nicholls, Working party on global and structural policies

BIOGEOPHYSICAL EFFECT			OTHER RELEVANT FACTORS	
			CLIMATE	NON-CLIMATE
Inundation, flood and storm damage		Surge	Wave and storm climate, morphological changes, sediment supply	Sediment supply, flood management, morphological changes, land claim
		Backwater effect (river)	Run-off	Catchment management and land use
Wetland loss (and change)			CO_2 fertilization Sediment supply	Sediment supply, migration space, direct destruction
Erosion			Sediment supply, wave and storm climate	Sediment supply
Saltwater Intrusion	Surface Waters		Run-off	Catchment management and land use
	Groundwater		Rainfall	Land use, aquifer use
Rising water tables/impeded drainage			Rainfall	Land use, aquifer use

Table 2-2. Aggregated results of country studies. Source: Bijlsma et al. (1996)

County	People Affected		Capital Value at Loss		Land At Loss		Wetland At Loss	Adaptation/Protection Costs	
	#People (1000s)	% Total	Mil US$	% GNP	Km^2	% Total	Km^2	Mil US$	% GNP
Antigua	38	50	-	-	5	1.0	3	71	0.32
Argentina	-	-	5000	>5	3400	0.1	1100	>1800	>0.02
Bangladesh	71000	60	-	-	25000	17.5	5800	>1000	>0.06
Belize	70	35	-	-	1900	8.4	-	-	-
Benin	1350	25	118	12	230	0.2	85	>400	>0.41
China	72000	7	-	-	35000	-	-	-	-
Egypt	4700	9	59000	204	5800	1.0	-	13100	0.45
Guyana	600	80	4000	1115	2400	1.1	500	200	0.26
Japan	15400	15	849000	72	2300	2.4	-	>156000	>0.12
Kiribati	9	100	2	8	4	12.5	-	3	0.10
Malaysia	-	-	-	-	7000	2.1	6000	-	-
Marshall I.	20	100	160	324	9	80	-	360	>7.04
Mauritius	3	<1	-	-	5	0.3	-	-	-
Netherlands	10000	67	186000	69	2165	5.9	642	12300	0.05
Nigeria	3200	4	17000	52	18600	2.0	16000	>1400	>0.04
Poland	235	1	24000	24	1700	0.5	36	1400	0.02
Senegal	110	>1	>500	>12	6100	3.1	6000	>1000	>0.21
St Kitts	-	-	-	-	1	1.4	1	50	2.65
Tonga	30	47	-	-	7	2.9	-	-	-
Uruguay	13	<1	1700	26	96	0.1	23	>1000	>0.12
U.S.A.	-		-	-	31600	0.3	17000	>156000	>0.03

Table2-2. Continued

Venezuela	56	330	1	5700	0.6	5600	>1600	>0.03
TOTAL	178834	1146310		149022		58790	27124	

Table 2-3. Potential cost of SLR along the developed coastline of the United States (billions of 1990 dollars). Source: Adapted from Neumann et al. (2001)

Source	Measurement	Annualized Estimate	Cumulative Estimate	Annual Estimate in 2065
Yohe (1989)	Property at risk of inundation	N/A	321	1.37
Smith and Tirpak (1989)	Protection	N/A	73-111	N/A
Titus et al. (1991)	Protection	N/A	156	N/A
Nordhaus (1991)	Protection	4.9	N/A	N/A
Fankhauser (1995a)	Protection	1.0	62.6	N/A
Yohe et al. (1996)	Protection and abandonment	0.16	36.1	0.33
Yohe and Schlesinger (1998)	Expected protection and abandonment	0.38	N/A	0.4

Table 2-4. Precipitation of Levy County. Source: Levy County, Florida Real Estate and Demographics

2010 Avarage Monthly Precipitation	Levy	Florida	United States
Avg. Annual Precipitation	58.11''	50.83''	N/A
Avg. January Precipitation	4.29''	2.45''	N/A
Avg. February Precipitation	3.32''	2.67''	N/A
Avg. March Precipitation	4.32''	3.31''	N/A
Avg. April Precipitation	3.15''	2.28''	N/A
Avg. May Precipitation	3.29''	3.92''	N/A
Avg. June Precipitation	7.20''	7.68''	N/A
Avg. July Precipitation	8.04''	7.77''	N/A
Avg. August Precipitation	9.23''	7.23''	N/A
Avg. September Precipitation	6.31''	6.30''	N/A
Avg. October Precipitation	2.93''	2.79''	N/A
Avg. November Precipitation	2.62''	2.33''	N/A
Avg. December Precipitation	3.40''	2.12''	N/A

Table 2-5. Forecast Relative Sea Level Rise from 2006-2080. Source: Climate Change in Coastal Areas in Florida: Sea Level Rise Estimation and Economic Analysis to Year 2080

Station	Relative Sea Level Rise (in meters) 1st Order	Relative Sea Level Rise (in meters) 2nd Order	Relative Sea Level Rise (in meters) Exponential
Fernandina, FL	0.16	0.25	0.27
Key West, FL	0.15	0.31	0.28
St. Petersburg, FL	0.18	0.35	0.36
Cedar Key, FL	0.11	0.27	0.16*
Pensacola, FL	0.13	0.34	0.21*

* parameter estimation suspect due to convergence problems

Table 2-6. Evaluation of adaptation strategies

	Solutions	Approach	Advantages	Disadvantage
Solution One	Build Barrier	A large dam, gate, or lock or a series of them that manages tidal flows in and out of the bay	Protect a large area of land in a single sweep	1. Expensive to build. 2. It may damage the ecosystem of the Bay. 3. It may increase the coastal erosion.
Solution Two	Build Levees and Seawalls	Build levees and seawalls to fix the shoreline in its current place	1. Can be used in combination with other strategies for sea level rise. 2. It can be designed to accommodate new development. 3. It can also protect threatened habitat.	1. It's a short-term solution. 2. It needs large amount of money to maintain. 3. It may be destroyed by unusual large storm.
Solution Three	Floating Development	Use floating structures to build development.	1. It's resilient to seismic activity. 2. It can manage uncertain high tides and earthquakes.	1. It only works in protected areas. 2. It's not effective in windy areas, such as ocean coastline.
Solution Four	Elevated Development	Raise the height of land or existing development and protect it with coastal armoring.	Structure can be built on the encroaching shoreline or in the vulnerable area.	1. It's a short-term strategy. 2. It needs protection just like low lying development.

Table 2-6. Continued

Solution Five	Living shorelines	Wetlands are the natural form of the shoreline. They absorb floods, slow erosion and provide habitat.	1. Living shorelines benefit society. 2. Wetlands filter pollutants out of water, sequester carbon, provide recreational open space and so on.	1. It requires space and time to work. 2. It also requires management, monitoring and time to become established.
Solution Six	Managed retreat, abandoning threatened areas near shoreline	Planning abandonment of threatened areas near the shoreline.	1. Minimizes human suffering. 2. Less expensive than armoring strategies. 3. It can be designed to wetlands and natural shoreline habitat which affords protection.	1. This strategy is a political quagmire. It involves lots of legal and equity issues. 2. The cost of retreat will beyond relocation.

CHAPTER 3
METHODOLOGY

The methodology in this thesis can be divided into 4 steps: Basic knowledge understanding, Data gathering and Design adaptation strategies.

Step 1: Basic knowledge understanding
- Gathering background scientific information about SLR.
- Learning precedent studies about different adaptation strategies towards SLR.
- Case studies in detail of how to deal with SLR in the United States.

Step 2: Data gathering
- Collecting data at local level from GIS.
- Organizing data

Step 3: Design adaptation strategies
- Comparing strategies learned from precedent studies and case studies.
- Design most suitable strategies for the study area—Cedar Key in Florida.

Case Studies

In this thesis, the author chooses four coastal areas which are suffering from SLR. From analyzing these case studies, different adaptive strategies can be understood for sustainable development for coastal areas. And the most suitable adaptive strategies can be evaluated for the study area—Cedar Key.

In the case studies, the author will analyze the resilience actions and planning in these cities towards the outcomes of SLR. All the cases presented in the thesis have already taken their strategies into practice.

Case Study Selection

A The case study areas are as follows: San Francisco Bay Area, California; Auckland, New Zealand; San Diego Bay, California, and Palm Beach County, Florida; The San Francisco Bay Area case is the primary case. Most of the strategies it using to deal with the impacts of SLR have been discussed in the Chapter 2 in this thesis. The first three case studies are focused on the planning for SLR. The last case—Palm Beach County

in Florida is mainly focused on the Post Disaster Redevelopment Plan towards the storm surge. It has done a lot of work for the coastal resilience planning. Storm surge is also one of the big concerns in Cedar Key.

Data Collection

The data in the thesis includes primary data and secondary data. It serves as the basis for the research design. The primary data comes from observation and interview. The secondary data comes from relative researches, government documents, academic fields, downloadable GIS data and so on.

GIS data serves as the fundament for this research. From the GIS data, the author can get a comprehensive understanding of the study area in the geographic, social and environmental aspects. Most of the analysis is based on the maps from GIS which is indispensable in this thesis. Due to the limitation of time and the expenses, the author cannot make the on-site observation. The author only conducts the interview in the Cedar Key and some general observations. As a result of this, the data collection in this thesis mostly comes from the secondary data.

CHAPTER 4
CASE STUDY ANALYSIS

Case Study I: San Francisco Bay Area, California

Introductory Remarks

San Francisco Bay is located in the state of California. It was designated a Ramsar Wetland of International Importance on February 2nd, 2013. This Bay is well developed with business, residential, industrial and port facilities and transportation corridors. As a result of this, it plays a very important role in the regional economic development. Additionally, significant recreation activities and tidal march habitat are located in the Bay.

Long-duration tide gauges indicate that sea level in San Francisco Bay estuary has raised 7.6 inches over the past 150 years, increasing at an average annual rate of 0.04 to 0.08 inches per year, which is consistent with global sea level rise (California Energy Commission, 2003). The California Climate Change Center estimates that mean sea level will rise between 4 and 35 inches by 2100 (California Environmental Protection Agency, 2006).

Adaptation Strategies

The main objectives of the SLR planning in San Francisco Bay are:

- Analyze excising information on Bay-related impacts of climate change, identify information needs, and provide a summary report.
- Engage the public in the planning process through an initial public outreach effort
- Identify adaptation strategies
- Update the pertinent policies of the *San Francisco Bay Plan*.
  (Leslie D. Lacko, 2007)

According to the objectives, the sustainable development policy director for the San Francisco Planning + Urban Research Association outlines some strategies as follows:

- Building barriers or tidal barrages to manage tidal flow in and out of the bay at the Golden Gate and other smaller, strategic points along San Francisco bay.
- “Armoring” the coast with seawalls and levees in an attempt to fix the coastline in place
- Elevating land and development in conjunction with coastal armoring
- “Floating” development on the surface of the water, either permanently or on occasion of flooding and storm surges, making the area secure against rising tides
- “Floodable” development specifically designed to withstand floodwaters and storm surges
- Restoring “living” shorelines and ecosystems with wetlands that provide protection from floods, minimize erosion and rehabilitate habitat for local and migratory species
- “Managed retreat” – moving existing development back from vulnerable coastlines and allowing the sea to rise unimpeded. New coastal development would be banned in coastal areas subject to sea level rise (Sea Level Rise: Adaptation for the San Francisco Bay Area)

Additionally, there is also an innovation for adaptation—Folding Water. Folding Water is considered as a self-sustaining “ventilated levee” and it is also designed to have minimal visual impact on the bay. It can protect and regulate inflow and outflow of tides to protect the sea level rise. By doing this, the Folding Water can also keep the circulation of bay and delta waters. This system works by exchanging of water through a perforated pump wall.

Conclusion

BCDC knows the importance of collaboration. It works together with the local jurisdictions and other regional agencies. With such action, the program will be moved on more easily and effectively. BCDC uses several strategies to deal with the SLR

which have been discussed in the former chapter. The planners combine such strategies and make them work very well towards the same target.

The planners working for the SLR adaptation strategies in San Francisco Bay Area are doing a very good job, especially the innovative design like Folding Water. This solution is effective. However, such strategies need plenty of time and money to be realized. The SLR will never wait. It is getting to us closer and closer day by day.

Case Study II: Auckland, New Zealand

Introductory Remarks

Auckland is the largest and most populous city of New Zealand. It's also the industry, commercial and economy center of the whole country. New Zealand's mean sea level rose at an average rate of 1.6mm per year throughout the twentieth century, corresponding approximately with observations of the global mean (Hannah, 2004). It is expected that New Zealand's mean sea level will continue to rise approximately in line with global mean levels over the coming century (MfE, 2008). For timeframes beyond 2100, SLR of 10cm per decade should be considered. New Zealand's current guidance on incorporating SLR into long-term council planning and coastal hazards management is based on the 2007 IPCC projections (Ministry for the Environment, 2008).

Adaptation Strategies

The IPCC (IPCC CZMS, 1990; IPCC, 2007a) outlines three broad strategic options for responding to the SLR:

- Protect landward property using structural and non-structural coastal engineering structures.
- Accommodate human settlements to the changing conditions through structural changes to buildings.
- Retreat from coastal-hazard-prone areas of the coast.

According to these three strategies, Auckland makes its own adaptation strategies for SLR.

- Use structural coastal engineering, sea walls, revetments, groynes; and non-structural coastal engineering, nourishment, dune creation and restoration work as coastal protection.
- Raising site levels, buildings, infrastructures, and changing building codes.
- Addressing the increasing limits to the commercial insurability of coastal property.
- Limit new development and redevelopment in coastal hazard areas and eventually removing or relocating buildings and assets landward in identified areas.

Conclusion

In New Zealand, the local authorities have the responsible for the management of natural resources. The local authorities have the independent power and responsibilities to guide and support the management of coastal hazards and SLR in New Zealand. To do the program, they have identified barriers and adaptation options of each strategy. By knowing what the barriers are, the planners can set up specific solving strategies to overcome them which can make the planning more effective. They also do interviews with the stakeholders to find the social and institutional barriers. Additionally, the planners working for the SLR project do the planning work under uncertainty, and the uncertainties are unlikely to be resolved. This makes the planning work more complicated.

Case Study III: San Diego Bay, California

Introductory Remarks

San Diego Bay is a natural harbor and deep water port located in San Diego of California. It is the economic and culture center of Southern California. San Diego Bay is very well-known as its beautiful landscape, biological diversity, economic prowess and prestigious academic institutions. The impacts of SLR may change the form and

function of the coastline habitats. According to the scientific research model, it predicts the sea level will raise 12 to 18 inches in San Diego. As the sea level continues to rise and the future importance of San Diego Bay, adaptation strategies for SLR in San Diego Bay becomes very important.

Adaptation Strategies

The adaptation strategies were prepared by ICLEI-Local Government for Sustainability.

- Create a staff-level regional sea level rise (SLR) adaptation working group consisting of representatives from public agencies around San Diego Bay to implement the Adaptation Strategy.
- Provide regular opportunities for stakeholder engagement around implementation of the Adaptation Strategy.
- Create and enhance existing outreach, education, training, and peer exchange programs tailored to public agency staff, stakeholders, and the general public.
- Establish and promote a regional research agenda to advance understanding of sea level rise impacts, vulnerabilities, and adaptation responses in the San Diego region.
- Engage regulatory agencies to advocate for clear and consistent regulatory guidance on how to address sea level rise impacts in development permitting.
- Engage the Federal Emergency Management Agency (FEMA) to encourage the incorporation of future risks from sea level rise into non-regulatory maps associated with upcoming Flood Insurance Studies (FIS).
- Institutionalize or mainstream sea level rise adaptation by incorporating sea level rise and associated impacts into relevant local and regional plans and projects.
- Consistently utilize guidance provided by the State of California Climate Action Team in developing sea level rise assumptions for planning purposes.

- Perform more detailed vulnerability assessments at a site-specific level as significant plans or capital projects are undertaken.
- Develop decision-making frameworks in each jurisdiction for selecting and implementing appropriate management practices in communities vulnerable to inundation or regular flooding, utilizing such frameworks as risk management and cost/benefit analysis. (Sea Level Rise Adaptation Strategy for San Diego Bay, ICLEI, 2012)

Conclusion

To do the planning, the Steering Committee, Stakeholder Working Group and Technical Advisory Committee work together. It is prepared by the ICLEI, including most of the public agencies and private sector. They have done the vulnerability assessment by sectors of San Diego Bay. Through the vulnerability assessment, we know where and when the impacts of SLR will occur and specific adaptation strategies can be taken out to deal with such impacts. The participating local jurisdictions can implement the recommendations in their own planning processes, as they know exactly what people living there caring about and what needs to be concerned.

Case Study IV: Palm Beach County, Florida

Introductory Remarks

Palm Beach County is located on the Atlantic coast of Florida, north of Miami. 40 percent of the county is highly productive agricultural use and the eastern part of the county is also highly urbanized. The development along the ocean is very intensive. In the county, there are large areas of wetlands and sensitive lands. The Loxahatchee National Wildlife Reserve is in the Palm Beach County.

Palm Beach County has the threat of hurricanes and costal storms. There are six major hurricanes have hit the county between 1900 and 1950. And in the 1980s and

1990s, a series of hurricanes and tropical storm strikes had been there. The extent of property and people in harm's way continues to rise here, with an estimated $370 billion in insured property in Dade, Broward, and Palm Beach counties combined (Palm Beach County 2004, 3-8)

Adaptation Strategies

Palm Beach County has taken many steps to enhance long-term resilience and community sustainability. It has created the innovative land use planning and growth management system and extensive post disaster planning.

The main point of comprehensive plan in Palm Beach County is the future land use. It employs a unique managed growth tier map that "defines distinct geographical areas within the County that currently either support or are anticipated to accommodate various types of development patterns and service delivery provisions that, together, allow for a diverse range of lifestyle choices, and livable, suitable communities" (Palm Beach County 2005,2). They gave five growth management tiers:

- Urban/suburban
- Exurban
- Rural
- Agricultural reserve
- Glades

The population in Palm Beach County is very large. How to arrange the population is one of the most important issues. According to the five tiers mentioned before, most of the population growth is intended to occur there. The population decrease from Urban/suburban tier to Glades tier. The County aims at arranging the most development into the urban/suburban tier. As a result of this, it built revitalization and redevelopment zone within these areas. The county also utilizes transfer of

development rights (TDR) to implement the tier system. That's to say, it receives areas within the urban/suburban tier and sends zones in the other tiers, including rural residential zones and environmentally sensitive lands. By doing these actions, in the urban/suburban tier, it will have important redevelopment. What's more, a very compact, land-conserving urban form will be realized there as well.

In addition to the comprehensive plan, Palm Beach County also has prepared a hazard mitigation plan and a post disaster redevelopment plan (PDRP) for the resilience planning. The county has a series of public workshops, the document is intended to serve as "a single reference for guiding decision-making and action during the difficult disaster recovery period, as well as detailing actions that can be taken before a disaster strikes to speed the recovery process" (Palm Beach County 2006, iii). The PDRP identifies a series of post disaster recovery and redevelopment goals.

