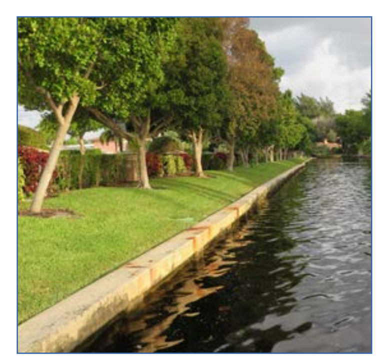
SUMMARY REPORT



Agreement RFQ No. 456-11637
City of Fort Lauderdale Project No. P12212
Task Order No. 1 Seawall Master Plan

Submitted by:
bcc engineering

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For:

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Prepared by:

engineering

BCC Engineering, Inc.
Certificate of Authorization No. 7184

February 5, 2018

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1.0 Introduction

1.1 Executive Summary

The majority of the City's seawalls are stable but exhibiting deficiencies typical of concrete structures in a corrosive environment and nearing the end of their design life. Several seawalls, primarily in the Cordova Road and Las Olas Boulevard areas, are overtopped and/or deteriorated, and require prioritization. All seawalls except one require raising to address Sea Level Rise. The majority of the City's natural banks and shorelines are in good condition. The shoreline adjacent to the Richard Mancuso Greenway frequently overtops and is adjacent to a street and residences. This Summary Report recommends a long-range maintenance and replacement program that addresses the highest priority seawalls and Richard Mancuso Greenway shoreline first. The below summarizes the costs anticipated over the next 20 years.

TABLE 1.1 – ANTICIPATED COSTS BY WORK PROGRAM WINDOW (YEARS)				
0-5	6-10	11-15	16-20	**Total**
$10,889,936	**$12,803,560**	**$410,898**	**$2,021,929**	**$26,126,323**

1.2 Purpose and Scope

Long range regional studies considering the effects of Climate Change and Sea Level Rise (SLR) predicted tidal flooding in Southeast Florida would advance from less than 10 annual events to more than 240 events by the year 2045 (Reference: Encroaching Tides: How Sea Level Rise and Tidal Flooding Threaten US East and Gulf Coast Communities over the Next 30 Years (2014) – Union of Concerned Scientists). In September of 2015 the City of Fort Lauderdale (City) experienced unprecedented flooding due to a King Tide 20 inches above the average high tide (10 inches above the predicted King Tide). Seawalls serve as an important defense against tidal flooding. After the September 2015 King Tide event, the City Commission requested that the City revise the seawall ordinance (ULDR Sec. 47-19.3) to align with the City's Fast Forward 2035 Vision. The original public discussion draft of the proposed seawall ordinance mandated all seawalls in the City be raised to 4.6 feet NAVD 88 by 2035. The final adopted ordinance set the minimum seawall elevation at 3.9 feet NAVD 88, and the maximum seawall elevation relative to the Base Flood Elevation for the area; the minimum seawall elevation in the adopted ordinance is equivalent to the maximum seawall elevation in the previous ordinance. The adopted ordinance also specified that property owners failing to prevent tidal waters from flowing overland and leaving their property may be cited.

Along with addressing City-wide sea level rise concerns, the City also recognized that the majority of the City-owned seawalls are past their lifespan and will be past their useful life by the year 2035. In September 2016, the City commissioned Project No. 12212 to develop a Seawall Master Plan (SMP) to address the resiliency of the City-owned seawalls and natural banks to be consistent with the Fast Forward 2035 Vision. There are thirty-five (35) seawalls (4.41 miles) in the City's seawall inventory. Seawall types range from coral rock, to concrete panel/T-pile, to king pile/panel, to steel sheet pile.

Locations range from Port Everglades to Coral Ridge, and from west of Federal Highway to Fort Lauderdale Beach. There are seven (7) natural banks (2.01 miles) in the City's shoreline inventory. Locations range from the South and North Forks of the New River to Lauderdale Harbours to the Las Olas area to Coral Ridge Isles. The locations of the City-owned seawalls and shoreline are shown on the following **Figure 1**.

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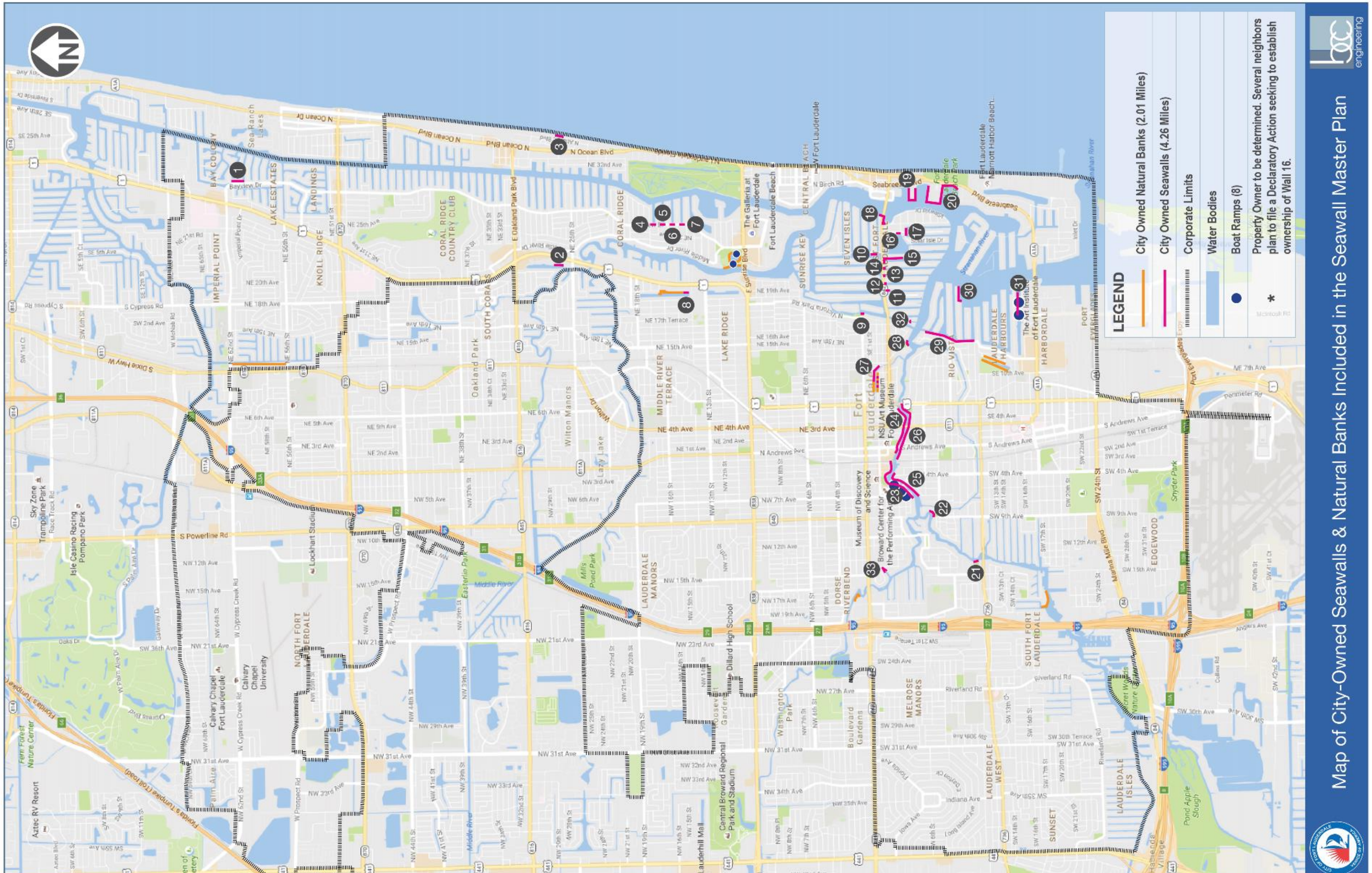
Map of City-Owned Seawalls & Natural Banks Included in the Seawall Master Plan
LEGEND
City Owned Natural Banks (2.01 Miles)
City Owned Seawalls (4.26 Miles)
Corporate Limits
Water Bodies
Boat Ramps (8)
* Property Owner to be determined. Several neighbors plan to file a Declaratory Action seeking to establish ownership of Wall 16.
engineering

Figure 1

BCC Engineering, Inc. (BCC) has conducted a limited visual inspection of the City's Seawall and Shoreline Inventory to serve as the basis for a seawall management system. Our findings and recommendations are included in this Summary Report. As part of this review, BCC performed visual inspections of the shoreline and seawalls (to include above and below water seawall conditions), generated hydrographic information at more vulnerable seawall locations, confirmed the top of seawall elevations, developed an inspection and reporting system, developed a deficiency and priority classification system, reviewed available existing plan information, reviewed the City's current seawall standards and City-preferred details, evaluated failure modes and areas for improvement, and quantified repair and replacement and raising costs (including design, construction, CEI, and special considerations such as constructability and site access), and the type of facility behind or adjacent to the seawall. Seawall locations were also prioritized according the City's 5-Year Increment Work Program Windows, areas of improvement identified and itemized, and then options presented to reduce the number of seawalls in disrepair, for the short-term and long-term. BCC also discussed with City staff the current types of seawall failures or overtopping observed, as well as the potential for innovative, cost-effective solutions. In addition, alternate seawall systems, repair types, and components were evaluated in an effort to ensure that the City is making best use of current technology.

