



Seawall Materials & Methods Feasibility Study City of Punta Gorda, Florida

Final Report
March 2021



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Prepared for

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EXECUTIVE SUMMARY

Taylor Engineering examined various aspects of the City of Punta Gorda Canal Maintenance program including designs, materials, manufacturing process, construction methods, maintenance, and inspection records. Much of our effort involved reorganizing the City's GIS database to inform an approach for forecasting remaining service life and budgeting for projected long-range costs associated with the seawall replacement program. This report is intended to provide recommendations as part of a phase I effort. Upon City selection of the preferred alternative, additional analysis may be warranted as part of a phase II effort.

In general, the City's seawall replacement program is well-planned and comprehensive. Original installation records account for all 109 miles of City-maintained seawall. City staff provided us with seawall inventory, replacement, and inspection data records that we used in our analyses to calculate future replacement scenarios and projections. The maintenance program has evolved since its inception as two residential maintenance districts (Punta Gorda Isles and Burnt Store Isles) in the 1980's and some variations in the record keeping and data collection formats were observed. However, Taylor Engineering was able to modify and re-organize the data in order to estimate the remaining service life of walls with respect to their approximate locations in each District. In addition, Taylor Engineering was contracted to review the current seawall design standards, manufacturing, and installation practices and make recommendations for improvement to the program.

In the report we offer several recommendations that could significantly improve the design life and structural integrity of the current seawall design with relatively little increase in installation first costs and negligible (if any) increases in life cycle cost. In addition, although extremely difficult to predict, Taylor Engineering developed a remaining service life estimate for existing walls based on our evaluation of the current design and installation methods. We estimated that the average annual seawall replacement rate of 8,000 linear feet per year must be significantly increased in the near future to proactively replace seawalls before they reach the end of their estimated service life. We also identified opportunities to standardize and streamline the City's seawall inspection process while providing a potential overall cost savings. Finally, Taylor Engineering listed alternatives for installation staging to anticipate that availability of presently vacant lots will diminish. The details of these recommendations are outlined in this report.

Over many years the City of Punta Gorda has developed and maintained a comprehensive, proactive management program that currently commits to replacing approximately 8,000 linear feet of seawall per year using a well-thought out selection of seawall type and structural details. It is clear that the City has been guided thus far by good decision making and continues to seek improvements to streamline the overall program. Our suggestions and recommendations outlined herein are intended as a 'fresh look' to improve the overall program efficiency, increase seawall structural integrity, and ensure that City residents will continue to enjoy their waterfront properties in the decades to come.

TABLE OF CONTENTS

1.0 PURPOSE1

2.0 BACKGROUND2

3.0 EXISTING DATA REVIEW3

 3.1 Historic GIS Data Records..... 3

 3.2 Seawall Operations Cost..... 4

 3.3 Annual Seawall Inspection Records..... 4

 3.4 Permit Records 7

 3.5 Existing Construction Staging 7

4.0 GIS ANALYSIS AND DATA CREATION8

 4.1 GIS Data Creation/Manipulation 8

 4.1.1 Existing GIS Data 8

 4.1.2 New GIS Data 9

 4.2 Seawall Categories 9

 4.2.1 Original Walls Still in Place 10

 4.2.2 Epoxy Coated Rebar-Reinforced Walls (Replaced prior to 2010) 10

 4.2.3 MMFX Rebar Reinforced Walls (Before Hurricane Irma)..... 11

 4.2.4 MMFX Rebar Reinforced Walls (Post Hurricane Irma)..... 11

 4.3 Other Considerations & Site Observations 11

 4.3.1 Canal Access via Bridges and Lock 11

 4.3.1 Rip Rap 14

 4.3.2 Other Obstructions 14

5.0 DATA EVALUATION AND ANALYSIS CRITERIA14

6.0 EXISTING SEAWALL DESIGN AND CONSTRUCTION OVERVIEW22

7.0 ALTERNATIVES ANALYSIS24

 7.1 Alternative Seawall Systems and Shoreline Stabilization..... 26

 7.2 Alternative Anchor Systems 27

 7.3 Alternatives Analysis Conclusions 29

 7.3.1 Option 1 – Modify Existing Concrete Panel Design and use MMFX 29

 7.3.2 Option 2 – Modify Existing Concrete Panel Design and use Stainless Steel Reinforcement..... 30

7.3.3	Option 3 – Vinyl Sheet pile.....	31
7.3.4	Issues Related to Construction and Site Access.....	31
8.0	ENVIRONMENTAL AND REGULATORY CONSIDERATIONS.....	32
9.0	SEAWALL REPLACEMENT PROJECTIONS	33
10.0	COST ANALYSIS	37
10.1	Existing Seawall Construction Cost.....	37
10.2	Alternatives 1 and 2 - Cost to Modify Existing Design using MMFX and Stainless Steel Reinforcement.....	38
10.3	Alternative 3 - Cost of Using Vinyl Sheet Pile	40
10.4	Barge Transport Costs and Material Considerations.....	41
11.0	SUMMARY RECOMMENDATIONS AND CONCLUSIONS	42
APPENDIX A	Figures and Maps	
APPENDIX B	Site Evaluation Notes and Photos	
APPENDIX C	Vacant Lot Location and Staging Area Maps	
APPENDIX D	Seawall Service Life and Replacement Projections Data	
APPENDIX E	City of Punta Gorda Waterfront Design Standards	

LIST OF FIGURES

Figure 1.1	City of Punta Gorda Location Map	1
Figure 3.1	Wall Conditions and Ratings Map	6
Figure 4.1	Map of Canal Access Bridges.....	13
Figure 5.1	Original Wall Installation Years.....	15
Figure 5.2	Distribution of Original Wall Installations by Year	16
Figure 5.3	Distribution of Current Walls by Zone	16
Figure 5.4	Seawall Replacement by Year and Rebar Type	20
Figure 6.1	Typical Sheet Pile Tie-back Seawall Cross-section	23
Figure 6.2	Tie-back Detail	23
Figure 9.1	Remaining Projected Seawall Replacement by Year	35
Figure 9.2	Cumulative Seawall Replacement Projections	36

LIST OF TABLES

Table 3.1	Summary of City’s Existing Condition Ratings and Descriptions.....	5
Table 3.2	Summary of Seawall Ratings Based on 2017 Assessment.....	5

Table 3.3 Summary of Existing Active Permits	7
Table 5.1 Length of Seawall by Zone	17
Table 5.2 Distribution of Original Walls Never Replaced.....	17
Table 5.3 Seawall Overall Conditions Lengths.....	18
Table 5.4 Epoxy Coated Rebar Wall Replacements by Zone.....	19
Table 5.5 2017 Condition Rating Summary by Zone for Each Wall Era	21
Table 7.1 Seawall Panel Alternative Materials	25
Table 7.2 Anchoring Alternatives.....	28
Table 9.1 Design Life and Adjustment Factor Summary.....	34
Table 10.1 City of Punta Gorda Current Operating Installed Cost	38
Table 10.2 Estimated Cost to Modify Existing Design using MMFX (Alternative 1).....	39

1.0 PURPOSE

Taylor Engineering Inc. was contracted by the City of Punta Gorda to evaluate alternative seawall materials and installation methods available in the industry to improve the City's seawall maintenance program for the Burnt Store Isles (BSI) and the Punta Gorda Isles (PGI) districts. The residential seawalls, primarily fronting shallow canals, are made of concrete panels, connected with a reinforced concrete cap, and supported with an upland anchor system. This type of structure design is typically referred to as an 'anchored bulkhead' but in order to be consistent with the City program and simplify readability, hereafter we will use the term 'seawall'. The City maintains nearly 109 miles of seawall within City limits, most of which lie within the PGI and BSI districts, show in Figure 1.1.