The most meaningful part for this case study is the strategies for the "economic vitality". The economic development is one of the top concerns of the sustainable planning for future SLR in the study area—Cedar Key. The PDRP seeks to prevent the relocation of core business and to utilize creative measures to reduce the disruption of business. The action plans are as follows:

- Establishing prearranged contracts with local businesses for recovery and redevelopment
- Identifying sites for post disaster temporary office space
- Securing mobile units that could be utilized as temporary business sites
- Identifying sites for business recovery centers
- Establishing these centers following a disaster

- Assisting small businesses with continuity planning and mutual aid agreement
  (Palm Beach County 2006, sec.4)

Conclusion

The Palm Beach County has done a lot of work for the coastal resilience planning, especially the PDRP. In the study area, Cedar Key, it also suffers storm surge and flooding seasonally. In the PDRP part, they give lots of strategies for the economy aspect. The protection of the economic development during the hazard is one of the most concerned parts in Palm Beach County. The PDRP of Palm Beach County can act as guidance for Cedar Key to develop its own PDRP. To get the strategies, the county did a series of public workshops. They had done a very good job in the public participation. In the comprehensive plan of Palm Beach County, it categorized 5 tiers for the future development. This is very helpful for assisting the formation of the community land trusts. The tiers are set as a guide for building the form of the future urban form.

CHAPTER 5
RESEARCH DESIGN

Site Selection and Analysis

Cedar Key is a city in Levy County, Florida. As Figure 5-1 and 5-2 show, Cedar Key is consisted of many islands near the mainland. According to the United States Census Bureau, Cedar Key has a total area of 2.1 square miles, of which 0.97 square miles is land and 1.2 square miles (54.28%) is water. As a result of this, Cedar Key becomes more and more danger with the rising sea level. This research is focused on future issues Cedar Key will meet caused by sea level rise and using planning ways to deal with these issues.

According to the City-Data, there were only 703 people living in Cedar Key in 2011. And as the map Figure 5-2 shows that Cedar Key is almost surrounded by the sea water. When the sea level has risen 1 meter compared with right now, most parts of Cedar Key will be submerged (Figure 5-3 and Figure 5-4), downtown Cedar Key might be one of them.

Future Issues Analysis

The next stage of research design is to analysis the issues Cedar Key have to face when the sea level has risen to some height. To be briefly, the impact of sea level rise can be short term, midterm and long term. The short term impact of sea level rise is powerful storms and economics shift. Midterm impact should be habitat loss and saltwater intrusion. Then the long term impact is the rising sea level which can be noticed by people. I categorized the issues as eco-system, transportation part and economic development:

Ecosystem

Saltwater intrusion. In SLR will enable saltwater to advance inland in both aquifers and estuaries. In estuaries, the gradual flow of freshwater toward the oceans is the only factor preventing the estuary from having the same salinity as the ocean. A rise in sea level will increase the salinity in many open bays because the increased the cross-sectional area would slow the average speed at which freshwater flows to the ocean (IPCC). Salinity can also make some areas that rely on unconfined aquifers just above sea level. Generally, these aquifers have a freshwater "lens" floating on top of the heavier saltwater. According to the Ghyben-Herzberg principle, if the top of the aquifer is one meter above sea level, the interface between fresh and saltwater is forty meters below sea level. If sea level rises one meter, aquifers would usually rise one meter as well (Salt Water vs. Fresh Water).

Figure 5-5 shows the process that sea water contaminates the coastal groundwater aquifers. The saltwater intrusion will hurt the fresh water system. As a result of this, the fresh water supply of coastal communities will be influenced. Now it's one of the most concerns of coastal residents in Cedar Key. Not only the fresh water supply, saltwater intrusion will also affect the coastal ecosystem in a long term.

In the Table 7, it shows the salinity tolerance ratings for a range of plant species and a range of salinity levels. Some plants cannot survive in a high salinity level environment, such as aspen, black walnut and cottonwood. Cedar Key has lots of palm trees living in the coastal area. However, some of these palm trees have already been hurt by the salt water intrusion. Figure 5-6 shows the current situation of some palm trees in the coastal area of Cedar Key. Dying of palm trees will definitely affect the balance of coastal ecosystem, because bird community and native habitats will be

influenced. With the intrusion of the saltwater, not only the palm trees but also other species of plants will be hurt and the reduction of plants will result in the vulnerability of coastal ecosystem.

Storm surge. Sea level rise will intensify the coastal storm surge. Storm surge will increase the mean water level 15 feet or more. It will result in severe flooding. The coastal flooding will then impact on many parts, such as the convenient lives of coastal residents, fresh water quality and so on. The storm surge can erode beaches and coastal highways, affect rivers and inland lakes, damage ships, marine facilities and even some buildings and etc. As Figure 5-8 shows that the surge levels are categorized in 5 levels. Cedar Key is in the Tropical Storm level area.

Transportation

With the rising sea level, lots of inland will be submerged. It's obvious that many coastal roads, airports, ports, harbors, bridges and etc. may be under water. Storm surge caused by sea level rise may result in airline delays, traffic disruptions and so on. In a word, the sea level rise will seriously influence the coastal transportation. Once the coastal transportation is influenced, the whole transportation network will be hurt more or less. Figure 5-8 shows all the roads in the Levy County and all the roads in Cedar Key. According to the road map, we can see that most roads locate in the coastal area in Cedar Key, especially the southeast of Cedar Key. It's the business area of the city. Figure 5-10 shows the scenario when sea level rise 0.5 meter. It's easy to figure out that many lands will be underwater at that time. Parts of the coastal roads will be submerged with the 0.5 meter higher sea level, and the transportation system will be influenced in a whole. According to Figure 5-11, there are several airports in Levy County and one of them is located in the coastal area of Cedar Key named George T Lewis airport. The

airport is 1.85 km west of the central business district of Cedar Key. It's a small general aviation airport serving Cedar Key and the surrounding communities in Levy County. This airport is in the dangerous area of the impact of sea level rise.

Economic

Clam framing: The contribution of cultured clam sales was assessed to be $34 million to the state's economy in 1999 increasing to $53 million in 2007, making clam farming an important agribusiness (UF economists' survey). When measuring economic impact of the aquaculture industry in Florida, specifically clam farming most recent data has been recorded through measurements dividing the state of Florida into 3 regions. When considering Region I which makes up the big bend area of Florida, economic data reveals that of the 53 million dollar impact on the Florida Economy, 44 million dollars of that impact is from Region I. That is 83% of the impact that clam farming has on the Florida economy. Levy County contributes to a major portion of the Region I total.

It is clear from the economic data and knowledge that we have on the clam industry in Levy County that this form of aquaculture is an essential part of Levy County's economy for it to survive. Now Cedar Key is one of the top US producers of farm-raised hard clams. This reliance on the clam industry has imbedded clam farming into the culture of Levy County. This reliance on clam farming is an alarming economic vulnerability.

Clams require very specific water qualities for growth. Any changes of the salinity of the surrounding water will proportionally reflected in the salinity of the clams' blood. Salinities of 20-30 pp are considered the optimal physiological range for hard clams. Within this range, pumping rates, feeding rates, growth and other activities are at their

maximum. Although hard clams can adjust to changes in salinity, as described above, there are upper and lower limits to their tolerance. Above and below these limits, the clams will begin to show gross signs of stress. If salinities remain outside these limits for an extended period of time, the clams will not survive (Shirley Baker, Elise Hoover, Leslie Sturmel, 2007)

Cedar key in particular is reputably known as having low salinity levels in general, thus any form of excessive rain or storms can cause the salinity levels to drop below 20pp salinity and thus ceasing clam growth until the salinity level returns to optimal conditions between 20pp to 30pp.

According to the more recent studies of University of Florida at the Dog Island near the coast of Levy County: From January to March 2009, the salinity level had occasionally reached above the 30ppt, In March-April, and June to July 2009, the salinity level had occasionally dropped to lower than 15 ppt; In Feb 2010, the salinity level had dropped below 15ppt, then in March 2010, the salinity level had dropped below 10ppt, and then from June to September 2010, the salinity level had occasionally dropped below 15ppt; in June 2011, the salinity level had dropped below 15ppt and almost reached 10ppt, then from September to October 2011 the salinity level had reached above 30ppt, and from August to November 2011, the salinity level had dropped below 20ppt and almost reached 15ppt.

The sea level rise will cause saltwater intrusion which will change the balance of fresh water and saltwater. It will have negative impact on the clam survival and growth. As a result of this, the clam farming will decrease which will hurt the economy of Cedar Key.

Agriculture: In Expect for the clam farming, the agriculture will also be bad influenced. Firstly, the rising sea level may submerge some farmland. Secondly, the salinity level of the soil will be influenced by the saltwater intrusion caused by SLR. Salt in high concentrations is toxic. It affects the way plants get nutrients from the soil and water for their transpiration cycle. Some farmland will be too salty to plant some particular vegetables. Table 8 shows the salt tolerance of some particular plants. High salinity in the soil will make some plants grow smaller and the amount will also be decreased, such as potatoes and cabbage.

Capital investment: When the sea water rises to some height to submerge parts of the roads, land, buildings and some critical infrastructures, the government has to use a large amount of money to rebuild or maintain them. What's more, the future improvement will also be badly influenced. Because the central business district of Cedar Key is in the coastal area, the future expansion will be restricted by the rising sea level.

Natural damage: "The Heinz Center (2000) estimates that roughly 1,500 homes in the United States will be lost to coastal erosion each year for several decades, at a cost to property owners of US$530 million/year" (IPCC). The IPCC also estimates that "the increase in storm damage because of sea-level rise increases the direct damages of sea-level rise from erosion of the shoreline by 5%, but storm damage could be as much as 20% of other sea-level rise damages" (IPCC). Cedar Key is in the tropical storm level area. Hurricane Elena hit Florida in 1985. The greatest levels of surge, (25-30 year events), were recorded at Cedar Key and in the vicinity of Alligator Point. In these areas, roadway damage, slab-on-grade construction failures, and flooding

resulted from the storm (Kevin & David, 1985). Not only Elena, other hurricanes also hit Cedar Key. This city has been hit by the hurricane in 1871, 1874, 1880,1886,1888,1893,1896,1935,1941,1950,1985 (Cedar Key's history with tropical systems). SLR will intensify storm surge which will cost the city more.

Tourism: According to Climate Change and the economy, Florida's economy and way of life are closely tied to its coasts. Tourism takes a major portion of the state economy. In 2005, nearly 86 million tourists visited Florida, generating more than $ 63 billion in revenue and creating more than 944,000 jobs (Julie Hauserman, 2006).

The tourism in Cedar Key also plays an important rule. The old-fashioned fishing village is now a tourist center with several regionally famous seafood restaurants. Cedar Key's historic structures and Old-Florida vernacular are meaningful to residents and visitors alike. Cedar Key holds two festivals every year. They are the Spring Sidewalk Art Festival and the Fall Seafood Festival. Each festival will attract over thousand tourists to enjoy.

Additionally, over 80,000 acres of Cedar Key is on the National Register of Historic Places for its archaeological and historic structural resources. "The historic resources in Cedar Key contribute to the sense of place...and...stimulate the local economy. With a projected impact of a severe tropical storm event, many of these resources could be undermined and potentially lost (Wolfe, 2006)." With the sea level rising, the tourism will be reduced more or less.

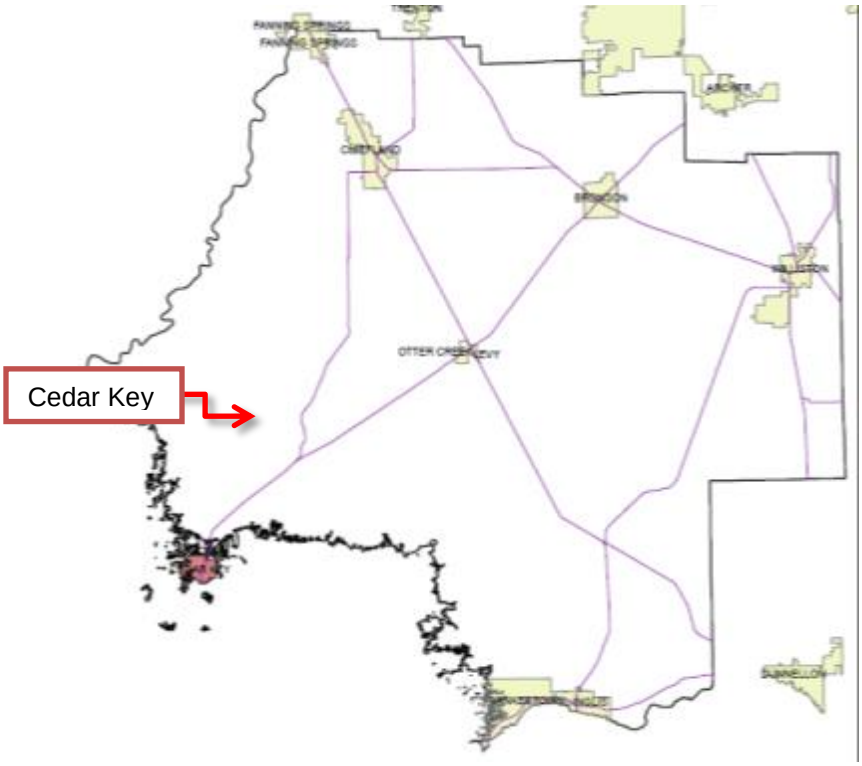


Figure 5-1. Cedar Key in Levy County

Figure 5-2. Cedar Key. Source: Google Map

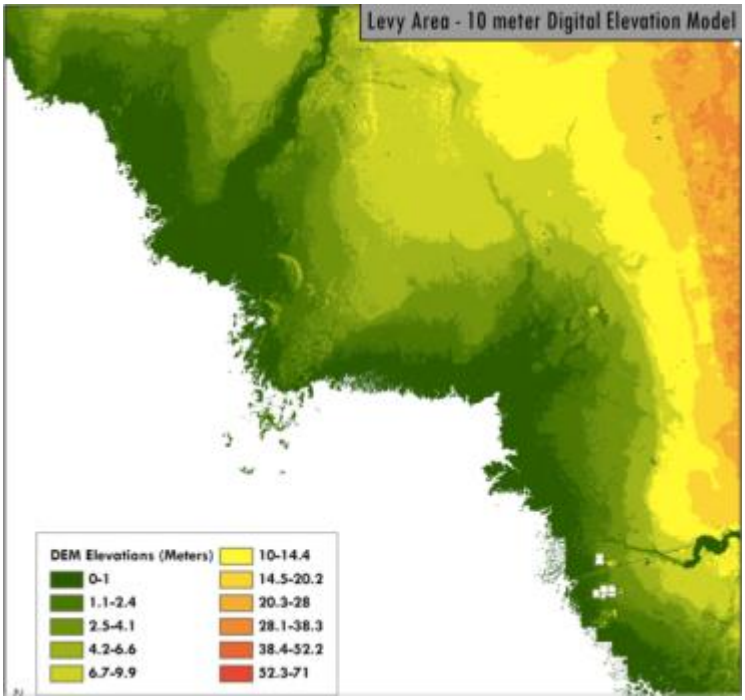


Figure 5-3. Levy Area 10 meter Digital Elevation Model. Source: http://changinglevycoast.org/

Figure 5-4. Future situation when sea level has risen 1 meter. Source: Weiss and Overpeck, Environmental Studies Lab. Univ. Arizona.

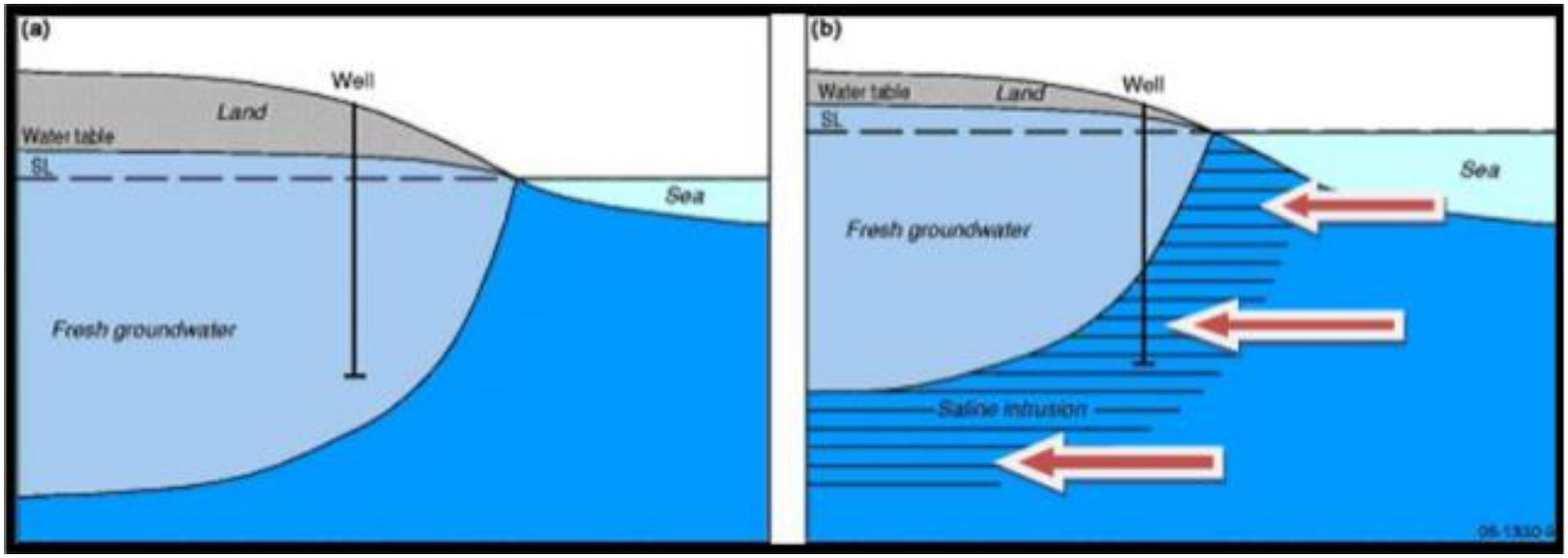


Figure 5-5. Saltwater Intrusion process. Source: http://changinglevycoast.org/page/2/

