MOTT MACDONALD

Ingleside on the Bay Relative Sea Level Rise Impacts and Adaptation

IOBCWA

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Mott MacDonald
10415 Morado Circle
Building One
Suite 300
Austin
TX 78759
United States of America

T +1 (512) 342 9516
mottmac.com

Ingleside on the Bay
Coastal Watch Association

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Executive Summary

This document was prepared by Mott MacDonald for The Ingleside on the Bay Coastal Watch Association (IOBCWA) to assess the risks to the Ingleside on the Bay posed by relative sea level rise. This document serves as one of the first steps towards increasing the resilience of this community towards relative sea level rise and future storms. The following is a brief outline summarizing the analysis conducted, topics discussed, and sea level rise mitigation options discussed in this report:

- Preliminary sea level projections and analysis determined that flooding along Ingleside on the Bay will become more frequent, severe, and will impact more properties as time passes if no action is taken to adapt to rising sea levels.
- There are a few funding sources available to help finance alternatives to increase the resilience of Ingleside on the Bay, but many have restrictions/preferences on how the funding is to be utilized which must be considered when applying for these funds. Few sources are available for funding projects benefitting private property owners. Due to the extent of the work to be undertaken, it is unlikely that a single source of funding will be sufficient to implement the necessary adaptation alternatives to ensure the resilience of the community. Multiple private investment and public funding sources will need to be leveraged by the community to implement the necessary measures.
- The zones within the community most at risk from rising sea levels were identified based on the approximate elevations within those zones (refer to Figure 10). Zone 1 is most at risk to these impacts as it is the lowest lying zone. Zone 2 is the largest and will require the most work to adapt to rising seas. Finally, there are areas within Zone 3 that will also need to be addressed, particularly along the lowest lying sections of roadway and exposed section of shoreline along the eastern end of Inglewood Drive.
- Options for adapting to RSLR are presented and preliminary conservative cost estimates for each alternative are provided in this report for planning purposes only. These estimates were produced to help develop an understanding of the scope and magnitude of the work necessary to improve the resilience of the Ingleside on the Bay community to projected future sea levels. Most zones will require raising of existing bulkheads, construction of shore protection, and raising of roadways as necessary to adapt to future sea levels.
- Below is a brief bulleted outline of the timeline for addressing the issues identified within each distinct zone:
    - Zone 1
        - Ingleside Beach Club
            - Stabilize Shoreline as soon as possible
            - Fill lot to increase elevation above +5' NAVD88 by 2040
        - Raising Bayshore Drive
            - Raise roadway from the Brass Turtle to S Sandpiper St above +5' as soon as possible.
            - Raise roadway to +6' by 2040
        - Zone 1 Private Property Alternatives
            - Raise all existing bulkheads in zone below +4' NAVD88 as soon as possible
            - Stabilize unprotected sections of shoreline as soon as possible
            - Fill lots to coincide with raising of Bayshore Drive

            - Raise homes on an as needed basis
  - Zone 2A
    - Raise all roads within zone
      - Raise roads above +5' NAVD88 as soon as possible
      - Raise roads above +6' NAVD88 by 2040
    - Raise All Bulkheads within zone
      - Raise all existing bulkheads in zone below +4' NAVD88 as soon as possible.
      - Repair and/or replace damaged bulkheads as necessary
    - Stabilizing unprotected shoreline
      - Stabilize unprotected shoreline as soon as possible
    - Raise Homes and Lots
      - Fill lots to coincide with raising of roadway
      - Raise homes on an "as needed" basis
  - Zone 2B
    - Shoreline Alternatives
      - Raise Bulkhead by 2040
      - Stabilize unprotected shoreline as soon as possible
    - Raise Boat Ramp Parking Lot and Ocean Drive
      - Raise parking lot above +5' NAVD88 by 2040
      - Raise Ocean St above +5' NAVD88 by 2040
  - Zone 3
    - Raise All Bulkheads within Zone
      - Repair and/or replace damaged bulkheads as necessary
      - Raise bulkheads on a case by case basis
    - Raise Roadways Identified
      - Raise roads above +5' NAVD88 by 2040
    - Stabilize Unprotected Shoreline
      - Stabilize unprotected shoreline on private lots as soon as possible
      - Construct Living shoreline at shoreline adjacent to Inglewood Drive and Post Oak Drive as soon as possible

This document represents the initial steps in planning for increasing the resiliency of this community, but future studies are necessary, including drainage analyses and further evaluation of potential alternatives and policies that may be implemented to increase the resilience of this community. A comprehensive drainage study with a focus on the RSLR impacts for Ingleside on the Bay and surrounding areas is recommended to further evaluate the potential impacts to the community from RSLR. This study will help to better quantify the impacts to the community as well as help determine the best adaptation measures to be implemented within the separate zones identified. Furthermore, this document does not evaluate the additional indirect impacts to utilities which will need to be evaluated in future phases to quantify the impacts to utilities and measures for mitigating these impacts

1 Introduction

As sea levels continue to rise around the world, including the Gulf of Mexico, low lying coastal areas are at increasing risk of flooding. “Nuisance” or high tide flooding occurs when high tides not associated with severe storm events, cause flooding which results in public inconveniences such as road closures, overwhelmed storm drains, and compromised infrastructure. According to the National Oceanic and Atmospheric Administration (NOAA), this type of flooding “has increased in the U.S. on average about 50 percent since 20 years ago and 100 percent since 30 years ago.” (NOAA, 2014) Current sea level rise projections for coastal Texas indicate that sea levels are not only expected to continue rising, but also expected to accelerate as they continue to rise in the next century.

Coastal communities in Texas are already experiencing the effects of this rise. Homeowners are becoming more concerned as frequent flooding of their properties has resulted in erosion of their shorelines, damage to shore protection structures such as bulkheads, and damage to their homes from flooding. These damages are costly to fix and are often not covered by insurance or public funding mechanisms, leaving the individual owners responsible for protecting their shorelines. Unfortunately, the costs to replace or construct new shoreline protection structures is often too great for many homeowners to bear and can exceed the value of the home and property. In many other cases, homeowners attempt to act to stabilize their shorelines, but often lack the information necessary to determine the most cost-effective solution. This often leads to homeowners choosing “cheap” options (such as installing non-engineered concrete riprap on their shorelines or conducting minor aesthetic repairs on failing bulkheads) which at best, don’t have an effect, and at worst, exacerbate erosion and flooding.

Public roads and utilities adjacent to the water have also been damaged by this frequent flooding. Furthermore, both public and private infrastructure have continually become more susceptible to damage during extreme storm events which are amplified by higher sea levels.

Concerned homeowners at Ingleside on the Bay have experienced these impacts first hand and have decided to act in order to strengthen their community’s resilience. The Ingleside on the Bay Coastal Watch Association (IOBCWA) was formed to ensure the ongoing resiliency of Ingleside on the Bay to Relative Sea Level Rise (RSLR) and storms.

Mott MacDonald was contacted by the IOBCWA to develop this report which identifies the risks to the community from rising sea levels and develops a framework for future planning to increase the resilience of Ingleside on the Bay. This was done by evaluating potential future sea levels and flooding scenarios, identifying areas most at risk to these sea level rise and flooding impacts, and developing preliminary alternatives to address the issues associated with rising seas. This report summarizes the results of this analysis and presents preliminary alternatives to adapt to rising sea levels.

2 History of Ingleside on the Bay

In 1954, the U.S. Army Corps of Engineers (USACE) cut the La Quinta Channel through Ingleside Point, creating the area we now know as Ingleside on the Bay. The community was officially "established in 1958 as the Ingleside Land Co. by W.D. Weller Investment Co." and later incorporated into its own city in 1991 (Ingleside on the Bay, 2020).

In 2014, the USACE, with funding from the Port of Corpus Christi Authority (POCCA), constructed a revetment and detached breakwater along a stretch of Bayshore Drive. The breakwater was constructed to protect existing seagrasses in the area from further deterioration due to erosion of the shoreline. The new revetment (Figure 1) has also effectively stabilized the shoreline along Bayshore Drive which, prior to its construction, was susceptible to collapse due to erosion of the shoreline. Since their construction, seagrasses have flourished and properties behind the structures have benefited from protection from storm waves.

Figure 1. Ingleside Revetment along Bayshore Drive

Review of historical aerials shows development within Ingleside on the Bay started around 1960 and peaked around 1972. Most bulkheads in the area were likely originally constructed around this time which would make these structures between 40 and 50 years old. This is of important note, as typical concrete bulkhead construction has an anticipated design life between 30 and 50 years, meaning that many bulkheads within the region are approaching, or have reached, the end of their intended useful life. Ingleside on the Bay's shorelines are predominantly lined with bulkheads, which are adjacent to waterfront homes and facilities; thus, the integrity and performance of these structures are critical to this community.

Bulkhead failure can occur in several ways, but the most common failures typically occur once the structure becomes overtopped by water. Vulnerability and frequency of overtopping is increased due to relative sea level rise. Areas exposed to wave energy are most susceptible, as overtopping starts to occur earlier and much more frequently as the sea level rises compared to a calm water environment. Once overtopping begins, salt water can reach the walls' anchor tiebacks which quickly begin to corrode, eventually failing and causing the wall to lean forward towards the water until it collapses. The photo below (Figure 2) shows a bulkhead within Ingleside on the Bay that has likely failed in this manner.

Figure 2. Failed Bulkhead

Many homeowners attempt to extend the life of these structures by constructing larger concrete caps or retaining walls to keep rising seas at bay. While these modifications may be an effective solution over the short term, the functionality and reliability of these repairs are often short lived. The added weight from such modifications can result in additional stresses on the already aging bulkheads, which often causes them to subside or fail at an accelerated rate. Once they begin to fail, usually the only viable repair option is to remove and replace the entire structure with a new bulkhead. Therefore, for a community with aging bulkheads, the recommended repair option is a full replacement with a new bulkhead. When constructed properly, bulkheads can sufficiently protect the shoreline for up to 50 years from water inundation. However, it is often observed that projected sea level rise is not properly accounted for in the installation of new bulkheads, resulting in structures that are at too low of an elevation. In this situation, this new structure becomes overtopped earlier in its life causing premature deterioration and failure. Therefore, it is critical that all new bulkheads are properly designed and constructed to an appropriate elevation that accounts for projected sea level rise over the duration of the structure's intended lifespan.

3 Water Levels and Projected Sea Levels

In order to better identify the risks to the Ingleside on the Bay community, an understanding of current and future sea levels is necessary. In the following sections, existing water level conditions and projected RSLR are evaluated to determine current and future water levels at the project site.

3.1 Tidal Datums

The current local tidal datums for this project area were established utilizing the local NOAA tidal station at the USS Lexington and are provided in Table 1 below. For the purposes of this study, all elevations are shown relative to NAVD88.

Table 1. Elevation datums (NOAA, Datums for 8775296, USS Lexington, Corpus Christi Bay, TX, 2019)

Datum	Elevation [ft NAVD88]
Mean Higher High Water (MHHW)	1.03
Mean Sea Level (MSL)	0.78
Mean Lower Low Water (MLLW)	0.44
North American Vertical Datum of 1988 (NAVD88)	0.00
Mean Low Tide (MLT)	-1.00

3.2 Extremal Water Levels

The extremal analysis was performed with all available water level data at the site and for water levels exclusively during September and October months (as the highest water levels primarily occur during these months). The NOAA Port Aransas gauge was used for this analysis as it is the station with the longest data record in the vicinity of the project site (2002-Present). The results of this extremal analysis are shown in Table 2. This table provides a select number of return periods, and their resulting water levels from the extremal analysis. A return period corresponds to a percent likelihood of the resulting event to occur in any given year (i.e., a 1-year return period has a 1/1 or 100% likelihood of occurring in any given year, while a 100-year return period has a 1/100 or 1% probability of occurring in any given year). Several factors affect water levels, but 1-year return period events are typically associated with "King Tides" which occur annually when the earth, moon, and sun are aligned, where the earth is closest to the sun. Whereas, 2 to 5-year events are commonly associated with weather events such as strong cold fronts, winter storms, and weaker tropical storms or hurricanes. Events beyond the 7.5-year return period are typically associated with tropical storms, hurricanes, and severe hurricanes.

The results show very little difference in return periods between the complete dataset and the Sep-Oct period. For comparison purposes only, reported water levels at Port Aransas reached an elevation of +6.3 NAVD88 during Hurricane Harvey (Zelinsky, 2018).

Table 2. Extremal water levels based on results from the Port Aransas Tide Gauge.

Return Period (years)	Resulting Water Level (ft NAVD88)
1	2.9
2	3.3
5	4.1
7.5	4.5
10	4.8
15	5.3
20	5.8
25	6.1
30	6.4
50	7.2

In addition, FEMA flood maps were reviewed to determine the approximate 100-year flood elevation for the project site. Review of FEMA Flood Insurance Rate Map (FIRM) maps show flood elevations ranging from +8 to +11' NAVD88 (FEMA, 2019) for the 100-year event.

3.3 Relative Sea Level Rise

Sea levels are highly dynamic and sensitive to many environmental factors such as lunar and solar cycles, winds, waves, barometric pressure. While land appears to remain static, ground elevations fluctuate over time due to subsidence or land rebound which can occur for different reasons.

Relative sea level rise (RSLR) is the change in the observed local water level elevations over time and is a combination of eustatic sea level rise and local land subsidence. Long-term variations in sea level occur over various time scales, from years to centuries, and are a result of several factors, such as variations in coastal and ocean circulation and temperature, vertical land motion, and the El Niño Southern Oscillation. Anthropogenic influences, such as groundwater and petrochemical extraction, and global climate change also contribute to these variations. Due to the many factors contributing to RSLR, relative sea levels vary temporally as well as specially which complicates prediction of future sea levels.

NOAA has been measuring sea levels for over 150 years and has computed rise at 142 long term water level stations. In addition, NOAA developed their own projections and estimates for regional RSLR within the United States at several stations for multiple sea level rise scenarios. The purpose being to examine the full range of scientifically plausible future rises in sea level by leveraging multiple lines of scientific evidence and providing scenario selection guidelines for planning and decision-making applications. (NOAA, Global and Regional Sea Levle Rise Scenarios for the United States, 2017)

There are two of these NOAA stations close to the project site that provide sea level rise projections: (1) the NOAA Bob Hall Pier Station; and (2) the NOAA Rockport Station. While the Rockport and Bob Hall Pier stations are a similar distance from the project site, sea level rise conditions may be different at the site due to local subsidence trends. The projections for the Rockport gauge were used in this analysis because that location is more representative of the tidal dynamics and sea level conditions at the project site.