Figure 1.1 City of Punta Gorda Location Map

2.0 BACKGROUND

As noted above, there are two primary residential canal fronting subdivisions within City limits – Punta Gorda Isles (PGI) and Burnt Store Isles (BSI). PGI was constructed in the mid-1960s through 1980 and has approximately 45 miles of canals (90 miles of seawalls). BSI was constructed in 1980 and has approximately 9 miles of canals (18 miles of seawalls). According to information provided by City staff, during the initial subdivision development the original seawall panels were cast on site and installed along with the upland improvements including roads and utilities. Canal dredging occurred prior to the installation of upland infrastructure and was finalized during the seawall installation.

The PGI Canal Maintenance Assessment District (CMAD) was created in 1979, via City Ordinance 549-79, and the BSI CMAD was created in 1986, via City Ordinance 825-86. The Ordinances created the special taxing districts and established canal advisory boards. The CMADs provide maintenance for canals, waterways, and navigable channels. Other duties include casting concrete seawall panels, depression filling along the backside of seawalls, seawall patching, cap patching, cap replacement, maintenance to aids of navigation, seawall inspections and other related tasks. The City’s Public Works Department, Canal Maintenance Division (Division), currently is the primary organization responsible for providing these services to each CMAD. As part of that responsibility, the Division performs an annual assessment of the seawall systems and records the condition of walls using a GIS database. GIS mapping allows the Division to prioritize maintenance and replacement tasks. In 2010 the City moved from a reactive to a more proactive wall maintenance and replacement approach.

The Division’s quality control and concrete panel production has continued to improve over time. Until 2009, the City used epoxy coated rebar to reinforce the concrete panels. However, in 2010 the City began to change the panel design, incorporating the use of marine grade concrete mix and a more corrosion resistant rebar known as MMFX. The marine grade concrete mix design was used to retard the intrusion of chlorides from the brackish canal water. That reduced intrusion in combination with the corrosion resistant MMFX rebar was expected to significantly extend the design life of new seawalls. The ‘design life’ can be thought of as the period of time a structure is expected to last by the designer while supporting the design loads. In our analyses we distinguish that term from the ‘service life’ of the structure which is the period a structure has continued to function after installation while supporting the design loads. The service life of a structure can be, and often is, longer than the expected or planned design life. This is the case for the original seawalls many of which are still in service today in Punta Gorda.

As part of the present study, Taylor Engineering was asked to evaluate the full scope of the City’s current design, manufacturing, and construction methodology and identify any other viable methods and technologies that may reduce the City’s long-term cost, improve the manufacturing and installation process, and streamline the City’s seawall maintenance program for future seawall replacements.

3.0 EXISTING DATA REVIEW

On March 19, 2019 the City provided us with an initial transmission of more than two decades worth of data in the form of Excel, PDF, PowerPoint files, and GIS data using the City’s platform “pgorda.sharefile.com”. Additional data records subsequently have been shared via email as well. These data included GIS files, seawall inspection data, permit authorizations, staging area locations, other tabulated data, and seawall panel fabrication and installation costs. A more detailed description of the multiple types of data received and reviewed is provided in Section 3.1, below.

Taylor Engineering initially reviewed the data, organized it in tabular format, and reconstructed the City’s seawall assessment data to achieve a common GIS schema. Taylor Engineering also prepared several maps using the GIS data to understand seawall location, age, and existing seawall conditions. Other maps were prepared to identify failure locations resulting from Hurricane Irma (September 2017) and the City’s progress on replacement of those failed walls.

3.1 Historic GIS Data Records

Multiple shapefiles were provided by the City using the ESRI File Geodatabase. The geodatabase contains feature classes that represent the City’s seawall assessment data for nearly 109 miles of wall, collected between 2010–2017. The assessment data were provided as separate feature classes for each fiscal year, representing annual seawall assessments. The assessment data also includes the year when a wall was reconstructed up to 2011. A temporal gap was identified within the data in spatially documenting when a wall was reconstructed between 2011–2017. There is also a gap in documenting seawall replacement years between 1981–2002.

This file geodatabase also contained background data including parcel boundaries, berm depths, building footprints, points used to split seawall lines at parcel boundaries, and a line file representing the original year that the City’s seawalls were constructed. Other data included:

- An ESRI shapefile that represents seawalls that have been rebuilt since 2018 (seawalls that failed during Hurricane Irma in September 2017).
- An ESRI shapefile that represents stormwater pipes within the PGI and BSI districts.
- An ESRI shapefile that represents subdivided zones within the PGI and BSI districts.

Following initial review of the City’s provided GIS data, the City also provided a Statement of Work (SOW) Excel file, which documents records for new wall construction as supplemental information in order to account for:

- The temporal gap (year constructed) in GIS data for walls constructed between 2011–2017.
- Information about post-Hurricane Irma wall construction.

This data was modified and formatted to highlight parcel ID, address, condition ratings records, seawall linear footage, and year of installation and subsequent replacement(s) for use in the GIS database.

3.2 Seawall Operations Cost

The City provided cost information for concrete panel manufacturing/production, which is performed in-house by the Canal Maintenance Division. Based on the City-provided information, the current total cost for manufacturing the panels, including materials, labor, and overhead is \$56.31/LF for typical 6 ft wide by 12 ft long panels.

The City maintains continuing services agreements with contractors for seawall installation during a finite period of time. As one example of typical installation cost, the City provided bid documentation from Marine Contracting Group Inc., who proposed a cost of \$261.25/LF to furnish the labor and equipment for the installation of seawalls under the service agreement.

In September 2017 Hurricane Irma contributed to failure of nearly 55,000 LF of seawall. The City applied for Federal Emergency Management Agency (FEMA) funding assistance as a result. Pursuant to Executive Order 11988 and 44 CFR Part 9.12 final notice, FEMA provided funding for the City's project to replace storm related damaged seawalls under the Public Assistance program. However, under the federal agreement the City was required to re-advertise for contractor bids, resulting in post-Hurricane Irma seawall installation cost of \$430.03/LF, an increase of nearly 60%. The City also provided the estimated cost per linear foot (prepared during the scope development of this study) of seawall installation for alternatives to the Division's cast concrete including vinyl at \$350/LF, and composite sheets at \$440/LF.

For budgetary planning, the City typically replaces on the order of 8,000 LF of seawall per year, prioritizing walls with the greatest level of deterioration.

3.3 Annual Seawall Inspection Records

Under the seawall maintenance program, the City performs annual visual seawall inspections, typically performed in the spring of each year, with the earliest inspection recorded in 2010 and the most recent performed in March 2017. These annual inspections are used to inform decisions about which seawall replacements are necessary for the following year, prioritizing replacements based on the areas of greatest damage. The City maintains seawall inspection records using both GIS database and an Excel spreadsheet. Based on City feedback, inspections are typically timed around the winter low tides when possible in order to observe the cap and seaward face of the wall down to the 'oyster line' The City's GIS dataset describes the structural evaluation process and includes a failure type index log. The seawall evaluation criteria use a numeric code system from zero to 5, as summarized in Table 3.1 below. From our review of these records, we concluded that the rating system is somewhat subjective and largely depends on the consistency, knowledge, and background of the individual inspector.