Figure 5-6. Coastal palm trees in Cedar Key. Source: Dr. Putz presentation

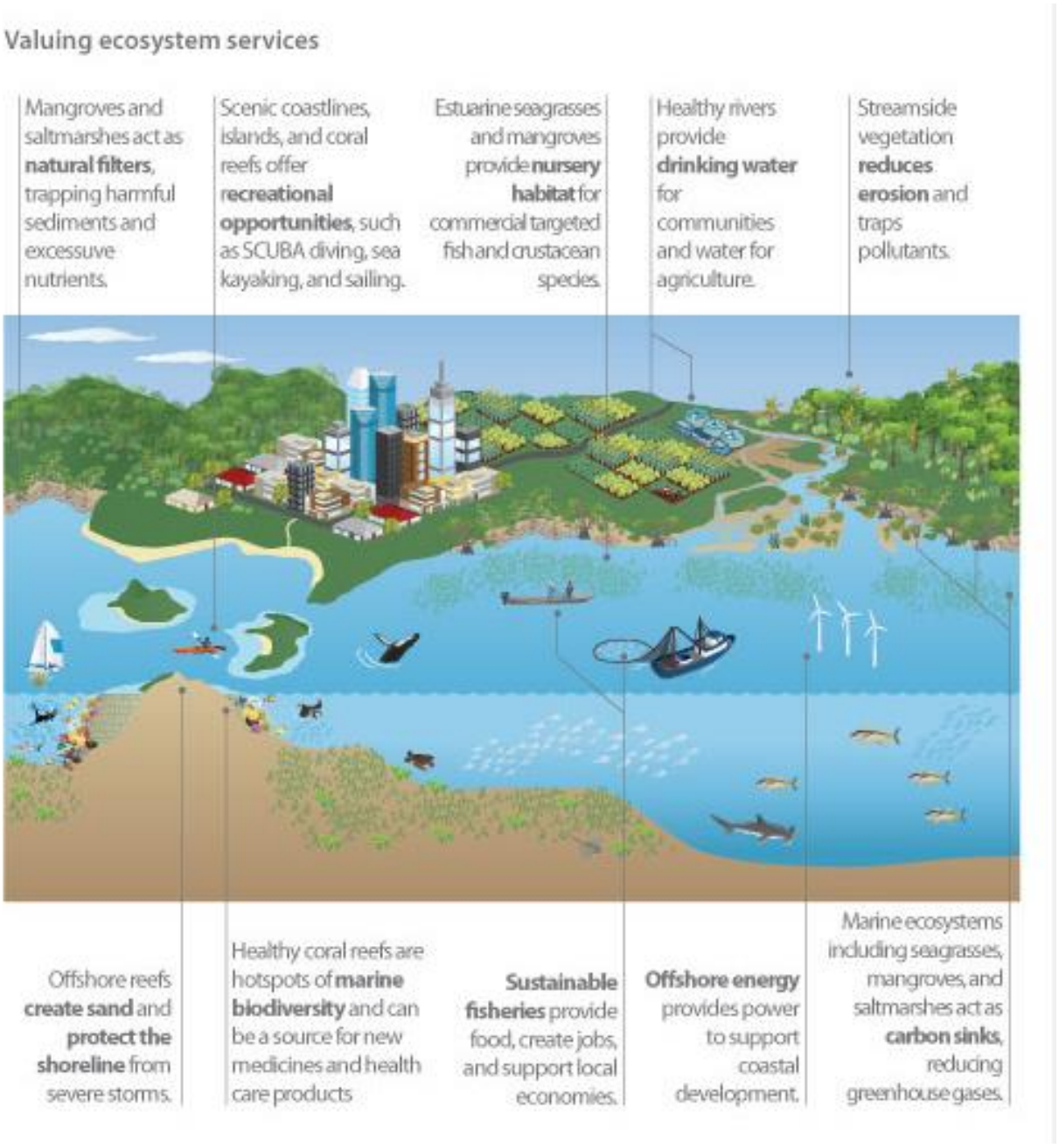
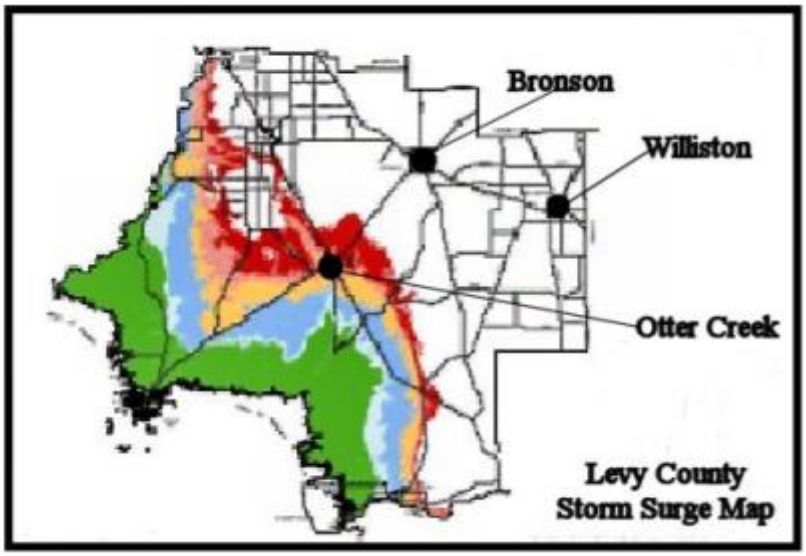


Figure 5-7. Valuing ecosystem services. Source: http://changinglevycoast.org/



Levy County Surge Map:

Green - Tropical Storm
Pale Blue - Catagory One (hurricane)
Medium Blue - Catagory Two
Orange - Catagory Three
Pink - Catagory Four
Red - Catagory Five

Figure 5-8. Levy County Surge Map. Source: Cedar Key News

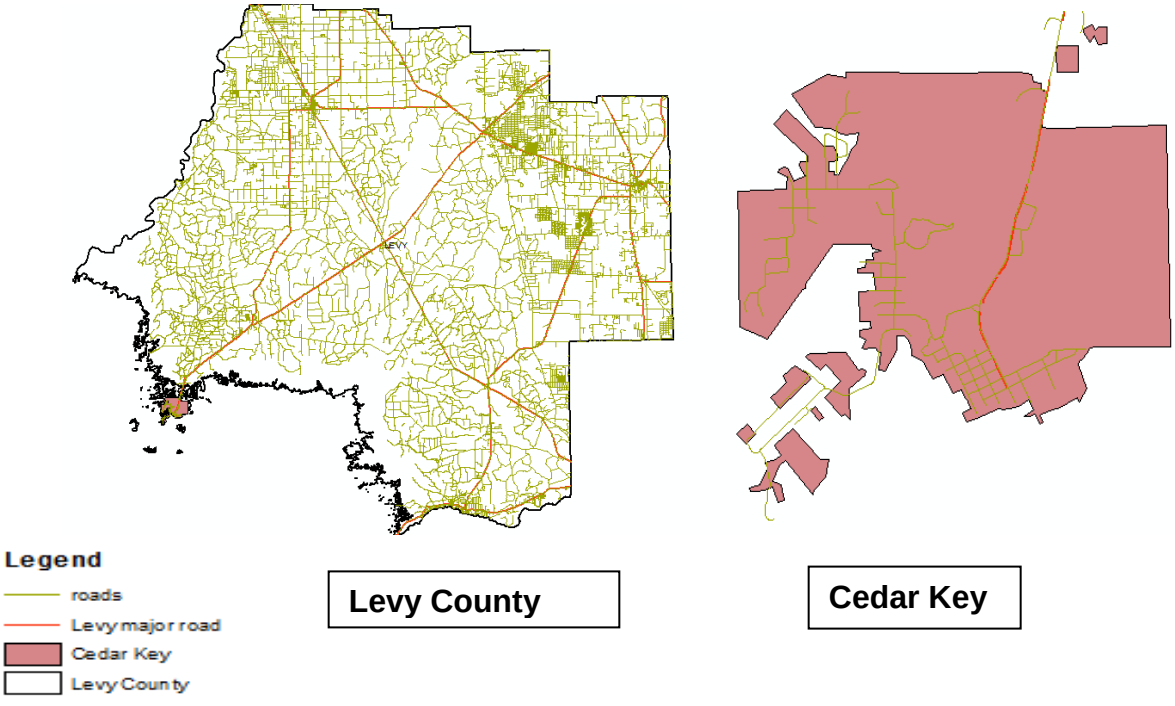


Figure 5-9. Roads in Levy County & Roads in Cedar Key

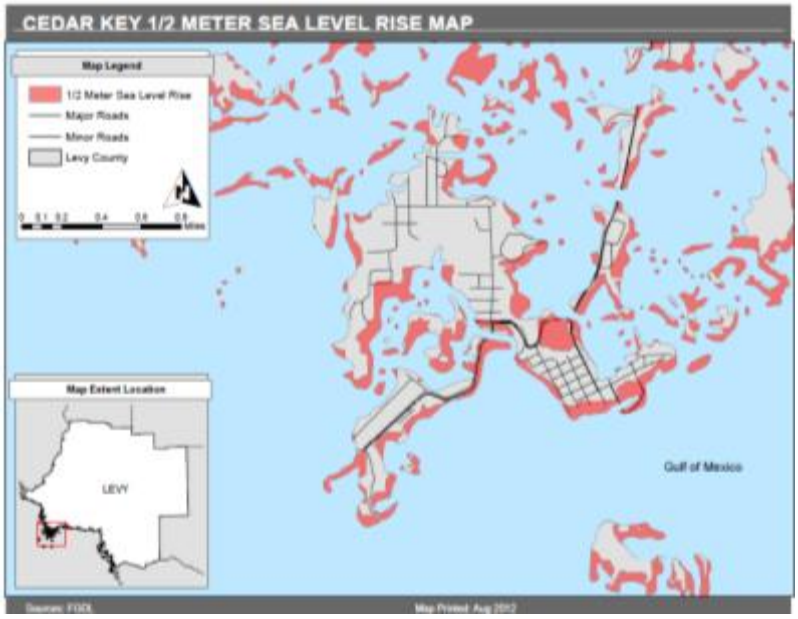


Figure 5-10. Cedar Key 0.5 meter sea level rise map. Source: http://ChangingLevyCoast.org

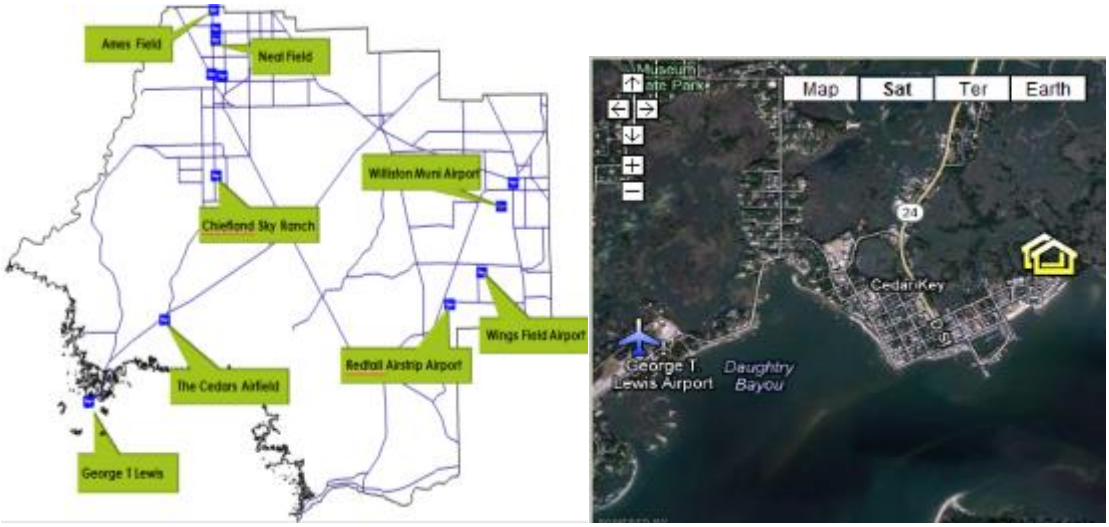


Figure 5-11. Airports in Levy County & George T Lewis airport in Cedar Key. Source: Google earth

Figure 5-12. Clam farming in Cedar Key. Source: http://changinglevycoast.org/

CHAPTER 6
PROPOSED SOLUTION

The solution analysis is based on the current situation of Cedar Key. In this thesis, the author will compare the advantages and disadvantages of different adaptation strategies, and then create the most suitable solution for the future sustainable development of Cedar Key.

From the Future Issues Analysis of Cedar Key, the solution should be designed to focus on the ecosystem, transportation and economic problems. Proposed the following solutions are as follows:

Ecosystem

Build living shoreline, in the eco-system analysis part, the future sea level rise will cause salt water intrusion, contamination of coastal groundwater aquifers and storm surge. There are many strategies to protect the inland, such as seawalls and levees. But they are short-term strategies and need costly annual maintenance. Additionally, they may also be destroyed by some unusually large storm event. Therefore SLR will likely cause some ecosystem problem. A living shoreline solution can provide habitats for fish, wildlife and some organisms which are the basis of aquatic food chains. This strategy can not only protect the shoreline but also help the coastal ecosystem to be more resilient. For these reasons the author proposes to use living shoreline as one of the adaptation strategies for Cedar Key. The technique consists of planting native wetland plants and grasses, shrubs, and trees at various points along the tidal water line. The benefits of living shorelines are:

- improve water quality by settling sediments and filtering pollution;
- provide shoreline access to wildlife, such as nesting turtles, horseshoe crabs, and shorebirds;

- provide shallow water habitat and a diversity of plant species for aquatic and terrestrial animals;
- provide shade to keep water temperatures cool, helping to increase oxygen levels for fish and other aquatic species;
- look natural rather than man-made and artificial;
- absorb wave energy so that reflected waves do not scour the shallow sub-tidal zone and hamper the growth of underwater grasses;
- less costly than wooden bulkheads and rock walls (also known as “revetments”).
- (Chesapeake bay foundation, 2007)

From the “Cedar Key 1/2 meter sea level rise map” (Figure 6-2), the red parts of Cedar Key will be submerged when the sea level raises 0.5 meter. Some of these submerged lands will be proposed to build the living shorelines.

Economic

According to the Levy County Economic Development Plan, the overall goal is to “promote the growth of a strong, stable and prosperous economy through public and private economic development initiatives that preserves and enhances a high quality of life for the residents while protecting the natural, recreational, historical and cultural resources of the County” (LCCP). The plan states that the development of a diversified economic base will lead to high paying jobs, educational and vocational training opportunities, and industrial growth. To realize the goal, this thesis proposes to create a diversified economic base in Cedar Key. The strategies are as follows:

Build Characteristic Commercial Area in the Coastal Area of Cedar Key

As discussed before, sea level rise will result in decline of economic development in Cedar Key. As a result of this, new stimulation for economic development of Cedar Key is needed.

From the Cedar Key Future Land Use map 2014-2020 (Figure 6-3) and Figure 6-2, some of the commercial area will be submerged when the sea level raises 0.5 meter. The strategy is to keep the current commercial area and develop the nearby coastal area as a whole, especially these which will be submerged when the sea level raise 0.5 meter as new commercial area. Some of the commercial area will be built on the floating development and some will be built on the elevated development which will be discussed in detail in the next chapter. The new type of commercial area is proposed to be built as the following figures shows:

In the Figure 6-4 – Coastal and Riverside development examples, is the future commercial style of Cedar Key. As the Figure 6-4a shows, some coastal area in Cedar Key can be built like this and serve as coastal bars and restaurant which can provide a really romantic atmosphere. Some coastal commercial area can be built like Figure 6-4b shows for people to shopping and doing other characteristic activities here.

Create New Industrial Development

Cedar Key is one of the top US producers of farm-raised hard clam. Therefore, some land can be set as industrial use to build factories which can be used to do the further processing for the hard clams and other seafood. In some countries, such as China, the deep processed seafood is very popular. In the future, the products can be exported to the whole world which may become a significant industry in Cedar Key.

Challenges of the Solutions

1. Build the living shoreline
    - It will cost lots of time, land and money to build the living shoreline. And it also asks for management and monitoring to become established
    - It must be sufficiently supplied with sediment to be able to "keep up" with sea level rise. Due to the many dams and modified hydrology of the Delta

and its major rivers, this is a concern for restoration success in San Francisco Bay. (THE URBANIST ,Issue 487, November 2009)

- Determining how much flooding new tidal marshes could attenuate, restoring them in appropriate places, and conducting restoration at a faster rate than we would without the looming threat of rising seas. (THE URBANIST ,Issue 487, November 2009)

2. Build characteristic commercial street in the coastal area of Cedar Key

    - To create new floating and elevated development do need time and plenty of money.

    - The author has visited Cedar Key and have talked about sea level rise with some residents. Most of them said that they were born there and never noticed any changes to the sea level. These residents didn't believe the sea level was changing. And they never considered moving out of the city. Considering this, it will be a challenge to build the characteristic commercial street, also because it requires an area which may be occupied by some residents. Resident's preference has influenced the proposed planning strategies in this thesis.

3. Create new industrial development

    - It has high requirement for the transportation. The place should be convenient to the origins of the seafood and also easy to be transported outside Cedar Key.

    - The land is limited. It's hard to find appropriate place to develop as industrial area.