The NOAA Rockport station documents a historical relative sea level rise trend of 5.58 mm/year, as shown in Figure 3 (NOAA, 2018c). The NOAA Rockport station also provides projection estimates for low, intermediate, and high sea level rise magnitudes (among others) for future years, up to the year 2100 (NOAA, 2018a), (NOAA, 2018b); these projections are shown in Figure 4. It is important to note that these projections show the rate at which sea level is rising is accelerating. While there is some uncertainty as to exactly how much this rate will accelerate, which is why ranges of rate estimates were developed, observed water level trends appear to be tracking between the intermediate and high RSLR scenarios. NOAA states that new evidence regarding the Antarctic ice sheet which significantly increase the probability of the Intermediate-High, High, and Extreme scenarios. Variability between the scenarios is not as significant in the near term (over the next couple of decades) thus scenario selection is not as critical in the near term. (NOAA, Global and Regional Sea Levle Rise Scenarios for the United States, 2017)

For the purpose of this study, the intermediate scenario was selected, and sea level rise values estimated from the curve on Figure 4. These estimated levels for this analysis are for preliminary planning purposes only. Continual evaluation of local relative sea level rise will be necessary when making long term planning decisions as more information becomes available and better projections become available.

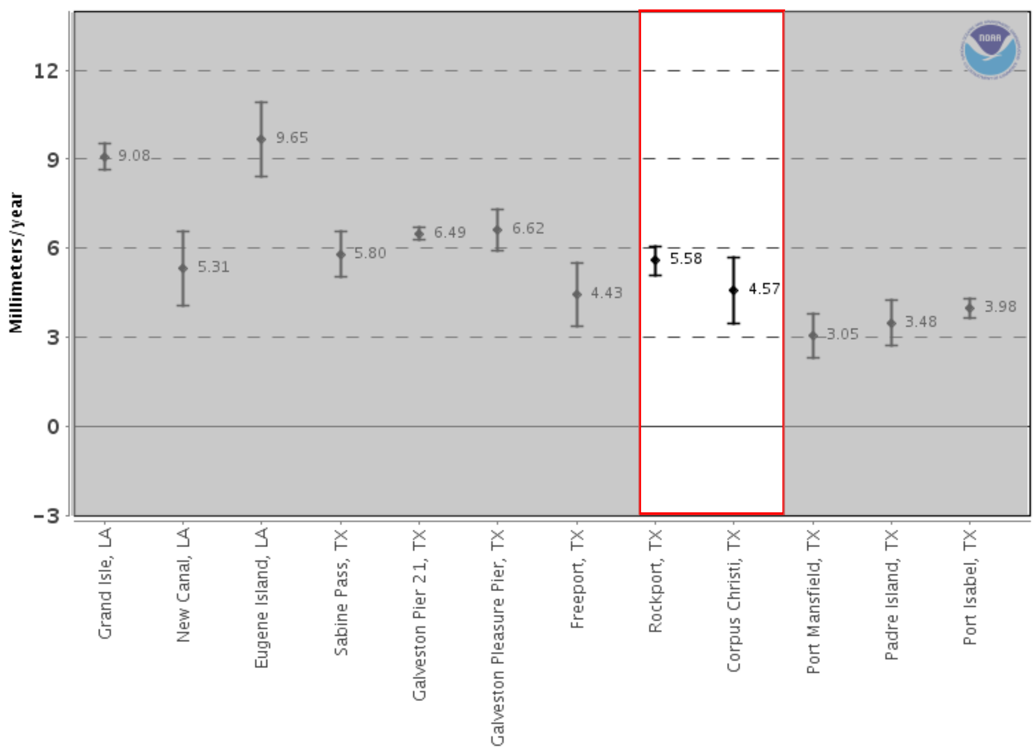

Figure 3. NOAA RSLR Trends for the Gulf of Mexico (NOAA, 2018c)

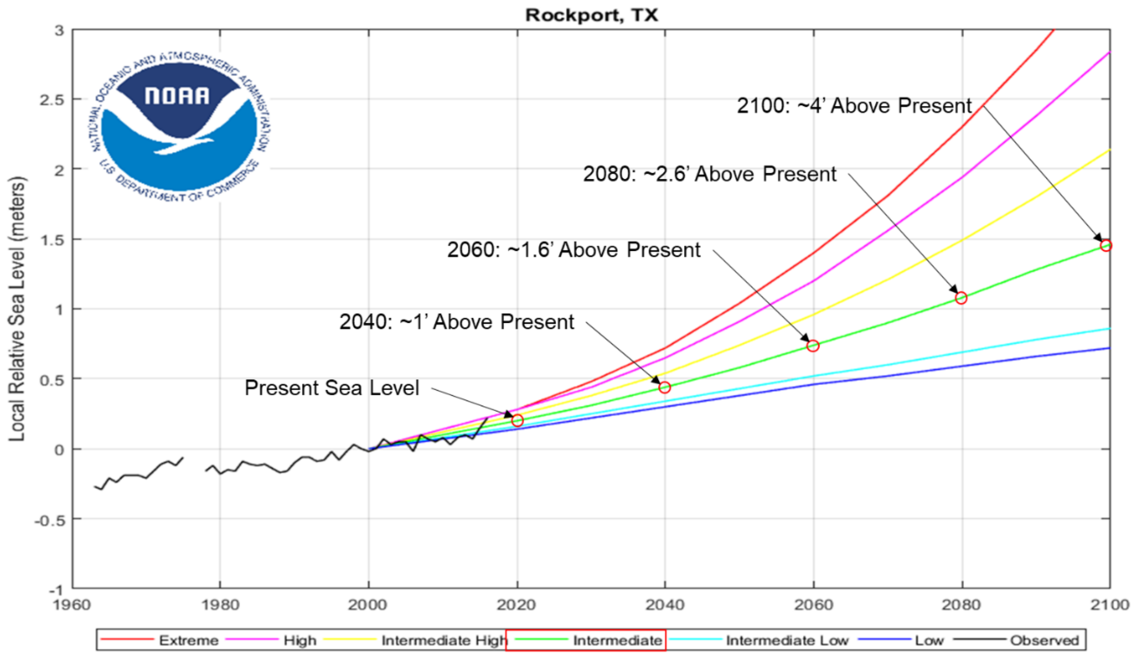

Figure 4. NOAA RSLR Projections for Rockport, TX (NOAA, 2018b)

4 RSLR Impacts to Ingleside on the Bay

4.1 Increasing Risks as Sea Level Rises

As sea levels rise, areas immediately become more vulnerable to extreme water level events and storms. Relative sea level rise often goes unnoticed along coastal communities until a storm event, such as Hurricane Harvey, impacts an area resulting in levels of damage not previously experienced or anticipated. This is the initial risk posed by RSLR that these communities face but are often not aware of. Every inch of sea level rise increases the vulnerability of a coastal community to extreme water level events and storms by allowing flood waters to progressively impact larger areas. The analysis below was conducted to demonstrate how rising sea levels increase this vulnerability for Ingleside on the Bay.

Per FEMA, the 100-year base flood elevation for Ingleside on the Bay is approximately +10 ft NAVD88 **(FEMA, 2019)**. With existing sea level there is a 0.01 percent chance in any given year of that water level being exceeded. As sea level rises the probability increases for inundation to that elevation. Table 3 below, lists the reduced return periods corresponding to elevation +10 ft NAVD88 for increments of sea level rise. This analysis shows that just 1 ft of sea level rise almost doubles the likelihood of exceedance of the +10 ft NAVD88 base flood elevation making that event twice as likely to occur on any given year.

Table 3. Return period storm event matching current FEMA 100-year water level for a given sea level rise increment

Sea Level Rise Amount (ft)	0	0.25	1	2	3	4	5	6	7	8
Return Period of Storm Tide Reaching Current 100-year Flood Level (+10 ft NAVD88)	100	90	60	34	17	8	3	1	<1	<<1

4.2 Flooding Extents

Currently, nuisance flooding within Ingleside on the Bay is increasing in frequency and severity due to RSLR. Water levels are exceeding the elevations of existing infrastructure and the shoreline causing more frequent flooding. Figure 5 shows areas along Ingleside below the present-day 1-year flood elevation in blue. These areas are highly likely to become flooded at that water level; they already experience frequent nuisance flooding and are currently most susceptible to flooding.

Figure 5. Map representing flood coverage in blue for the present-day 1-year event (2.9 ft NAVD88)

As sea levels rise, this flooding will continue to become more frequent and the extent of the flood coverage will increase. Table 4 shows the projected RSLR levels for the intermediate and high projections as well as the corresponding return period water level elevations for the projected intermediate relative sea level rise scenario. This also means that, over time, the 100-year flood elevation increases, resulting in flooding of areas that did not flood previously and extending the areas impacted by flooding.

Table 4. Projected sea level rise and future extremal water levels

Level	2020	2040	2060	2080	2100
Intermediate RSLR [ft]	0.0	1.0	1.6	2.6	4.0
High RSLR [ft]	0.0	1.3	3.3	5.6	8.2
1-year return period elevations with projected Intermediate RSLR [ft NAVD88]	2.9	3.9	4.5	5.5	6.9
5-year return period elevations with projected Intermediate RSLR [ft NAVD88]	4.1	5.1	5.7	6.7	8.1
10-year return period elevations with projected Intermediate RSLR [ft NAVD88]	4.8	5.8	6.4	7.4	8.8
20-year return period elevations with projected Intermediate RSLR [ft NAVD88]	5.8	6.8	7.4	8.4	9.8
50-year return period elevations with projected Intermediate RSLR [ft NAVD88]	7.2	8.2	9.0	9.8	11.2
100-year return period elevations with projected Intermediate RSLR [ft NAVD88]	10.0	11.0	11.6	12.6	14.0

The 1-year flood levels were then plotted spatially over a bathymetric surface representing the existing ground elevations along Ingleside on the Bay to identify areas that may begin to flood in the future. The figures below show the projected spatial flooding within Ingleside on the Bay for the 2040 through 2100 for a 1-year flooding event.

Figure 6. Map representing flood coverage in blue for the 2040 1-year flood event (+3.9 ft NAVD88)

Figure 7. Map representing flood coverage in blue for the 2060 1-year flood event (+4.5 ft NAVD88)

Figure 8. Map representing flood coverage in blue for the 2080 1-year flood event (+5.5 ft NAVD88)

Figure 9. Map representing flood coverage in blue for the 2100 1-year flood event (+6.9 ft NAVD88)

The figures highlight the areas most vulnerable to flooding and RSLR within the community. The figures also show that the extent of flooding does not vary substantially between 2040 and 2100. This indicates that the areas flooded are all at similar elevations (approximately below the +3.9 ft NAVD88 flood elevation). The steep bluff (McGloin's Bluff) at the landward side of the community helps to contain flooding to the lower lying properties along closer to the shoreline. This also indicates that the seaward facing properties, as expected, are most vulnerable to these RSLR impacts. Finally, once the coastal zone boundary shifts landward of these properties (i.e., these areas become permanently submerged) the land becomes property of the State of Texas per the Submerged Lands Act (NOAA, Submerged Lands Act, 2020).

4.3 Priority Zones

Utilizing these flood maps, three priority zones were identified and ranked relative to how soon the areas flood and the severity of flooding within each. Note that only physical parameters such as flood depth and density of development were considered when determining the severity; monetary parameters such as property values, house values, or facility importance was not considered. The priority zones identified are shown in Figure 10. These zones are color coded and numbered in terms of repair priority with Zone 1 being of highest priority needing immediate action to mitigate the effects of RSLR and existing nuisance flooding and Zone 3 being lowest priority as flooding has not yet become as severe as in the other zones.

Figure 10. Ingleside on the Bay RSLR mitigation priority zones

These priority zones represent locations where actions will need to be taken to address relative sea level rise in the near future. Zone 1 covers the southeast end of the community along Bayshore Drive, from Starlight Drive southeast up to the Brass Turtle. This is the lowest lying area within the community and is one of the areas currently most susceptible to flooding. Frequent flooding along Bayshore Drive has already been observed, especially along the Ingleside Beach Club and at the Brass Turtle. Based on the intermediate sea level rise projections, most of this area could become permanently submerged by 2060 if no action is taken to address present flooding and relative sea level rise.

The second priority zone is separated into two distinct areas. Zone 2A contains all properties along Bayshore Drive, from Starlight Drive up to the Bahia Marina as well as the properties along South Sandpiper Street and properties just north of Bayshore Drive, from Starlight Drive to the Brass Turtle. Several areas within this zone are already experiencing frequent nuisance flooding which is currently concentrated along Bayshore Drive, as this area is, on average, at a lower elevation than the surrounding properties. Drainage structures within this zone are frequently submerged during high tides. Figure 11 shows properties along South Sandpiper Drive which are so frequently submerged that mangroves and native marsh vegetation have started to grow at these locations. This vegetation is growing approximately 20 feet from Sandpiper Street, which is at a slightly higher elevation than the adjacent properties. While property lots within this zone are slightly higher than Zone 1, the roadways are generally low lying and if no action is taken, could become permanently submerged in most areas by 2060.

Figure 11. South Sandpiper Street property lots

Zone 2B consists of the Ingleside Boat Ramp and Ocean Drive. This zone is also extremely low lying and subject to frequent nuisance flooding but, since there are fewer properties in the area, the direct impact from flooding to the public is slightly less severe than Zone 2A.

Zone 3 encompasses the remaining properties within Ingleside on the Bay that would be impacted by RSLR before 2100. North Sandpiper Street and Woodhaven Drive are most vulnerable, as these roadways are also low lying and are already at risk of frequent nuisance flooding. In addition, the intersection between Post Oak Drive and Inglewood Drive was also identified as an area susceptible to nuisance flooding and RSLR. This area also happens to face Ingleside Cove and would become increasingly vulnerable due to erosion as sea levels rise and allow more wave energy and passing vessel wakes to impact and overtop the shoreline. Zone 3 also includes the private property just south of the boat ramp since part of that property will flood under higher water levels and with future sea level rise.

5 Funding Sources

Below is a brief summary of potential funding sources available in Texas for coastal restoration, flood impact mitigation, and sea level rise adaptation. While currently available, it is still unclear whether the Ingleside on the Bay community would be eligible to receive these types of funding sources.