Table 3.1 Summary of City’s Existing Condition Ratings and Descriptions

Code	Rating	Description
0	Excellent	New condition
1	Good	Some minor problems
2	Fair	All primary structural elements are sound, but may have minor section loss, cracking, spalling or scour
3	Moderate	Neither 2 nor 4, but no other specific description provided
4	Serious	Loss of section, deterioration, spalling, or scour have seriously affected primary structural components; local failures are possible
5	Failure	Failure of primary structural elements

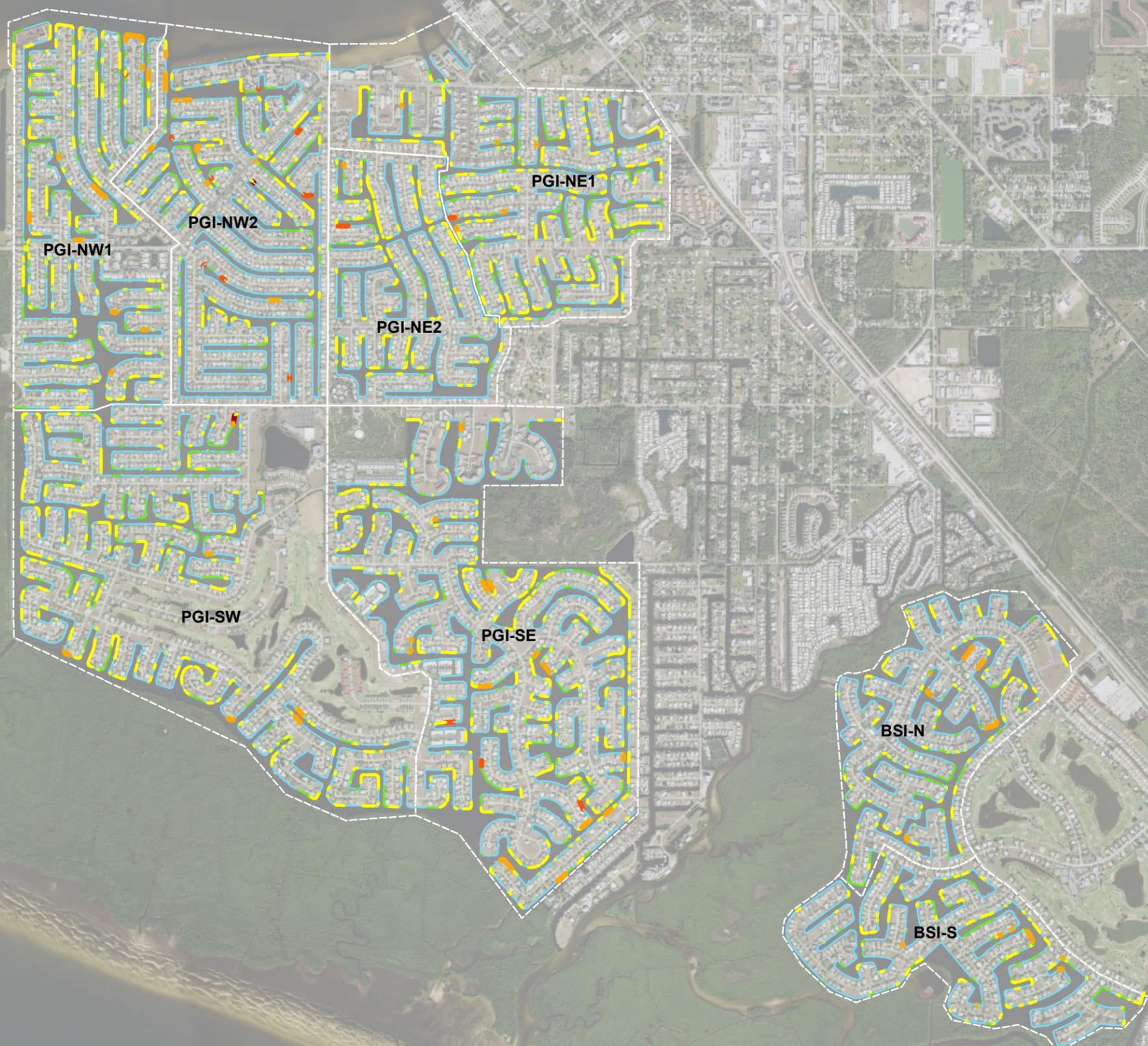
The most recent conditions assessment rating was performed in March 2017, providing an update on seawall conditions for the entire 109 miles of wall. Based on a review of the 2017 conditions assessment data, Table 3.2 below summarizes the length of seawalls under each condition rating category. Approximately 479,751 linear feet of wall were evaluated within PGI, of which nearly 80% (386,266 LF) were rated as Good or Excellent. Similarly, approximately 95,042 LF of wall were evaluated in BSI, of which 86% (81,739 LF) were rated as Good or Excellent. Figure 3.1 represents a general geographic distribution of walls with corresponding 2017 condition ratings throughout City limits. *Note that the assessment was performed prior to Hurricane Irma, which occurred in September 2017 and impacted over 55,000 linear feet of wall.*

Table 3.2 Summary of Seawall Ratings Based on 2017 Assessment

Rating	PGI (LF)	BSI (LF)
Excellent	48,617	9,041
Good	337,649	72,698
Fair	86,445	11,769
Moderate	5,836	1,530
Serious	1,118	0
Failure	172	0



Harborwalk

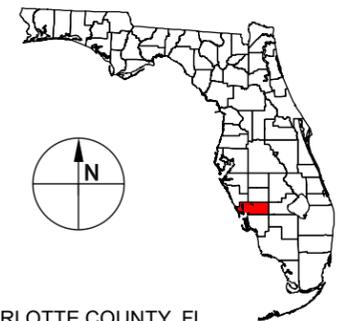
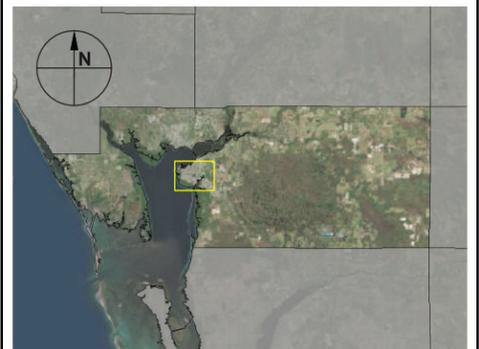


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CERTIFICATE OF AUTHORIZATION # 4815

CITY OF PUNTA GORDA
SEAWALL REPLACEMENT STUDY
WALL CONDITION
AS OF MARCH 2017

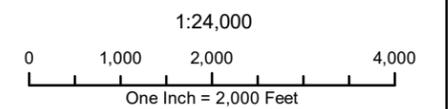


CHARLOTTE COUNTY, FL

WALL CONDITION
AS OF MARCH 2017

- Excellent — Moderate
- Good — Serious
- Fair — Failure

Note: Hurricane Irma made landfall on the Florida mainland on September 10, 2017.



PROJECT	C2019-018
DRAWN BY	PL
DATE	6/18/2019

3.4 Permit Records

The City provided a copy of the current USACE seawall construction permit exemption, a 10-year permit that expires on March 10, 2021. In addition, a copy of the Florida Administrative Code (F.A.C. 62-330.051) and Florida Statutes (403.813) was provided. The statute identifies that placement of rip rap in front of a seawall is considered an exempt activity by FDEP; this authority may be relevant to the future of the City’s seawall program. FDEP defines riprap as natural boulders one to three feet in diameter; clean concrete rubble with a similar average dimension can be used but there can be no reinforcing rods or other similar protrusions in the concrete. The City also holds a permit for the dredging of the inlets and navigable canals within the project area. Regulatory authorizations are summarized in Table 3.3.

Table 3.3 Summary of Existing Active Permits

Permit Type	Permit number	Permit Info	Date	Expiration	Additional Comments
USACE	SAJ-2011-00037(IP-BEM)	Seawall Replacement for Both PGI & BSI	3/10/2011	3/10/2021	10-Year Permit
USACE	SAJ-2011-02755(IP-BEM)	Maintenance Dredging of All Inlets and Navigable Canals Within PGI & BSI	5/14/2012	4/14/2022	10-Year Permit for Dredging: Snook Inlet, Pompano Inlet, Isles Cross Channel, Bass Inlet, Punta Gorda Isles, Burnt Store Isles
FDEP	08-0202050-004	Dockside Dredging in Existing Manmade Canals within PGI/BSI	9/6/2002	9/2/2022	10-Year Permit with Extension

3.5 Existing Construction Staging

The following information was provided pertaining to the City’s current approach for construction access and staging areas:

- The locations of empty (non-developed) lots throughout PGI and BSI.
- The location of the dredge spoil area on Colony Point Drive.
- Some specific lots that the installation contractor usually prefers.
- The empty lots that are for sale and their approximate price.
- An analysis of the rate at which the vacant lots are being developed.
- Projections as to when they all could be unavailable to use.
- Vacant lots with water access.
- Commercial parcel location for possible City acquisition for permanent staging station.