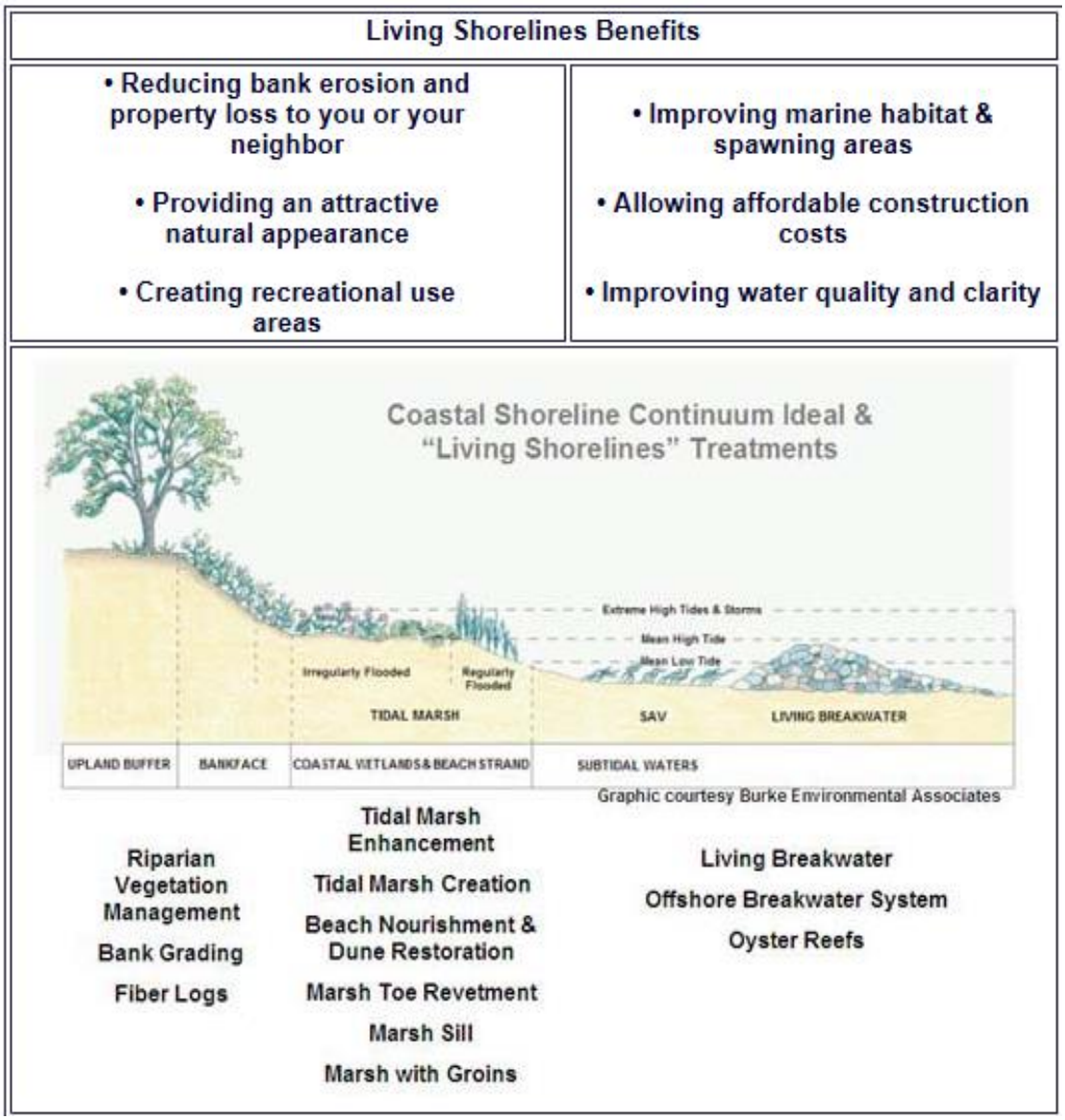


Figure 6-1. Living Shoreline Benefits. Source: http://ccrm.vims.edu/livingshorelines/

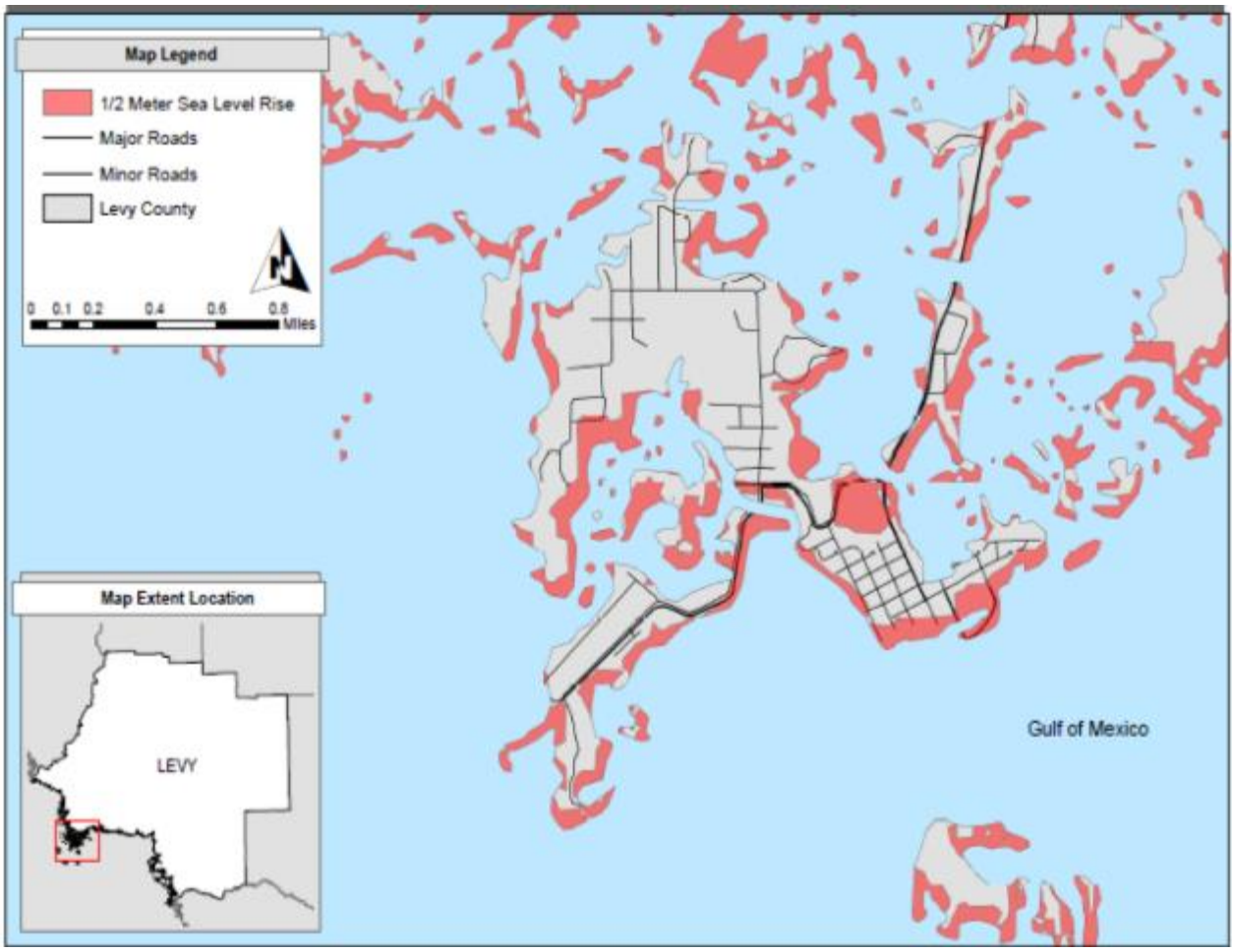


Figure 6-2. Cedar Key 0.5 meter sea level rise map. Source: http://ChangingLevyCoast.org

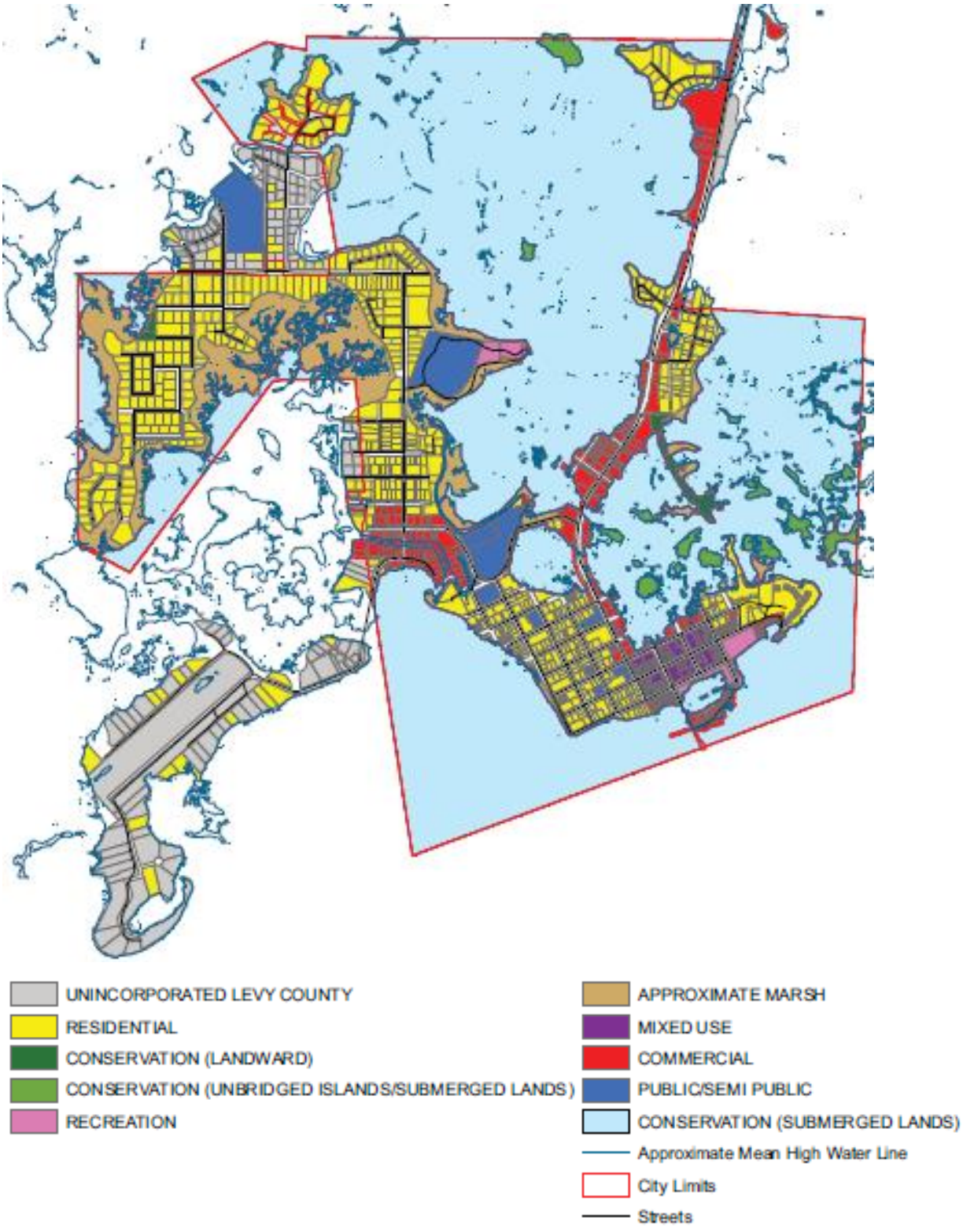


Figure 6-3. Cedar Key Future Land Use map 2014-2020. Source: Laws of Cedar Key

Figure 6-4. Coastal and Riverside development example. Source: Baidu Picture

Figure 6-5. deep processed hard clams and shrimp

CHAPTER 7
PRELIMINARY ANALYSIS IN CEDAR KEY

Current Buildings in Cedar Key

From figure ground of Cedar Key (Figure 7-1), it's clear to see that the locations and density of buildings in Cedar Key. Most of the constructions in Cedar Key are located in the southeast which is also very close to the sea. Figure 7-2 is the overlay of figure ground of Cedar Key and the current functional zoning of Cedar Key. From this figure, most of the land in Cedar Key is for residential and commercial use. The most populous area (southeast area) of Cedar Key is residential use. This area is also very close to the sea.

Impacts of 0.5 Meter SLR

During the 21st century, sea level will raise another 18 to 59 cm (7.1 to 23 in). However, these numbers even do not include "uncertainties in climate-carbon cycle feedbacks nor do they include the full effects of changes in ice sheet flow"(IPCC, 2007).

In the Figure 7-3, it shows the situation of Cedar Key when the sea level raises half meter. From this figure, it's clear that many current buildings in Cedar Key will be under water at that time.

From Figure 7-3, after doing the calculation in GIS, about 23.4% buildings in Cedar Key will be submerged by the sea water when the sea level raises half meter. Most of these buildings are in the residential area

Solution Analysis

From the situation of buildings in Cedar Key when sea level raises half meter, the problem that 23.4% buildings in Cedar Key will be under water should be solved. In the Figure 7-4, it shows the elevation of Cedar Key. The whitest parts are the highest parts

in Cedar Key which means these places are safer to build future buildings. To deal with the future sea level rise, new development in Cedar Key is needed. These higher elevation lands are good choices.

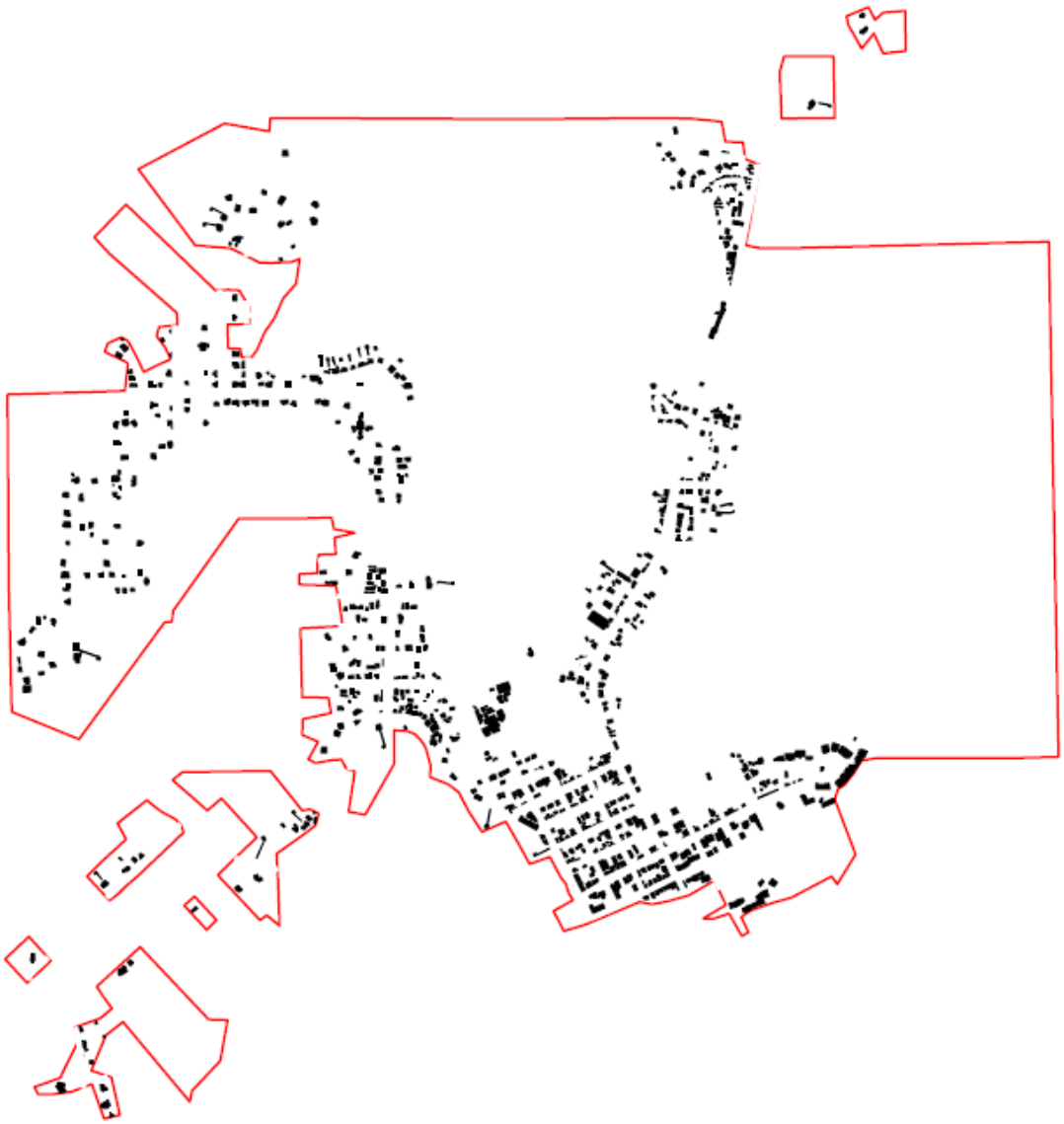


Figure 7-1. Cedar Key Figure Ground

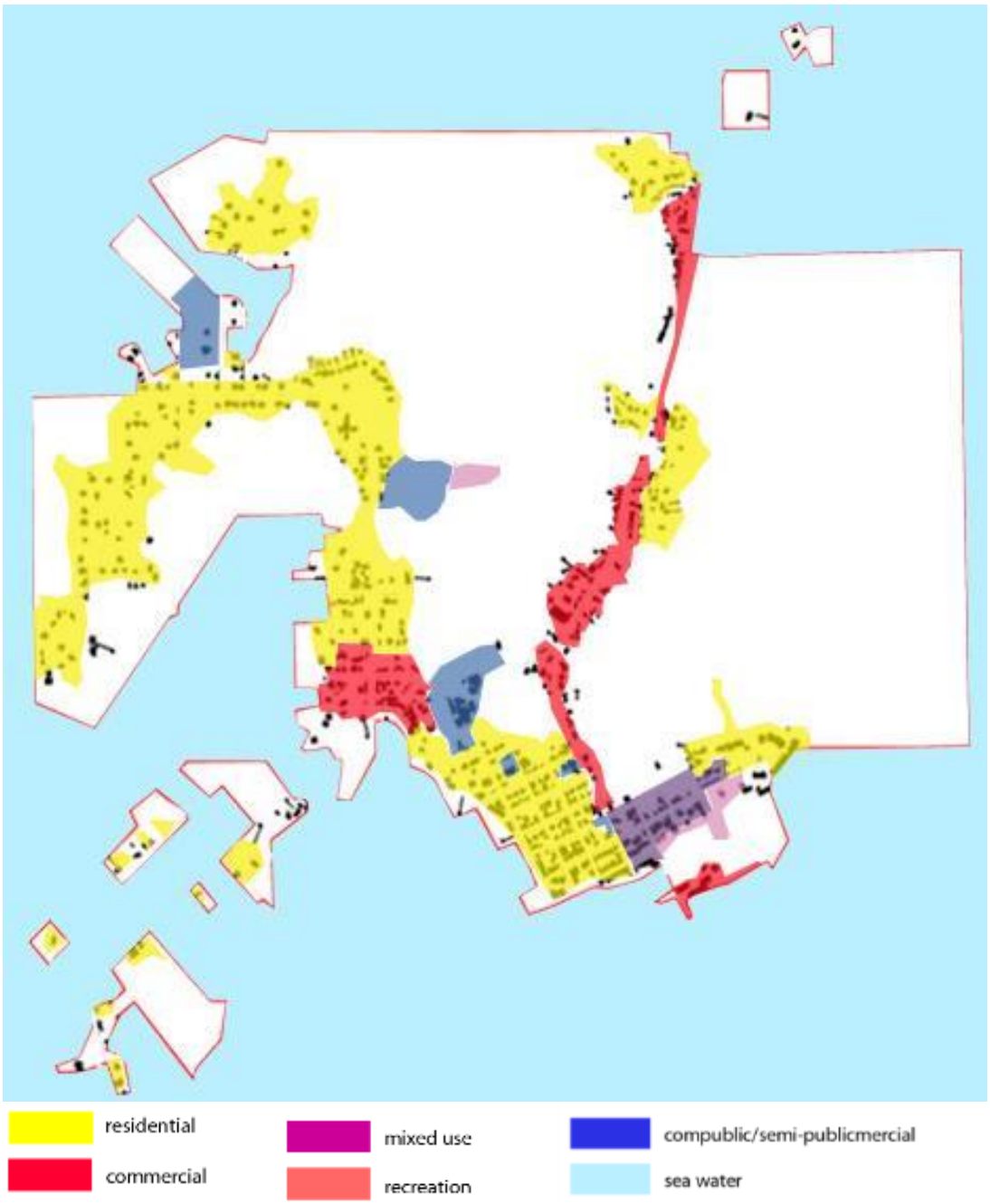


Figure 7-2. overlay of Figure ground of Cedar Key and the current functional zoning of Cedar Key