5.1.1 GOMESA

The Gulf of Mexico Energy Security Act (GOMESA) was signed into law on December 20, 2006 (GOMESA, 2019). The act significantly enhances Outer Continental Shelf (OCS) oil and gas leasing activities and revenue sharing in the Gulf of Mexico. The act created revenue sharing provisions for the four Gulf of Mexico oil and gas producing states of Alabama, Mississippi, Louisiana, and Texas. In Texas, these revenues are shared with the state which then passes on these funds to all Texas coastal counties to be used for funding of coastal projects targeting the restoration of coastal damage from hurricanes and enhancing the resiliency of the Texas shoreline to prevent future threats. GOMESA funding is authorized for the following uses:

- Projects and activities for coastal protection, including conservation, coastal restoration, hurricane protection and infrastructure directly affected by coastal wetland losses;
- Mitigation of damage to fish, wildlife or natural resources;
- Implementation of federal approved marine, coastal or comprehensive conservation management plan;
- Mitigation of the impact of OCS activities through the funding of onshore infrastructure projects; and
- Planning assistance and administrative costs, not to exceed 3 percent of the amounts received.

In 2019, San Patricio County received $298,699.69 to be used to support restoration of the Texas shoreline. These funds have already been allocated to the County whom decides how to effectively utilize these funds. Since all alternatives discussed here would enhance the resiliency of Ingleside on the Bay, they are eligible to be funded through GOMESA. The use of these funds is at the discretion of San Patricio County; therefore, the County should be engaged early on and throughout the planning of these projects.

While the amount is typically not sufficient for major construction projects, this funding source can be used as match to other grants or can be used to fund the engineering design and development of construction documents for the preferred alternatives. Also, this funding is distributed to each county on an annual basis and is currently expected to increase in the coming years.

The State of Texas also has GOMESA funds that are currently being used to pay for all construction costs associated with CEPRA eligible projects including both Tier 1 and non-master plan projects. Projects would need to be vetted and approved through CEPRA for funding for this match to apply. GOMESA funds do not require a match. For more information regarding GOMESA please visit https://www.boem.gov/oil-gas-energy/energy-economics/gulf-mexico-energy-security-act-gomesa

5.1.1.1 Eligibility

As these funds are distributed to coastal counties, eligibility is decided by San Patricio County. This funding can be applied to any project activities focusing on coastal protection, preservation, restoration, hurricane protection, etc. at the discretion of the County. The proposed alternatives discussed herein would be applicable for these funds under the definitions provided by GOMESA, but final eligibility is determined by San Patricio County.

5.1.2 CEPRA

The Coastal Erosion Planning & Reponses Act (CEPRA) program is described by the Texas General Land Office (GLO) as follows:

> "The Coastal Erosion Planning & Response Act program was developed by the State of Texas to implement coastal erosion repose projects and to reduce the effects of and to understand the process of coastal erosion as it continues to threaten public beaches, natural resources, coastal development, public infrastructure, and public and private property.
>
> The CEPRA program provides funding on a biennial basis for the following types of projects and studies, with priority given to projects that include construction of an erosion response solution during the biennium." (Coastal Erosion Planning & Response Act, 2019)

CEPRA, in most cases, requires project partners to match funding for the shared project cost. A specified minimum percentage of the shared project cost is determined based on the project type. Funds from other sources can be used to offset the cost sharing requirement. CEPRA fund matching requirements are shown in Table 5.

Table 5. CEPRA project types and required match (Coastal Erosion Planning & Response Act, 2019)

Project Type	Minimum Partner Match Required
Beach nourishment and associated enhancement project on a public beach or bay shore.	Not less than 25%
Any other coastal erosion response study or project, including a marsh restoration project or a bay shoreline protection project other than a beach nourishment and associated enhancement project.	Not less than 40%
Each biennium, the Land Commissioner may undertake at least one erosion response project without requiring a match. This has limitations per TNRC, §33.603(f) & 31 TAC §15.42(e): the total of these may not exceed one-half of the amount appropriated to the GLO for coastal erosion planning and response.	None
Other projects per TNRC §33.603(h).	The Land Commissioner determines the percentage.

Demonstration projects. This has limitations TNRC, §33.603(g) & 31 TAC §15.42(d): the total of these may not exceed one-tenth of the appropriated amount to the GLO for coastal erosion planning and response.	The Land Commissioner determines the percentage
Tier 1 Master Plan Project	None (Tier 1 projects are "shovel ready", meaning that the engineering design and construction documents have been completed under prior phases)

For more information regarding CEPRA please visit glo.texas.gov/coast/grant-projects/funding/

5.1.2.1 Project Location Requirements

Any CEPRA actions must occur within the coastal zone boundary (CZB). The CZB was established by the Texas legislature in 1995.

Additionally:

- If the site to be studied or location of construction is within the jurisdiction of a local government subject to the Open Beaches Act (OBA) and Dune Protection Act (DPA), the local government must be adequately administering the OBA, the DPA and have submitted a local Erosion Response Plan (ERP) in accordance with TNRC, §33.607(e) and 31 TAC §15.17;
- All projects must protect the common law rights of the public in public beaches as affirmed by the Open Beaches Act (Natural Resource Code, Chapter 61);
- All projects must declare whether they would be located within a coastal area subject to a FEMA Hazard Mitigation Plan and would therefore be eligible for FEMA Public Assistance and Hazard Mitigation Grant Program funding consideration; and
- Any erosion response project conducted on state-owned submerged land will require a special document or surface lease.

5.1.2.2 Funding Categories

Erosion response projects and studies for which CEPRA funding may be used must address one of the following:

- Beach nourishment and associated enhancements on both Gulf-facing and bay shorelines;
- Shoreline stabilization;
- Habitat restoration and protection;
- Dune restoration;
- Beneficial uses of dredged material for beach nourishment or habitat restoration;
- Coastal erosion related studies and investigations;
- Demonstration projects;
- Relocation of structures from the public beach;
- Storm damage mitigation, post-storm damage assessments, and debris removal; or
- Acquisition of real property necessary to facilitate the construction, repair, maintenance, or expansion of an erosion response project.

5.1.2.3 Evaluation Requirements

The following general criteria are utilized by the GLO for evaluation and scoring of CEPRA projects:

- Feasibility and cost-effectiveness of the proposed project;
- The economic impacts of erosion in the area of the proposed project;
- The effect of the proposed project on public property, public infrastructure, private property, or natural resources threatened by erosion;
- The effect of the proposed project on Coastal Natural Resource Areas threatened by erosion;
- If the proposed project is to be located within the jurisdiction of a local government that administers a beach/dune program, whether the local government is adequately administering its duties under the Open Beaches Act (Texas Natural Resources Code, Chapter 61) and the Dune Protection Act (Texas Natural Resources Code, Chapter 63);
- If the proposed project is to be located within the jurisdiction of a local government that administers a beach/dune program, whether the local government has submitted to and received approval from the GLO of a local erosion response plan for reducing public expenditures due to erosion and storm damage losses established under Texas Natural Resources Code §33.607, pursuant to Texas Administrative Code §15.17(d)(4);
- Whether the proposed project will provide for beneficial use of beach-quality sand dredged in constructing and maintaining of navigation inlets and channels of the state;
- Whether the potential partner has leveraged other sources of funding and already made or received a binding commitment to fund all or a portion of a given proposed project type, and a description of potential co-sponsors and associated funding;
- If the proposed project is on a Gulf-facing beach, whether the erosion rate is greater than two feet a year, using data from the Bureau of Economic Geology's most recent data set. Currently, that is the period 1950 – 2012 https://coastal.beg.utexas.edu/shorelinechange2012/ ;
- If a proposed project involves construction or retrofitting of dams, jetties, groins or other structural impoundments, whether such structures will be designed with a sediment bypass system; and
- If a proposed project involves structural shoreline protection on or landward of a public beach, whether the proposed project uses innovative technologies designed to minimize beach scour in accordance with Texas Natural Resources Code §33.603(b)(14).

The general requirements evaluation criteria include the following:

- The relative severity of erosion in each area;
- Whether the project will enhance community resiliency;
- The needs in other critical coastal erosion areas;
- Whether the proposed project will maximize leveraging of federal and local financial participation;
- Whether financial participation by private beneficiaries of the proposed project is maximized;
- Whether the proposed project achieves efficiencies and economies of scale;
- Whether funding the proposed project will contribute to balance in geographic distribution of benefits for coastal erosion response projects in Texas that are proposed or have received funding from the Coastal Erosion Response Account;
- The economic benefits to the State relative to the State cost of the proposed project;

- The relationship of the proposed project cost to the funds available in the Coastal Erosion Response Account; and
- Whether the proposed project will address an emergency erosion situation in the area.

5.1.2.4 Eligibility

Any individuals or entities are eligible as potential project partners. The following lists examples of entities eligible for CEPRA funds per the GLO:

- Political subdivisions of the state, including cities, county governments, navigation districts, port authorities, river authorities, soil and water conservation districts, councils of government, and other regional governmental entities;
- Texas state agencies;
- Federal agencies;
- Institutions of higher education;
- Homeowner's associations; and
- Any public or private entity enters into an agreement with the GLO to finance, study, design, install or maintain an erosion response project.

While a project may be eligible, CEPRA scoring criteria and processes tend to benefit large scale coastal restoration response projects along publicly owned shorelines.

5.1.3 RESTORE

The Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE Act) established the Gulf Coast Ecosystem Restoration Council (Council) in July 2012. The RESTORE Act allocates 80 percent of all penalties related to the Deepwater Horizon oil spill to a Gulf Coast Restoration Trust fund to be utilized to restore and protect natural resources, ecosystems, marine wildlife habitats, beaches, coastal wetlands, and economy of the Gulf Coast region. (RESTORETHEGULF.ORG, 2019)

The Council oversees 60 percent of the funds available, 30 percent of which is administered for restoration projects identified in the Council's initial Comprehensive Plan. The remaining 30 percent is allocated to states under the Spill Impact Component.

The remaining 40 percent of funds are allocated as follows:

Two and a half (2.5) percent of the funds are allocated to the NOAA Science Component to carry out research, observation, and monitoring to support the long-term sustainability of the Gulf of Mexico.

Another 2.5 percent of the funds are allocated to a Centers of Excellence component dedicated to the Centers of Excellence Research Grants Program.

Thirty-five (35) percent of the funds are allocated to the direct component, which is divided equally among Florida, Alabama, Mississippi, Louisiana, and Texas for ecological and economic restoration. The following activities are eligible under the Direct Component:

- Restoration and protection of the natural resources, ecosystems, fisheries, marine and wildlife habitats, beaches and coastal wetlands.
- Mitigation damage to fish, wildlife, and natural resources
- Implementation of Federally approved marine, coastal, or comprehensive conservation management plan, including fisheries monitoring;

- Workforce development and job creation.
- Improvements to or on state parks located in coastal areas affected by the Deepwater Horizon oil spill;
- Infrastructure projects benefitting the economy or ecological resources, including port infrastructure;
- Coastal flood protection and related infrastructure;
- Planning and assistance;
- Promotion of tourism in the Gulf Coast Region, including promotion of recreational fishing;
- Promotion of the consumption of seafood harvested from the Gulf Coast Region; and
- Administrative costs.

More information regarding RESTORE can be found at https://www.restorethetexascoast.org/.

5.1.3.1 Eligibility

In Texas, the office of the Governor or an appointee to the office of the Governor, the TCEQ commissioner, and the Commission to Rebuild Texas (CRT) are responsible for selecting the projects to be funded through each RESTORE Bucket. While there is some potential for habitat restoration within Ingleside on the Bay, it is unlikely that the alternatives required to address sea level rise impacts within this community would be eligible for RESTORE funding.

5.1.4 CDBG-DR

Community Development Block Grant Disaster Recovery Program (CDBG-DR) is managed by the U.S. Department of Housing and Urban Development (HUD) to provide flexible grants to help cities, counties, and states recover from Presidentially declared disasters, especially in low-income areas. In order to be eligible for this type of funding, the activity must provide benefits to all area residents and at least 51 percent of the area residents must be low- to moderate-income persons. For more information regarding the CDGB-DR program please visit https://www.hudexchange.info/programs/cdbg-dr/.

5.1.4.1 Eligibility

Review of available census information through the HUD’s map tool indicates that the Ingleside on the Bay community is currently only approximately 22 percent low- to moderate-income (HUD, 2019); therefore, it is unlikely that a request for funding through this program would be approved at this time. (Community Development Block Grant Disaster Recovery Program, 2019)

5.1.5 CDBG-MIT

Community Development Block Grant Mitigation (CDBG-MIT) were allocated to Texas by the HUD for mitigation-related programs, projects, and planning in areas affected by Hurricane Harvey as well as the 2016 and 2015 floods. Approximately $3.1 billion have been allocated for infrastructure programs including the Coastal Resiliency program which provides funds for a combination of green/grey infrastructure, or nonstructural CDGB-MIT eligible projects identified in the Texas Coastal Master Plan in the Hurricane Harvey HUD Most Impacted and Distressed (MID) and State MID areas that enact long-term coastal resiliency. Counties, cities, navigation districts, port authorities, non-governmental organizations and state agencies are eligible to apply. Examples of projects include wetland protection, beach nourishment and dune restoration, regional infrastructure improvements, and oyster reef enhancements.

For more information regarding the CDGB-DR program please visit https://recovery.texas.gov/action-plans/mitigation-funding/index.html.

5.1.5.1 Eligibility

A summary of factors that impact eligibility is provided below:

- Does not require a "tie-back" to the specific qualified disaster;
- Meets the definition of mitigation activities;
- Addresses the current and future risk in the MID areas;
- Are CDGB-eligible activities:
  - Infrastructure: construction of risk reduction infrastructure or retrofitting existing infrastructure to increase resilience to disasters;
  - Housing: buyouts, residential retrofits, new construction;
  - Economic development: financing programs for commercial mitigation functions;
  - Planning and administration: developing building codes and land use plans, updating FEMA Hazard Mitigation Plans and risk-related mapping and data collection;
  - Matching funds: use of CDGB-MIT funds as match to other federal agency programs' state/local cost share;
- Meet a HUD national objective; and
- Project must benefit at least 50 percent low- to moderate-Income homes.

As previously mentioned, the Ingleside on The Bay Community is approximately only 22 percent low- to moderate-income, thus it is unlikely that this funding mechanism would be applicable to the Ingleside on the Bay community at this time.