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2.0 Assessment Supporting the Recommendations

2.1 Inspection and Classification System

The intent of the inspection and classification system is to closely follow the National Bridge Inspection Standards (NBIS). The purpose of the inspection is to be thorough and identify conditions and defects of each seawall component, document deficiencies, and provide alerts to issues that may impact safety or the integrity of the structure. The inspection reports are formatted to address all seawall conditions, components, and features, using language common across the industry to account for different inspectors completing the report over the lifespan of the seawall.

The "Condition State" classification system provides consistency in reporting conditions. On the first page of the report, overall conditions are provided to highlight the condition of each seawall component on a scale of 1 to 4 (1 being best). For clarity, a written description of each Condition State, customized for each seawall component, is provided next to the Condition State number so there is an immediate understanding of the condition. This process is repeated throughout the report in greater detail for each seawall component.

2.2 Existing Data

The below table summarizes the existing data and source used in developing this report.

TABLE 2.2 – EXISTING DATA

DATA	SOURCE
Wall and Shoreline Locations	City-Owned Seawall Map, GIS information
Shoreline Inspection Reports	Inspections conducted 10/19/16, 10/20/16
Wall Inspection Reports	Above Water Inspections conducted 10/26/16 - 5/30/17
	Below Water Inspections conducted 10/25/16 - 12/27/16
Hydrographic Information	Field measurements conducted 12/1/16 - 12/29/16
Dimensions	Existing Plans, Field Reviews, Property Appraiser Website
Year Constructed	Existing Plans
Top of Wall Elevations	Survey conducted 11/1/16 - 5/30/17
Base Flood Elevations	FEMA Flood Maps
Sea Level Rise/Overtopping	City Vision Plan (Unified Sea Level Rise Projection)
Conceptual Repair and Wall Details	City Standards

2.3 Above Water Inspection

Above water inspection included visual inspection of all visible seawall components, using inspections from the water and from land. Variations in seawall type were documented as well as conditions behind the seawall such as facilities, properties, and drainage. The water inspection team consisted of three individuals: two inspectors; a Supervising Professional Engineer identifying conditions and limits, and a supporting Structural Designer documenting then findings into electronic inspection report files; and a boat captain. The following photographs summarize the above water inspections.

Figure 2.3.1 Water Inspection

Figure 2.3.2 Land Inspection

Conditions were confirmed by hand measurements and sounding using a 2 lb sounding/chipping/scaling hammer. Conditions were documented by digital photograph. Any inaccessible areas were noted for detailed follow up during the land inspection. Deficiency locations were measured from the end of seawall or landmark feature. The land inspection team consisted of the same two inspectors as the water inspection. Conditions were confirmed by hand measurements and sounding using a 2 lb sounding/chipping/scaling hammer. Conditions were documented by digital photograph and, where required, video. Crack widths were measured using an Elcometer 143 Crack Width Ruler. Relatively widespread deficiencies were documented as "General Conditions" and quantities based on regular measurements and overall percentage of seawall. Cause of deterioration (i.e. impact spall vs. delamination vs. overload deflection) were identified where appropriate and any loss of section documented. In all cases, deficiencies were noted in certain terms, such as *shallow spall with no exposed rebar, spall with exposed rebar, crack with staining, crack with efflorescence, crack (solid when sounded), crack (hollow when sounded).* Top of seawall elevations were confirmed in NAVD '88 and Base Flood Elevations confirmed using FEMA Base Flood Maps.

2.4 Below Water Inspection

Below water inspection included visual inspection of all visible seawall components, as well as confirmation of seawall embedment and conditions of scour, voids, or loss of fill. The underwater inspection team consisted of two individuals: a diver identifying conditions and limits, and a supporting tender at the water surface for safety. Deficiency locations were measured from the end of seawall or using a range or percentage of total seawall length undergoing distress. Hydrographic information included measuring 30 feet out from the face of seawall at intervals regular enough to capture the overall condition at the base of the seawall. Hydrographic information is presented relative to the top of seawall.

2.5 Vulnerability Evaluation

Evaluating the City's seawalls and shorelines from storm related hydrodynamic loading requires knowledge of the force mechanisms that can occur during a storm event. Hurricane storm surge at the coast results from a combination of tide elevations, wind setup, wave setup, and central pressure depression. Tide elevations are dependent upon the timing of when the storm makes landfall. This can either augment or depress the meteorological related factors. Wind setup results from the stress that the wind places on the ocean causing a super elevation of the water at the coastline. Wave setup is the increase in water elevation associated with breaking waves at the shoreline. Finally, the central pressure depression associated with the eye of the storm can also contribute to the elevation of the storm surge. The storm surge at a coastline propagates into the interior waterways via tidal inlets (Port Everglades Inlet) where it then propagates north and south of the inlet location. Local wind stress can cause additional local wind setup and wave generation within interior waterways. Wave growth within interior waterways is a function of both the depth of the waterways and the distance of open water over which the wind blows (fetch length).

Elevated water levels and waves can impact the City's assets in a number of ways. Elevated water levels above the seawall cap elevation will flood upland areas. Waves propagating to the shoreline or seawall can break at the location of the asset creating high flow velocities and turbulence that may erode shorelines and fill upland of seawalls even when the surge elevation does not overtop the seawalls. Additionally, waves breaking on seawalls create cyclical wave loads on the structure itself that my result in damage to the cap or panels or reduce the passive pressure upon which seawall tie backs rely for support. The vulnerability of a shoreline or seawall to wave impact is a function of both the exposure of the asset (fetch length) and the orientation of the asset.

For example, Seawall No. 3 located on the Atlantic Ocean will experience high waves and surge. Waves will propagate from the ocean to the seawall from a direction perpendicular to the seawall creating a high potential for beach erosion in front of the seawall, high likelihood for wave impact and overtopping, and, as such, a high vulnerability of the seawall to erosion and wave loading. As a comparison, some of the seawalls lining the New River such as Seawalls 24 and 26 may experience elevated surge and high waves, but the waves generated on the river will be traveling parallel to the seawall reducing the potential for wave loading and wave overtopping yet still experiencing upland flooding. Notably, SLR will progressively increase the vulnerability of seawalls and shorelines by raising the baseline water surface elevations creating the scenario where storms of the same strength create higher winds and surge.

Preliminary examination of the vulnerability of the seawalls is accomplished through a comparison of the seawall cap elevations with recent observed Extreme High Tide (King Tide) elevations adjusted to include the expected SLR for future time periods. This study considered available Unified SLR Projection data for Key West, Vaca Key, and Miami Beach and applied the most conservative data of those three locations.

For the purposes of this study, the following approach was used to determine the water elevation established as the elevation at which the existing seawalls would be overtopped:

1) **Current Overtopping Elevation**: This elevation was established as the September 2015 Lake Worth Pier King Tide El. 2.615 plus the SLR projected from 2015 to 2017, which (per below point #2 "SLR Increment") is based on the Unified SLR Projection data for Miami Beach "High" values, 5.16" – 4.56" = 0.6" (0.05'). Therefore, the baseline overtopping elevation for the SMP is established as El. 2.615 + 0.05' = El. 2.665.