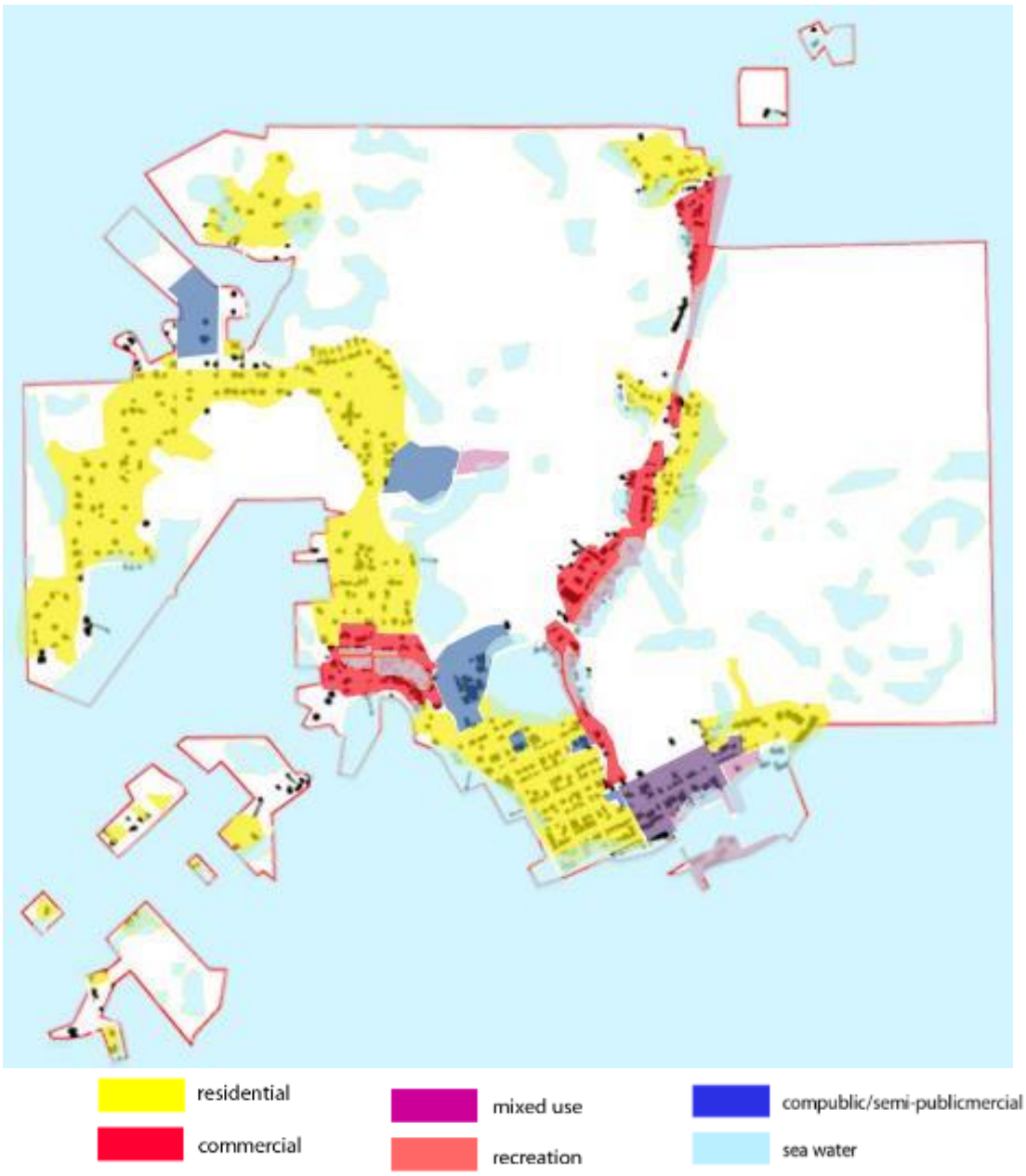


Figure 7-3. Cedar Key when the sea level raises half meter

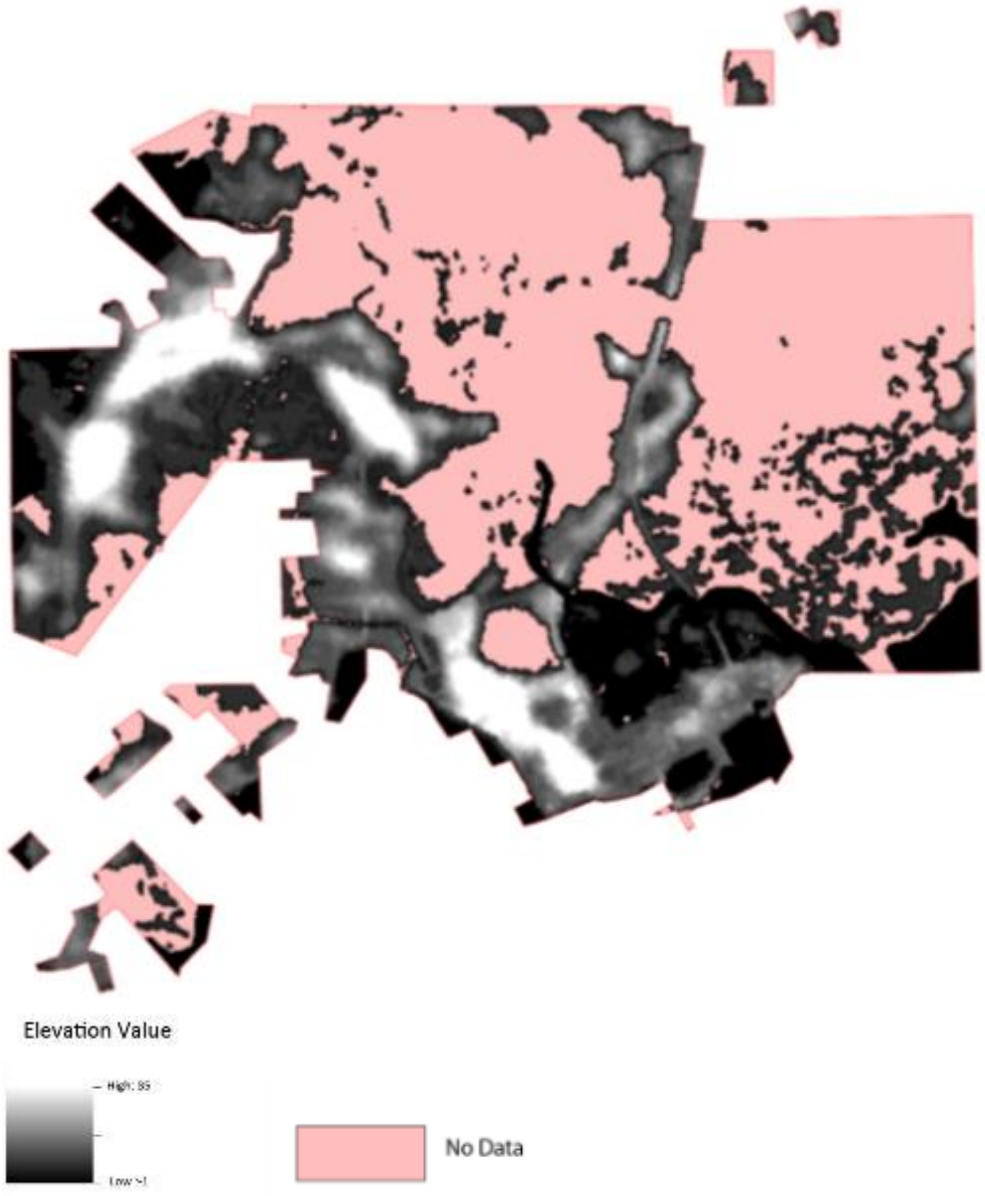


Figure 7-4. Cedar Key elevation map

CHAPTER 8
URBAN DESIGN IN CEDAR KEY WHEN SEA LEVEL RISE HALF METER

Design Concept

The local economy in Cedar Key relies heavily on the aquaculture industry and the eco-tourism. Future sea level rise definitely has negative effect not only on clamming industry and tourism, but also farming. The urban planning in Cedar Key should guide the new economic development. Diversified economic development will be helpful to build more stable development in Cedar Key. In this thesis, the author proposed to develop new commercial and industrial development to make the city develop more healthily.

Commercial Development

This study proposed to create a continuous area in Cedar Key developed as a typical commercial district. This commercial district should be designed to work with the tourism. Cedar Key is famous for its natural resources, historical significance and fresh seafood. These are the main attractions for the tourists. This commercial district should make full use of such attractions. The detailed features of the new commercial district will be discussed later on.

Industrial Development

As discussed in Chapter 6, Cedar Key has very good resource of seafood, especially the farm-raised hard clam. The world seafood market, which encompasses fresh, canned and frozen seafood products, is expected to excess $370 billion by 2015, according to Global Industry Analysts. It is predicted the market will be fuelled by a rising global population, increased discretionary incomes, and technological advances such as packaging and improved transportation.

This thesis proposed to create a new industrial area in Cedar Key. Many factories to do the deep processing of the seafood, such as producing dried seafood, will be built there. Though the Americans don't like eating deep processed seafood, it has a large market outside US. Many countries consume a large amount of deep processed seafood, especially in the Asia. Table 10 shows the changes in processed seafood sales in Japan. The local market cannot satisfy the consumption. Japan will import some of the processed seafood from other countries. For example, Japan imports 10,000 tons processed mackerel in 2006, over 10,000 tons in 2010 and 11,000 tons in 2011 (Fish update.com, 2012). As a result of this, the market of processed seafood is very huge and profitable.

Residential Development

According to the interviews the author did in Cedar Key, many people living there over 30 years don't believe the sea level is rising. Despite lots of workshops and disseminations to educate people about the expected SLR have been done there, they only believe what they have experienced for themselves. In their perspective, the sea level has never changed since they were born in Cedar Key till now. As a result of this, most of the residential use areas will remain as residential use when the sea level raises half meter and new residential use area to support population growth will be created in other areas.

Conceptual Functional Zoning in Cedar Key

The global sea level will raise about 0.1m to 0.65m by 2080. The sea level of Florida will raise about 0.25m to 0.34m by 2080 (Julie Harrington, ToddL Walton, 2008). In this thesis, it's talking about the urban design towards half meter sea level. As a result of this, the planning period should be at least to 2080.

Population of Cedar Key when sea level raises half meter. Figure 8-1 shows the population trend of Cedar Key from 1900 to 2010. From the figure, it's clear that Cedar Key doesn't have a stable population trend in the recent 110 years. According to Figure 8-2, the population of other cities in Levy County in 2010, most cities had larger population than Cedar Key at that time.

As discussed before, the planning time should be at least to 2080. Future economic development is one of the most concerned parts in this thesis. To stimulate the future economic development, the new adaptation strategies aim to explore new development in Cedar Key which will be discussed later. Therefore, the new development will create more working opportunities and attract more people to live here.

According to Projection of Florida Population by County, 2015-2040, with Estimates for 2012 (BEBR, March 2013), the estimate annual population growth of Levy County is 2.0%. According to Population of Cedar Key from 1900-2010, the growth rate for Cedar Key every 10 years is 16.9%,-24.3%, 53.4%, -7.8%,-9.8%, -34.7%, 6.9%, -2%, -4.8%, 18.2%, -12.5%. The growth rate of Cedar Key was not stable from 1900-2010. This city was not well-developed and it suffered storms sometimes. This thesis proposed to develop Cedar Key into a new developing city, it will attract more people to live and work here in the future. As a result of this, the growth rate of Cedar Key from now to 2080 is proposed to be 2.0%. So the estimate population of Cedar Key is about 2808 in 2080.

Future Land Use in Cedar Key When Sea Level Raise Half Meter

Combining the half meter sea level rise map and the elevation map of Cedar Key, the author gets the Figure 8-3. It shows the usable land in Cedar Key when sea

level raises half meter. According to calculation of ArcGIS, the whole Cedar Key is about 1,344 acre. The usable land is about 369 acre. That's to say about 27.5 % of Cedar Key's land can be built for future use when sea level raises half meter. Table 11 shows the comparison of the land before and after sea level raises half meter.

The functional zoning in Cedar key when sea level raises half meter is generally based on the Cedar Key future land use map 2014-2020 which is shown in Figure 6-3. According to what have been discussed before, the proposed conceptual functional zoning in Cedar Key when sea level raises half meter is as follows:

Strategies to Deal With the Half Meter Sea Level

Build Living Shorelines in Cedar Key

Chapter 6 has discussed the strategies in Cedar Key to deal with sea level rise. Build living shoreline is one of these strategies. Ideal locations for the placement of living shorelines include:

- Bank erosion caused by storm waves instead of regular tidal action;
- Low, cleared banks where a riparian can be restored;
- Tidal marshland with an eroding edge;
- Failed bulkheads on tidal creeks where there is tidal marsh;
- Failed or under-sized revetments with existing tidal marsh;
- Sandy banks that can be graded;
  (NJ Coastal Management Office, November 2009)

Some locations of the half meter sea water will be chosen to be built as living shorelines. To make the living shoreline continuously and more effective, more underwater land will be built with living shorelines. Figure 8-5 shows the proposed living shoreline in Cedar Key when sea level raises half meter. The reason why choose such location to build living shoreline is as follows:

- These areas are land now. They will be submerged by the half meter sea level in the future. So the banks are low which is easier for the riparian to be restored.

- Area A (Figure 8-5) has existing marsh.
- These areas are close to the inland of the city. Living shoreline can protect the inland very well.

Additionally, the living shoreline will also provide a good view for the bank of the city. The nearby inlands are proposed to be built as residential and commercial use.

From the above figure, after calculation in ArcGIS, there will be about 94.98 acre land will be built as living shoreline at that time. Figure 8-6 shows the ideal living shoreline.

Floating Development

From Figure 8-4, there will be two continuous commercial areas. However, some parts of such commercial areas will be submerged by sea water when the sea level raises half meter. To keep the commercial areas as a whole, parts of the commercial area proposed to be built on floating development. The floating development is consisted by two parts:

- The current commercial use land which will be submerged by the half meter sea level.
- Extending parts of the current commercial areas to the sea. Because the population is proposed to be much larger than now. The current land for commercial use will not be enough for the future. The commercial use land should be extended.

These floating commercial areas will be designed as one of the attractive features in Cedar Key. They are designed to build restaurants and bars. The floating parts of the restaurants and bars will not only provide a very nice view of the sea but also create a very romantic atmosphere. In the Figure 8-7, it shows the locations of the sea water which will be built as floating development. From the calculation of ArcGIS,

there will be about 13.63 acres land be built as floating development when sea level raises half meter.

Elevated Development

When the sea level raises half meter, some land will be underwater. To keep these areas develop as a whole, some land should be elevated for the future development. The elevated areas are for residential and commercial use. Figure 8-8 shows the recent development in Cedar Key. Elevating buildings reduce flooding exposure to storm surges and rising sea level, but it also results in distinctive building character that requires additional design measures to maintain cohesion with community vernacular (Planning for Coastal Change in Levy County, University of Florida, 2014).

In the Figure 8-9, it shows the locations of the elevated areas. The elevated residential use land is proposed to build buildings as Figure 8-8 shows. The elevated parts in the commercial use area will be built hotel and restaurants. The distinctive character of such buildings will be designed as the attractive element of the hotel and restaurants. From the calculation of ArcGIS, there will be about 12.57 acre land will be elevated when sea level raises half meter.

Managed Retreat, Abandon Shoreline

When the sea level raises half meter, more land will be submerged by the sea water. Managed retreat is a strategy that safely removes settlement from encroaching shorelines, allowing the water to advance unimpeded. It involves abandoning, demolishing or moving existing buildings and infrastructure to higher ground. It also includes banning new development in areas likely to be inundated (THE URBANIST, Issue 487, November 2009). The lands facing the danger of being submerged by the

half meter sea level haven't been developed now or are far away from other development may be abandoned in the future. Such strategy is less expensive and more worthy than other strategies for the undeveloped lands which will be inundated by the half meter sea level.

Comprehensive Plan in Cedar Key When Sea Level Raises Half Meter

According to the analysis has been done, the comprehensive plan of Cedar Key when sea level raises half meter is shown in Figure 8-10a. Figure 8-10b shows the current land use of Cedar Key

By comparing the Comprehensive Plan when sea level raises half meter with Future Land Use map 2014-2020 in Cedar Key, the author gets the Table8-2.

That's to say, to hold the increased 2,106 residents, the density of houses built when sea level raises half meter will be higher.

The total acreage of commercial area in the new plan is smaller than the old commercial use area. Because some of the commercial use land in the old plan will be submerged when sea level raises half meter. Most of the old commercial area will be used as it used to be. As Figure 8-7 and Figure 8-9 shows, parts of the submerged old commercial land will be built on floating development and elevated development. According to the design concept discussed before, to encourage the economic development, the new adaptation plan aims at creating a characteristic commercial district. The floating development and elevated development will be built as one of the attractive characters of the commercial district.

Another adaptation strategy to increase the economic development is to explore new developing type in the future. The new development type is to set up an industry area (shown in Figure 8-10a). Since Cedar Key has very good natural resource—hard

clams and other seafood, the industry area will be built factories to do the processing of the seafood. The reason why choose the location as industrial use for the seafood factory is as follows:

A food processing plant shall provide (quoted from Troller, 1993):

- adequate space for equipment, installations and storage of materials
- separation of operations to avoid cross contamination
- adequate lightning and ventilation
- protection against pests.

The chosen location can satisfy these requirements. It used to be public/semi-public use and now there are few constructions there (Figure 8-11). It will be much easier to turn this area into industrial use land. The whole industrial use land is 9.57 acre.

According to Golden Alaska Seafoods, LLC in Seattle (seafood processing company), it has over 130 employees. Peter Pan Seafoods Inc. in Alaska has 250-499 staffs. The seafood processing factory to be built in Cedar Key when sea level raises half meter is proposed to hire about 200 workers.

Transportation System When Sea Level Raises Half Meter

The figure above shows the transportation system of Cedar Key when sea level raises half meter. Most of the roads are kept as they used to be, except the ones which will be submerged by the sea water. The underwater roads will be abandoned and left under water, because it will be very costly to elevate these roads.

According to the “Cedar Key Future Land Use map 2014-2020”, the main residential area is the southwest of Cedar Key. As discussed before, most of the residential areas will be maintained. Since there will be another 1,300 people living Cedar Key when sea level raises half meter. The southwest residential area will be used

to build more houses. To support the future development of the new residential area, more roads will have to be built. These roads are shown blue in the Figure 8-12.

Urban Design in Southeast Area of Cedar Key When Sea Level Raises Half Meter

Current Situation of Southeast Cedar Key

Figure 8-12 shows the current situation of southeast Cedar Key. The reason why choose this area is because: firstly, this area is the most populous area in Cedar Key. It's also one of the main developing areas in the future. Secondly, when sea level raises half meter, some of the constructions will be submerged by the sea water in this area. To do the urban design in this area can show the changes between before and after sea level rise.

Urban Design in Southeast Cedar Key When Sea Level Raises Half Meter

From the Figure 8-14, when sea level raises half meter, some buildings and road will be under water. This is one of the concerns in the urban design for half meter SLR. According to the land use plan of Cedar Key when sea level raises half meter, the southeast area of Cedar Key is one of the main residential areas. So some new houses will be built in this area. Additionally, part of the characteristic commercial district will be built in this area. This is another concern in this urban design.