6 RSLR Mitigation Alternatives

6.1 Introduction

In this section, several preliminary alternatives have been developed for addressing the projected impacts due to RSLR within Ingleside on the Bay. The preliminary alternatives discussed herein are for planning purposes only. The information provided is intended to be used to identify funding needs for the Ingleside on the Bay Community. The implementation of these options will depend on if and how quickly these projects are funded. Regardless of the construction alternatives, there are four items that should be considered when developing these RSLR response alternatives which include:

- Proactive Protection: Protecting coastal communities before storm damage occurs is more cost effective than repairing or replacing structures, facilities, and other assets after damage occurs from storms and flood events.
- Resilient Construction: Any new structures, homes, etc. constructed within the community need to be designed and constructed to be resilient to the expected storms and relative sea level rise impacts.
- Future-Proofing Communities: Building codes should account for future sea levels and storm impacts to help guide resilient construction within the community.
- Conservative Planning: Mitigation options will need to consider the risks of sea level rise and flooding and realistic financial plans should be developed to determine the benefits vs risk of each option considered.

The alternatives discussed within this report were developed based on what's necessary for mitigating the impacts from RSLR to existing properties along Ingleside on the Bay. Many of the solutions necessary will need to be implemented within private and public property encompassing these zones. Regardless of whichever alternative is selected as the preferred alternative, coordination with private property owners, the City of Ingleside on the Bay, and San Patricio County will be necessary in order to effectively implement these proposed solutions. The following report sections briefly describe the possible options for addressing current and future impacts from RSLR including coastal erosion, flooding, and damage to existing infrastructure. Cost estimates for the alternatives are preliminary and based on current (2020) local construction costs. Costs will vary depending on the final design alternative, time and construction, contractor availability, etc.

6.1.1 Coastal Protection

Several alternatives exist for stabilizing the shoreline and addressing the impacts from RSLR. The following sections describe several of the most common alternatives that provide coastal protection.

6.1.1.1 Bulkheads

The most common structural alternative is bulkheading. Bulkheads are presently implemented within Ingleside on the Bay and along other coastal communities.; however, these structures only serve as solutions for mitigation against RSLR impacts if they are designed and constructed to a proper elevation. Bulkheads are fixed structures built along a shoreline or canal to create a hard point past where a shoreline cannot erode. These structures are popular with waterfront homes as they provide unobstructed access and views to the water and provide a space to moor a boat. These structures can be constructed out of several materials such as timber, vinyl, fiberglass, concrete, or steel, but vinyl and concrete are the most popular amongst homeowners due to their relatively long design life and low maintenance costs. These types of structures typically have a useful life from 30 to 50 years. Most residential bulkheads are constructed by driving sheetpiles into the ground at the shoreline and then anchoring them in place using an anchor tieback system into the adjacent soil. The top of the wall is then capped, typically with concrete.

Bulkheads are relatively simple to construct on a vacant property before homes are built, but maintenance repairs can be difficult once homes are built along lots. Homes, patios, pools, or other structures are often built over the bulkhead's anchors and tiebacks which need to be accessed periodically for repair. Bulkhead maintenance and inspections are often overlooked, and issues go unnoticed until the structure becomes overtopped or begins to fail. Some alternatives for repairing these structures exist, but these become ineffective once the structure approaches the end of its useful life. The cost of replacing a bulkhead typically ranges between $2,000 and $3,000 per linear foot of structure constructed. Often the cost of replacing a bulkhead is too great for homeowners and these structures fall into disrepair. In order for this alternative to effectively mitigate the impacts from RSLR all bulkheads within the community must be above flood elevations. A single bulkhead that is too low can allow flood waters to enter the community, not only affecting the property where the bulkhead was constructed, but also affecting adjacent properties.

6.1.1.2 Revetments

Revetments are hardened structures constructed along a shoreline slope to stabilize the shoreline from erosion. These structures are particularly suited for higher wave energy environments, as they can effectively dissipate wave energy at the shoreline and limit overtopping when designed appropriately. These structures typically have a useful life between 25 and 50 years but can be repaired and retrofitted as necessary to extend the life of the structure. Revetments are often constructed using stone riprap since stone is durable in the marine environment and is relatively inexpensive, making it a cost-effective material. Other materials such as concrete and marine mattresses may also be used to construct revetments, but the lifespan, cost and maintenance requirements vary among the materials. Since revetments are sloped, these structures take up much more space along the shoreline than vertical structures, such as bulkheads. Therefore, revetments are generally not preferred where space is limited. Also, revetments may not be as aesthetically pleasing to the public due to their size.

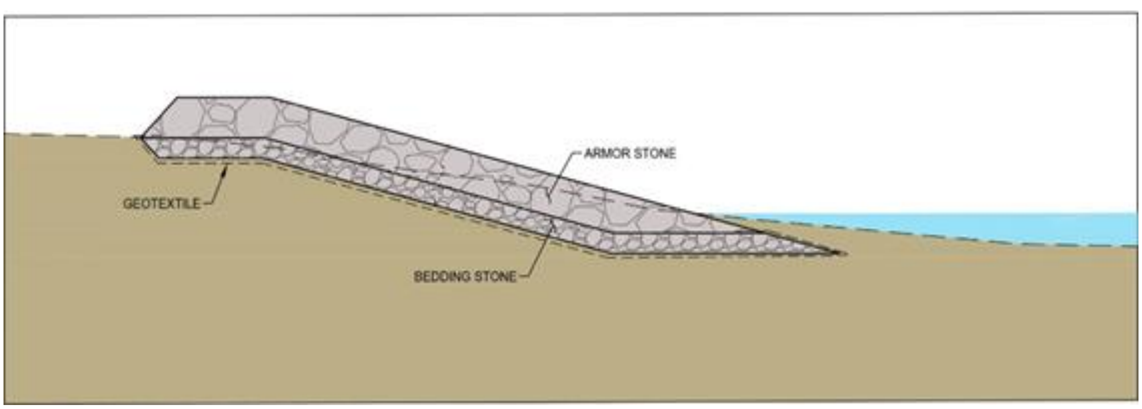

Figure 12. Typical revetment cross section

6.1.1.3 Living Shorelines

Living shorelines are hybrid solutions that utilize a combination of hardened structures and living vegetation to stabilize a shoreline. Often this is achieved by constructing small detached breakwaters seaward of the shoreline and planting local marsh plants or mangroves along the shoreline. The plants help retain soil along the shoreline as they dissipate wave energy and their roots hold the soil in place, allowing for a smaller hardened structure to be used. Vegetation can also adapt to rising sea levels as it captures new sediment and grows at higher elevations as the sea level rises. Furthermore, materials conducive to the growth of oysters can be incorporated in the structural design to promote oyster growth on the structure. Oyster reefs can also dissipate wave energy. Oysters increase the resilience of the structure by continually growing as sea levels rise, maintaining the structure crest just below mean sea level. Living shorelines also enhance the habitat where they are constructed, and their natural looks are more aesthetically pleasing than a hardened structure. Figure 13 provides a cross section of a typical living shoreline concept, featuring vegetation plantings along the shoreline and an offshore breakwater.

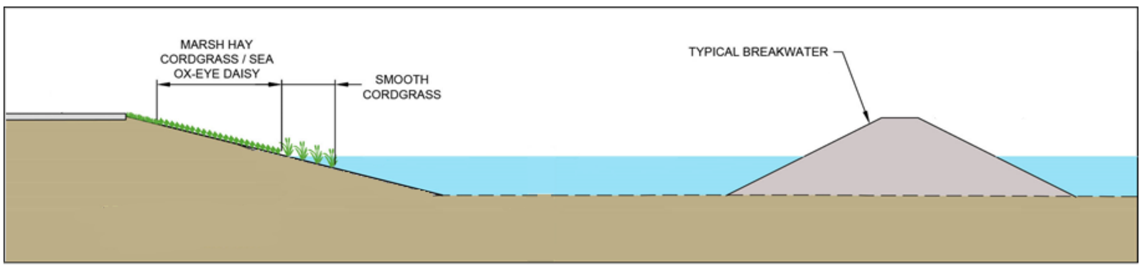

Figure 13. Typical living shoreline cross section

6.1.2 Infrastructure

Rising sea levels can wreak havoc on local infrastructure that is critical to a community. Drainage utilities are typically the first to be impacted by rising sea levels as, in coastal communities, most storm drains flow to the waterfront. As the sea level rises, flood waters begin to back up these drainage structures which then become pathways for rising waters to penetrate deeper into the upland area; this concept is demonstrated in Figure 14. Also, as these structures become backed up by rising sea levels, the entire community becomes more likely to flood and remain flooded since the pathways for floodwaters to recede become blocked (also demonstrated by Figure 14). In order for the community to adapt to rising seas, this infrastructure will need to be maintained and upgraded to keep rising seas from flooding the community while still effectively draining water from the uplands. The first step to improving this infrastructure is to evaluate the existing drainage features to determine the current condition, elevation, and performance of these utilities. Once this drainage study is completed, a complete infrastructure plan can be developed to determine the best approach to continually maintaining this infrastructure. Future changes to the community must also be considered when evaluating drainage because small changes to the ground or road elevations can significantly impact drainage effectiveness.

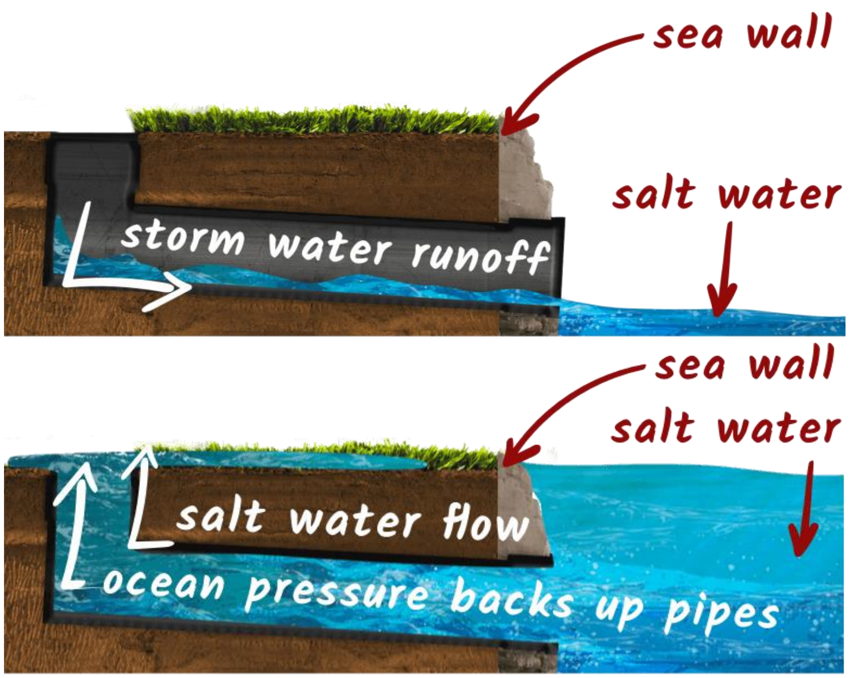

Figure 14. Hight tide impacts to drainage structures (Sea Level Rise.org, 2020)

Also vulnerable to RSLR, are the roadways within Ingleside on the Bay which are the critical arteries allowing homeowners to access their properties. As previously discussed, many roads within Ingleside on the Bay are already experiencing frequent flooding which is only expected to worsen. The only option in this case would be to raise these roadways as necessary to ensure that they remain above expected flood levels. This is critical, as these are the only access routes into and out of the community by land. Flooding will eventually make these routes impassable, potentially leaving homeowners without an adequate evacuation route. This is essentially critical during storm events when flooding is likely and when a property owner may need to quickly leave the area to evacuate to higher ground. Roadway raising can be done gradually overtime but can be costly to execute.

6.1.3 Buoyant Foundations

Buoyant foundations or amphibious architecture has been successfully employed in flood prone areas in Louisiana and Europe. Instead of attempting to overcome the continually rising water levels, these innovative structures adapt to the elevated water levels by transitioning from land-based to floating structures. This is done by retrofitting existing or constructing new buildings with buoyant foundations that allow the structure to float during flood conditions as shown in Figure 15.

Currently, buoyant foundation designs are not intended for coastal regions subject to wave action or high velocity flows, but more robust designs can be constructed at higher cost to account for these forces. Floating foundations have the added benefit of keeping the structure close to the ground which makes the structure less susceptible to wind damage than elevated homes. Finally, this type of construction is about half the cost of permanently elevating a home.

Figure 15. Buoyant foundations (Buoyant Foundation Project, 2020)

6.2 Priority Zones

As previously discussed, the Ingleside on the Bay community was subdivided into three distinct zones ranked in terms of flooding risks for each of those areas. Note that the zone boundaries shown on Figure 16 are approximate. These boundaries are based on the footprint of flooding per the previous analysis and are subject to change as new information becomes available.

Zone 1 is currently at highest risk of damages due to flooding impacts and RSLR and Zone 3 being the least at risk. Implementation of solutions for zones 1 and 2 should begin as soon as possible as flooding impacts are already occurring and beginning to become more frequent. Flooding in Zone 3 has not yet become as sever but as time passes impacts will become more severe and the cost of implementing a solution will only continue to increase.

Figure 16. Ingleside on the Bay RSLR mitigation priority zones

6.3 Do nothing

In order to properly evaluate mitigation alternatives, the consequences of not acting need to be considered to determine whether a project is truly feasible. The “do nothing” alternative was evaluated to determine what the ultimate cost would be for not acting. If no action is taken, the priority zones will begin to flood more frequently over time until the areas become fully flooded. Zone 1 is already experiencing frequent flooding and based on the relative sea level rise projections described previously, most of the area would become fully submerged as soon as 2050. Zone 2, on average is slightly higher, but low-lying areas are also frequently flooding including drainage structures along Bayshore Drive. This zone could be fully submerged as soon as 2055 per the possible RSLR projections. Finally, while Zone 3 is at a higher elevation, the area along the southern end of Woodhaven Drive is already susceptible to nuisance flooding during storm tide events. Frequency of flooding in this location is also increasing as sea levels continue to rise and this area could become permanently submerged by 2060 if nothing is done. Continually increasing damages from storms and regular flooding could render each zone inaccessible well before the zones become fully submerged.