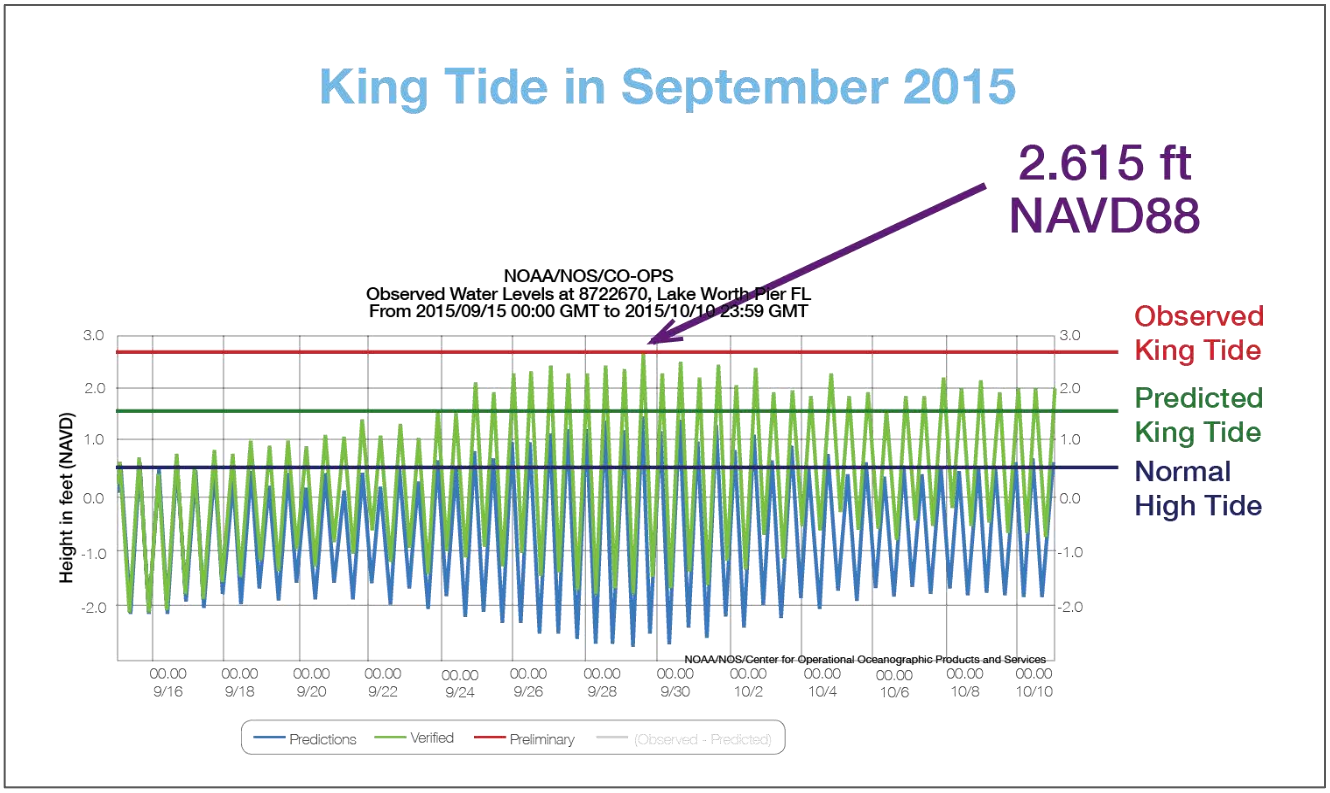

Figure 2.5.1 King Tide September 2015

2) **SLR Increment:** Every 5-Year Work Program Window.

   a) The blue shaded zone of the Unified SLR Projection represents the "Likely" rise. To be conservative, the upper limit of the "Likely" zone is used for the purposes of the Seawall Master Plan to estimate when the existing seawall may be overtopped and determine the minimum recommended seawall height. The upper limit of the "Likely" zone was selected for use in the Seawall Master Plan because in the Unified Sea Level Rise Projection for Southeast Florida, the USACE High (or upper limit of the "Likely" zone) can be applied to most infrastructure projects for short term use until 2060, particularly those with a design life expectancy of less than 50 years. Use of the NOAA High (highest curve) was considered during this study. Use of the higher NOAA SLR projection is typically limited to critical infrastructure that is interdependent with other infrastructure, has catastrophic impacts, or the community is reliant upon in an emergency (such as evacuation routes). The City's seawalls in the Las Olas Boulevard area are an example of where the NOAA SLR projection may be used. However, in discussion with the City, it was decided for the purposes of the Seawall Master Plan to use the upper limit of the "Likely" zone uniformly at this time, and since this Seawall Master Plan is considered a "Living Document" future evaluations would consider the use of NOAA SLR projection in select areas as updated projections are released. The upper limit of the "Likely' shows a 10" rise from 1992 to 2030:

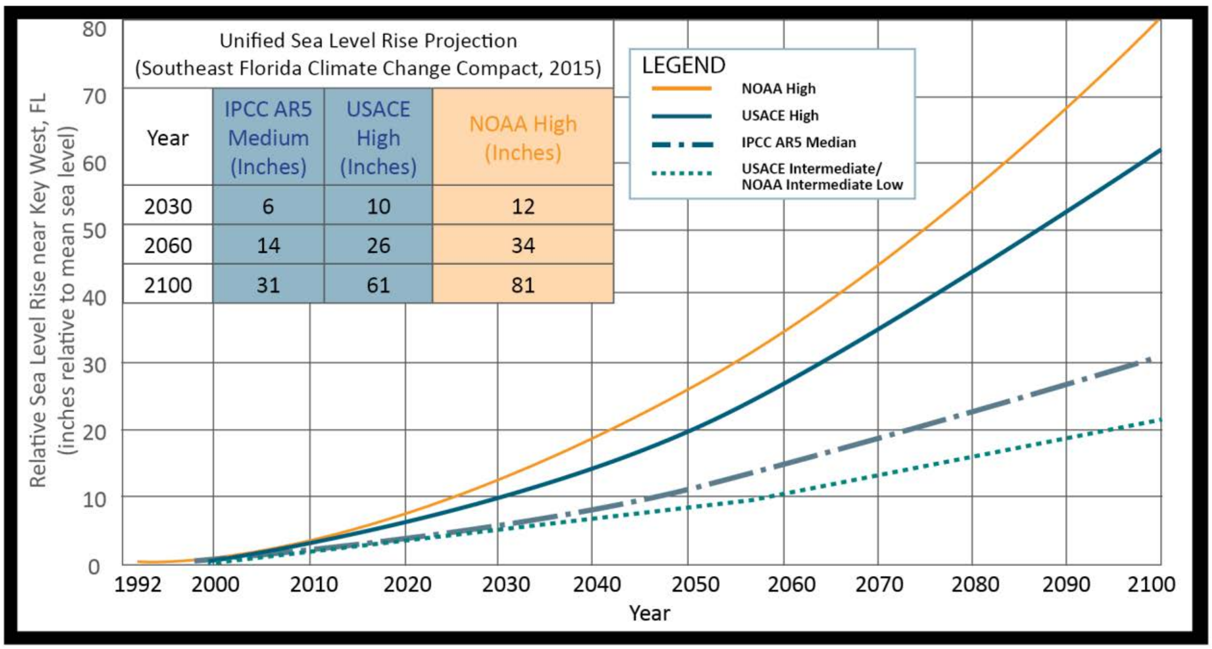

Figure 2.5.2 King Tide September 2015

b) The 10" rise for Key West corresponds to the "High" value in the excel spreadsheet for Key West (9.72" by 2030). Therefore, the "High" value in the spreadsheet is considered as the upper limit of the "Likely" zone.

Time	Low(0.5)	IPCC AR5 Medium(0.73m)	High (1.5m)	Highest (2m)	Low (0.5)	IPCC AR5 (0.73m)	High (1.5m)	Highest (2m)
2028	0.38	0.46	0.74	0.92	4.56	5.52	8.88	11.04
2029	0.39	0.48	0.77	0.97	4.68	5.76	9.24	11.64
2030	0.4	0.5	0.81	1.01	4.8	6	9.72	12.12

Figure 2.5.3 Key West SLR Data

c) The local "High" SLR data (Miami Beach) was higher than Key West (9.96" vs. 9.72"), therefore Miami Beach values shall be used for the purposes of the City's SMP.

d) Using January 2017 as month/year zero for the purposes of the SMP, and projecting out the work program windows, the anticipated SLR for each 5-Year Work Program Window per the Unified SLR Projection Miami Beach data is determined as follows:

Work Program Window	Year Range	SLR per 5-Year Work Program Window
0-5	2017-2021	6.48" – 5.16" = 1.32"
6-10	2022-2026	8.4" – 6.48" = 1.92"
11-15	2027-2031	10.44" – 8.4" = 2.04"
16-20	2032-2036	12.72" – 10.44" = 2.28"

e) The presence of critical facilities such as roadways, fire stations, hospitals will factor into prioritizing walls when considering all the factors weighed during the final recommendations.

In January 2018, the City performed LIDAR in the areas behind the existing banks and shorelines to evaluate vulnerability and potential impacts due to shoreline overtopping. The USACE High curve was used to be conservative. The LIDAR information indicated potential impacts to adjacent properties/building structures in the 16-20 Year Work Program Window (2032-2016) at Bill Keith Preserve, Cliff Lake, Lake Melba, Northfork Riverfront, and Richard Mancuso Greenway. Considering the long range of this approximation and the far-reaching impacts, at this time it is recommended that the banks and shorelines be evaluated further, including more accurate topographical survey information, to support long term planning decisions. For the purposes of the Seawall Master Plan, the LIDAR information has been included in Volume 1, Tab 1.2.