Regarding the use of vacant lots for staging, the City's Code, Chapter 6, Article 1, Section 6-7(c) authorizes the use of private property by the Canal Maintenance Districts by its employees and agents "...for the purpose of maintaining or reconstruction seawalls or appurtenances" (as outlined in an email from David Levin (City Attorney) to the Mayor on February 6, 2014). The attorney's email continues that "...provisions of Section 6-7(c) do not provide any specific limitations regarding the use of private property, provided such use is consistent with the stated purpose". Note that this explanation suggests that no prior specific consent from the landowner seems to be required under the provisions that section before such property may be utilized.

However, the City staff has expressed concern over the lack of existing vacant lots for use as temporary staging necessary to maintain the seawall maintenance program. In July 2014, the City's Urban Planning Department calculated the number of remaining vacant single-family lots with water access; concluding 676 lots were available in PGI and 230 in BSI. The buildout analysis (provided by the City) suggests that PGI lots were 84% built out and that BSI lots were 77% built out at the time of the analysis. In 2016, the City evaluated the potential purchase of one or more lots for permanent use. The City's "PGI Lot Closeout Summary" indicated that in 2016, there were 579 possible staging lots available. The average lot price at that time for 96 vacant lots was on the order of \$314,391 per lot. However, upon further discussion the PGI Canal Advisory Committee (CAC) requested that the vacant lot discussion be removed from further maintenance alternatives for the following reasons (as summarized in the City's PGI Lot Closeout Summary):

1. Not a popular option with residents,
2. Adjacent lots would be impacted forever if a lot were purchased for City use,
3. Alternative technologies would be more beneficial,
4. A central staging lot (spoil site) would not impact the neighboring residents,
5. FPL does not have any underground substations planned.

The City provided GIS maps depicting vacant lot locations as of 2016 based on the City lot mowing program. These figures are provided in Appendix C.

4.0 GIS ANALYSIS AND DATA CREATION

4.1 GIS Data Creation/Manipulation

Upon receipt and review of the City-provided data outlined in sections 3.1 to 3.6, Taylor Engineering evaluated the various data sets and types, developed a set of criteria and assumptions in order to compile, organize, and catalog the data as necessary to develop a more comprehensive database intended to assist the City in streamlining future record-keeping and provide a basis for subsequent analysis related to future seawall replacement projections.

The following details outline the assumptions made in this analysis:

4.1.1 Existing GIS Data

To simplify the use of the City's GIS data, Taylor Engineering created a common attribute schema that uses attributes from all six of the City's assessment feature classes. Data from the City's original feature classes were loaded into this common schema for consistency.

4.1.2 *New GIS Data*

- Taylor Engineering created point, line and polygon feature classes (GIS data) representing approximate locations of seawalls that were rebuilt between 2011–2017.
- The SOW Excel spreadsheets provided by the City were used to create these data.
- Due to schedule and budget constraints, Taylor Engineering was not able to follow the City’s protocol/methods to update the City’s GIS data using the provided SOW Spreadsheets. Some assumptions in the SOW data were made when converting these data to GIS:
 - If the Statement of Work number is the same for more than one home address and one of them is completed, then it is assumed that all of those properties were subject to new seawall installation.
 - The year of seawall replacement was assumed to be the end of the fiscal year that was issued.
- Additionally, inconsistencies in the SOW data made it difficult to create GIS features from the SOW records. For example:
 - Some addresses were missing the street number and the property cannot be located.
 - Many street names were spelled incorrectly or inconsistently, and the property cannot be located.
 - Many street types (road, lane, street, etc.) were missing.
- Taylor Engineering used the following steps to create GIS data from the SOW spreadsheets:
 - Combined data for BGI and PGI into one continuous worksheet.
 - Cleaned up street name misspellings and street types as much as possible within schedule and budget constraints.
 - Assigned year rebuilt using Fiscal Year column.
 - Used SOW Number to group wall sections with the assumption that a wall was constructed for all parcels related to the SOW Number.
 - Tabularly joined SOW spreadsheet records to GIS Parcels using the account and address fields.
 - Spatially joined GIS parcels to seawall line files that were split at parcel boundaries.

Note that the steps above are a very approximate method to create GIS data from the SOW records. Given this task’s time and budget constraints it is difficult to create accurate line representations of the exact location of seawalls that have been constructed.

4.2 **Seawall Categories**

The data was cataloged into three separate eras: original walls that had not yet been replaced, walls replaced with epoxy coated rebar reinforcement, and walls replaced with MMFX rebar reinforcement. From City records, we determined that walls replaced between 1981 and 2009 were replaced using epoxy coated rebar. In 2010 the City modified the design of their concrete panel systems to include marine grade concrete mix design and MMFX rebar. Therefore, walls that were replaced during and after 2010 were installed using MMFX rebar (termed the MMFX era). Records indicate that some wall locations have been replaced multiple times (two or even three time (see Appendix F)) and/or that several sections of wall were replaced at different times along the same property.

Following completion of the data review and cataloging, Taylor Engineering performed a one-day City staff-guided site evaluation to observe the seawall characteristics and identify and photo document the following attributes:

- Condition assessment rating category examples
- Original vs. epoxy vs. MMFX era walls
- Hurricane Irma replaced walls

Below is a general summary of the site visit observations made for each seawall category and type. A copy of the full site evaluation report and photos can be found in Appendix B for more details.

4.2.1 Original Walls Still in Place

The original seawalls were initially installed primarily between 1965 and the 1980s. Prior to 2010, a majority of these seawalls were repaired by replacing the deteriorated cap with a new oversized cap and using epoxy coated rebar but typically without replacing the panels. The panels were found in better condition than expected in some locations, but most of them show abrasion and some type of deterioration. Some panel unions and weep holes were patched along the original seawall installations. City staff indicated that the practice of patching was modified in 2009 due to the significant hydrostatic pressure and stress exerted on the panels for extended periods of time. The modifications include patching from the submerged berm up to the oyster line and leaving the seams open from that point to the cap. The weep holes are now left open as well.

During the site visit, minor cracks were observed on some panels, typically just below the cap. Moderate to serious cracks were found on some of the panels below the oyster line. A limited number of these cracked panels are scheduled for replacement during the next fiscal year based on budget constraints.

4.2.2 Epoxy Coated Rebar-Reinforced Walls (Replaced prior to 2010)

The seawall repair program in started around 1986 and from then through 2009, seawalls were repaired by installing an oversized epoxy coated rebar reinforced cap. New cap installations often extended beyond the limits of any panel replacement sections, terminating in the middle of older adjacent panels. The City indicated that panel breakage often occurred at these locations due to the differential loading of different cap sizes/weights.

Locations were observed where a new seawall system was installed along a majority of the property length but did not continue along areas where residential docks were present. Historically as a convenience to the homeowner, this replacement pattern typically occurred where the dock had been pinned to the original seawall for support. As a result, the dock would have needed to be removed if the supporting seawall panels were removed/replaced. However, City staff noted that such an approach is no longer part of the replacement policy. Taylor staff also noted at several locations that only a few panels were replaced rather than all panels along a parcel. There are many locations where replacement along one parcel length or contiguous lot length occurred over multiple years but took place in discontinuous section year-by-year.

4.2.3 *MMFX Rebar Reinforced Walls (Before Hurricane Irma)*

The first generation of seawalls with the more corrosion resistant MMFX rebar was installed between 2010 and 2017. New weep holes also were placed at a lower elevation during casting than those on the original seawall design and other weep holes were placed during this period.

Some of the walls that were replaced between 2010 and 2017 have since been replaced again as have some of the 1986 to 2009 replacements. For example, one seawall we observed was replaced during this era but recently failed with the top of the wall rotating waterward. Based on this failure mode, it is evident that either the upland anchor (deadmen) or the connection to it failed. As expected, several large depressions in the upland soil were observed at the time of the site visit. The majority of walls replaced during this time were either older section or later sections tied to older walls.