There are several consequences to doing nothing. First and foremost is that the community is increasingly more vulnerable to future storm events. As sea level rises, these areas only become more vulnerable as less powerful storms continue to result in increasingly severe damage to homes and infrastructure. Damages from each storm would become more costly to repair after each event until repairs are no longer viable and the properties would need to be abandoned. How quickly this occurs would depend on the frequency of future storms, but current trends indicate that, due to climate change, extreme weather events are becoming more frequent further exacerbating the damages to the community.

As discussed, most of the shoreline along Ingleside on the Bay is stabilized by aging concrete capped bulkheads that are vulnerable to damage from storms and RSLR. These structures are most vulnerable as they are right at the land-water interface where they are directly affected by tides, flood events, and waves. If these structures are not maintained and upgraded as necessary, they will eventually fail, allowing wave energy and flood waters to reach the properties behind them. As these structures fails, land behind the structure is immediately lost due to the initial collapse and then continually lost due to erosion which can be further caused by waves, tides, and runoff from the uplands. On the bay facing properties, rapid erosion would be expected as these areas are exposed to more wave energy. Failure of bulkheads along the canals would eventually restrict navigation in these areas as material eroded from the properties would deposit in the canals. Erosion would continue in most areas, threatening the properties behind the bulkheads. Also, as the structures begin to fail, they lose effectiveness at serving as a barrier against the waterway, resulting in even more frequent and severe flooding of the upland properties.

Many properties along all zones would also become inaccessible by land as sea levels rise and the access roads become inaccessible due to constant flooding. Eventually, if nothing is done, homeowners will be forced to abandon their properties and relocate.

Based on San Patricio County Tax Appraisal information, all properties within the priority zones identified are worth a combined total of over $46 million. The approximate total property values for each priority zone are shown in Table 6.

Table 6. Ingleside Regional Property Values

Priority Zone	Approximate Total Property Value
Zone 1	$4,400,000
Zone 2	$27,900,000
Zone 3	$14,100,000

The loss of these property values represents the minimum potential cost of the do nothing alternative. These costs do not include the costs of lost infrastructure to the county including roadways, electrical, and telecommunications infrastructure. Nor does it include the costs to repair homes and infrastructure from increasing damage from future storms which could far exceed the total property values for all priority zones.

Furthermore, homeowners will be forced to bear part of these costs as the lost value of the properties cannot be fully revered. FEMA will currently pay for 75 percent of the cost of a home that has to be abandoned due to frequent flooding, but the remaining 25 percent of the cost is either borne by the local government or the property owners themselves which, based on current property appraisal values, would be on the order of $11.5 million.

Finally, there’s a loss of tax revenue for local government from the loss of these properties which would also be significant. In 2019, the median tax rate for San Patricio County on average is 1.76 percent of a property’s assessed fair market value. That is over $800,000 per year of tax revenue from the currently at-risk properties that could be lost if no action is taken. Table 7, below, shows the approximate property tax revenue breakdown for the properties within each priority zone.

Table 7. Priority Zone Approximate Annual Tax Revenue

Priority Zone	Approximate Annual Tax Revenue
Zone 1	$75,000
Zone 2	$475,000
Zone 3	$250,000

Another related alternative to be considered would be managed retreat, which involves the coordinated movement of homes away from the areas at risk to sea level rise. This could involve actually moving homes and infrastructure out of harm’s way, or (more realistically) involve the relocation of residents out of the community, removing homes and infrastructure, and restoring natural resources in the area to enhance the ecosystem and to provide protection from flooding to the properties that do not need to be relocated. While this concept is fairly simple, this option can be controversial as the community would need to decide which areas are worth protecting vs which areas are to be vacated. This option, as with the do nothing alternative, would ultimately result in the same losses of properties and property values, but, if executed properly would avoid the additional costs associated with future storms which would progressively result in greater damage to properties as sea levels rise.

6.4 Zone 1

6.4.1 Ingleside Beach Club

Specific alternatives were developed for the Ingleside Beach Club as most of the land owned by the club is extremely low lying and frequently experiences tidal flooding. The stretch of land between the beach club building and the Ingleside revetment is especially vulnerable and sees frequent flooding. The shoreline along that area is partially stabilized from erosion by the revetment and adjacent breakwater, but evidence of erosion, likely due to end effects from the revetment and overtopping from tidal flooding, is present along the shoreline.

The area where the beach club building facility is located is partially stabilized by a concrete-capped bulkhead. The property lot where the Ingleside Beach Club facility sits is at a slightly higher elevation than the surrounding area, but this area is still at risk of flood during extreme high tides. Preliminary alternative extents for the Ingleside Beach Club are shown in Figure 17.

Figure 17. Ingleside Beach Club alternatives

Primary focus should be on raising ground elevation of the beach club parcel lots and mitigating erosion of the shoreline to prevent future loss of land since, any land that becomes submerged below the present high tide line becomes property of the State of Texas and any construction at that point would require a USACE individual permit. Presently, filling of the beach club land can be completed without an individual permit since the area has not yet become permanently submerged. The area should be filled to the highest elevation practical to minimize any future filling events. Approximate estimates were developed for filling this area to +4 ft, +5 ft, and +7 ft NAVD88 (Table 8). A conservative fill cost of $20/CY was utilized in this estimate, but actual material costs will vary depending on the source of material and installation methods used. Various potential material sources are present in the area including adjacent privately and Port owned placement areas. Materials dredged from the adjacent La Quinta and Corpus Christi Ship Channels may also be beneficially used for this purpose.

Table 8. Preliminary shoreline fill cost estimates for the Ingleside Beach Club

Item	Quantity	Unit	Unit Cost	Total Cost	Minimum Life (No flooding up to 1-year event)
Shoreline Fill to +4	11,000	CY	$20	$220,000	2040
Shoreline Fill to +5	16,000	CY	$20	$320,000	2065
Shoreline Fill to +7	27,000	CY	$20	$540,000	2147

The beach club building would also eventually need to be raised in order to protect the structure from rising sea levels. An approximate cost estimate for raising the structure is included in Table 9. The cost is based on general national estimates for home raising relative to the size of the home. Actual costs will vary depending on the condition of the beach club building, elevation the building is raised to, building structure type, contractor availability, and the total square footage of the building. The square footage of the club was estimated based on property information and plan view measurements of the building from aerials. Depending on the condition of the building, it may be more cost effective to construct a new, more resilient facility on the property rather than raising the existing structure.

Table 9. Preliminary estimated costs for raising Ingleside Beach Club

Item	Quantity	Unit	Unit Cost	Total
Raise Beach Club above 100-year flood elevation	6,250	SF	$100	$625,000

In addition, the unprotected shoreline along the north end of the beach club property should be stabilized from future erosion. While the existing breakwater and revetment provide protection for this area, as sea levels continue to rise the breakwater structure will become frequently overtopped resulting in increasing wave energy reaching the shoreline, causing erosion of the beach club shoreline to accelerate. The existing breakwater is at an elevation of +5 ft MLT, which at current sea levels would be overtopped during an approximate 20-year return period water level or at lower water levels during high wave events. Based on the current sea level projections, this structure could become fully overtopped by a 1-year flooding event by 2070, but the reduced protection from the structure would become evident before this time as erosion would continue to increase as the structure freeboard is reduced. Future storm events could also accelerate erosion in this area causing part of the property to be lost. In order to prevent the future loss of this property, preliminary structural alternatives were developed to stabilize the exposed shoreline along the beach club. It was estimated that the structures would need to be approximately 450 ft in length in order to span the gap between the Ingleside revetment and the existing Beach Club Bulkhead. Table 10 shows the approximate costs for stabilizing the beach club shoreline.

Table 10. Ingleside Beach Club preliminary shoreline stabilization alternative cost estimates

Item	Quantity	Unit	Unit Cost	Total
New Bulkhead Along Beach Club Shoreline	450	LF	$2,500	$1,125,000
Extend Revetment	450	LF	$1,500	$675,000
Living Shoreline	450	LF	$1,000	$450,000
Beach Nourishment*	1,500	CY	$20	$30,000

** Beach Nourishment would need to be conducted at regularly scheduled intervals in perpetuity in order to be effective*

Another option to be considered would be for the periodic renourishment of that shoreline. Nourishments would need to be conducted at regularly scheduled intervals (typically on the order of 5-10 years) in perpetuity in order to effectively stabilize the shoreline. This option would be more sustainable, as fill can be added periodically to continually adapt to rising sea levels, but as the breakwater effectiveness is reduced over time, more frequent or larger fill events will be necessary to account for the increased erosion rates as well as raising of the breakwater once it becomes overwhelmed by RSLR. Special care will need to be taken during construction to ensure that this fill does not impact the adjacent seagrass. Strict turbidity control and monitoring measures would be necessary to ensure the seagrasses are not impacted by these fill activities. Finally, each the fill volume required per event will depend on the overall condition of the shoreline, for this analysis it was estimated that, at minimum, approximately 1,500 CY of material would be placed along the 450 LF of shoreline assuming a 2 ft thick and 45 ft wide profile is added to the beach during each event.

Each alternative will need to be further evaluated to determine the preferred option for protecting the Ingleside Beach Club. Regardless of the stabilization alternative chosen, the Beach club lot should be filled to at least an elevation of +5’ NAVD88 by 2040 before the lot becomes permanently submerged and the shoreline stabilized as soon as possible to prevent further loss of land.

6.4.2 Raising Bayshore Drive from the Brass Turtle to Starlight Dr

Raising Bayshore Drive will be critical for the future resilience of this community, as well as the homeowners along this stretch of roadway. Generally, this roadway is at an average elevation of +3 ft to +3.5 ft NAVD88, which makes it susceptible to flooding during extreme high-tide events. Even low levels of flooding may make the roadway inaccessible to first responders and/or homeowners. Figure 18 shows the approximate section of Bayshore Dr to be raised within Zone 1.

Figure 18. Zone 1 section of Bayshore Dr to be raised

Prior to raising the roadway, the proper design elevation must be selected based on the best benefit. Ideally the roadway would be raised to a maximum elevation necessary as gradual raising of the roadway would be much more costly long term. The roadway should be at an elevation which minimizes flooding throughout the design life of the roadway. Table 11 was developed to determine the minimum elevation necessary to ensure flooding does not occur below the 1-year return period water level along the roadway.

Table 11. Roadway raising elevations

Roadway Raising	2025	2030	2040	2045	2070	2120
Design life (no flooding at 1-yr flood event) [years]	5	10	20	25	50	100
Minimum Elevation [ft, NAVD88]	4’	4’	4’	5’	6’	8’
Elevation of FEMA 100-year Floodplain Intermediate SLR [ft, NAVD88]	10’	10’	11’	11’	12’	15’

The roadway should ultimately be raised above the 100-year flood elevation (+10 ft NAVD88) and maintained above that elevation as sea level rises to ensure the resilience of the community to future storms. This ensures access to the properties along Bayshore Drive is maintained, especially during extreme storm events, when first responders may need to access the area or homeowners may need to evacuate. The higher roadway will also act as a barrier, which will help protect properties behind the road from waves and surge during extreme storm events.

Approximate cost estimates for raising Bayshore Drive are shown in Table 12. Roadway raising costs do not include the costs associated with planning and design for the roadway work. Costs also do not include any necessary improvements/relocation of existing drainage structures. Upgrading of drainage utilities will be necessary as part of the roadway raising to ensure drainage is maintained. The costs in Table 12 are shown in incremental elevations for planning purposes, as raising of the road above the 100-year flood elevation would require drastic changes to adjacent infrastructure, private properties, and utilities. The cost associated with one-time construction efforts to raise the roadway to the various elevations are also provided in Table 13. Adjacent property lots and homes would need to eventually be raised along with the roadway in order to maintain proper drainage and access to those lots.

Table 12. Preliminary estimated costs for incrementally raising Bayshore Drive within Zone 1

Item	Quantity	Unit	Unit Cost	Total
Raise Bayshore Drive to +4 ft NAVD88	3,300	LF	$ 500	$ 1,650,000
Raise Bayshore Drive from +4 ft to +5 ft NAVD88	3,300	LF	$ 500	$ 1,650,000
Raise Bayshore Drive from +5 ft to +7 ft NAVD88	3,300	LF	$ 1,000	$ 3,300,000
Raise Bayshore Drive from +7 ft to +10 ft NAVD88	3,300	LF	$ 1,500	$ 4,950,000

Table 13. Preliminary estimated costs for one-time raising Bayshore Drive within Zone 1

Item	Quantity	Unit	Unit Cost	Total
Raise Bayshore Drive from existing to +4 ft NAVD88	3,300	LF	$ 500	$ 1,650,000
Raise Bayshore Drive from existing to +5 ft NAVD88	3,300	LF	$ 500	$ 3,300,000
Raise Bayshore Drive from existing to +7 ft NAVD88	3,300	LF	$ 1,000	$ 6,600,000
Raise Bayshore Drive from existing to +10 ft NAVD88	3,300	LF	$ 1,500	$ 11,550,000

While Table 12 shows costs associated with incremental raising and Table 13 shows costs associated with one-time raising, raising the roadway to that maximum elevation possible should be considered as this would be the most cost-effective solution long term since it minimizes redundant costs associated with a contractor mobilizing multiple times to the site. The final elevation selected will ultimately be limited by the funding available to construct the new roadway. Final roadway elevation will also depend on the implementation status of the other alternatives, especially the home raising and lot filling alternatives. If the roadway is raised to an elevation much higher than the adjacent homes, it could cause issues for homeowners attempting to access their properties or issues with drainage. Roadway raising to an elevation of +5' NAVD88 for Zone 1 should begin as soon as possible as nuisance flooding has already begun to impact this roadway. The roadway should then be raised to +6' NAVD88 by 2040 to ensure nuisance flooding is minimized up to 2070.

6.4.3 Zone 1 Private Property Alternatives

The following alternatives are proposed for protecting the private properties along Zone 1. The Zone 1 alternatives are shown in Figure 19 and discussed further in the following sections.