Most of the constructions in this area will be maintained as they used to be. Some areas have been built new constructions, especially in the coastal commercial area. This area will be built almost entirely into a characteristic commercial district as part of the whole characteristic commercial district. And this part can hold more than 1000 customers. To support more people living there, some residential areas have been built a few houses. These newly built houses can hold 180 people by estimation.

Challenges

To put these strategies into practice will meet lots of challenges. For example:

a. Building the living shorelines needs lots of time and space. What's more, it also calls for management and monitoring. All of these need plenty of money to be realized. Where does such large amount of money come from is a big challenge.

b. According to the target of the plan, economic development is one of the most important parts. Some new form of development will be created, such as the industrial development. New residential area should be set to hold the additional 1300 residences and the residences whose houses been submerged by the sea level when sea level raises half meter. However, the usable land in Cedar Key is limited. Floating development and elevated development can be applied only in small and particular areas. It is very costly and unrealizable to be used in large area, such as the storm surge area cannot hold floating development. Exploring enough suitable land to support the future development is a big challenge.

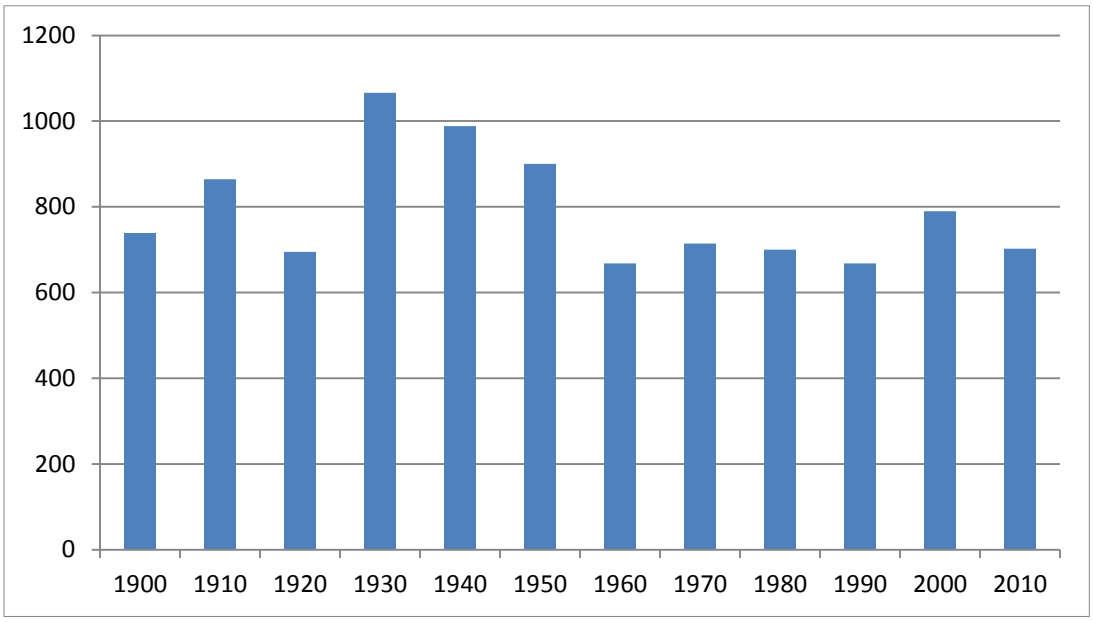


Figure 8-1. Population of Cedar Key from 1900-2010. Data Source: US Census

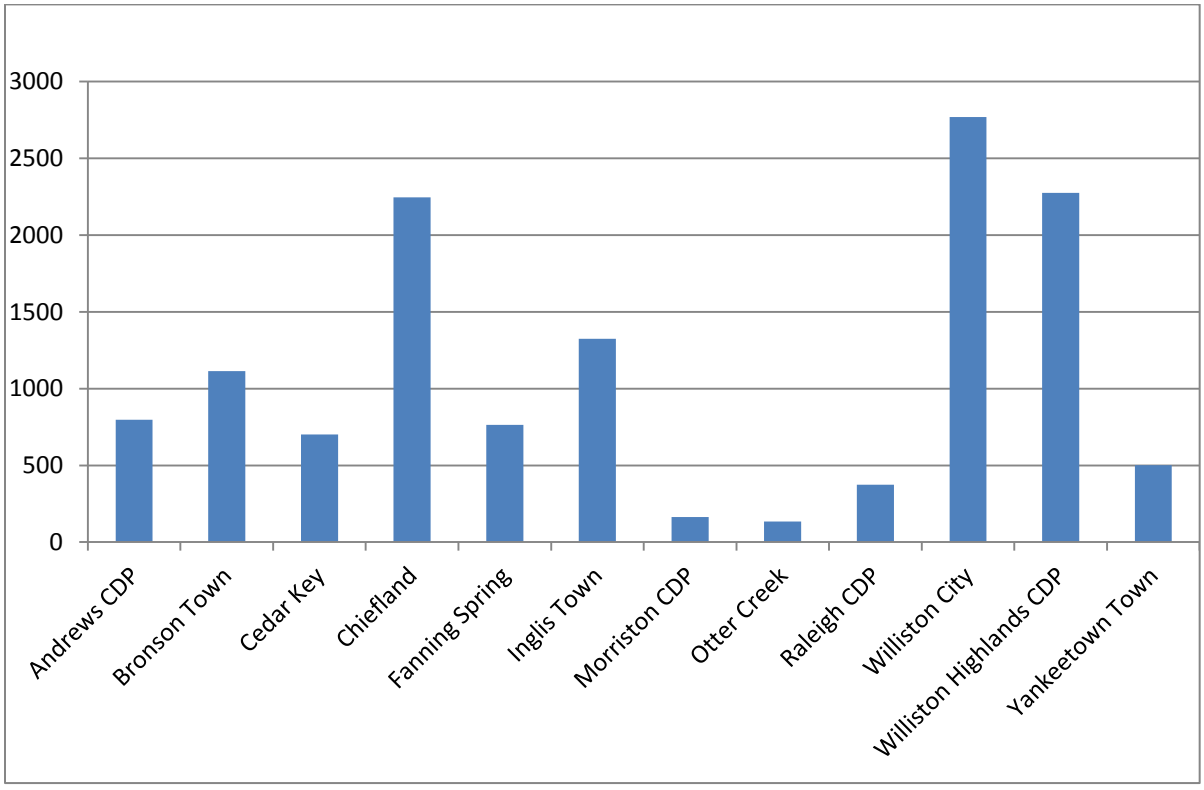