4.2.4 *MMFX Rebar Reinforced Walls (Post Hurricane Irma)*

Hurricane Irma passed along the Gulf coast in September 2017, resulting in excessive rainfall combined with an extreme negative tide in Punta Gorda. This combination caused widespread damage and failure to the aging seawalls. Following the storm, the City hired a company to assist the Canal Maintenance Division with manufacturing seawall panels to keep up the storm recovery production demands. The most common failure type observed following the storm was a 'toe kick-out', indicative of insufficient panel soil penetration/embedment. The City noted that the seawalls installed post-Irma to the present are referred to as the 'new' era of MMFX' seawalls and refined installation techniques and methods have been employed.

4.3 **Other Considerations & Site Observations**

Although not typical for the residential canal maintenance program, the City also maintains seawalls abutting access bridges. We were asked to review and comment on observations made for those wall sections. A detailed observation summary can be found in Appendix B.

4.3.1 *Canal Access via Bridges and Lock*

Canal access in some locations must cross under three fixed clearance bridges along West Marion Avenue. The first bridge (Bass Inlet bridge) serves as the only water access to both zones within PGI-NE. All the piles in the middle of the canal were protected around the splash zone with timber boards. Large spalls were observed at multiple different elevations along many of the prestressed concrete piles, presumably due to repeated vessel impacts. The vertical clearance around the normal high tide is also in the 12 ft range. However, maneuverability of construction barges below the bridge at this location combined with strong currents and a sharp turn is a likely challenge.

A second bridge, known as Sailfish bridge, is located near the north end of the PGI-NW2 subdivision and has a vertical clearance of approximately 12 ft during the normal high tide. Taylor staff noted that some of the seawall panels near the bridge abutment were about 2 ft wide. City staff stated that those panels were possibly installed by FDOT at the time of the bridge construction.

The third bridge (Colony Point) is located at the west end of the subdivision PGI-NW1. To estimate clearance heights, at the time of the site visit we noted that the tide was about 1.2 ft above MLLW; the water mark at the gage rod level indicated that an approximate vertical clearance of 13 ft would result during the normal high tide. The bridge substructure was observed to be in good shape. City staff warned about the strong currents that occur due to the narrower section just below the bridge.

An entrance lock serves as the primary access way to BSI. The lock system is no longer in operation, but part of the structure is still present, constricting the only entrance to BSI canals to a very narrow channel. It is presumed that only one boat at a time could use this access entrance. Once in use, the vessels must signal other boats before doing a sharp right or left turn right after entering the BSI canal system. The maneuverability of construction barges around this location presents another challenge.



Figure 4.1 Map of Canal Access Bridges

4.3.1 Rip Rap

As noted above, F.A.C. 62-330.431 defines rip rap as natural boulders or clean concrete rubble, one to three feet in diameter in average dimension. Rip rap was observed in a few intermittent sections on the northwestern canal of PGI-NW1 and on the north side of PGI facing the bay during the morning mid-incoming tide. The majority of the panels facing the bay are from the original installations. The City indicated that even with the exposure to wind generated waves and boat wakes, the rip rap helps to provide scour protection to the panels. For this reason, the City is considering pursuing regulatory authorizations to install rip rap on the majority of the seawall system damaged during Hurricane Irma using potentially available FEMA mitigation funding.

4.3.2 Other Obstructions

Under the City's ordinances, large landscaping installations are not allowed within 10 ft of a seawall. However, in some cases, residences were observed with landscaping and trees in close proximity to the seawalls (examples referenced in the site observation memo, Appendix B). Similarly, several palm trees and other large trees (including an orange poinciana) were observed close to the seawall on the northwestern PGI-NW1 canal. The roots of these trees add lateral pressure to the seawalls and could damage the tie-back system. The City noted that removal of trees and large landscaping is required on a case by case basis based on site conditions.

Additionally, there are cases where seawall deadmen have been covered by patios or structural foundations, most typically on older established home sites. This creates issues with access for installation of new tie-back systems. In such cases, the City noted that extra caution must be taken by the contractor so that the upland structure is not compromised. The City also indicated that contractors have recently been using alternative methods for anchoring in place of deadmen, such as Manta Rays™ and/or helical soil anchors to tie-back the wall in areas where a more traditional deadman tie-back system is not feasible.

5.0 DATA EVALUATION AND ANALYSIS CRITERIA

Following completion of the initial analysis and GIS database compilation, Taylor Engineering developed maps to identify the distribution of initial wall installations, historical replacements, and wall failures as a result of Hurricane Irma. A significant effort was made to review, analyze, catalog and organize the City's annual seawall inspection and replacement records for 109 miles of wall; which provided the basis for estimating remaining service life and subsequent planning level seawall replacement projections (Section 9.0). Section 5.0 describes our analysis of the data, which was organized and evaluated based on geographic location using the two district neighborhoods (PGI and BSI). The two districts were divided into 8 smaller zones (PGI-NW1, PGI-NW2, PGI-NE1, PGI-NE2, PGI-SW, PGI-SE, BSI-N, BSI-S), identifying the length of wall within each zone.

Figure 5.1 illustrates the distribution of original seawall installations by zone, with the earliest installation occurring in PGI-NW1 and PGI-NW2 in 1965.