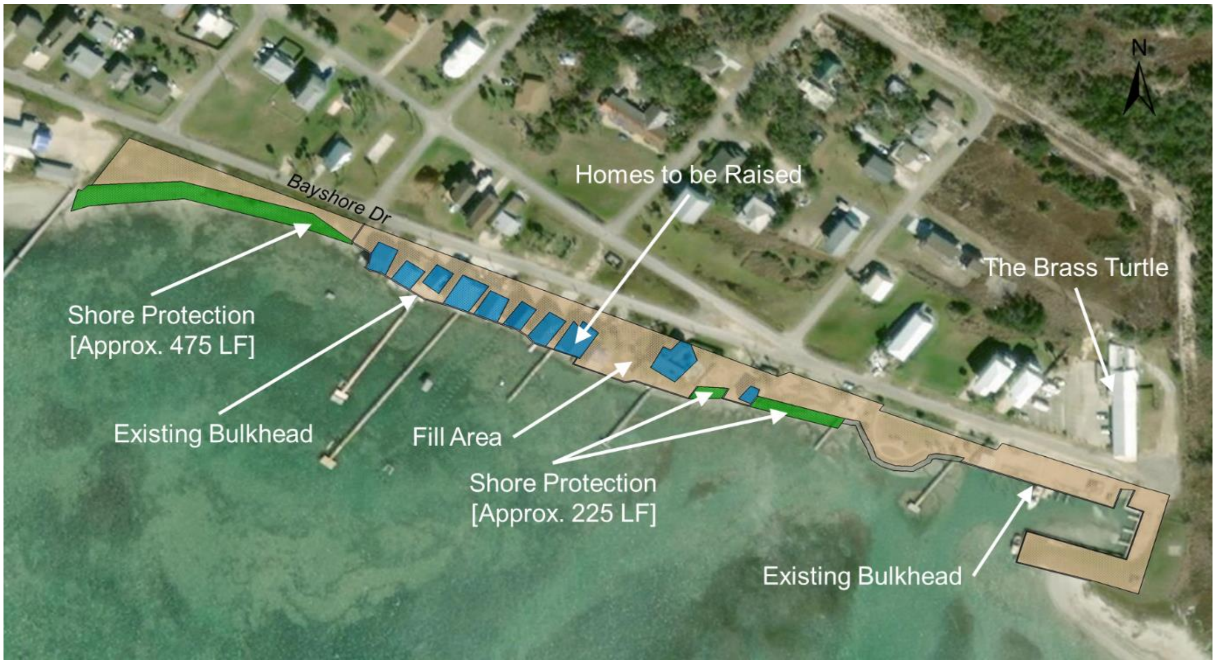

Figure 19. Zone 1 Alternatives for Private Properties

6.4.3.1 Raising Existing Bulkheads Along Bayshore Drive

There are approximately 10 seaward facing homes along Bayshore Drive where the shoreline is stabilized with bulkheads. There is also a bulkhead along the Brass Turtle shoreline. These bulkheads are close to becoming fully overtopped and will need to be raised to prevent flooding of the properties behind them. If the structures are older than 30 years old, homeowners should consider replacing the bulkheads, as raising of these older structures can often result in premature failure of the bulkhead. If a new bulkhead is constructed, the structure should be designed and constructed as necessary for the structure to remain effective throughout its design life, which is typically between 25 and 50 years. Freeboard should also be incorporated to minimize flooding behind the structure during high wave events. Table 14 shows the approximate minimum bulkhead cap elevation necessary to ensure flooding does not occur below a 1-year event at the end of the structure life. For example, if a bulkhead with a 50-year life is constructed along the shoreline today, it should be constructed to a minimum elevation of +6 ft NAVD88 or higher (equivalent to the approx. 2070 1-year flood elevation); additional freeboard should also be included to minimize overtopping due to waves or passing vessel surges. While overtopping of the structure should be minimized throughout its life, the structures do not need to be above the 100-year FEMA flood elevation, as the homes behind the bulkheads should be constructed above this elevation to avoid flooding during these extreme events. It is also more cost effective to build the home to a higher elevation than it is to construct a higher bulkhead as bulkhead construction tends to be much more costly than building a home. Bulkheads within this zone in poor condition or with cap elevations at or below +4’ NAVD88 should be raised as soon as possible.

Table 14. Example bulkhead raising elevations

Bulkhead Cap Elevations	2025	2030	2040	2045	2070	2120
Design life without flooding for events below 1-year return period water level [years]	5	10	20	25	50	100
Minimum Elevation [ft NAVD88]	4	4	4	5	6	8

Table 15 shows the approximate costs for raising all of the bulkheads within Zone 1. The unit costs assume that the structures would be replaced with a new higher structure meeting the necessary design elevation. These costs do not include engineering or other costs associated with the construction of these structures. Actual costs will vary depending on contractor availability and specific conditions at each property, and bulkhead cap elevation selected. Figure 20 shows a preliminary conceptual cross section for this alternative.

Table 15. Preliminary estimated costs for replacing and raising existing bulkheads within Zone 1

Item	Quantity	Unit	Unit Cost	Total
Replacing/Raising Existing Bulkheads	2,500	LF	$ 3,000	$ 7,500,000

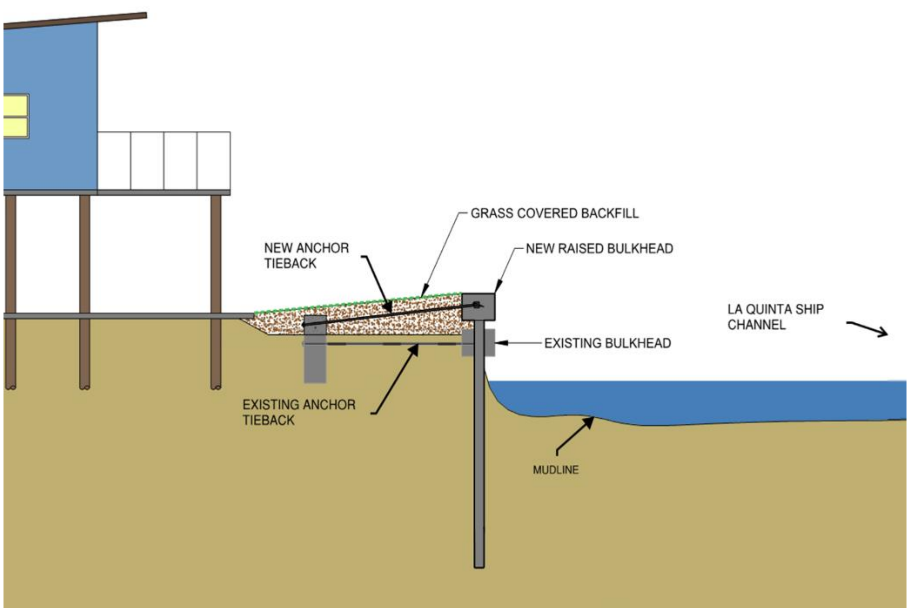

Figure 20. Conceptual design for replacing existing bulkheads

Economies of scale apply to bulkhead construction, meaning cost savings can be achieved if the full length of shoreline is constructed instead of individually replacing the bulkheads at each property, but this will require close collaboration between property owners to ensure agreements are in place for each owner to fund the replacement of their section of bulkhead. This approach has been successful in other coastal communities with bulkheads. Some communities have developed or hired organizations that manage the maintenance of bulkheads within the communities. Homeowners pay a recurring fee which is saved or utilized as necessary for the maintenance of the bulkheads. This system works well as the homeowners do not need to bear the cost of replacing a bulkhead when it fails and ensures that repairs are performed as necessary to ensure the community shoreline remains stabilized. The community also sees cost savings, as larger scale repairs can be completed at one time resulting in more competitive bids from contractors.

Often in communities where homeowners are required to maintain their bulkheads, structures tend to fall into disrepair as many homeowners do not consider the maintenance of their bulkhead when estimating homeownership costs or owners may unknowingly purchase a home with a failing bulkhead which they cannot afford to repair. Or homeowners will attempt to repair structures at the end of their design life which, at best have minimal benefit to the structure, and can in some cases accelerate failure of the crumbling bulkhead. Most often, the condition of these structures is ignored, and they continue to age until they collapse, and the property shoreline begins to erode. Once this land becomes permanently submerged it no longer belongs to the property owner resulting in further losses until eventually the home is lost and the lots become abandoned. This has already been observed throughout Zone 2, especially along South Sandpiper Street.

This system also complicates repairs because, often, original bulkheads are constructed continuously along the shoreline spanning multiple properties, thus when a homeowner repairs a section along their shoreline there's a risk the repair could cause the adjacent sections of the structure to fail or become weakened. This puts the homeowners at risk of further expense and costly legal battles, as adjacent owners could claim that this damage was a result of the repair.

Bulkheads within this zone will need to be raised on a case by case basis depending on the condition and elevation of the structure. Bulkheads within this zone in poor condition or with cap elevations at or below +4' NAVD88 should be raised as soon as possible to minimize flooding impacts.

Once the new, higher bulkheads are in place, the areas behind the bulkheads should also be raised to ensure proper future drainage of the lots. This fill can be added in gradually or all at once as necessary to keep water from pooling within these properties as the sea level rises. In addition to the negative effects to the property, seawater impounded behind a bulkhead could lead to accelerated corrosion, exacerbating the deterioration of the new structure. New bulkheads should be designed to accommodate this future fill to ensure that the additional loading from this fill does not result in damage or premature failure to the structures. The fill material will need to be properly graded and levelled as necessary to ensure proper drainage at the property and along Bayshore Drive. Filling of lots should coincide with the roadway raising to ensure proper drainage. Preliminary volume and cost estimates for filling these areas are provided in Table 16.

Table 16. Preliminary estimated costs for filling property lots within Zone 1

Item	Quantity	Unit	Unit Cost	Total
Fill lots to +4 ft NAVD88	21,000	CY	$20	$420,000
Fill lots to +5 ft NAVD88	35,000	CY	$20	$700,000
Fill lots to +7 ft NAVD88	63,000	CY	$20	$1,260,000

Eventually, homes will also need to be raised to ensure that they remain above the 100-year FEMA flood elevation. Preliminary estimated costs for raising the homes within Zone 1 are provided in Table 17. Actual costs will vary depending on the condition of each home, structure type, contractor availability, and the total square footage of the building. The total square footage was estimated based on property data found online through the website Zillow.com (Zillow, 2019). The total square footage does not include the Brass Turtle building, which is included under Zone 2.

Table 17. Preliminary estimated costs for raising homes within Zone 1

Item	Quantity	Unit	Unit Cost	Total
Raise all Homes above 100-year flood elevation	27,300	SF	$100	$2,730,000
Size and cost of average Home to be raised	1,900	SF	$100	$190,000

Any new homes to be built within the community should be constructed above the 100-year flood elevation, as this is required in order to obtain flood insurance by FEMA. However, homeowners should also consider the design life of the structure and account for anticipated sea level rise when constructing their homes, which may warrant constructing the houses at an elevation that exceeds the minimum requirement. Timelines for raising homes will need to be evaluated on a case by case basis.

6.4.3.2 Stabilizing Unprotected Sections of Shoreline

Finally, there are sections of shoreline within Zone 1 that are either not stabilized or currently stabilized utilizing non-engineered concrete riprap as shown in Figure 21. These unprotected sections of shoreline are highlighted by the green hatches in Figure 19. Those properties do not currently have any homes built on them, and if the shoreline in those areas is not stabilized, the shoreline will continue to erode until it reaches Bayshore Drive, which will lead to undermining and damage to the road. This erosion could also compromise adjacent bulkheads and allow flooding to circumvent the bulkhead structures, thus it is recommended that the shorelines at these locations be stabilized. Multiple options for stabilizing the shoreline at these locations are proposed including installation of bulkheads, construction of a living shoreline, or installation of an engineered stone riprap revetment. Preliminary cost estimates for constructing these options along all exposed sections of shoreline within Zone 1 are shown in Table 18.

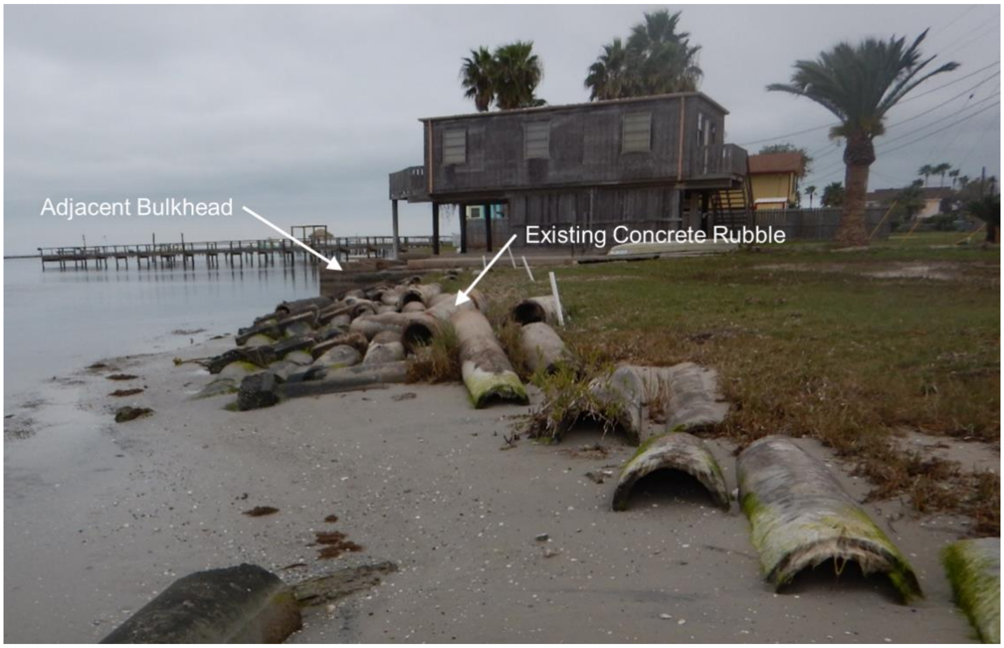

Figure 21. Existing concrete riprap along Zone 1 shoreline

Table 18. Zone 1 preliminary shoreline stabilization alternative cost estimates

Zone 1 Unprotected Shoreline Alternatives	Quantity	Unit	Unit Cost	Total
New Bulkhead Along Shoreline	700	LF	$3,000	$2,100,000
Living Shoreline	700	LF	$1,000	$700,000
New Revetment	700	LF	$1,100	$770,000

The stabilization alternative selected will depend on the specific location to be stabilized, budget available, and funding source. For private properties along this zone, bulkheads are typically preferred as their small footprint provides unhindered access to the shoreline which is typically more desirable to homeowners. These shorelines should be properly stabilized as soon as possible to avoid further erosion of the shoreline and loss of upland property.