Figure 8-2. Population by cities in Levy County, 2010. Data Source: US Census

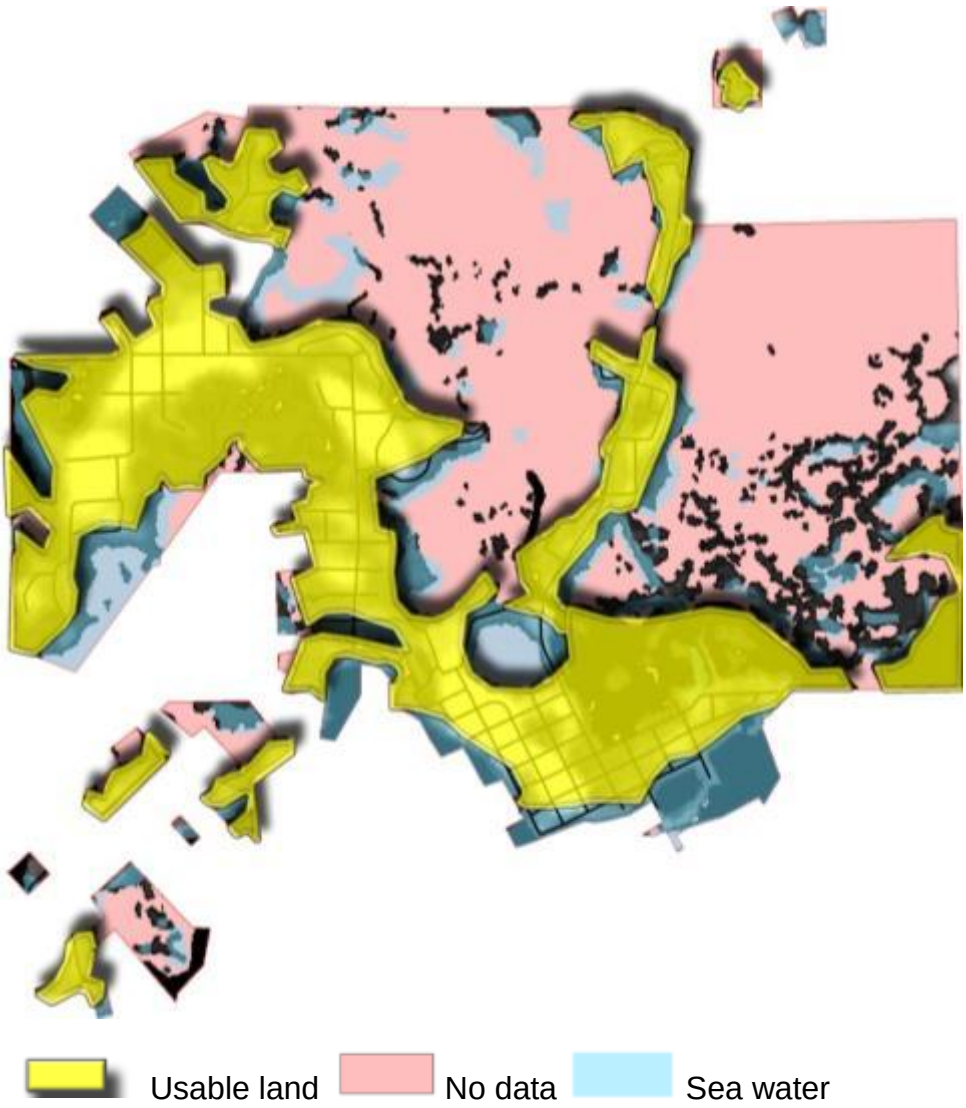


Figure 8-3. Usable land in Cedar Key when sea level raises half meter

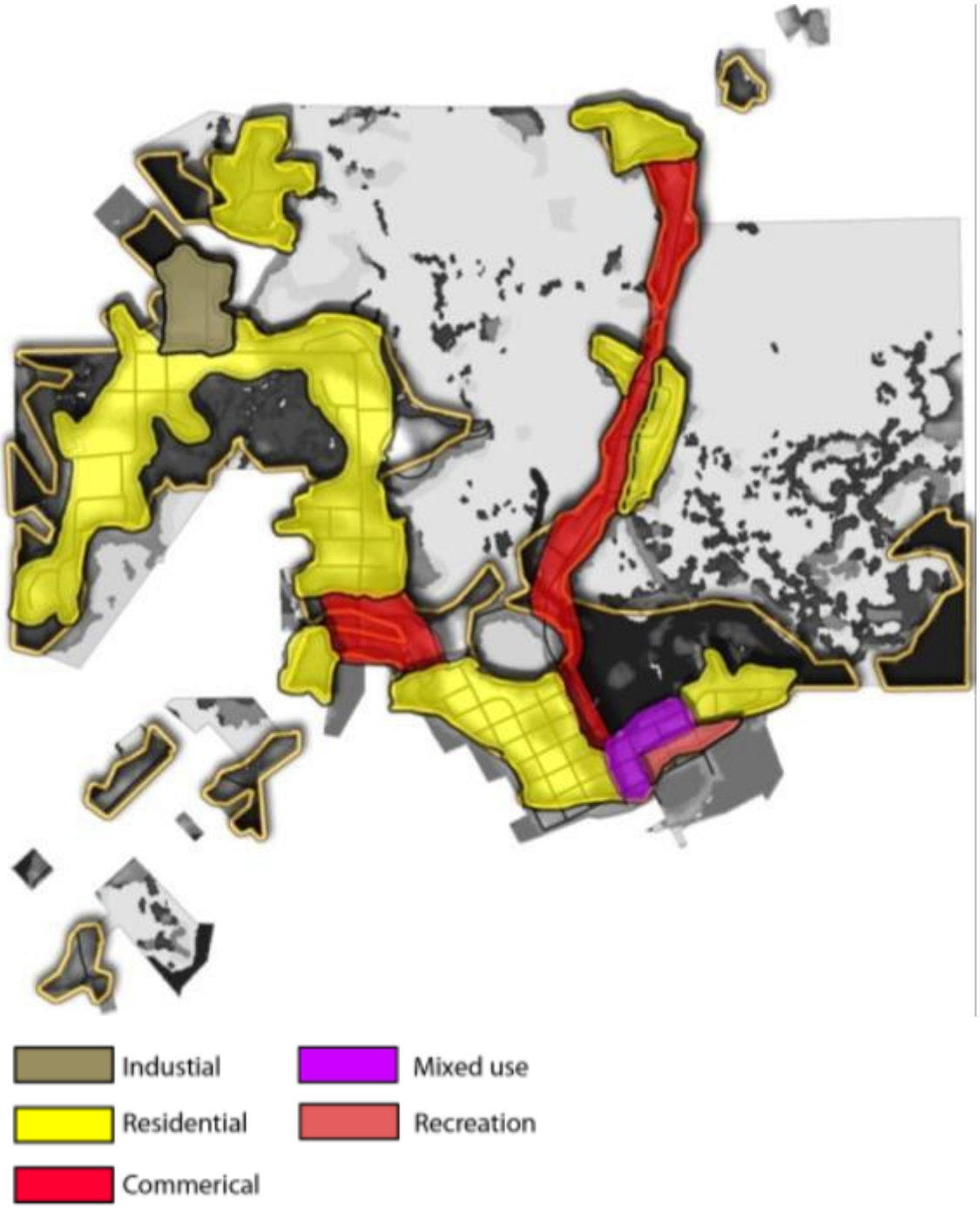


Figure 8-4. General functional zoning in Cedar Key

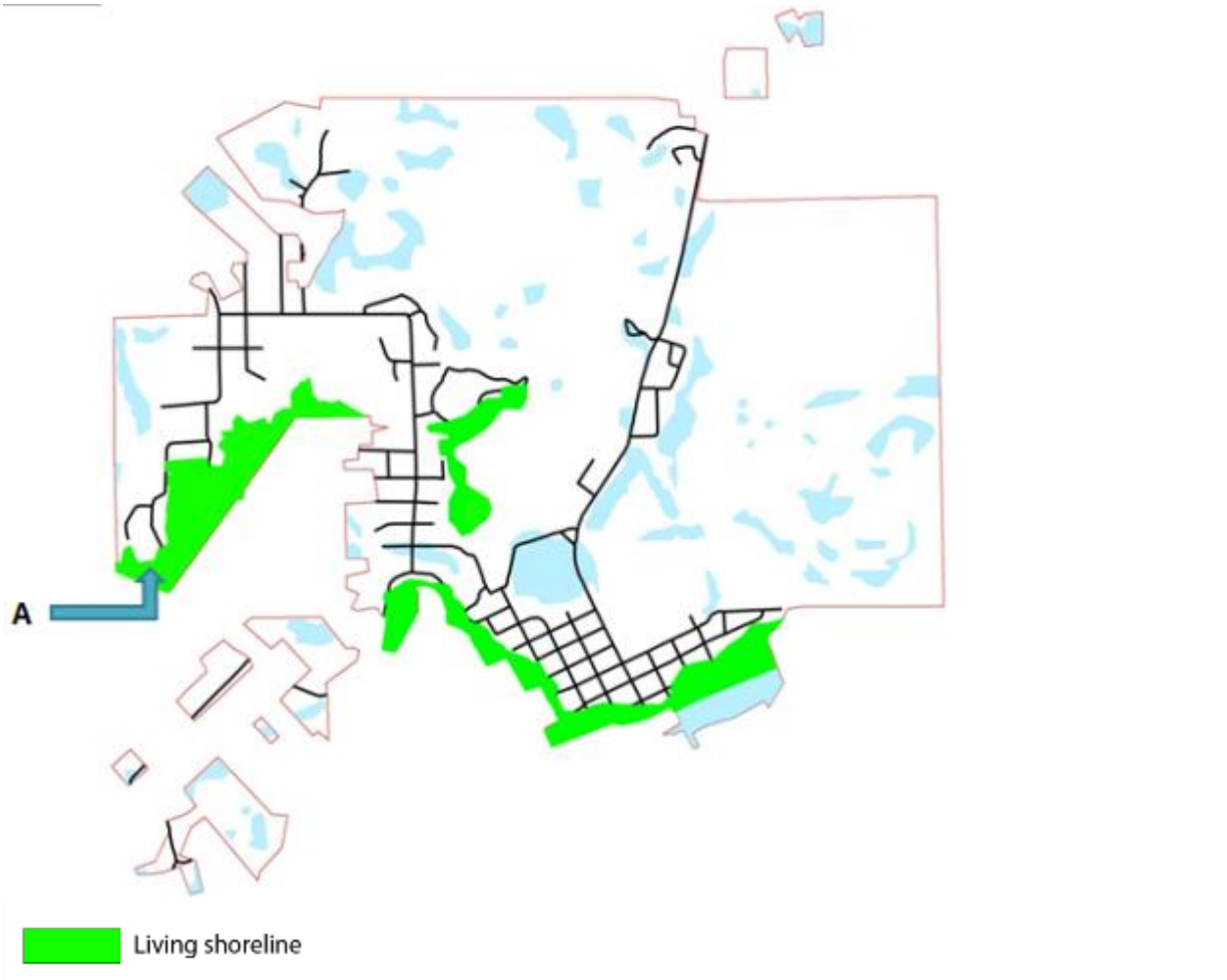


Figure 8-5. Living shoreline in Cedar Key when sea level raises half meter

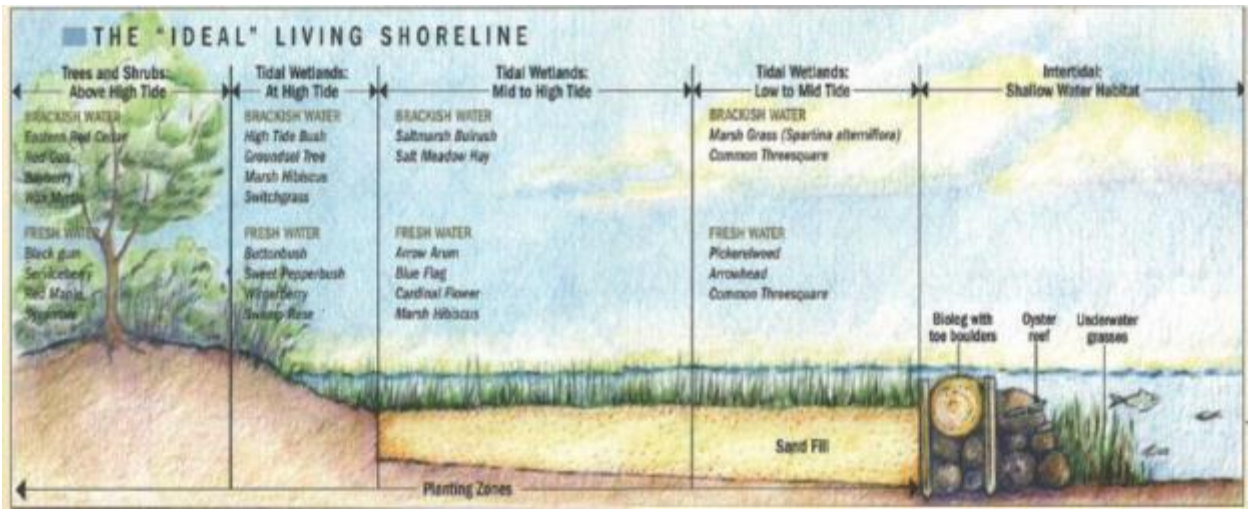


Figure 8-6. Ideal living shoreline. Source: Chesapeake Bay Foundation, 2007

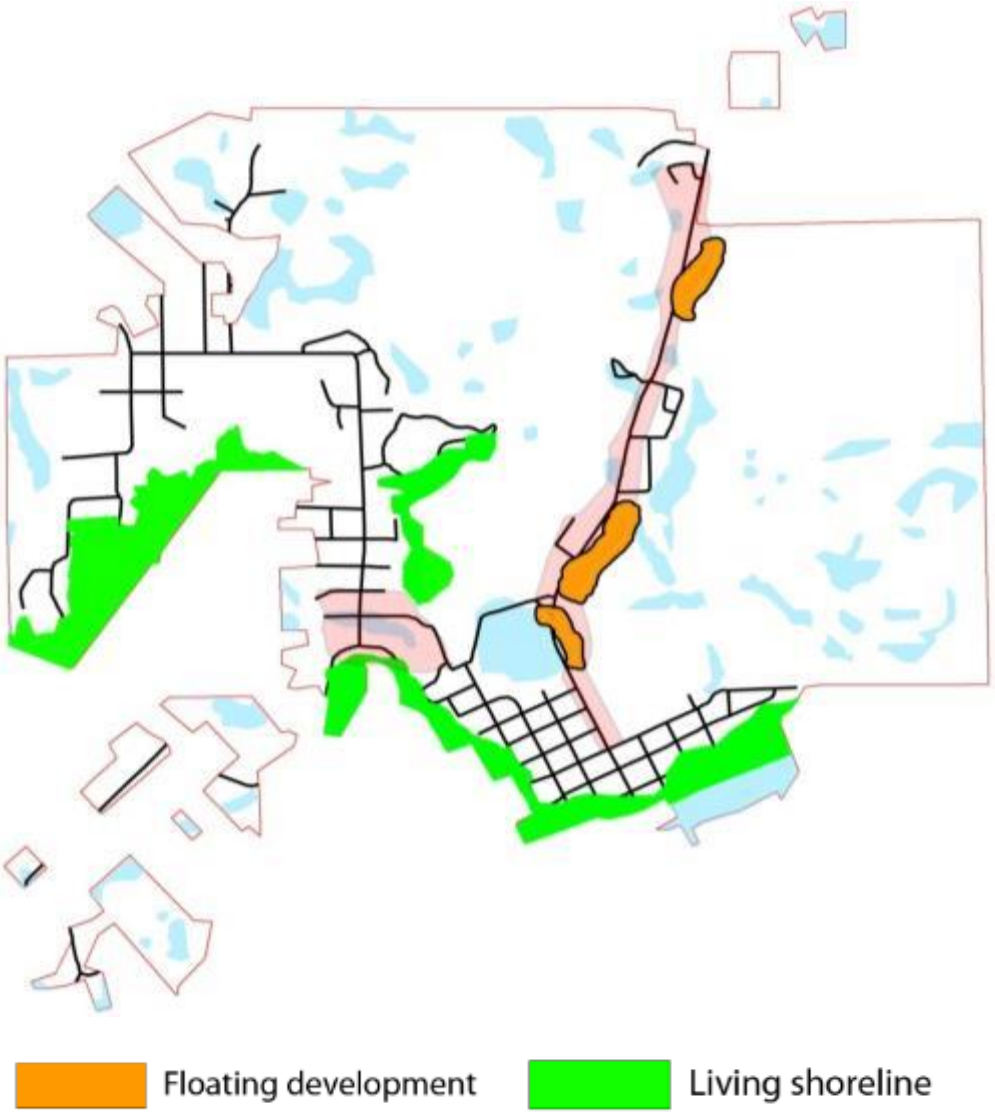


Figure 8-7. Floating development area in Cedar Key

Figure 8-8. Recent elevated development in Cedar Key. Source: Planning for Coastal Change in Levy County, University of Florida project funded by Florida Sea Grant

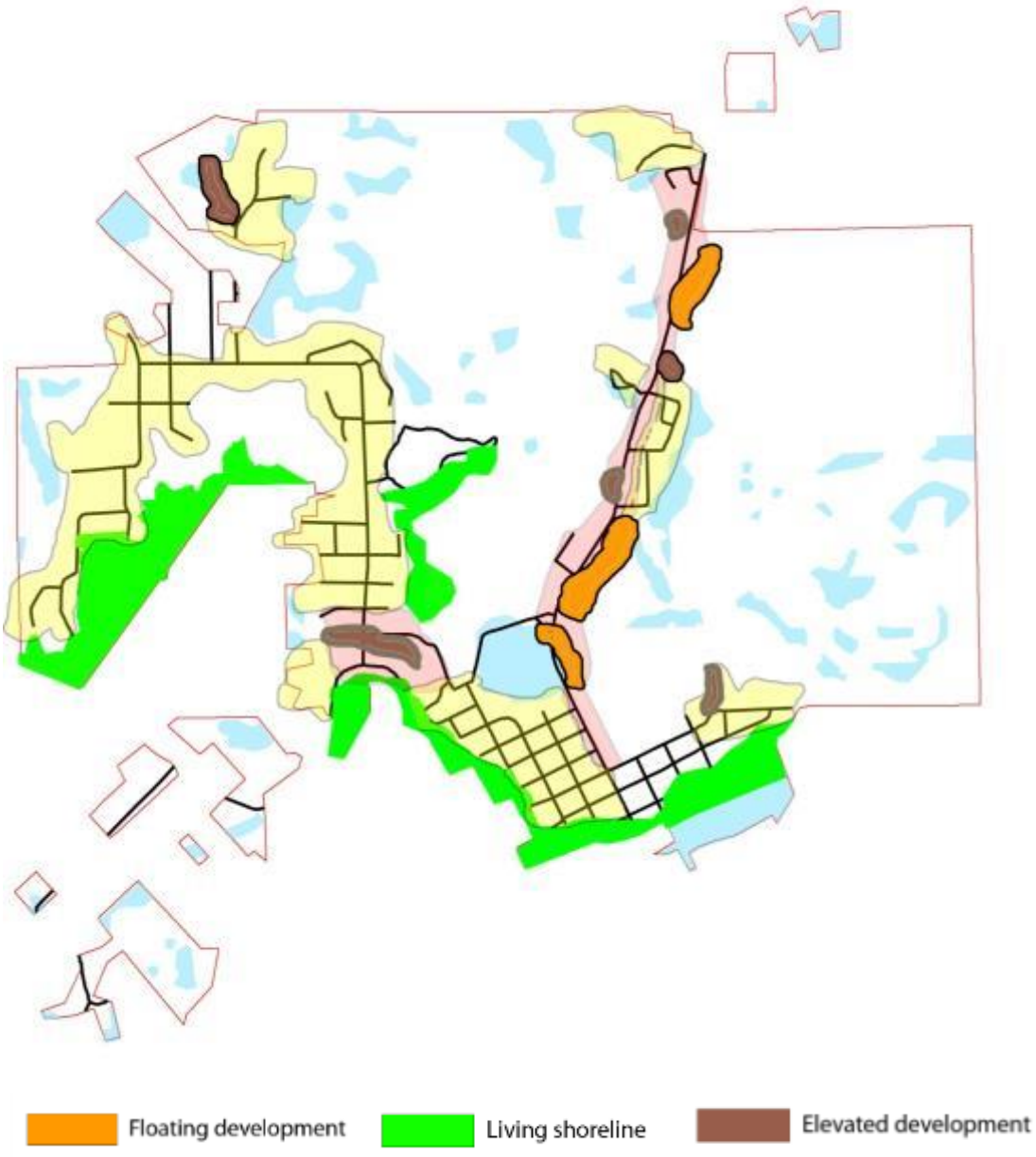
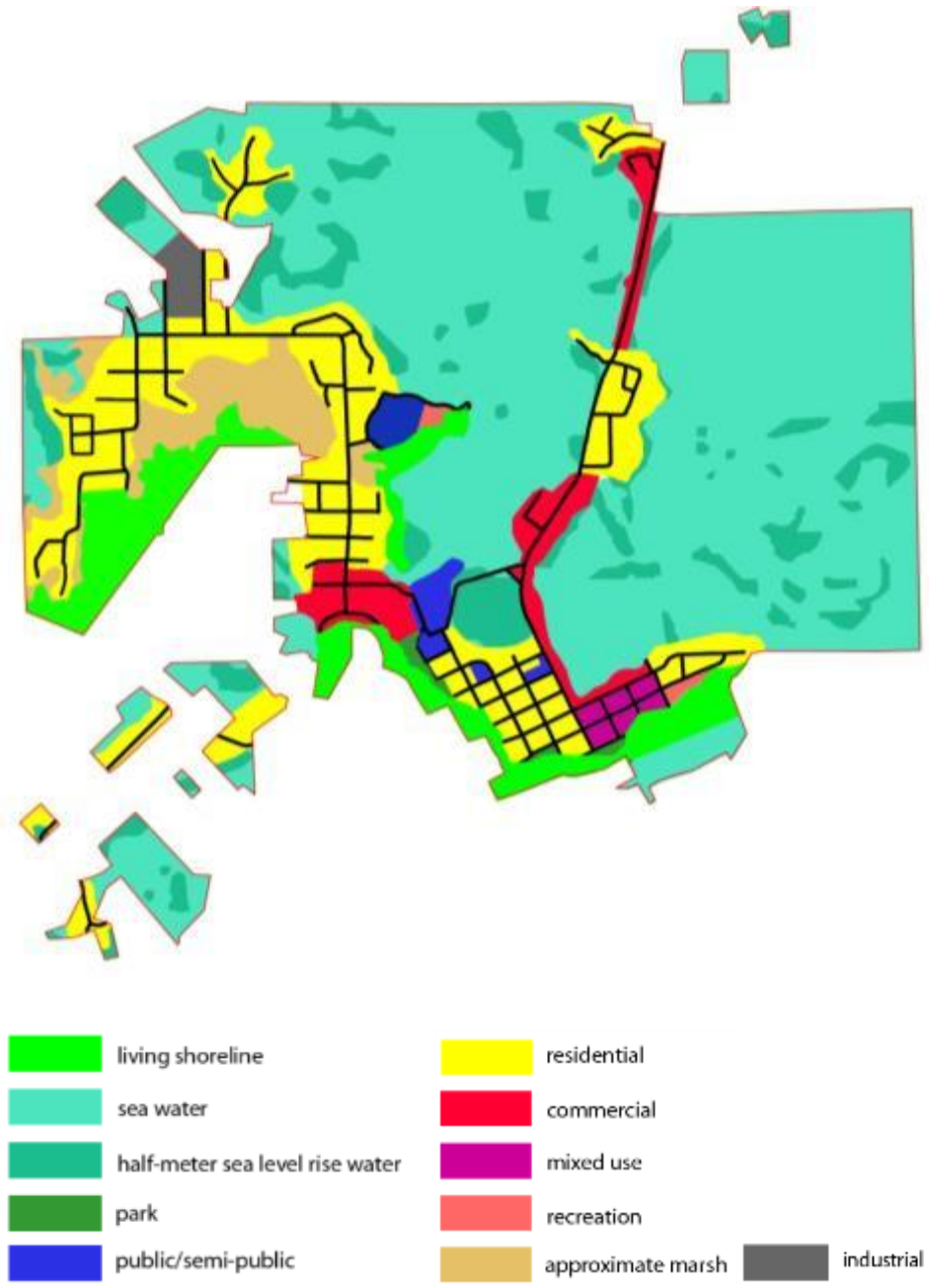


Figure 8-9. Elevated development area in Cedar Key


living shoreline
sea water
half-meter sea level rise water
park
public/semi-public
residential
commercial
mixed use
recreation
approximate marsh
industrial

A

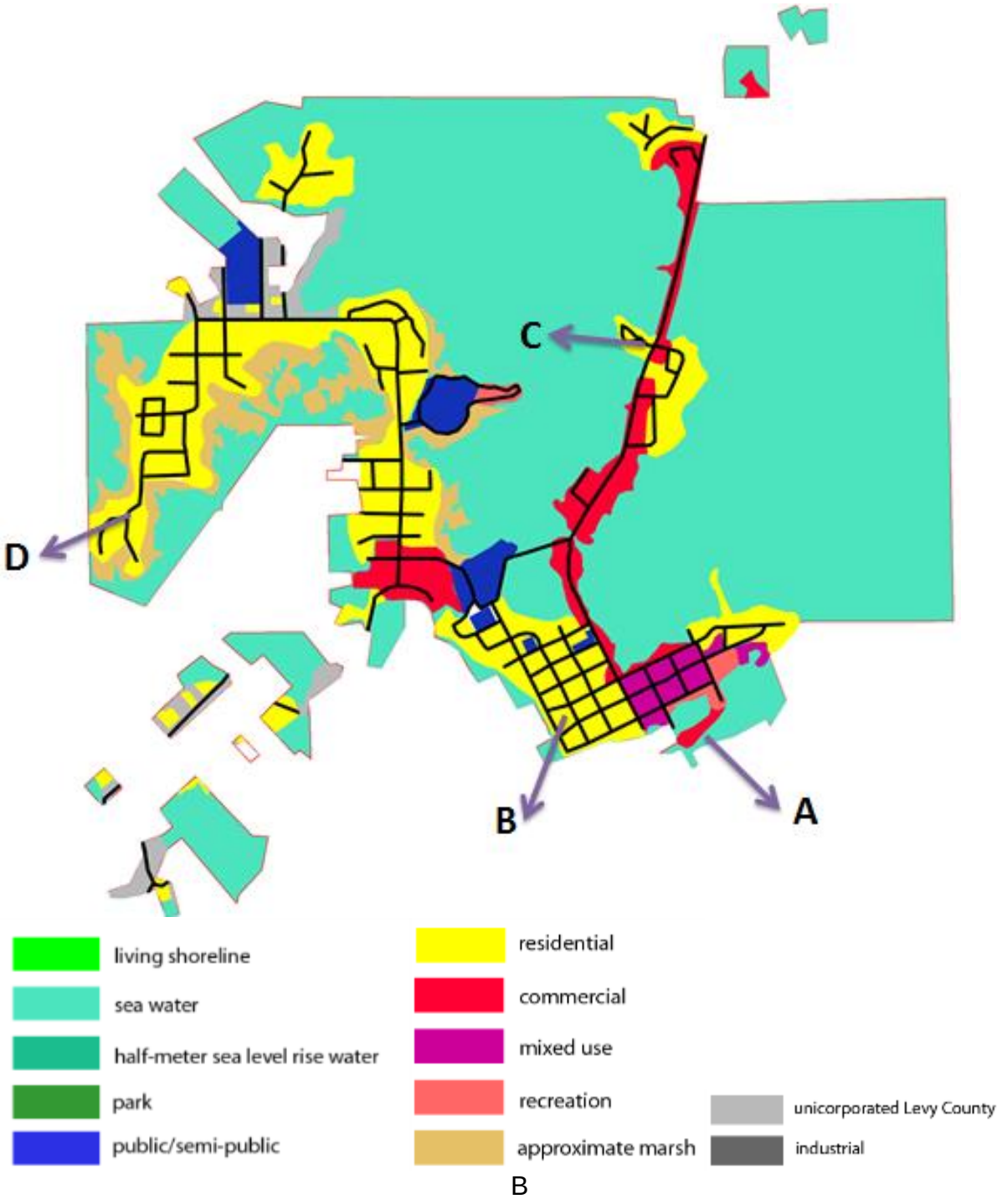


Figure 8-10. Land use in Cedar Key A) When sea level raises half meter. B) Cedar Key land use map 2014-2020

Figure 8-10. B) Continued

A

B

C

D

Figure 8-11. Current situation of the future industrial use area. Source: Google earth

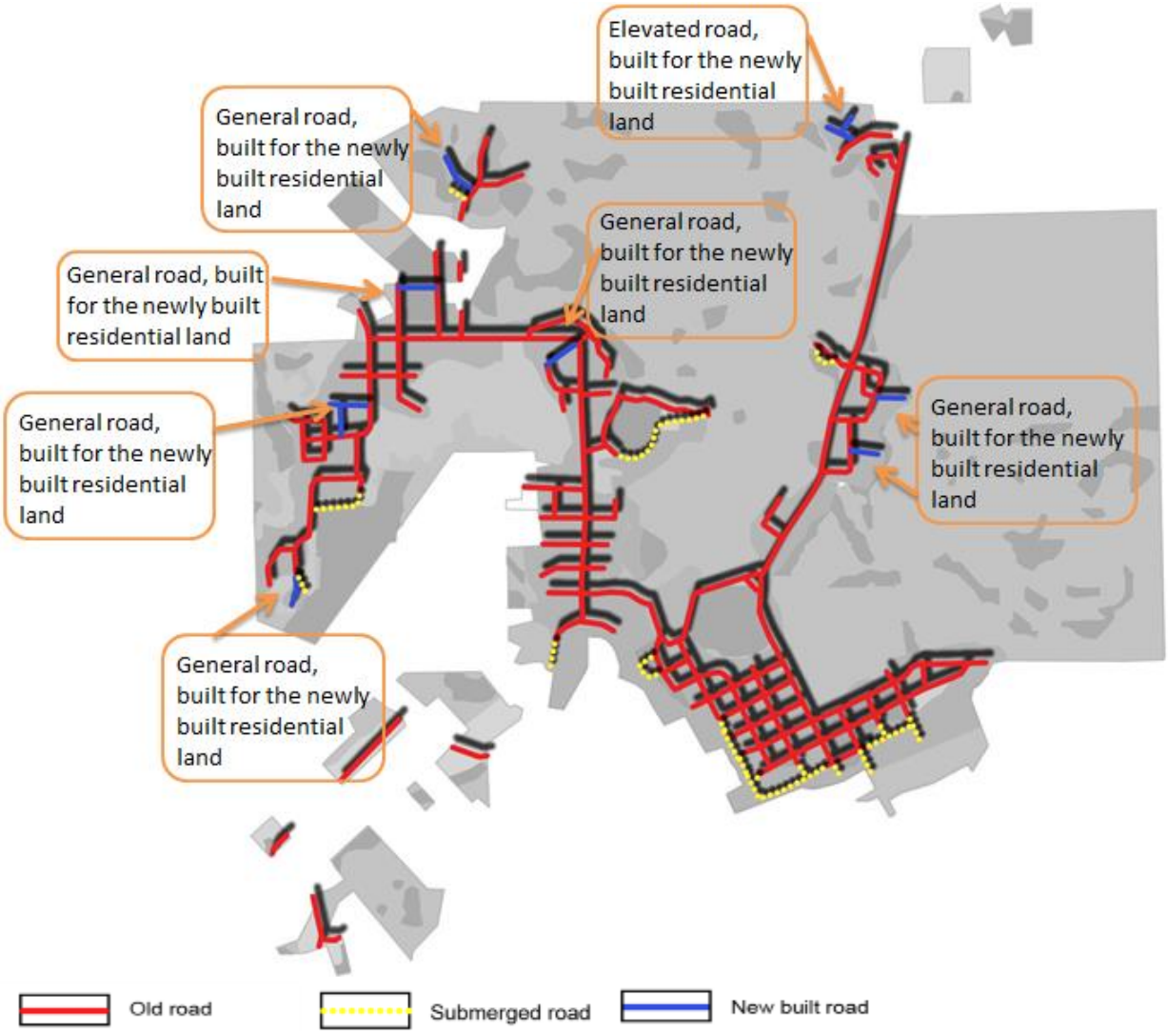


Figure 8-12. Transportation system when sea level raises half meter

Figure 8-13. Current situation of southeast Cedar Key

Figure 8-14. Half meter sea level in southeast of Cedar Key

Figure 8-15. Functional division of southeast Cedar Key A) 2014-2020. B) when sea level raises half meter