It is important to note that the comparison between existing top of wall and shoreline elevations and the anticipated overtopping elevation should only serve to assess the relative vulnerability to SLR and prioritize adaptation. The seawall or shoreline may be vulnerable to hurricane wave and surge induced erosion and loading well before overtopping occurs. Actual vulnerability, as described above, is a function of the seawall and shoreline orientation, exposure to long fetches or significant boat wake, as well as top of seawall/top of bank elevation. It is recommended that a full vulnerability assessment be performed (including topographical survey, as well as wave and surge modeling incorporating estimates of SLR for several future conditions) to properly design rehabilitation solutions at each specific seawall and shoreline location. Additionally, projected SLR is an approximation that is subject to change. Therefore, this comparison between existing top of wall/top of bank elevations and the anticipated overtopping elevation, as well as the ground line elevations behind the seawalls and shorelines, should be "re-calibrated" on an annual basis to confirm wall priorities and approach to the City's overall improvement program. The below table summarizes the seawall vulnerability used in developing this report.

TABLE 2.5 – WALL VULNERABILITY* (Reference Figure 1 for seawall locations)

Wall	When Overtopped	Raising Required	When Addressed**	Funds Encumbered	Requiring Funding	Comments	Common Name
1	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. 0-5 Yr overtopping, deficiencies, portions failing.	Bayview Dr. at Bay Colony
2	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. 0-5 Yr overtopping, deficiencies, majority has failed.	Budget Inn Property
3	N/A	N/A	6-10 Yr	6-10 Yr	6-10 Yr	Deficiencies and exposure (beach) warrant 6-10 Yr replacement.	Loggerhead Park
4	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Deficiencies warrant 6-10 Yr replacement.	Bayview Dr. north of NE 17th St.
5	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Deficiencies warrant 6-10 Yr replacement.	Bayview Dr. north of NE 16th St.
6	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Deficiencies warrant 6-10 Yr replacement.	Bayview Dr. north of NE 15th St.
7	16-20 Yr	11-15 Yr	6-10 Yr	6-10 Yr	6-10 Yr	Deficiencies warrant 6-10 Yr replacement.	Bayview Dr. north of NE 14th St.
8	2036+	2036+	6-10 Yr	6-10 Yr	6-10 Yr	Deficiencies warrant 6-10 Yr replacement.	Lake Melva north of Ford Dealer
9	0-5 Yr	0-5 Yr	11-15 Yr	11-15 Yr	11-15 Yr	Lower risk location. Projected as overtopping, but no record of overtopping.	Victoria Park
10	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. Deficiencies and high-profile location.	Seven Isles Dr. at Del Mar Pl.
11	16-20 Yr	11-15 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. Deficiencies govern when wall is addressed.	City Pump Station
12	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	High priority. High profile location along critical east-west roadway.	E. Las Olas Blvd. east of Lido Dr.
13	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	High priority. High profile location along critical east-west roadway.	E. Las Olas Blvd. east of San Marco Dr.
14	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	High priority. High profile location along critical east-west roadway.	E. Las Olas Blvd. east of Coral Way
15	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. Currently overtopping. High profile location.	Isle of Palms Dr.
16	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. Currently overtopping. High profile location.	SE 25th Ave.
17	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	Mid-priority. Not currently overtopping. Available funds may bump to 0-5 Yr.	SE 5th St.
18	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. Condition and high profile location along Las Olas Blvd.	E. Las Olas at ICWW
19	16-20 Yr	16-20 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Deficiencies warrant 0-5 Yr repair prior to raising 16-20 Yr.	Swimming Hall of Fame
20	11-15 Yr	11-15 Yr	11-15 Yr	11-15 Yr	11-15 Yr	Lower priority. Good condition and overtopping 11-15 Yr.	Bahia Mar
21	6-10 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	0-5 Yr overtopping but no overtopping noted. Low risk (park) location.	Coontie Hatchie Landings Park
22	11-15 Yr	6-10 Yr	6-10 Yr	6-10 Yr	6-10 Yr	Minor 6-10 Yr overtopping. Low risk (park) location. Recently rehabilitated.	Lewis Landing Park
23	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Partial repair/raising.	Riverwalk North west of CSX
24	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Partial repair/raising.	Riverwalk North east of CSX
25	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Partial repair/raising.	SW 5th Ave.
26	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Partial repair/raising.	Riverwalk South
27	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Currently overtops.	Richard Mancuso Greenway
28	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Partial repair/raising.	Colee Hammock Park
29	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Top priority. Currently overtopping and structural deficiencies. High profile.	Cordova Rd.
30	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Currently overtops. High profile.	SE 10th St.
31	0-5 Yr	0-5 Yr	6-10 Yr	6-10 Yr	6-10 Yr	No record of currently overtopping. Replace 6-10 Yr.	Cox's Landing Boat Launch
32	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	Currently overtopping. High profile.	Mola Ave.
33	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	No record of currently overtopping, however survey indicates overtopping.	Sailboat Bend Preserve
34	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	No record of overtopping. Survey indicates overtopping. High profile location.	Barcelona Dr. East of NE 26th Terrace
35	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	0-5 Yr	No record of overtopping. Survey indicates overtopping. High profile location.	SE 8th St.

*Timeframes are based on Work Program Windows in absence of detailed Vulnerability Analysis and uncertainties/variations in SLR projections.

**Wall Vulnerability (overtopping) may not govern when wall is addressed. See "Comments" for clarification.

2.6 Wall and Shoreline Inspection Reports

An inspection report was prepared for each individual seawall and natural bank. Each report includes all deficiencies noted during the inspection. Photographs were used to supplement and support noted conditions, as well as clarify conditions and locations. Photographs were numbered and referred to in the inspection report text as required. Shoreline photographs were also supplemented by Global Positioning System (GPS) coordinates and shoreline overviews depicting the vantage point from which each photograph was taken. For consistency, each report followed the same general format:

- Photograph of seawall or natural bank
- Location Map showing location of the seawall or natural bank
- Condition classification summary
- Detailed conditions of each component
- Summary of classification and priority system

Hydrographic information for the seawalls considered most vulnerable are included with the underwater inspection reports.

In addition to documentation of deficiencies, each report includes discussion of necessary short-term and long-term recommendations. Short-term recommendations reflect the need for work to be performed relatively sooner and focus on serious conditions that may require action before the long-term recommendations should take place. Recommendations are grouped into five-year program windows (i.e. 0-5 years, 6-10 years, 11-15 years and 16-20 years) from the time of inspection.

Long-term recommendations focus on anticipated remaining life of the seawalls and the need for rehabilitation or replacement, as well as long-term needs for bank protection and stabilization. The remaining life of the seawalls considered factors such as the year that the seawall was constructed, the current condition, the use of the property behind the seawall, general vulnerability and exposure, and methods to increase service life such as repairs and cathodic protection. Long-term recommendations also address potential structural and bank modifications needed to address the challenges associated with SLR. Opinions of probable costs are provided for both short-term and long-term recommendations. Costs include design, construction, construction engineering and inspection, site-specific factors such as access and construction restrictions or constraints, and contingencies such as repair quantity overruns or additional deterioration anticipated from the time of the inspection to the time the seawall is repaired. Lastly, each inspection report includes the Basis of Estimates used to develop the opinions of probable cost.

2.7 Primary Considerations

The City's seawall inventory is located in a dense urban environment and varies in seawall type, location, abutting conditions/facilities/structures, vulnerability, and exposure. Adjacent facilities vary from parks to streets, from commercial areas to residential. Waterways range from heavily travelled, deep-water access waterways such as the New River to relatively isolated canals with access restricted by low-level fixed bridges. Therefore, the considerations evaluated when investigating the seawalls cover a wide range of issues. The following summarizes the primary considerations used as a basis for the SMP.

1) External (global) stability. Signs of overall distress or loss of stability threatening property adjacent to or behind the seawall.

Figure 2.7.1 Lateral Movement/Rotation

Figure 2.7.2 Lateral Movement/Separation

2) Internal (structural) stability. Deterioration or failure of a seawall component.

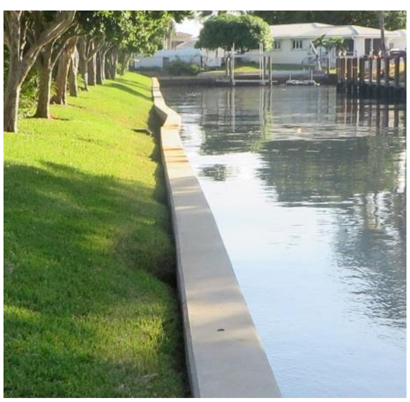

Figure 2.7.3 Tie Back Failure

Figure 2.7.4 T-Pile Spall and Panel Cracking

3) Channel condition. The stability of the ground line in front of the seawall and the seawall penetration into the ground.
4) Failure Mode/Cause. The existing seawalls have exhibited a number of different failure modes. Each is due to a specific failure or degradation of a particular element of the seawall system and

drives the engineering decisions moving forward. Correctly diagnosing the cause is critical to providing a long-term solution that alleviates the burden on City Maintenance. Also, confirmation of a longstanding or recent condition.