6.5 Zone 2A

As discussed previously, Zone 2A contains all properties along Bayshore Drive from Starlight Drive up to the Bahia Marina as well as the properties along South Sandpiper Street and properties just north of Bayshore Drive from Starlight Drive to the Brass Turtle. Most properties in this Zone are adjacent to the water, and all have stabilized the shoreline utilizing bulkheads except for a select few properties along South Sandpiper Street where the bulkheads have collapsed due to their age. These areas are highlighted in green and labelled as “Shore Protection” on Figure 22 and were identified as areas to be stabilized using one of the proposed shoreline alternatives discussed in the following sections.

Figure 22. Zone 2A Alternatives

6.5.1 Raise all Roads within Zone 2A

As with Zone 1, the roadways within Zone 2A will need to be raised in the near future to prevent flooding of these vital evacuation routes. These roads are at an approximate average elevation of +3 ft NAVD88 and already experience frequent nuisance flooding.

Table 19 shows the approximate incremental costs for raising the roadways within Zone 2A. Roadway raising costs do not include the costs associated with planning and design for the roadway work. Costs also do not include any necessary improvements/relocation of existing drainage structures. Upgrading of drainage utilities will be necessary as part of the roadway raising to ensure drainage is maintained. The costs are shown in incremental elevations for planning purposes as raising of the road above the 100-year flood elevation would require drastic changes to adjacent infrastructure, private properties, and utilities. For comparison purposes, costs associated with one-time raising efforts for the various elevations are provided in Table 20. Adjacent property lots and homes would need to eventually be raised to along with the roadway in order to maintain proper drainage and access to those lots.

Table 19. Preliminary estimated costs for incrementally raising Bayshore Drive within Zone 2A

Item	Quantity	Unit	Unit Cost	Total
Raise All Roads in Zone 2 from +3 ft to +4 ft NAVD88	5,100	LF	$500	$2,550,000
Raise All Roads in Zone 2 from +4 ft to +5 ft NAVD88	5,100	LF	$500	$2,550,000
Raise All Roads in Zone 2 from +5 ft to +7 ft NAVD88	5,100	LF	$1,000	$5,100,000
Raise All Roads in Zone 2 from +7 ft to +10 ft NAVD88	5,100	LF	$1,500	$7,650,000

Table 20. Preliminary estimated costs for one-time raising Bayshore Drive within zone 2A.

Item	Quantity	Unit	Unit Cost	Total
Raise All Roads in Zone 2 from existing to +4 ft NAVD88	5,100	LF	$500	$2,550,000
Raise All Roads in Zone 2 from existing to +5 ft NAVD88	5,100	LF	$500	$5,100,000
Raise All Roads in Zone 2 from existing to +7 ft NAVD88	5,100	LF	$1,000	$10,200,000
Raise All Roads in Zone 2 from existing to +10 ft NAVD88	5,100	LF	$1,500	$17,850,000

As with Zone 1, the appropriate design elevation must be selected for the roadways within this zone to minimize flooding throughout the roadway design life. The ultimate goal would be to raise these roadways above the 100-year flood elevation (currently approximately +10 ft NAVD88) . Also, Roadway raising to an elevation of +5' NAVD88 for Zone 2A should begin as soon as possible as nuisance flooding has already begun to impact this roadway. The roadway should then be raised to +6' NAVD88 by 2040 to ensure nuisance flooding is minimized up to 2070.

6.5.2 Raise All Bulkheads within Zone 2A

Most of the Zone 2A shoreline is stabilized using bulkheads, thus this option is most critical to the resilience of this zone from flooding. Many bulkheads within this zone appear to be at the end of their design life, and some have already failed resulting in sections of unprotected shoreline in this zone. When homeowners are considering replacing their bulkheads, they should ensure to build them with caps well above the existing structures in order to ensure the structure has sufficient freeboard throughout its useful life between 30 and 50 years. Table 21 shows the approximate estimated cost of replacing all of the bulkheads within Zone 2A. This estimate assumes that each homeowner would replace their bulkheads as needed, but costs could be greatly reduced if homeowners are able to coordinate construction with their neighbors, because typically the unit costs are reduced for longer lengths of bulkheads to be constructed.

Table 21. Preliminary estimated costs for replacing and raising existing bulkheads within Zone 2A

Item	Quantity	Unit	Unit Cost	Total
Replacing/Raising Existing Bulkheads	7,500	LF	$ 3,000	$ 22,500,000

Bulkheads should be raised and or replaced on a case by case basis to ensure proper freeboard is maintained. Bulkheads within this zone in poor condition or with cap elevations at or below +4' NAVD88 should be raised as soon as possible.

6.5.3 Raising Homes and Lots within Zone 2A

Table 22 shows the total approximate estimated costs for raising homes within Zone 2A. The second row shows the approximate cost per house to raise homes based on the average square footage of homes within the zone. As with the other zones, raising of the homes would be necessary to ensure they are above the 100-year FEMA flood elevation.

Table 22. Preliminary estimated costs for raising homes within Zone 2A

Item	Quantity	Unit	Unit Cost	Total
Raise Homes above 100-year flood elevation	164,000	SF	$100	$ 16,400,000
Size and cost of average Home to be raised	1,750	SF	$100	$175,000

Table 23, below shows the preliminary costs for raising the lots within zone 2A. Raising of these property lots should coincide with raising of the roadways to ensure proper drainage is maintained.

Table 23. Preliminary estimated costs for filling property lots within Zone 2A

Item	Quantity	Unit	Unit Cost	Total
Fill lots to +4 ft NAVD88	33,000	CY	$20	$420,000
Fill lots to +5 ft NAVD88	72,000	CY	$20	$700,000
Fill lots to +7 ft NAVD88	165,000	CY	$20	1,260,000

6.5.4 Stabilizing Unprotected Sections of Shoreline

There’s a 115 ft long section of shoreline along South Sandpiper Street where the bulkheads have collapsed into the adjacent canal, causing a loss of elevation and material from the lots behind the structure. This area has become so low lying that it has now been inhabited by mangroves, which are protected coastal vegetation, as can be seen in Figure 23.

Figure 23. Exposed shoreline along South Sandpiper Street.

Due to the presence of mangroves and the proximity of the shoreline to the roadway, alternatives for stabilizing the shoreline in this area are limited. A new bulkhead would stabilize the shoreline but would need to be constructed in a manner that does not impact the mangroves, otherwise mitigation of this vegetation may be necessary. This area could be stabilized utilizing living shoreline with armoring along the slope to protect vegetation behind it, but space is limited, and this would further render these lots unusable. Finally, a revetment could be constructed along this area, but it would also impact vegetation and, due to the limited space, would also render a portion of those lots unusable.

The second section of exposed shoreline within this zone consists of an approximately 45 ft gap along the shoreline at the very northeastern end of Bayshore Drive within the Bahia Marina property. It appears that this shoreline may have been previously stabilized with a bulkhead that has collapsed. While erosion at this area does not currently threaten adjacent infrastructure, erosion of the shoreline will continue to result in shoaling of the adjacent canal and threaten the adjacent bulkheads. Because of the short span and limited space, construction of a new bulkhead along this section of shoreline is recommended.

Table 24 below, shows the preliminary cost estimates for the three options for stabilizing both sections of exposed shoreline within Zone 2A. As mentioned previously, due to the length of these shorelines, a new bulkhead would be the preferred alternative for these shorelines. This new bulkhead should be installed as soon as possible to prevent further erosion of the shoreline and undermining of the adjacent roadway.

Table 24. Zone 2A preliminary shoreline stabilization alternative cost estimates

Zone 2A Unprotected Shoreline Alternatives	Quantity	Unit	Unit Cost	Total
New Bulkhead Along Shoreline	160	LF	$3,000	$480,000
Living Shoreline	160	LF	$1,000	$160,000
New Revetment	160	LF	$1,500	$240,000

6.6 Zone 2B

As previously mentioned, Zone 2B consists of the Ingleside Boat Ramp and adjacent Ocean Drive as shown in Figure 24. This area is equally low lying as Zone 2A and is already experiencing frequent nuisance flooding. There is approximately 250 LF of exposed shoreline along the south end of this zone, followed by an approximately 350 LF of bulkhead which stabilizes the shoreline along the boat ramp parking lot. Finally, the boat ramp parking lot and Ocean Road are equally low lying and will need to be raised in order to prevent future flooding. There is also a small drainage area just northeast of the boat ramp parking lot that drains towards Ingleside Bay. This area has already become permanently submerged, resulting in local marsh vegetation starting to grow in this area. Due to the sensitive nature of that vegetation and the topography, this area can be left in place in order to avoid disturbing the marsh habitat. Alternatives for this area include stabilizing the exposed section of shoreline, raising the boat ramp bulkhead and parking lot, and raising Ocean Road.

Figure 24. Zone 2B Alternatives

6.6.1 Zone 2B Shoreline Alternatives

Prior to raising the boat ramp parking lot, the existing bulkhead will need to be replaced with a higher crest elevation, as this structure is extremely low and subject to frequent nuisance flooding. The estimated costs for raising this bulkhead is provided in Table 25, which assumes that the structure would be replaced in its entirety in order to be properly raised. Further evaluation of the bulkhead elevation and condition will be necessary, based on the current SLR projections, raising of this bulkhead will need to occur by 2040.

Table 25. Preliminary estimated costs for replacing and raising existing bulkhead within Zone 2B

Zone 2B Raising Bulkheads	Quantity	Unit	Unit Cost	Total
Replacing/Raising Existing Bulkheads	350	LF	$3,000	$1,050,000

There is also approximately 250 LF of unprotected shoreline in this zone that would require stabilization to mitigate future sea level impacts. This can be done either by constructing a new bulkhead, living shoreline, or revetment along this shoreline. Table 26 below shows the preliminary cost estimates for stabilizing this portion of exposed shoreline.

Table 26. Zone 2B preliminary shoreline stabilization alternative cost estimates

Zone 2B Unprotected Shoreline Alternatives	Quantity	Unit	Unit Cost	Total
New Bulkhead Along Shoreline	250	LF	$3,000	$750,000
Living Shoreline	250	LF	$1,000	$250,000
New Revetment	250	LF	$1,500	$375,000

6.6.2 Raise Boat Ramp Parking Lot and Ocean Drive

Following raising of the bulkhead, the boat ramp parking lot and Ocean Drive should also be raised in order to mitigate the effects of RSLR. Incremental estimates for raising these areas are shown in Table 27 and Table 28 below. For comparison purposes, costs associated with one-time raising are provided in Table 29 and Table 30 for the parking lot and roadway, respectively. Raising of the parking lot and roadway should take place by the year 2040 to prevent permanent flooding of this infrastructure.

Table 27. Preliminary estimated costs for incrementally raising the boat ramp parking lot within Zone 2B

Zone 2B Parking Lot Alternatives	Quantity	Unit	Unit Cost	Total
Raise Parking Lot from +3 ft to +4 ft NAVD88	50,265	SF	$1	$50,265
Raise Parking Lot from +4 ft to +5 ft NAVD88	50,265	SF	$1	$50,265
Raise Parking Lot from +5 ft to +7 ft NAVD88	50,265	SF	$2	$100,530
Raise Parking Lot from +7 ft to +10 ft NAVD88	50,265	SF	$3	$150,795

Table 28. Preliminary estimated costs for incremental raising of Ocean Drive within Zone 2B

Zone 2B Roadway Alternatives	Quantity	Unit	Unit Cost	Total
Raise Ocean St from +3 ft to +4 ft NAVD88	350	LF	$500	$175,000
Raise Ocean St from +4 ft to +5 ft NAVD88	350	LF	$500	$175,000
Raise Ocean St from +5 ft to +7 ft NAVD88	350	LF	$1,000	$350,000

Zone 2B Roadway Alternatives	Quantity	Unit	Unit Cost	Total
Raise Ocean St from +7 ft to +10 ft NAVD8	350	LF	$1,500	$525,000

Table 29. Preliminary estimated costs for one-time raising of the boat ramp parking lot within Zone 2B

Zone 2B Parking Lot Alternatives	Quantity	Unit	Unit Cost	Total
Raise Parking Lot from existing to +4 ft NAVD88	50,265	SF	$1	$50,265
Raise Parking Lot from existing to +5 ft NAVD88	50,265	SF	$1	$100,530
Raise Parking Lot from existing to +7 ft NAVD88	50,265	SF	$2	$201,060
Raise Parking Lot from existing to +10 ft NAVD88	50,265	SF	$3	$351,855

Table 30. Preliminary estimated costs for one-time raising of Ocean Drive within Zone 2B.

Zone 2B Roadway Alternatives	Quantity	Unit	Unit Cost	Total
Raise Ocean St from existing to +4 ft NAVD88	350	LF	$500	$175,000
Raise Ocean St from existing to +5 ft NAVD88	350	LF	$500	$350,000
Raise Ocean St from existing to +7 ft NAVD88	350	LF	$1,000	$700,000
Raise Ocean St from existing to +10 ft NAVD8	350	LF	$1,500	$1,225,000

6.7 Zone 3

As previously discussed, Zone 3 is most elevated of the three zones, but there are some critical areas at risk for impacts from RSLR, as shown in Figure 25. All bulkheads within this zone are equally susceptible as those within the other zones discussed. Also, as these structures are likely the same age as the bulkheads within the other zones, the same issues related to repair, replacement, and constructability apply to this zone as well. Apart from the bulkheads, there is a section of unprotected shoreline at the confluence of Inglewood Drive and Post Oak Street that, if not stabilized could result in the undermining and collapse of the adjacent roadway. Finally, there are low lying sections of North Sandpiper Street, Live Oak Street, Woodhaven Drive, Post

Oak Street, and Inglewood Drive that will flood during extreme storm events and will see more frequent flooding as the sea level rises.

Figure 25. Zone 3 Alternatives

6.7.1 Raise All Bulkheads within Zone 3

There are approximately 4,130 LF of bulkheads within this zone, all with cap crest at varying elevations. As with the other zones, these bulkheads are the first line of defense against rising sea levels and will need to be replaced, raised and maintained as necessary to ensure the shoreline remains stabilized in this area. Approximate cost estimates for raising the bulkheads within this zone are shown in Table 31, which assume full replacement of the bulkheads.

Table 31. Preliminary estimated costs for replacing and raising existing bulkheads within Zone 3

Zone 3 Shoreline Alternatives	Quantity	Unit	Unit Cost	Total
Replacing/Raising Existing Bulkheads	4,130	LF	$3,000	$12,390,000

Bulkheads should be raised and or replaced on a case by case basis to ensure proper freeboard is maintained, but because the lots in this area quickly slope up to higher elevations, raising of the bulkheads in this area is currently not as critical as it is for Zone 1 and 2.