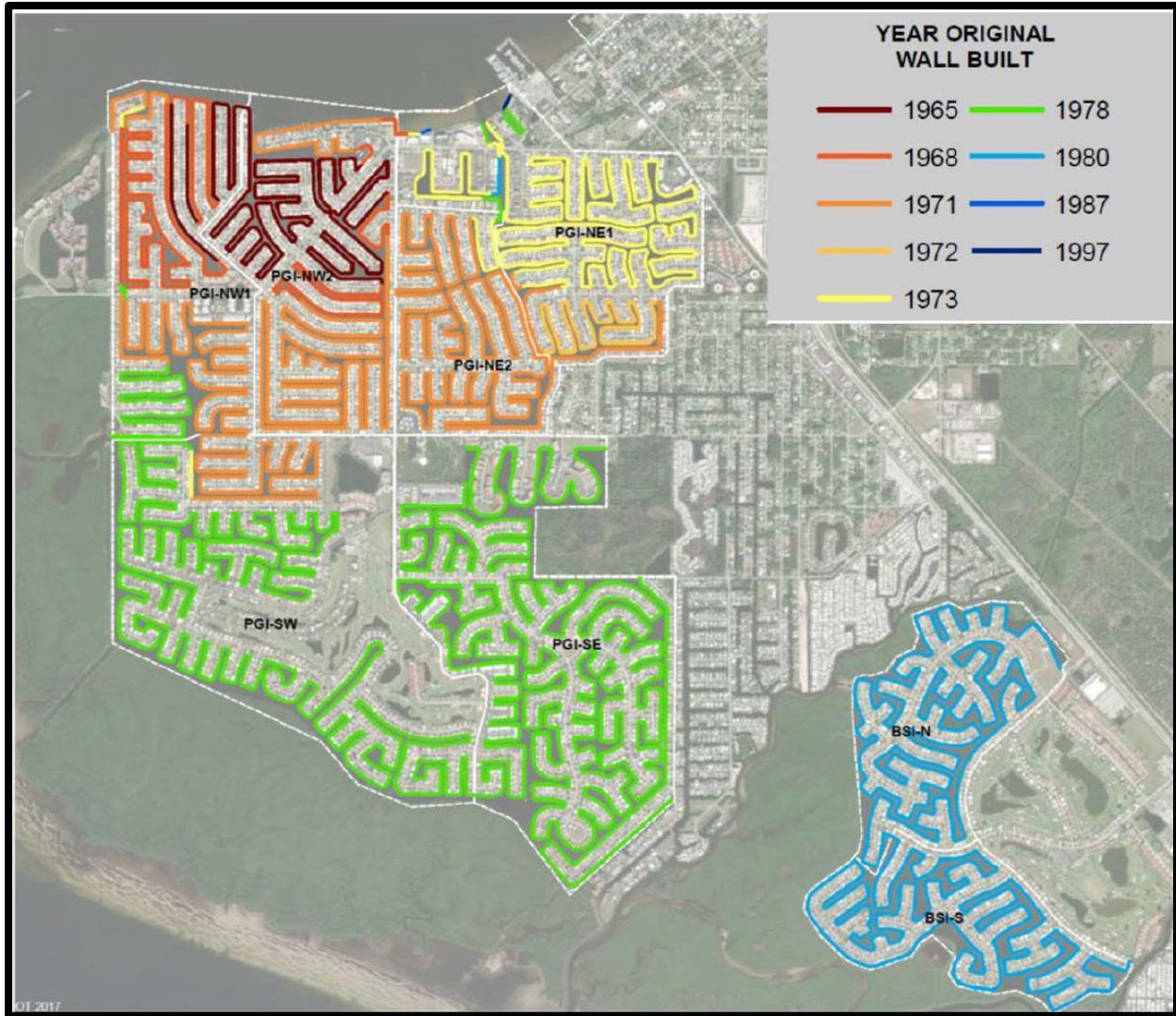


Figure 5.1 Original Wall Installation Years

The total seawall length located in PGI and BSI is 575,289 ft. Figure 5.2 shows a bar graph distribution of original seawall installations by year. The greatest number of walls installed were in 1971, 1978 and 1980.

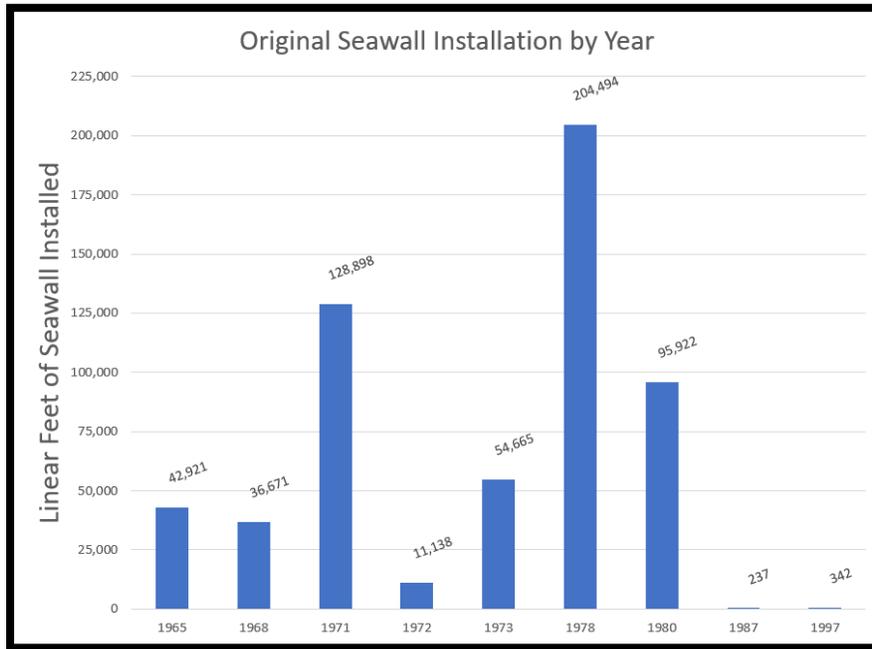


Figure 5.2 Distribution of Original Wall Installations by Year

For comparison, we summarized the length of wall that presently exists within each zone, for a total of 575,289 linear feet (109 miles) of wall within City limits.

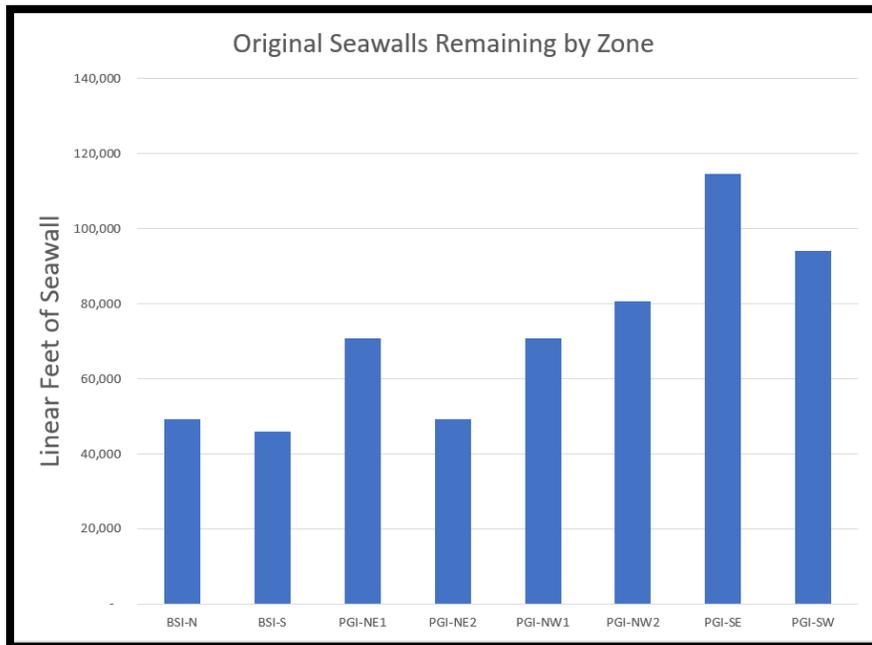


Figure 5.3 Distribution of Current Walls by Zone

Table 5.1 summarizes total length of wall within each zone and the percentage of those walls that have been replaced through 2017.

Table 5.1 Length of Seawall by Zone

Zones	Total Wall Length by Zone (LF)	Total Length of Walls Replaced (LF)	Percentage of Walls Replaced By Zone
BSI-N	49,204	8,275	17%
BSI-S	45,834	8,974	20%
PGI-NE1	70,846	48,973	69%
PGI-NE2	49,256	21,666	44%
PGI-NW1	70,677	36,995	52%
PGI-NW2	80,643	33,581	42%
PGI-SE	114,748	30,448	27%
PGI-SW	94,082	35,287	38%
Total	575,289	224,200	-

In addition to separating the total seawall length by district zones, the GIS data also evaluated walls by era of installation. Based on City feedback and records, seawall eras include original wall installations, epoxy coated rebar reinforced walls, and MMFX rebar reinforced walls. The majority of original walls were installed between 1965 to 1980, with the exception of about 579 feet installed in PGI-NE1 between 1987 and 1997 (Figure 5.2). Among the original walls installed, nearly 61% of all original walls are still in place today with an average in place age of 39 to 51 years, as shown in Table 5.2 below.

Table 5.2 Distribution of Original Walls Never Replaced

Zones	Original Installation Year	Avg Weighted Installation Year	% of Original Walls Never Replaced	Average Age of Original Walls (Yrs)
BSI-N	1980-1980	1980	83%	39
BSI-S	1980-1980	1980	80%	39
PGI-NE1	1968-1997	1973	31%	46
PGI-NE2	1971-1978	1971	56%	48
PGI-NW1	1965-1978	1970	48%	49
PGI-NW2	1965-1971	1968	58%	51
PGI-SE	1978-1978	1978	73%	41
PGI-SW	1971-1978	1977	62%	42

Table 5.3 shows the total length of walls never replaced (61%), replaced during the epoxy coated rebar era (18%), and those replaced during the MMFX rebar era (11%).

Table 5.3 Seawall Overall Conditions Lengths

Seawall Replacement Category	Quantity (LF)	% of Total Length
Original Walls (never replaced)	351,089	61%
Walls Replaced Between 1981-2009 (Epoxy)	102,911	18%
Walls Replaced Between 2010-2017 (MMFX)	66,203	11%
Walls Replaced Post Irma	55,314	10%
2017 Conditions Assessment 0,1, and 2	566,218	98.5%
2017 Conditions Assessment 3,4, and 5	8,656	1.5%

Note: 414 linear feet of walls were not assessed

Based on detailed review of the 2017 conditions assessment data, Table 5.3 summarizes the length of seawalls under each condition rating category. Approximately 479,838 linear feet of wall were evaluated within PGI, of which nearly 80% (386,266 LF) were rated as Good or Excellent. Similarly, approximately 95,038 LF of wall were evaluated in BSI, of which 86% (81,739 LF) were rated as Good or Excellent. Among those, more than 98% of the walls evaluated at that time had a condition rating of Excellent (0), Good (1), or Fair (2) whereas only 1.5% were given a condition rating of Moderate (3), Series (4), or Failed (5).