5) Redundancy. Any redundancy in the seawall design or construction that may render deficiencies less critical that those of a non-redundant seawall system.
6) Exposure/Overtopping Vulnerability. Seawalls that have increased exposure or are determined to be susceptible to overtopping. Seawalls that are currently overtopped are given highest priority.

Figure 2.7.5 Cordova Road (Seawall No. 29) During King Tide Conditions

7) Wall importance. General impacts should the seawall fail. In terms of impact, a seawall along a gradually sloping shoreline or park is considered relatively less important than a seawall directly adjacent to a heavily used roadway or other facility/property that would threaten public safety or commerce. The use of the waterway also factors into the seawall importance.

Figure 2.7.6 Varying Importance of Seawalls

8) Type of seawall. The type of seawall factors into the type of repair or how the seawall may be raised.
9) Drainage. The drainage characteristics and patterns of the land behind the seawall.
10) Raising impacts. Facilities or conditions that would be impacted by raising the seawall.
11) Budget. The City's needs require establishing a reasonable budget limit that could be used for seawall improvements. For the purposes of this study, a maximum budget limit of $20M per 5-Year Work Program Window was used. Additionally, since the majority of the City's seawalls are projected to overtop within the next 10 years, an effort was made to evenly distribute seawall work over the 0-5 Year and 6-10 Year Work Program Windows.

2.8 Constructability

Issues effecting constructability vary by location, orientation, disposition, and use. The following highlights the primary issues centered around constructability or repairs, raising, or replacing the City's seawalls.

1) Access. Seawalls accessible by land requiring access through private property impacts construction. Seawalls accessible by water restricted by low-level bridges creates issues with equipment access. Seawall 2 (pictured below) involves both of these challenges due to a fixed bridge on NE 26th Street, restricted waterway bordering a residential area, and its location directly behind a Budget Inn.

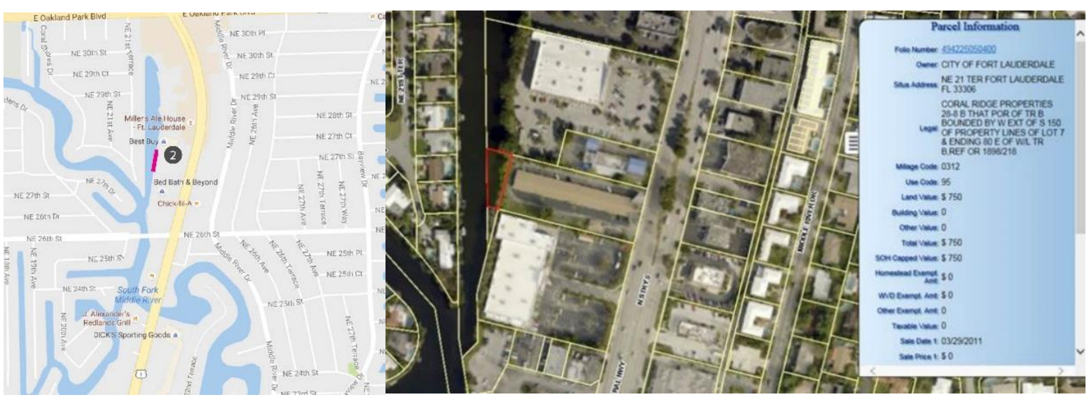

Figure 2.8.1 Accessibility Issues – Featuring Seawall No. 2

2) Type of property behind seawall. Many seawalls support residential and commercial properties. Minimizing impacts not only to the condition of the property but the operations and access to the property are key construction considerations.

Figure 2.8.2 Seawall No. 19 Supports Parking and Structure Facilities

3) Wall proximity to facilities. Many seawalls are in close proximity to existing roadways, driveways, sidewalks, bridges, or structures. Influences on construction range from limiting the size of the available work zone to overhead restrictions to mitigating vibrations during seawall removal and/or installation.
4) Utilities. Seawalls are in close proximity to existing utilities, both buried and overhead that would need to be considered during construction.
5) Presence of Tie Backs. Tie backs may extend below private property and critical structures or facilities.
6) Existing seawall capacity. Maintaining the integrity of the existing seawall during raising may involve considerations such as constructing the new cap using multiple pours in order to enable the new piling to support the additional dead load.
7) Environmental sensitivity. Presence of environmentally sensitive resources.

Figure 2.8.3 Mangroves at the North End of Seawall No. 15

2.9 Summary of Conditions

The majority of the City's seawalls are stable but exhibiting deficiencies typical of concrete structures located in a corrosive environment that are nearing the end of their original design life. Some seawalls have significant structural deficiencies, but only for certain components or limited lengths of the seawall. Several seawalls, primarily in the Cordova Road and Las Olas Boulevard areas, are undergoing active overtopping and/or significant deterioration and require prioritizing. All of the City's seawalls except four are projected to overtop within the next 10 years. Raising to address SLR is recommended at all seawall locations except two (Walls 3 and 8).

The majority of the City's natural banks and shorelines are in good condition, protected, and well vegetated. The shoreline adjacent to the Richard Mancuso Greenway frequently overtops, with water reaching the edge of the roadway pavement. New seawall is recommended at this location.

We recommend that the City move forward with a long-range inspection/monitoring program in conjunction with a repair/replacement/raising program that is based upon deliberately addressing the highest priority seawalls and shorelines first.

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3.0 Tiered Rehabilitation System

3.1 Wall Priority

The volume of the City's inventory and the need to optimize budget and support long range planning necessitates a tiered rehabilitation system where seawalls are prioritized based on factors such as condition, vulnerability to SLR, and importance.

As a result, an Importance of Repair Classification/Priority System was developed to prioritize work using a scale of 1 (emergency) thru 4 (low priority). Each individual inspection report contains a priority assigned to each seawall component. This system was used in part to rank the overall priority of the seawalls from 1 (most urgent) to 35 (least urgent). Additional factors considered when prioritizing seawalls include wall proximity to critical facilities/roadways/services, profile/political sensitivity, and overall Work Program Window budget. The table on the following page summarizes the timing of short-term and long-term work and identifies where each seawall will fall within the 5-Year Work Program Windows, with the associated justification.

3.2 Maintenance Plan

Any effective maintenance plan begins with routine monitoring. Biennial visual inspections updates are recommended for infrastructure of this type, with annual inspections reserved for the more severely deteriorated and/or critical locations. The effort involved with subsequent inspections may be reduced, for example by focusing on key deficiencies or inspecting from land and only engaging inspections from the water or subaqueous inspections if land inspections indicate a distress. Inspection results are tracked by updating the inspection reports and documenting any changed conditions (i.e. increases in deficiency number, sizes) or the status of repairs performed since the previous inspection. Conditions may be summarized in tabular form, cost estimates updated, and the seawalls itemized by the new 5-Year Work Program Window to remain in line with budgeting schedules and the need to encumber funds in advance of the proposed work.

Where utilized, post-Installed Weep Hole Backflow Preventers (Reference Appendix D for more detailed information) should be included in the routine maintenance plan. The backflow preventer is comprised of a geotextile filter media cartridge encased within a housing that is attached to the seawall. The cartridge may be removed from the front (exposed) face of the wall by removing a series of screws and cleaned or replaced as needed. Frequency of cartridge cleaning/replacement will vary according to factors such as wall location, soil conditions, and performance.

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TABLE 3.1 – WALL PRIORITY AND SUMMARY OF SHORT AND LONG TERM WORK					
Wall	Program Window and Priority				Justification
	0-5 Yr	6-10 Yr	11-15 Yr	16-20 Yr	
1	6				Top priority. 0-5 Yr overtopping, deficiencies, portions failing.
2	7				Top priority. 0-5 Yr overtopping, deficiencies, majority has failed.
3		20			Deficiencies and exposure (beach) warrant 6-10 Yr replacement.
4		23			No record of currently overtopping. Deficiencies warrant 6-10 Yr replacement.
5		22			No record of currently overtopping. Deficiencies warrant 6-10 Yr replacement.
6		21			No record of currently overtopping. Deficiencies warrant 6-10 Yr replacement.
7		24			Deficiencies warrant 6-10 Yr replacement.
8		25			Deficiencies warrant 6-10 Yr replacement.
9			34		Lower risk location. Projected as overtopping, but no record of overtopping.
10	4				Top priority. Deficiencies and high-profile location.
11	9				Top priority. Deficiencies govern when wall is addressed.
12	10				High priority. High profile location along critical east-west roadway.
13	11				High priority. High profile location along critical east-west roadway.
14	12				High priority. High profile location along critical east-west roadway.
15	3				Top priority. Currently overtopping. High profile location.
16	8				Top priority. Currently overtopping. High profile location.
17		32			Mid-priority. Not currently overtopping. Available funds may bump to 0-5 Yr.
18	14				Top priority. Condition and high profile location along Las Olas Blvd.
19	13			36	Deficiencies warrant 0-5 Yr repair prior to raising 16-20 Yr.
20		30			Lower priority. Good condition and overtopping 11-15 Yr.
21		29			0-5 Yr overtopping but no overtopping noted. Low risk (park) location.
22			35		Minor 6-10 Yr overtopping. Low risk (park) location. Recently rehabilitated.
23		31			No record of currently overtopping. Partial repair/raising.
24		19			No record of currently overtopping. Partial repair/raising.
25		27			No record of currently overtopping. Partial repair/raising.
26		28			No record of currently overtopping. Partial repair/raising.
27	5				Currently overtops.
28		26			No record of currently overtopping. Partial repair/raising.
29	1				Top priority. Currently overtopping and structural deficiencies. High profile.
30	15				Currently overtops. High profile.
31		33			No record of currently overtopping. Replace 6-10 Yr.
32	2				Currently overtopping. High profile.
33	16				No record of currently overtopping, however survey indicates overtopping.
34	17				No record of overtopping. Survey indicates overtopping. High profile location.
35	18				No record of overtopping. Survey indicates overtopping. High profile location.