Figure 8-16. Master plan of southeast Cedar Key when sea level raises half meter

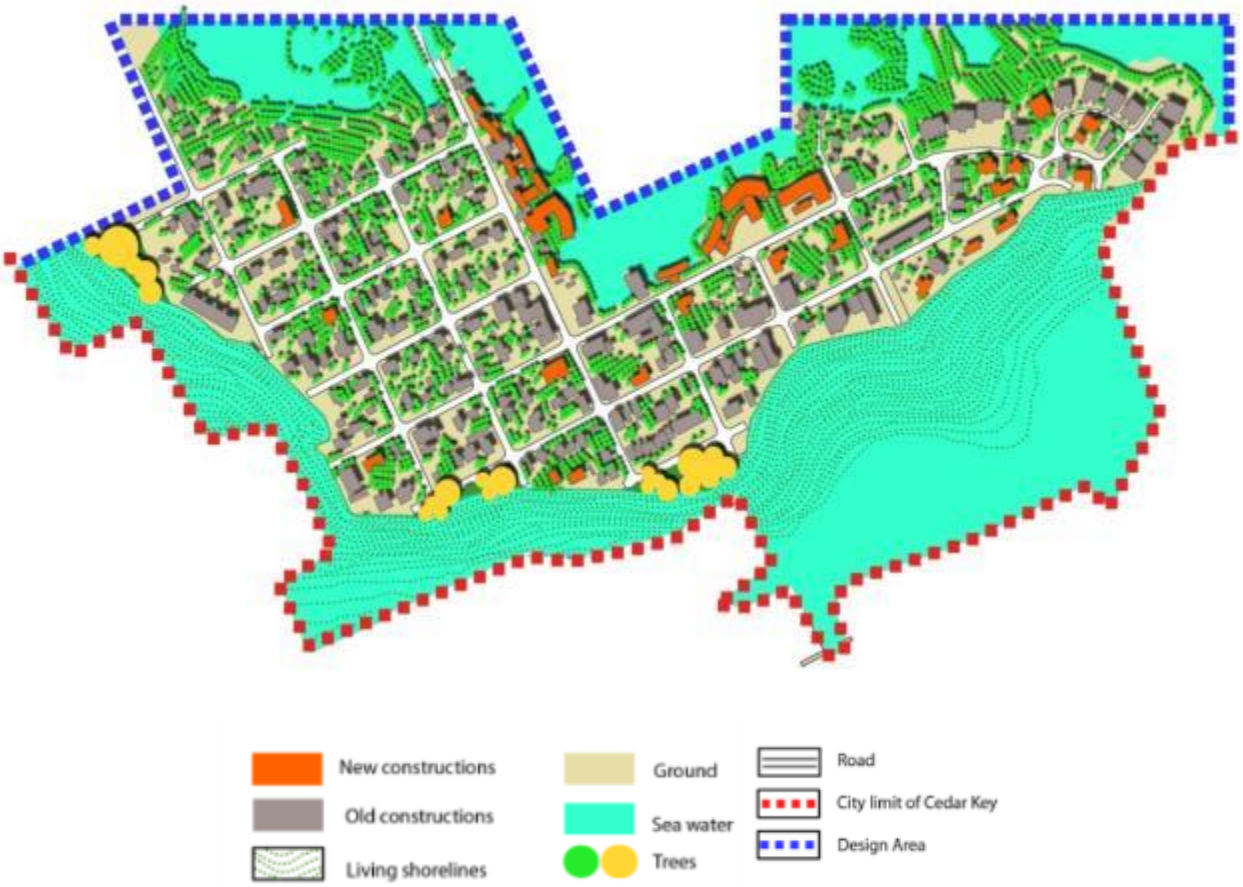


Figure 8-17. Analysis of Master plan of southeast Cedar Key

Table 8-1: Land comparison before and after sea level raises half meter

Land of Cedar Key (now)	640 acre
Submerged land when sea level raises half meter	271 acre
Usable land when sea level raises half meter	369 acre

Table 8-2: Land use comparison

Area	2014-2020 (acre)	Sea level raises half meter (acre)
Residential	212.92	220.76
Commercial	57.55	55.85
Mixed use	125.17	11.33
Recreation	4.16	3.33
Public/Semi-public	27.48	19.04
Industrial	0	9.57

CHAPTER 9
COMPARISON WITH STUDIO'S WORK

The goal of 2013 Spring studio work was to use adaptive design and planning methods to mitigate the negative effects of coastal change and sea level rise to the coastal communities. The studio conducted case studies and visual analysis, SWOT analysis and physical analysis.

The differences between this thesis and studio's work are:

- The studio studied 3 feet SLR scenarios, different from half meter SLR scenario considered in this thesis.
- The studio analyzed the vulnerability to SLR based on elevation, ecological modeling (SLAMM), flood zones, storm surge and erosion, vulnerability of structures and building stock, and fiscal and economic vulnerability. In this thesis, the author analyzed the potential impacts of SLR and apply these impacts in the study area.
- The studio developed an analysis of adaptive capacity, including physical adaptive capacity, legal and political adaptive capacity, technical, financial and civic adaptive capacity in the study area. This can be helpful for the further recommendations. This thesis doesn't evaluate the adaptive capacity of Cedar Key.
- This thesis make recommendations based on the impacts of SLR in the study area and the studio make recommendations based on the vulnerabilities and adaptive capacity.

Table 9-1. Comparison with studio work

	Studio's work	This thesis
Objectives	This studio's work is built upon the work done by the previous studio. Aiming to use adaptive design and planning methods to mitigate the negative effects of coastal change and sea level rise to the coastal communities.	• Analyze effects of SLR in eco-system, transportation and economic development. • Explore solutions towards problems identified caused by SLR. • Create most suitable strategies for the study area.
Methods	• Inventory and Sea Level Rise • Visual Analysis • SWOT Analysis • Case Studies • Physical Analysis • Make recommendations	• Basic knowledge and understanding • Data gathering • Design adaptation strategies
Findings	• Cedar Key's transportation network is restricted by extensive wetlands • The city is less vulnerable to water quality issues • Clam aquaculture and wholesaling are important industries in Cedar Key, followed by recreation and tourism • Cedar Key's land use is primarily residential, public and semipublic and half of the parcel zoned for residential use are vacant • 500 of approximately 800 structures in the town were built prior to 1985 which means they may be more vulnerable to future hazards	• Cedar Key is in the Tropical Storm level • Clam industry plays an important role in Cedar Key's economy • Salt water intrusion will result in the reducing of clam industry • About 23.4% buildings will be submerged by the sea water when sea level raises half meter

Table 9-1. Continued

Recommendations	Reduce vulnerability to coastal hazards: • Elevate buildings retrofitting critical buildings for storm “hardening” • Stabilizing shorelines • Controlling development in hazard prone areas • Protect and migrate wildlife habitat • Structure adaptation • Infill development • Managed retreat	• Build living shoreline • Floating development • Elevated development • Create new industrial development • Managed retreat

CHAPTER 10
CONCLUSION AND FURTHER STUDIES

Conclusion

The author conducted the research based on several adaptation strategies for the impacts of SLR through literature review and four case studies. These strategies are evaluated. Benefits and shortcomings of them are also both identified.

This thesis focuses on exploring potential solutions for the study area—Cedar Key, Florida to deal with the impacts of sea level rise. The author analyzed the demographic, geographic, ecological, economic and transportation aspects of Cedar Key. Based on these conditions and considering the challenges and benefits of the adaptation strategies, the author proposed some adaptation strategies which the author argues would be more suitable to deal with the impacts of SLR in the study area. The proposed strategies are: living shorelines, floating developments, elevated developments, abandon some shoreline, and a new type of economic development.

The author presents a general future planning concept of the study area with a more concrete design proposal for the most populous area of Cedar Key that applies the identified adaptation strategies. Living shorelines, elevated development and floating development are shown in this area. The author compared before and after sea level rise scenarios of the study area to show the expected changes when the strategies have been applied.

There are some limitations in this thesis. First, some data are approximate due to limited access to more accurate data. Secondly, this thesis explores a scenario for a half meter sea level rise but doesn’t consider the tide range which very likely will go above half meter. Third, the projection of the future population when sea level raises

half meter is an estimate that assumes that population will only grow in the future. This has not always been the case with Cedar Key population historically. In some cases Cedar's Key population has actually decreased.

Further studies

Planning for the coastal resilience is a long-term process that requires more developed science, technology and innovation. Collaboration is also very important for the study. From the case study I—San Francisco Bay Area, the BCDC worked together with the local jurisdictions and other regional agencies. Cedar Key can collaborate with some regional agencies in the future.

More specifically, the following items should be explored to help address Cedar Key sea level rise challenges:

Firstly, Cedar Key should start a survey to record the number of property owners that don't want to move. Because the sea level rise is a long-term process, it takes years for people to notice the changes. Many people have been living there since they were born and they don't want to move until one day they find that they have to. This result will influence the future land use planning in the coastal area.

Secondly, Cedar Key should start a post-disaster redevelopment plan (PDRP). Storm surge is one of the concerns in Cedar Key. The rising sea level will intensify the storm surge. Florida has had 62 major disaster declarations between 1960 and 2009 (FEMA, 2009). The coastal cities as Cedar Key should be better prepared for any of these disasters. The post-disaster redevelopment plan can be added into the comprehensive plan of Cedar Key. As indicated by the case study, Palm Beach County has developed a very effective post disaster redevelopment plan to enhance the long-term resilience and community sustainability. The reasons why to develop a PDRP are:

1) reduce community vulnerability to disasters; 2) it is required for coastal communities and encouraged for all other communities; 3) the Plan will allow for a more successful community recovery from disaster impacts. (Post-Disaster Redevelopment Planning Guidebook, October, 2010).

Thirdly, public participation should be done more effectively. The communication with the public is very helpful for the planners to know what is really needed for the local people and what their concerns are. Additionally, through the public participation process, more and more people can be educated about the sea level rise and impacts it will bring in the future. So far, the studio has done a very good job at public participation. Two workshops have been held. One was held on Feb 27th, 2013. Another was held in April 24th, 2013. To increase public participation, more activities should be held in Cedar Key. The studio has engaged in Cedar Key Art's Festival Exhibition to encourage the communications with public. In the future, some special event can be set for the SLR, such as setting up a "Sea Level Rise Day" in some schools to encourage more students to get involved which will also bring more parents to participate. Since the seafood festival is very popular in Cedar Key, it's a really good opportunity to disseminate the knowledge about sea level rise. Additional options may include creating games for children, a better informative website and additional surveys. If the residents can get some bonus when they participate in the survey, more people would like to reply.

LIST OF REFERENCES

Ahern, J. (2012). From fail-safe to safe-to-fail: sustainability and resilience in the new urban world. *Landscape and Urban Planning, 100*(4), 320–343.

Assessment, M. E. (2003). Millennium ecosystem assessment. Ecosystems. Retrieved from http://www.pme.gov.sa/en/summary1.pdf

Arnell, N.W., Cannell, M.G.R., Hulme, M., Martens, P., Mitchell, J.F.B. McMichael, A.J., Nicholls, R.J. Parry, M.L., and White, A. 2002. The consequences of CO2 stabilisation for the impacts of climate change? Climatic Change, 53, 413-446.

Barnett, Jonathan and Hill, Kristina. 2008. Design for Rising Sea Level. *Harvard Design. Magazine*, Fall: 14-21.

BEBR, (2013), Projection of Florida Population by County, 2015-2040, with Estimates for 2012

Best, M., & Stein, T. (2005). *Ecotourism in Florida.* University of Florida, 33-35.

Coastal Management Element. (n.d.). *Levy County Comprehensive Plan*.

Corner, James. 2006. Terra Fluxus. In *Landscape Urbanism Reader*, ed. Charles Waldheim, 23-35.

Crooks, Stephen. (2004). The Effect of Sea-Level Rise on Coastal Geomorphology.

Chang, Muncel. “Salt Water vs. Fresh Water - Ghyben-Herzberg Lens” Ask.com. 19th, Sep. 2000. 16th. Retrieved from http://geography.about.com/library/misc/ucghyben.htm

Deyle, E. Robert, et al. “Adaptive Response Planning to Sea Level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning.” 48th Annual Conference of the Association of Collegiate Schools of Planning. Page 3, 5, 15. 18th,

Douglas, B.C., 2000. Sea-level Change in the Era of the Recording Tide Gauge. In Douglas, B.C. Kearney, M.S. and Leatherman, S.P. (eds) Sea-level Rise: History and Consequences. Academic Press, London, pp. 37-64.

Douglas, B.C. and Peltier. W.R. 2002. The puzzle of global sea level rise: Physics Today. V. 55 (March 2002). P.35-40.

Environment Agency. (2005). *River Thames: Waterway Plan 2006-2011.* Managing the River Thames and Protecting and improving people’s enjoyment of the countryside

Florida Dept. of State. (n.d.). Retrieved 2012, from Historical Resources: http://dhr.dos.state.fl.us/facts/reports/contexts/paleo.cfm

Florida Department of Economic Opportunity (FDEO). (n.d.). *Adaptation planning*. Retrieved from http://www.floridajobs.org/community-planning-and-development/programs/technical-assistance/community-resiliency/adaptation-planning

Florida Department of Economic Opportunity (FDEO). (n.d.). *Adaptation planning in Florida*. Retrieved from http://www.floridajobs.org/fdcp/dcp/AdaptationPlanning/AdaptationPlanninginFlorida.pdf

Government of Alberta Agriculture and Rural Development Ministry: Salt Tolerance of Plants; November 2001. Retrieved from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3303/$file/518-17.pdf

Ibis (*The International Journal of Avian Science*) 146: 1, 18-20.

Japan Market Investigation & Analysis. December 1997. Retrieve from http://www.nmfs.noaa.gov/mb/sk/saltonstallken/japan.pdf

Julie Hauserman (2006), Florida's Coastal and Ocean Future

Julie Harrington & ToddL Walton, Jr (August, 2008), Climate Change in Coastal Areas in Florida: Sea Level Rise Estimation and Economic Analysis to Year 2080

Levycounty.org (n.d.). Economic Element. *Levy County Comprehensive Plan*. Cedar Key, Florida. Retrieved March 2, 2012, Retrieved from http://www.zoomprospector.com/CommunityDetail.aspx?id=6489

Levy County, Florida and Incorporated Area. November 30th, 2009. *Flood Insurance Study*.

Local Governments for Sustainability (ICLEI). (n.d.). *Groton, Connecticut coastal climate adaptation workshop: meeting notes and presentations*. Retrieved from http://www.icleiusa.org/climate_and_energy/Climate_Adaptation_Guidance/groton-connecticut-coastal-climate-adaptation-workshop-meeting-notes-and-presentations?searchterm=groton

National Oceanic and Atmospheric Administration (NOAA). (2010). *Florida community is progressively planning to adapt to climate change*. Retrieved from http://www.csc.noaa.gov/magazine/2010/05/article1.html

Pachauri, R.K. ,A. Reisinger, eds. 2007. *Climate change 2007: Synthesis Report.*

Robert J. Nicholls (2002), *Working party on global and structural policies*

Romero, Fernando (2005): Princeton Architectural Press.

Rowe, G., & Frewer, L. J. (2000). *Public participation methods: A framework for evaluation. Science, Technology & Human Values, 25(1), 3-29.*

Shirley Baker, Elise Hoover, and Leslie Sturmer (2007).The Role of Salinity in Hard Clam Aquaculture

Shome, Debika and Marx, Sabline. "The Psychology of Climate Change Communication" A guide for scientists, journalists, educators, political aides, and the interested public. Center for Research on Environmental Decisions

The International Ecotourism Society. (n.d.). What is Ecotourism? Retrieved March 22, 2012, from The International Ecotourism Society: http://www.ecotourism.org/what-is-ecotourism

*THE URBANIST (*Issue 487, November 2009*), Sea Level Rise and the Future of the Bay Area. Retrieved from http://www.spur.org/publications/article/2009-11-01/strategies-managing-sea-level-rise*

Titus, J. G. (1998). *Rising seas, coastal erosion, and the takings clause: how to save wetlands and beaches without hurting property owners. Md. L. Rev.,57, 1279.*

Titus, J.G. *"Greenhouse Effect, Sea Level Rise, and Land Use." Climate Change-Health and Environmental Effects. April, 1990. 12th Feb. 2012.*

U.S. Decennial Census. Retrieved from http://www.census.gov/prod/2002pubs/pol02marv.pdf

Winters, J. (2010). Children's participation in planning and regeneration. *Journal for Education in the Built Environment, 5*(2), 85-111.

Wolfe, J. M. (2006). *Historic Context at Risk: Planning for Tropical Cyclone Events in Historic Cedar Key.* University of Florida. University of Florida.

Zan Skelton (1982), Seafood processing: A factory visit Fisheries and Aquaculture Department, Assessment and Management of Seafood Safety and Quality. Retrieved from http://www.fao.org/docrep/006/y4743e/y4743e0h.htm

Zhang, K., Douglas, B.C. and Leatherman, S.P., 2000. Twentieth-century storm activity along the US east coast. Journal of Climate, 13, 1748-1761.

BIOGRAPHICAL SKETCH

Yehan Xu grew up in Choingqing. It’s a mountainous city of China. Since her father works in the construction department of the government, she is very interested in the urban planning. Yehan received a Bachelor of Urban Planning at Chongqing University. Yehan received her Master of Arts in Urban and Regional Planning from the University of Florida. She continues to develop her knowledge and skills of planning with the aim of becoming a professional planner.