Using the joined GIS database, among the walls that have never been replaced, Taylor Engineering identified how those walls were rated by City staff in the 2017 conditions assessment. According to the 2017 conditions assessment:

- Nearly 98% of the original walls that have never been replaced were rated as having a 0, 1, or 2 rating (excellent, good or fair).
- Considering the age of the existing original walls, the 2% of walls that were rated at that time as 3, 4, and 5 are of priority concern. However, nearly 6 months after the completion of the 2017 conditions assessment, approximately 55,314 linear feet of walls were damaged due to Hurricane Irma and subsequently replaced in 2018/2019 using FEMA Hazard Mitigation funds.
- Therefore, all walls that failed and were replaced as a result of Irma were removed from the analysis and given a default ‘excellent’ rating condition.
- Nearly 351,089 linear feet of original wall *did not* fail during the passage of Irma.
- Only 350,676 linear feet are accounted for in the GIS database as 413 linear feet of wall were not attributed with a condition rating in 2017.
- Of the 351, 089 linear feet of original walls that did not fail during Irma only 4,953 feet, 250 feet, and 25 feet of that total – had been rated in 2017 as moderate, serious or failed, respectively .

For walls that did not fail during Irma, we evaluated the total length of walls replaced and their overall condition assessment rating during the 2017 last inspection. Among the 39% of walls that have been replaced at least once, it is not clear how many linear feet were installed between the years 1981 and 2002 within all zones. Similarly, only replacement dates between 2003 and 2009 were identified from the GIS database with data represented for only 2 of the zones (PGI-NE1 and PGI-NW1). Notably these

walls with missing installation dates represent walls installed using epoxy coated rebar. According to City provided GIS and Excel records, removing from the analysis the walls that failed and were subsequently replaced in 2018/2019 after Hurricane Irma, Taylor Engineering identified:

- A total of 115,289 linear feet of wall that had been replaced between 1981 to 2002 using epoxy coated rebar.
- A total of 108,773 linear feet of wall that had been replaced once after 2002. Note that replacements that occurred during 2003 and 2009 were only recorded within 2 subdivisions (PGI-NE1 and PGI-NW1) which accounts for 4,421 linear feet total (2,659 ft in PGI-NW1 and 1,762 ft in PGI-NW1).
- A total of 224,200 linear feet of wall has been replaced once using epoxy coated rebar.
- A total of 18,904 linear feet of wall appear to have been replaced a second time, with 6.2% occurring in PGI-NE1 and 5.9% in PGI-NW2.

Table 5.4 illustrates the distribution of epoxy coated rebar walls installed with unknown installation dates.

Table 5.4 Epoxy Coated Rebar Wall Replacements by Zone

Zones	Total LF Per Zone	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002
BSI-N	49,204	1,446	3%	6,829	14%
BSI-S	45,834	2,198	5%	6,776	15%
PGI-NE1	70,846	32,667	46%	16,306	23%
PGI-NE2	49,256	6,467	13%	15,199	31%
PGI-NW1	70,677	20,439	29%	16,556	23%
PGI-NW2	80,643	15,879	20%	17,702	22%
PGI-SE	114,748	14,801	13%	15,648	14%
PGI-SW	94,082	21,529	23%	13,758	15%
Totals:	575,289	115,427	-	108,773	-

Epoxy coated rebar reinforced walls account for nearly 39% (224,200 linear feet) of the City’s walls. Based on GIS records, nearly 102,909 linear feet of epoxy coated rebar reinforced wall is still in place and were not impacted by Hurricane Irma. The 2017 condition ratings of those walls that remain in place are as follows:

- 1,948 ft with a rating = 0
- 93,999 ft with a rating = 1
- 6,838 ft with a rating = 2
- 111 ft with rating = 3
- 14 ft with a rating = 4
- Zero ft with a rating = 5

As a result, nearly 121,291 ft of epoxy coated rebar reinforced walls were not accounted for in the GIS and Excel data records. The epoxy seawall dataset was supplemented with data from historical invoices documenting money spent between the years of 1994 to 2010; this data was subsequently used to calculate the estimated linear footage of wall installed per fiscal year. The average installation cost per linear foot per year was calculated using City invoicing records, resulting in a cost per linear foot of \$161.45 for the BSI seawalls and \$176.81/LF for the PGI seawalls. The total length of epoxy coated rebar reinforced seawalls replaced between 1994 and 2010 was 85,917 LF according to the City’s budget records. However, the location of these wall replacements is unknown and not identified in the budget/invoice records. While this supplemental data reduced the missing data gap, records are still missing for nearly 35,374 LF of wall installations.

The distribution of seawall replacements using epoxy vs. MMFX rebar is illustrated in Figure 5.4. The amount of GIS data for linear feet installed per year is identified in hatched green with the supplemental budget/invoice data illustrated in solid green. The spike in replacements observed in the year 2004 was due to the passage of an unnamed storm, causing widespread seawall failures.

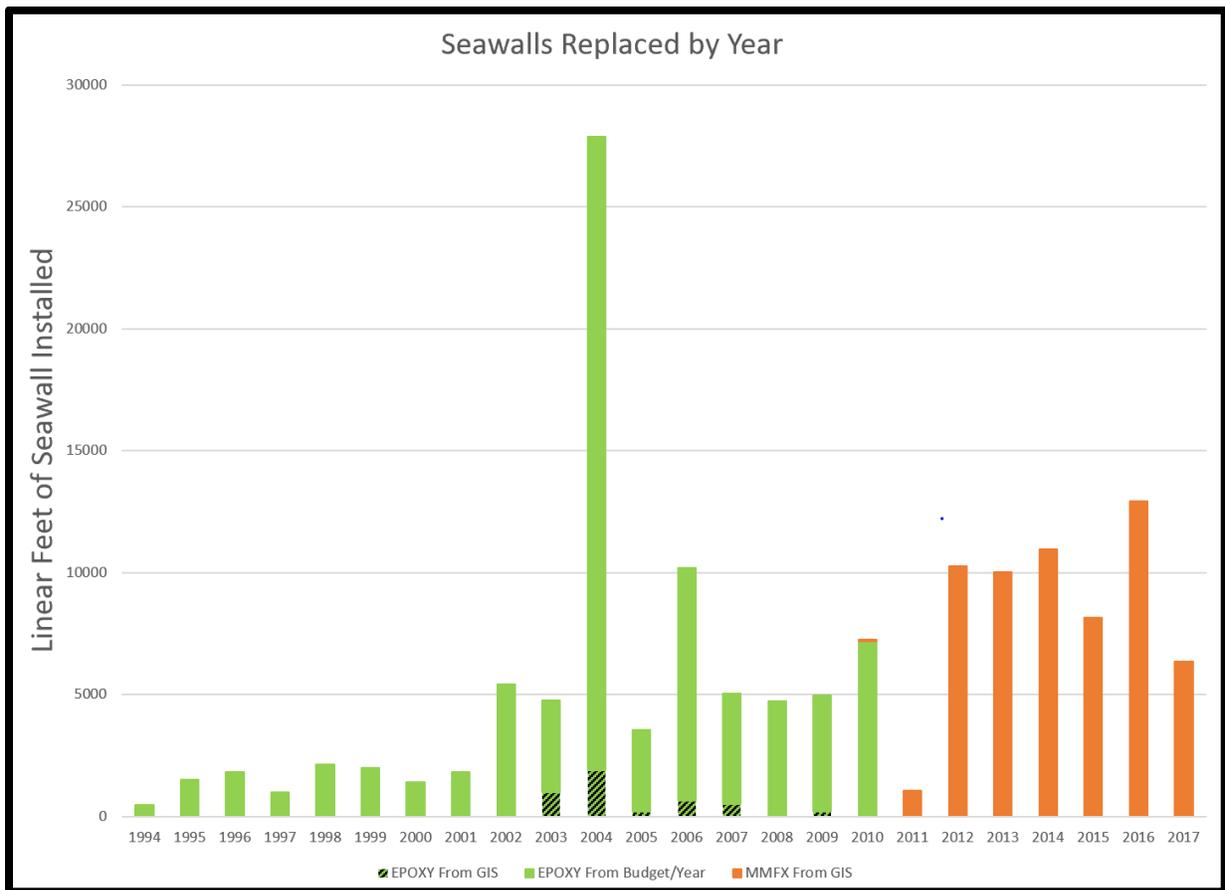


Figure 5.4 Seawall Replacement by Year and Rebar Type

The use of MMFX rebar for wall replacements began in 2010. In some cases, walls were replaced for the first, second or third time using this rebar type. Among the walls replaced using MMFX rebar,