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4.0 Recommendations

4.1 Methods to Reduce the Number of Seawalls in Disrepair

The overall recommendation is to begin a scheduled maintenance and repair program following the tiered rehabilitation system where seawalls are repaired based on the priority within the inventory. The nature and volume of the work lends itself well to the development of repair and rehabilitation schemes (Standards) that may be used at multiple locations. Priority seawalls can be designed first, and then shelved for immediate repair once construction funding becomes available.

Several repair methods can effectively reduce the number of City seawalls in disrepair. Applying innovation where appropriate and identifying the most constructible, durable, appropriate repair or retrofit for each location is critical to maximizing longevity and reducing cost while minimizing disruption to the public. The goal is to maximize the remaining service life of the structure by extending the life beyond the original design life. The following summarizes several methods to reduce the number of seawalls in disrepair that may be evaluated further during the design at each location. Appendix A includes conceptual details for wall repairs and replacement.

4.2 Spall Repair

Spall repairs are used to restore section loss or loss of concrete cover over top reinforcing in reinforced concrete components. Once the area of unsound concrete is delineated, concrete is removed for the limits of the deficiency and excavated to a depth required to reach unsound concrete. Light (hand-held) tools are used to control the amount of concrete removal and avoid damage to existing reinforcing. Repairs may be sequenced to be performed in place without compromising structural integrity or stability. As an option, temporary shoring may be designed to support load while repairs are being performed. Reinforcing with significant section loss is restored by splicing/lapping new reinforcing steel. Repair edges are squared, and the interface between existing concrete prepared by roughening to a required amplitude, pressure cleaning, soaked to create a saturated surface dry condition, bonding agent applied, and new concrete placed. When performed correctly and materials prepared and placed by qualified personnel and in accordance with the material manufacturer's recommendations, these types of repairs endure upwards of 15 years without issue. Reference Appendix A. Gunite is another method to restore concrete cover over top reinforcing in reinforced concrete components. Once the area of unsound concrete is delineated, concrete is removed for the limits of the deficiency and excavated to a depth required to reach unsound concrete. Light (hand-held) tools are used to control the amount of concrete removal and avoid damage to existing reinforcing. Repairs are typically shallower than a spall repair. Steel anchors and wire mesh is used to improve the connection between the gunite material and the existing structures. Repair edges are squared, and the interface between existing concrete prepared by roughening to a required amplitude, pressure cleaning, soaked to create a saturated surface dry condition, bonding agent applied, and new gunite pneumatically projected at high velocity onto the surface. Reference Appendix A.

4.3 Crack Repair

The procedure of epoxy crack injection is effective in addressing cracking conditions in concrete components to prohibit the penetration of chlorides and stop deterioration from increasing to spalls or delaminations. Cracks are cleaned, and holes drilled at regular intervals. Epoxy ports are inserted in the holes, and the ports injected with epoxy until the epoxy protrudes outside of the cracked surface. Once the epoxy cures, the ports are cut at the concrete surface and ground smooth. The epoxy creates and impenetrable barrier stronger than the surrounding concrete. Reference Appendix A.

One challenge with crack repairs is when cracks exhibit efflorescence. Efflorescence is a white staining created by chemicals in hardened concrete being carried to the surface by water moving through the concrete. Efflorescence can create conditions where the crack opening cannot accept the epoxy. An effective solution to this condition is to router a groove for the length of the crack and seal the routed area with a high strength epoxy. This epoxy will not penetrate the crack but create a membrane to prohibit water intrusion into the exposed side of the crack from further accelerating the deterioration.

4.4 Jacketing

Pile Jacketing restores loss of pile section by encasing the pile in a concrete jacket. The jacket typically extends the length of pile exposed to the “wet-dry” cycle above and below the water line, which accelerates deterioration, therefore the jacket envelops the pile perimeter from the seawall cap to a point below the water line. Jackets may be structural (contain reinforcing steel) or non-structural (no reinforcing steel). Both structural and non-structural jacket repairs are handled similar to spall repairs. Once the area of unsound concrete is delineated, concrete is removed for the limits of the deficiency and excavated to a depth required to reach unsound concrete. Light (hand-held) tools are used to control the amount of concrete removal and avoid damage to existing reinforcing. It is important to maintain structural integrity by limiting the depth of concrete removal extending into the reinforcing cage and avoid damaging any rebar or prestressing. Repairs may be sequenced to be performed in place without compromising structural integrity or stability, such as work only allowed on one pile at a time. As an option, temporary shoring may be designed to support load while repairs are being performed. Reinforcing with significant section loss is restored by splicing/lapping new reinforcing steel. Strands with section loss are evaluated for their location and if along a compressive face of the pile, may remain with section loss and cover restored. Repair edges are squared, and the interface between existing concrete prepared by roughening to a required amplitude, pressure cleaning, soaked to create a saturated surface dry condition, bonding agent applied, and new concrete placed. Below water work is required in order to extend the jacket below the low water line. When performed correctly and materials prepared and placed by qualified personnel and in accordance with the material manufacturer’s recommendations, these types of repairs endure upwards of 20 years without issue. Reference Appendix A.

4.5 Cathodic Protection/Metalizing

Seawater contains chloride ions that can cause the reinforcing steel in seawalls to corrode. The corrosion can cause the concrete to crack and spall. Cathodic protection systems present the option of rehabilitating, rather than replacing, damaged structures and can result in significant cost savings. A cathodic protection system will prevent the corrosion from worsening and will prevent new corrosion from starting. This could save the City money on repairs and minimize the delays the repairs will cause to the public. It is worth noting that the price of cathodic protection systems, once considered costly, has dropped because contractors have become more familiar with the technology and more efficient at designing and installing these systems. That experience means Contractors can get the systems in place much more quickly than in the past, reducing the cost of labor which is one of the larger expenses.

Cathodic protection is a technique used to control the corrosion of a metal surface, in this case the reinforcing steel of a reinforced concrete section, by making it the cathode of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded "sacrificial metal" to act as the anode. The sacrificial metal then corrodes instead of the protected metal. This type of system utilizing a sacrificial anode, is referred to as a galvanic system. For structures such as long seawalls, an external DC electrical power source is typically the most effective cathodic protection system. This type of cathodic protection system utilizing an external power source is referred to as an impressed current system. While effective, an impressed current cathodic protection system typically involves a cost at the high end of cathodic protection systems.

Metalizing is a form of cathodic protection that coats metal on the surface of reinforced concrete structures. Metalizing can provide corrosion protection lasting decades long. Because electrical continuity must be established for the reinforcing steel, the best candidate for cathodic protection are concrete pile/panel bulkhead walls or sheet pile walls. Reference Appendix A. Another cost-effective alternative to impressed current cathodic protection system is use of an embedded galvanic anode. Reference Appendix B for one provider of this innovative solution to extending seawall design life in corrosive environments.

4.6 Slope Stabilization/Scour Protection

Stabilizing slopes and providing scour protection is critical where seawall embedment is inadequate to avoid undermining. Undermining is the result of water removing channel bottom from the toe of the seawall, allowing fill to escape from underneath the seawall. The ground behind the seawall settles, resulting in further distress to the overall seawall stability as well as the property and assets behind the seawall. Effective means of slope stabilization and scour protection include extending the footing by driving sheet piling as well as more cost-effective countermeasures such as sand-cement bags, concrete filled mats, articulated block, rubble riprap, gabion mats, and other revetment mats. The optimal solution is specific to the hydraulic conditions at each location, and highly dependent on skilled personnel and correct installation. Reference Appendix A.

4.7 Weep Holes

Proper draining and alleviating hydrostatic pressure created by seawalls retaining water after a flooding event is critical to seawall stability. Conventional weep holes allow water to pass through from the front of the seawall as well. The City should ensure periodic maintenance of the weep holes is conducted. Over time the weep holes can become clogged with rocks, oyster shells, etc. and in order to perform their job of relieving hydrostatic pressure behind the seawall they need to be kept open. Additionally, cleaning and sealing of the existing seawalls and caps could extend their life by reducing the chloride penetration and resultant corrosion of rebar. A sealer could be used to purge existing chlorides, halt current corrosion activity, and prevent re-entry.