6.7.2 Raise Roadways Identified

As with the other zones, the roadways identified within Zone 3 should also be raised to account for rising sea levels and ultimately should be maintained to ensure that they remain above the FEMA 100-year flood elevation. Table 32 shows the approximate incremental cost estimates for raising these sections of roadway. Table 33 provides the approximate costs associated with one-time construction efforts to raise the roadway to the various elevations.

Table 32. Preliminary estimated costs for incrementally raising Bayshore Drive within Zone 3

Zone 3 Roadway Alternatives	Quantity	Unit	Unit Cost	Total
Raise Roads Identified from +3 ft to +4 ft NAVD88	1,875	LF	$ 500	$937,500
Raise Roads Identified from +4 ft to +5 ft NAVD88	1,875	LF	$500	$937,500
Raise Roads Identified from +5 ft to +7 ft NAVD88	1,875	LF	$1,000	$1,875,000
Raise Roads Identified from +7 ft to +10 ft NAVD88	1,875	LF	$1,500	$2,812,500

Table 33. Preliminary estimated costs for one-time raising of Bayshore Drive within Zone 3.

Zone 3 Roadway Alternatives	Quantity	Unit	Unit Cost	Total
Raise Roads Identified from existing to +4 ft NAVD88	1,875	LF	$500	$937,500
Raise Roads Identified from existing to +5 ft NAVD88	1,875	LF	$500	$1,875,000
Raise Roads Identified from existing to +7 ft NAVD88	1,875	LF	$1,000	$3,750,000
Raise Roads Identified from existing to +10 ft NAVD88	1,875	LF	$1,500	$6,562,500

Raising of these sections of roadways should begin by the year 2040.

6.7.3 Stabilizing Unprotected Sections of Shoreline

There are two sections unprotected shoreline within this zone. The first is on approximately 62 ft of waterfront shoreline at 318 North Sandpiper Drive. It is unclear whether a bulkhead had been previously constructed along this section, but it is likely. While there is no home currently on the property, if this shoreline remains unprotected, erosion will continue. As material continues to erode, it will continue to deposit in the adjacent canal, restricting navigation, as well as resulting in further loss of the property. Excessive erosion of this shoreline will also result in future losses to adjacent properties as the shoreline erodes past the end of the bulkhead wing wall. This has already started to occur at this location, which can be seen in Figure 26.

Figure 26. 318 North Sandpiper Drive Shoreline

The second section of unprotected shoreline within this zone is at the confluence of Inglewood Drive and Post Oak Drive as shown in Figure 27. This location is particularly vulnerable to impacts from RSLR and erosion as it is less protected from incoming waves and passing vessel wakes. Also, the roadway is close enough to the shoreline where further erosion of the shoreline threatens to collapse the roadway at this location. The shoreline itself is currently partially stabilized by local marsh vegetation that has grown in that location. Eventually, as sea levels continue to rise, the vegetation will be pushed to higher elevations until it becomes submerged and can no longer survive at that location. Also, more wave energy will continually reach the shoreline, affecting the remaining vegetation and accelerating erosion. This shoreline needs to be stabilized before this occurs and the roadway becomes undermined. Due to the existing vegetation and bathymetry at this location, a living shoreline would be preferred as both other options (bulkhead/revetment) would require mitigation of the existing marsh vegetation in order to be constructed. The living shoreline option would enhance and protect the existing habitat while stabilizing the shoreline.

Figure 27. Unprotected shoreline adjacent to Post Oak Street and Inglewood Drive (Source: Google Earth)

Table 34. Zone 3 preliminary shoreline stabilization alternative cost estimates

Zone 3 Unprotected Shoreline Alternatives	Quantity	Unit	Unit Cost	Total
New Bulkhead Along Shoreline	455	LF	$3,000	$1,365,000
Living Shoreline	455	LF	$1,000	$455,000
New Revetment	455	LF	$1,500	$682,500

Shorelines along private property lots should be stabilized as soon as possible to prevent further erosion of the adjacent properties. Marsh grass along the shoreline adjacent to Post Oak Street and Inglewood drive has been steadily eroding, a living shoreline should be constructed in this location as soon as possible to prevent further loss of valuable marsh and undermining of the adjacent roadway.

6.8 Alternative Development Summary

The preliminary alternatives and cost estimates presented in the previous sections were developed for preliminary planning purposes only. Conservative costs were developed to help establish the scope of work to be conducted as necessary to improve the resilience of the Ingleside on the Bay Community. These estimates are intentionally conservative and incomplete as they are only intended to generally quantify the scope of the work to be conducted. Table 35 summarizes all discussed alternatives, costs, and approximate project useful lifetimes for each zone as discussed in the previous sections. The project life and end of life years were estimated based on the typical useful life of such projects as well as on the estimated RSLR rates for Ingleside on the Bay.

Table 35. RSLR response alternatives summary table

Alternative	Approximate Cost	Project Service Life	End of Project Life Year
Zone 1 Ingleside Beach Club Upland Alternatives			
Shoreline Fill at Ingleside Beach Club to +4 ft NAVD88	$ 220,000	10-20 years	2040
Shoreline Fill at Ingleside Beach Club to +5 ft NAVD88	$ 320,000	35-45 years	2065
Shoreline Fill at Ingleside Beach Club to +7 ft NAVD88	$ 540,000	>50 years	>2100
Raise Beach Club above 100-year flood elevation	$625,000	>50 years	>2100
Zone 1 Ingleside Beach Club Shoreline Alternatives			
New Bulkhead Along Beach Club Shoreline	$1,125,000	30-50 years	2070
Extend Revetment	$675,000	30-50 years	2070
Living Shoreline	$450,000	20-30 years	2050
Beach Nourishment	$30,000	5-10 years	2030
Zone 1 Roadway Alternatives			
Raise Bayshore Drive to +4 ft NAVD88	$1,650,000	10-20 years	2040
Raise Bayshore Drive to +5 ft NAVD88	$3,300,000	25-35 years	2055
Raise Bayshore Drive to +7 ft NAVD88	$6,600,000	40-50 years	2070
Raise Bayshore Drive to +10 ft NAVD88	$ 11,550,000	>50 years	>2100
Zone 1 Shoreline Alternatives			
Replacing/Raising Existing Bulkheads	$7,500,000	30-50 years	2070
New Bulkhead Along Unprotected Shoreline	$2,100,000	30-50 years	2070
Living Shoreline	$700,000	20-30 years	2050
New Revetment	$770,000	30-50 years	2070
Zone 1 Upland Alternatives			
Fill property lots to +4 ft NAVD88	$420,000	10-20 years	2040
Fill property lots to +5 ft NAVD88	$700,000	35-45 years	2065
Fill property lots to +7 ft NAVD88	$1,260,000	>50 years	>2100
Raise Homes above 100-year flood elevation	$2,730,000	>50 years	>2100
Zone 2A Roadway Alternatives			
Raise All Roads to +4 ft NAVD88	$2,550,000	10-20 years	2040
Raise All Roads to +5 ft NAVD88	$5,100,000	25-35 years	2055
Raise All Roads to +7 ft NAVD88	$10,200,000	40-50 years	2070
Raise All Roads to +10 ft NAVD88	$17,850,000	>50 years	>2100
Zone 2A Shoreline Alternatives			
Replacing/Raising Existing Bulkheads	$22,500,000	30-50 years	2070
New Bulkhead Along Unprotected Shoreline	$480,000	30-50 years	2070
Living Shoreline	$160,000	20-30 years	2050
New Revetment	$240,000	30-50 years	2070

Alternative	Approximate Cost	Project Service Life	End of Project Life Year
Zone 2A Upland Alternatives			
Fill property lots to +4 ft NAVD88	$420,000	10-20 years	2040
Fill property lots to +5 ft NAVD88	$700,000	35-45 years	2065
Fill property lots to +7 ft NAVD88	$1,260,000	>50 years	>2100
Raise Homes above 100-year flood elevation	$16,400,000	>50 years	>2100
Zone 2B Shoreline Alternatives			
Replacing/Raising Existing Bulkheads	$1,050,000	30-50 years	2070
New Bulkhead Along Unprotected Shoreline	$750,000	30-50 years	2070
Living Shoreline	$250,000	20-30 years	2050
New Revetment	$375,000	30-50 years	2070
Zone 2B Upland Alternatives			
Raise Parking Lot to +4 ft NAVD88	$50,265	10-20 years	2040
Raise Parking Lot to +5 ft NAVD88	$100,530	25-35 years	2065
Raise Parking Lot to +7 ft NAVD88	$201,060	>50 years	>2100
Raise Parking Lot to +10 ft NAVD88	$351,855	>50 years	>2100
Raise Ocean St to +4 ft NAVD88	$175,000	10-20 years	2040
Raise Ocean St to +5 ft NAVD88	$350,000	25-35 years	2065
Raise Ocean St to +7 ft NAVD88	$700,000	>50 years	>2100
Raise Ocean St to +10 ft NAVD88	$1,225,000	>50 years	>2100
Zone 3 Roadway Alternatives			
Raise All Roads to +4 ft NAVD88	$2,550,000	10-20 years	2040
Raise Bayshore Drive to +5 ft NAVD88	$5,100,000	25-35 years	2065
Raise Bayshore Drive to +7 ft NAVD88	$10,200,000	40-50 years	>2100
Raise Bayshore Drive to +10 ft NAVD88	$17,850,000	100 years	>2100
Zone 3 Shoreline Alternatives			
Replacing/Raising Existing Bulkheads	$12,390,000	30-50 years	2070
New Bulkhead Along Unprotected Shoreline	$1,365,000	30-50 years	2070
Living Shoreline	$455,000	20-30 years	2050
New Revetment	$ 682,500	30-50 years	2070

7 Conclusion

Relative sea level rise is a challenge that all coastal communities must contend with in the coming years. This challenge can be overcome with careful planning, collaboration with community stakeholders and local and federal government. Defense strategies against RSLR must be implemented communitywide to be effective. For example, all bulkheads must be raised to effectively keep floodwaters at bay otherwise any gaps would allow these waters to enter the community. The purpose of this document is to identify the specific risks from flooding to the Ingleside on the Bay community and to provide preliminary alternatives for addressing these issues before they intensify. This document has the secondary purpose of raising awareness of the potential issues that the Ingleside on the Bay and other coastal communities adjacent to the Corpus Christi Bay may face as sea levels continue to rise and floods become more frequent in the future. Below is a summary of the main topics addressed in this report:

- Preliminary sea level projections and analysis determined that flooding along Ingleside on the Bay will become more frequent, severe, and will impact more properties as time passes if no action is taken to adapt to rising sea levels.
- There are a few funding sources available to help finance alternatives to increase the resilience of Ingleside on the Bay, but many have restrictions/preferences on how the funding is to be utilized which must be considered when applying for these funds. Few sources are available for funding projects benefitting private property owners.
- The zones within the community most at risk from rising sea levels were identified based on the approximate elevations within those zones. Zone 1 is most at risk to these impacts as it is the lowest lying zone. Zone 2 is the largest and will require the most work to adapt to rising seas. Finally, there are areas within Zone 3 that will also need to be addressed, particularly along the lowest lying sections of roadway and exposed section of shoreline along the eastern end of Inglewood Drive.
- Options for adapting to RSLR are presented and preliminary conservative cost estimates for each alternative are provided in this report for planning purposes only. These estimates were produced to help develop an understanding of the scope and magnitude of the work necessary to improve the resilience of the Ingleside on the Bay community to projected future sea levels. Most zones will require raising of existing bulkheads, construction of shore protection, and raising of roadways as necessary to adapt to future sea levels.
- Below is a brief bulleted outline of the timeline for addressing the issues identified within each distinct zone:
    - Zone 1
        - Ingleside Beach Club
            - Stabilize Shoreline as soon as possible
            - Fill lot to increase elevation above +5’ NAVD88 by 2040
        - Raising Bayshore Drive
            - Raise roadway from the Brass Turtle to S Sandpiper St above +5’ as soon as possible.
            - Raise roadway to +6’ by 2040
        - Zone 1 Private Property Alternatives
            - Raise all existing bulkheads in zone below +4’ NAVD88 as soon as possible
            - Stabilize unprotected sections of shoreline as soon as possible

        - Fill lots to coincide with raising of Bayshore Drive
        - Raise homes on an as needed basis
- Zone 2A
    - Raise all roads within zone
        - Raise roads above +5’ NAVD88 as soon as possible
        - Raise roads above +6’ NAVD88 by 2040
    - Raise All Bulkheads within zone
        - Raise all existing bulkheads in zone below +4’ NAVD88 as soon as possible.
        - Repair and/or replace damaged bulkheads as necessary
    - Stabilizing unprotected shoreline
        - Stabilize unprotected shoreline as soon as possible
    - Raise Homes and Lots
        - Fill lots to coincide with raising of roadway
        - Raise homes on an “as needed” basis
- Zone 2B
    - Shoreline Alternatives
        - Raise Bulkhead by 2040
        - Stabilize unprotected shoreline as soon as possible
    - Raise Boat Ramp Parking Lot and Ocean Drive
        - Raise parking lot above +5’ NAVD88 by 2040
        - Raise Ocean St above +5’ NAVD88 by 2040
- Zone 3
    - Raise All Bulkheads within Zone
        - Repair and/or replace damaged bulkheads as necessary
        - Raise bulkheads on a case by case basis
    - Raise Roadways Identified
        - Raise roads above +5’ NAVD88 by 2040
    - Stabilize Unprotected Shoreline
        - Stabilize unprotected shoreline on private lots as soon as possible
        - Construct Living shoreline at shoreline adjacent to Inglewood Drive and Post Oak Drive as soon as possible

This document represents the initial steps in planning for increasing the resiliency of this community, but future studies are necessary, including drainage analyses and further evaluation of potential alternatives and policies that may be implemented to increase the resilience of this community. A comprehensive drainage study with a focus on the RSLR impacts for Ingleside on the Bay and surrounding areas is recommended to further evaluate the potential impacts to the community from RSLR. This study will help to better quantify the impacts to the community as well as help determine the best adaptation measures to be implemented within the separate zones identified. Furthermore, this document does not evaluate the additional indirect impacts to utilities which will need to be evaluated in future phases to quantify the impacts to utilities and measures for mitigating these impacts

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