Another innovative solution is post-installed Tidal Valves, also known as Weep Hole Backflow Preventers. These retrofits effectively accomplish both aspects of allowing water to weep through the seawall from the backside while avoiding influences of tidal fluctuation and surge, while preventing the loss of fines. Installation is performed by coring a hole through the seawall and installing the preventer. The preventer is encased in a cartridge that permits easy replacement and maintenance. Reference Appendix B.

4.8 Joint Sealing

Proper sealing of the interface between piles and panels or interlocking sheets is key to avoiding long-term settlement issues. This can be accomplished by routine maintenance sealing of joints and cracks.

4.9 Wall Raising

All seawalls except Wall Nos. 3 and 8 require raising. Raising amounts vary from just over 1 foot to over 3 feet. For the purposes of this study, it was assumed raising by more than 1 foot will require a built-up reinforced concrete cap doweled into the existing seawall cap, and additional battered piling used to support the additional lateral load due to surcharge. Raising of the ground line behind the seawall was evaluated from the standpoint of impacts to adjacent facilities and drainage. Depending on the size of the built-up cap, areas where existing seawalls have undergone movement or rotation would require stabilization before the raising is performed and/or additional piling installed adjacent to the existing seawall. Given the different types of seawalls and different conditions of each seawall, this would need to be evaluated on a site-specific basis. There is also potential for developing generic wall raising details that could be utilized at multiple seawall locations. Reference Appendix A.

4.10 Wall Replacement

The most effective method to replace existing seawalls without compromising the properties behind the seawalls is to bury the walls in place using a seawall comprised of sheet piling tied together at the top with a reinforced concrete cap or precast panels and piling installed immediately in front of the existing wall. Sheet piles can be fabricated from concrete, aluminum, fiberglass, and steel. Aluminum and fiberglass offer increased corrosion resistance which is critical in the harsh environment surrounding the seawalls. Steel sheet piles are more commonly installed than aluminum or fiberglass sheet piles. Available means for dealing with the corrosion of the steel include cathodic protection systems, epoxy coatings and additional sacrificial thickness to increase the life span of steel sheet pile seawalls. However, sheet piles of these various materials in the height range required for the City's seawalls would require corrugated shapes and would alter the visual appearance of the current seawalls and require consideration on a case by case basis. These types of seawalls may be cantilevered, tie back, or utilize a king pile/battered pile configuration for additional lateral support. Conventional seawall installations are performed using water-based equipment. An innovative alternative to conventional equipment is the Press-In method where conditions and constraints preclude a conventional installation. Reference Appendix A.

Figure 4.10.1 Conventional Seawall Installations

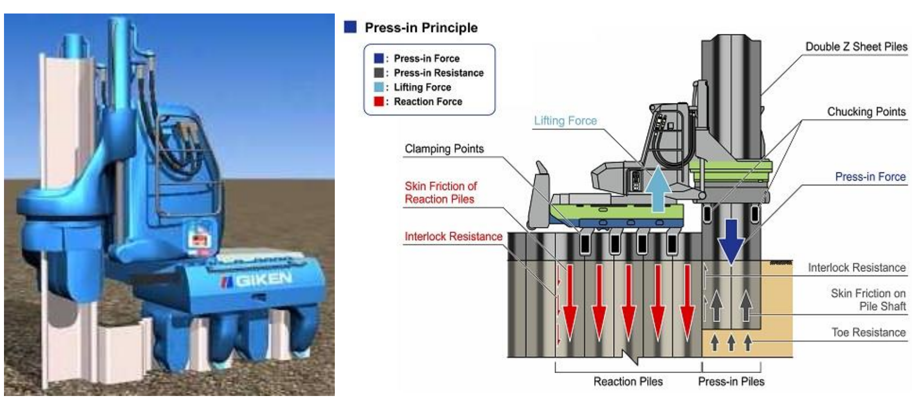

Figure 4.10.2 Press-In Sheet Pile Method

4.11 City Standards

The City would benefit by establishing City Standards for use in reducing the number of City seawalls in disrepair. Standards could include repairs as well as replacement. Benefits of Standards include establishing the level of quality expected for City projects, providing uniformity and consistency for City seawalls, and enabling Contractors to maximize familiarity with the work, leading to high quality construction and minimizing construction cost. Appendix C represents a compilation of available copies of previous City Standards and details to be considered for updating as new City Standards. Appendix A includes Conceptual Sea Wall Standards based in part on the examples provided in Appendix C as well as similar projects completed for other South Florida municipalities and FDOT. The Conceptual Standards include concrete piles, repair and rehabilitation, wall raising, common seawall types, riprap, and common construction details for potential further development as City Standards.

4.12 Recommendations and Costs

The majority of the City's seawalls are recommended for repair/rehabilitation/raising within the next 10 years. The following tables summarize which walls are included in each 5-Year Work Program Window. Costs are also totaled for each 5-year Work Program Window. Costs include Design, Construction, Construction Engineering Inspection (CEI), and Inflation. Design costs include Structural, Survey (land, hydrographic), Geotechnical, and Permitting (support, benthic, fees). Design costs are estimated specific to each location. Notably, for small walls, design costs can exceed the construction cost of the wall. This anomaly is expected to adjust, for example, should multiple smaller walls be grouped into a single design project. For the purposes of this study, the design costs for shorter walls (less than 150' long) are grouped and therefore involve a relatively lower average engineering cost per wall than if the wall was a stand-alone project. Construction costs are based on wall type and cost per linear foot of seawall according to local seawall contractors who have been performing similar seawall work for decades and would likely bid on the City's seawall projects. Construction costs include contingency for quantity overruns and increase in deterioration from the time of the initial inspection, increase for constructability issues such as restricted work area, increase for access issues (such as private property or low-level fixed bridges), and an increase for mobilization (typically for shorter walls – longer walls absorb mobilization in the overall cost). CEI costs are based on a percentage of the construction costs. Lastly, the cost includes a 2% annual inflation, assuming work is not completed until the last year of each 5-Year Work Program Window. It should be noted that the City's Banks and Shorelines are in good condition. Monitoring and minor (routine) maintenance is recommended, with the exception of the shoreline at Richard Mancuso Greenway, where overtopping was observed. This shoreline abuts a roadway and is in close proximity to residences. As a result, recommendations include adding 440 feet of new seawall at this location. The cost of this new seawall is included in the cost of the Wall 27 location.

TABLE 4.12.1 – SHORT AND LONG-TERM ANTICIPATED COST SUMMARY*											
0-5 YEARS			6-10 YEARS			11-15 YEARS			16-20 YEARS		
$10,889,936			$12,803,560			$410,898			$2,021,929		
REPAIR	REPAIR/ RAISE	REPLACE/ RAISE	REPAIR	REPAIR/ RAISE	REPLACE/ RAISE	REPAIR	REPAIR/ RAISE	REPLACE/ RAISE	REPAIR	REPAIR/ RAISE	REPLACE/ RAISE
19	12	1		20	3		9				19
	13	2		21	4		22				
	14	10		23	5						
	18	11		24	6						
	32	15		25	7						
	33	16		26	8						
	34	27		28	17						
		29			31						
		30									
		35									

* Reference Figure 1 for seawall locations
This table should be worked with the following Table 4.12.2 for additional information such as wall common names, the height to which the wall requires raising, and a detailed breakdown of costs.

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TABLE 4.12.2 – SHORT AND LONG TERM ANTICIPATED COST BREAKDOWN*

Work Period (Years)	Wall No.	Common Name	Wall Length (ft)	Recommendation	Minimum Recommended Top of Wall Elevation	Wall Type		Costs				
						Existing	Proposed	Design	Construction	CEI	Inflation	Total
0-5	1	Bayview Dr. at Bay Colony	625	Replace and Raise	2.36 / 4.60	T-Pile	King/Batter Pile w/Panel	$100,500	$537,000	$53,700	$71,941	$763,141
0-5	2	Budget Inn North Property	150	Replace and Raise	2.51 / 4.60	CMU Block	King/Batter Pile w/Panel	$59,000	$196,307	$19,631	$28,616	$303,554
0-5	10	Seven Isles Dr. at Del Mar Pl.	291	Replace and Raise	2.99 / 4.60	Coral Rock	King/Batter Pile w/Panel	$62,000	$254,625	$25,463	$35,605	$377,693
0-5	11	E. Las Olas Blvd. east of Coconut Isle Dr.	100	Replace and Raise	1.10 / 4.60	T-Pile	King/Batter Pile w/Panel	$57,000	$254,100	$25,410	$35,024	$371,534
0-5	12	E. Las Olas Blvd. east of Lido Dr.	101	Repair and Raise	2.41 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$73,000	$26,437	$3,965	$10,762	$114,164
0-5	13	E. Las Olas Blvd. east of San Marco Dr.	89	Repair and Raise	2.22 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$73,000	$23,612	$3,542	$10,424	$110,578
0-5	14	E. Las Olas Blvd. east of Coral Way	91	Repair and Raise	2.22 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$72,000	$24,813	$3,722	$10,464	$110,999
0-5	15	Isle of Palms Dr.	894	Replace and Raise	3.34 / 4.60	Coral Rock	King/Batter Pile w/Panel	$95,500	$858,240	$85,824	$108,199	$1,147,763
0-5	16	Riviera Isle Dr./SE 25th Ave.	168	Replace and Raise	2.50 / 4.60	Concrete	King/Batter Pile w/Panel	$60,000	$152,880	$15,288	$23,748	$251,916
0-5	18	E. Las Olas west side of ICWW	551	Repair and Raise	1.46 / 4.60	T-Pile, Coral Rock, Concrete Sheet Pile	Steel Sheet Pile	$104,000	$909,150	$90,915	$114,912	$1,218,977
0-5	19	Swimming Hall of Fame	1410	Repair	0.00 / N/A	Concrete Sheet Pile	Concrete Sheet Pile	$55,000	$289,145	$28,914	$38,828	$411,887
0-5	27	North and South sides of Himarshee Canal	972	Replace and Raise	2.65 / 4.60	Coral Rock, Concrete	King/Batter Pile w/Panel	$113,000	$1,087,240	$108,724	$136,238	$1,445,202
0-5	29	Cordova Rd.	2186	Replace and Raise	2.25 / 4.60	Coral Rock, Pile/Panel, T-Pile	King/Batter Pile w/Panel	$156,000	$1,912,750	$191,275	$235,225	$2,495,250
0-5	30	SE 10th St.	376	Replace and Raise	2.74 / 4.60	Coral Rock	King/Batter Pile w/Panel	$74,000	$289,520	$28,952	$40,849	$433,321
0-5	32	Mola Ave.	33	Repair and Raise	2.65 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$8,000	$13,728	$2,059	$2,476	$26,262
0-5	33	Sailboat Bend Preserve	300	Repair and Raise	1.32 / 4.60	Coral Rock, Concrete Sheet Pile	Coral Rock w/Batter Pile	$87,000	$102,797	$10,280	$20,824	$220,901
0-5	34	Barcelona Dr. East of NE 26th Terrace	104	Repair and Raise	2.68 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$73,000	$31,356	$4,703	$11,351	$120,410
0-5	35	SE 8th St.	637	Replace and Raise	2.99 / 4.60	Coral Rock	King/Batter Pile w/Panel	$90,500	$713,440	$71,344	$91,100	$966,384
0-5	**SUBTOTAL COST**							**$1,412,500**	**$7,677,140**	**$773,711**	**$1,026,586**	**$10,889,936**
6-10	3	Loggerhead Park	100	Replace	0.00 / 4.60	Concrete Sheet Pile	Concrete Sheet Pile	$58,000	$84,420	$12,663	$33,962	$189,045
6-10	4	Bayview Dr. north of NE 17th St.	126	Replace and Raise	2.22 / 4.60	T-Pile and Batter Pile	King/Batter Pile w/Panel	$58,000	$97,020	$14,553	$37,136	$206,709
6-10	5	Bayview Dr. north of NE 16th St.	126	Replace and Raise	1.80 / 4.60	T-Pile and Batter Pile	King/Batter Pile w/Panel	$58,000	$194,334	$19,433	$59,515	$331,282
6-10	6	Bayview Dr. north of NE 15th St.	124	Replace and Raise	1.84 / 4.60	T-Pile and Batter Pile	King/Batter Pile w/Panel	$58,000	$112,840	$11,284	$39,884	$222,008
6-10	7	Bayview Dr. north of NE 14th St.	127	Replace and Raise	1.15 / 4.60	T-Pile and Batter Pile	King/Batter Pile w/Panel	$58,000	$224,383	$22,438	$66,754	$371,575
6-10	8	South end of Lake Melva	297	Replace and Raise	1.32 / 4.60	CMU Block	King/Batter Pile w/Panel	$97,000	$228,690	$22,869	$76,332	$424,891
6-10	17	Solar Plaza Dr./SE 5th St.	234	Replace and Raise	1.98 / 4.60	Coral Rock	King/Batter Pile w/Panel	$77,000	$73,214	$10,982	$35,301	$196,497
6-10	20	Bahia Mar	3018	Repair and Raise	1.43 / 4.60	Pile/Panel/Steel Sheet, T-Pile	Pile/Panel/Steel Sheet, T-Pile	$204,500	$1,134,803	$113,480	$318,151	$1,770,934
6-10	21	Coontie Hatchie Landing Park	213	Repair and Raise	1.89 / 4.60	T-Pile	King/Batter Pile w/Panel	$86,000	$164,010	$16,401	$58,343	$324,754
6-10	23	Riverwalk North west of CSX	2498	Repair and Raise	2.33 / 4.60	Coral Rock, T-Pile, Steel Sheet, Pile/Panel	Coral Rock, T-Pile, Steel Sheet, Pile/Panel	$190,000	$1,379,793	$137,979	$373,993	$2,081,765
6-10	24	Riverwalk North east of CSX	2208	Repair and Raise	1.67 / 4.60	T-Pile, Pile/Panel, Concrete Sheet Pile	T-Pile, Pile/Panel, Concrete Sheet Pile	$186,000	$1,666,151	$166,615	$442,098	$2,460,864
6-10	25	SW 5th Ave.	1580	Repair and Raise	1.64 / 4.60	Coral Rock, Concrete, T-Pile, Pile/Panel, Concrete Sheet Pile	Coral Rock, Concrete, T-Pile, Pile/Panel, Concrete Sheet Pile	$175,500	$671,012	$67,101	$200,076	$1,113,689
6-10	26	Riverwalk South	2561	Repair and Raise	1.34 / 4.60	T-Pile, Pile/Panel, Concrete Sheet Pile	T-Pile, Pile/Panel, Concrete Sheet Pile	$196,500	$978,144	$97,814	$278,661	$1,551,119
6-10	28	Colee Hammock Park	165	Repair and Raise	2.23 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$74,000	$67,277	$10,092	$33,149	$184,518
6-10	31	Cox's Landing Boat Ramp	473	Replace and Raise	1.74 / 4.60	T-Pile, T-Pile/Batter Pile	Steel Sheet Pile	$112,500	$922,350	$92,235	$246,825	$1,373,910
6-10	**SUBTOTAL COST**							**$1,689,000**	**$7,998,441**	**$815,939**	**$2,300,180**	**$12,803,560**
11-15	9	Victoria Park	120	Repair and Raise	2.31 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$73,000	$33,412	$5,012	$38,538	$149,962
11-15	22	Lewis Landing Park	245	Repair and Raise	1.64 / 4.60	Coral Rock	Coral Rock w/Batter Pile	$77,000	$106,254	$10,625	$67,057	$260,936
11-15	**SUBTOTAL COST**							**$150,000**	**$139,666**	**$15,637**	**$105,595**	**$410,898**
16-20	19	Swimming Hall of Fame	1410	Replace and Raise	1.43 / 4.60	Concrete Sheet Pile	Concrete Sheet Pile	$110,000	$1,137,000	$113,700	$661,229	$2,021,929
16-20	**SUBTOTAL COST**							**$110,000**	**$1,137,000**	**$113,700**	**$661,229**	**$2,021,929**
0-20	**TOTAL COST**							**$3,361,500**	**$16,952,247**	**$1,718,987**	**$4,093,590**	**$26,126,324**

*** Reference Figure 1 for seawall locations**

4.13 Maintenance Plan

The core of the maintenance plan is establishing the City Standards required to conduct the rehabilitation and repairs. The Standards should be vetted with City units and departments such as Structures and Maintenance as well as local Contractors who are anticipated to bid for the work, and then utilized on the majority of the City's seawalls to assure quality and control construction costs. This is particularly important with innovative aspects that are relatively new to the construction industry where additional education and/or instruction may be required. From that point, with the seawalls prioritized, maintaining steady progress on the City's inventory and continually monitoring for changes in conditions that may alter seawall priorities and result in advancing seawalls within the 5-Year Work Program Windows. Where utilized, post-Installed Weep Hole Backflow Preventers (Reference Appendix D for more detailed information) should be included in the routine maintenance plan as well. The condition of the Weep Hole Backflow Preventers may be documented during routine biennial wall inspections and/or separate weep hole inspections.

4.14 GIS System

A key aspect of the City's Seawall Management System is maintaining a detailed, accurate GIS System. The City's GIS file includes the following seawall information:

-Location map with wall stationing

-Photograph

-Wall type

-Overall seawall condition

-Seawall priority number

-Date of most recent inspection