nearly 65,955 LF of wall were evaluated in the 2017 conditions assessment that did *not* fail during Hurricane Irma. The condition ratings of those walls are as follows:

- 39,676 feet with a rating = 0
- 20,495 feet with a rating = 1
- 4,847 feet with a rating = 2
- 818 feet with rating = 3
- 118 feet with a rating = 4
- Zero feet with a rating = 5

A review of the walls replaced in 2017, prior to Hurricane Irma impacts, determined that approximately 6,714 linear feet of walls were replaced during the period between January to early September 2017, following completion of the 2017 condition assessment. Among the walls that were replaced during that timeframe, 90% of them were for walls recently rated as 0, 1, and 2. The City noted the Spring of that year to be unseasonably wet. This may have led to an increase in hydrostatic pressure along newly replaced panels that may have been anchored to older, existing tie-backs and deadmen. Based on GIS records, a summary of the 2017 pre-Irma seawall replacement distribution compared to the 2017 conditions rating is as follows:

- 39,304 ft of wall previously given a 2017 rating = 0
- 16,764 ft of wall previously given a 2017 rating = 1
- 2,985 ft of wall previously given a 2017 rating = 2
- 71 ft of wall previously given a 2017 rating = 3
- All walls given a rating 4 were replaced

According to the GIS database, seawall replacements began in 1994. A limited number of walls or wall segments appear to have been replaced twice between the years 2011 and 2016.

Table 5.5 provides a summary of the 2017 conditions rating assessment by zone for each of the three seawall rebar eras – original, epoxy coated, and MMFX rebar. The values represent the percentage of the wall designated with each rating with respect to the total length of wall within each zone.

Table 5.5 2017 Condition Rating Summary by Zone for Each Wall Era

Condition Rating Percentage within Each Zone									
Original Walls Not Failed During Irma		BSI-N	BSI-S	PGI-NE1	PGI-NE2	PGI-NW1	PGI-NW2	PGI-SE	PGI-SW
2017 Conditions Rating	0 = Excellent	2%	2%	5%	1%	3%	2%	2%	3%
	1 = Good	69%	67%	15%	47%	30%	50%	54%	42%
	2 = Fair	11%	11%	10%	8%	13%	6%	16%	17%
	3 = Moderate	2%	1%	0%	0%	2%	1%	1%	0%
	4 = Serious	0%	0%	0%	0%	0%	0%	0%	0%
	5 = Failure	0%	0%	0%	0%	0%	0%	0%	0%
Epoxy Rebar Walls Not Failed During Irma		BSI-N	BSI-S	PGI-NE1	PGI-NE2	PGI-NW1	PGI-NW2	PGI-SE	PGI-SW

2017 Conditions Rating	0 = Excellent	0%	0%	1%	0%	0%	0%	0%	1%
	1 = Good	2%	4%	37%	10%	26%	14%	11%	19%
	2 = Fair	0%	0%	6%	0%	2%	0%	0%	1%
	3 = Moderate	0%	0%	0%	0%	0%	0%	0%	0%
	4 = Serious	0%	0%	0%	0%	0%	0%	0%	0%
	5 = Failure	0%	0%	0%	0%	0%	0%	0%	0%
MMFX Rebar Walls Not Failed During Irma		BSI-N	BSI-S	PGI-NE1	PGI-NE2	PGI-NW1	PGI-NW2	PGI-SE	PGI-SW
2017 Conditions Rating	0 = Excellent	7%	7%	6%	6%	10%	7%	5%	8%
	1 = Good	4%	5%	3%	2%	4%	4%	4%	3%
	2 = Fair	1%	1%	1%	0%	1%	1%	1%	1%
	3 = Moderate	0%	1%	0%	0%	0%	0%	0%	0%
	4 = Serious	0%	0%	0%	0%	0%	0%	0%	0%
	5 = Failure	0%	0%	0%	0%	0%	0%	0%	0%

6.0 EXISTING SEAWALL DESIGN AND CONSTRUCTION OVERVIEW

Although the City’s concrete panel seawall system design has evolved over time, Taylor Engineering reviewed the existing 2019 seawall design and installation methods to identify strengths and potential shortcomings that could be improved. The existing design consists of concrete panels topped with a concrete cap. Concrete deadmen, 5-ft by 2-ft by 1-ft in size, are utilized to anchor the tie-rods. The concrete deadmen are specified using epoxy coated rebar (City’s Waterfront Design Standards). For concrete caps, epoxy coated rebar is specified for cap replacement; however, MMFX rebar is used to reinforce the cap for newly installed panels (City communication).

The sheet pile panels are manufactured at the City’s Public Works Facility using marine grade 5,500 psi silica fume concrete and MMFX rebar. MMFX rebar is a steel alloy that has similar corrosion characteristics as 304 stainless steel; but 304 stainless steel is generally not considered adequate for use in direct contact with saltwater and is not as effective as a 316 stainless rebar. However, in general across all rebar types, properly protect from chloride-induced corrosion by using a concrete mix design that inhibits the migration of water and water-borne salts to the encapsulated rebar. The properties of the concrete mix and of the rebar work together as a corrosion resisting system.

There are four design lengths for the panels, depending on the water depth at the site; 10 ft., 12.5 ft, 14 ft and 16 ft lengths. Three of the design panel sections are 6 ft wide and 6-inches thick, shown in the typical cross-section in Figure 6.1, with a rebar concrete cover of 2.5-inches. The 16 ft panels are 4 ft wide based on verbal discussion with City staff.

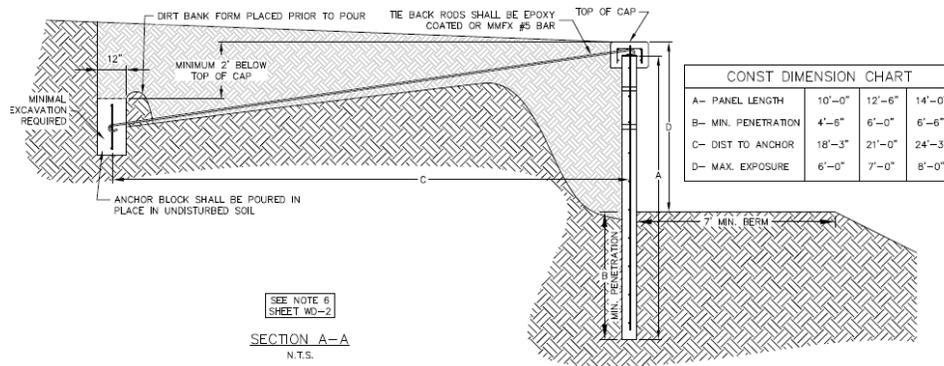


Figure 6.1 Typical Sheet Pile Tie-back Seawall Cross-section

General Observations: No structural analysis was performed as part of this scope, however, we have provided comments based on review of the City’s waterfront design standards. The City has indicated that the 10 ft long panel section is manufactured and utilized almost exclusively. Within the City’s design drawings, under the General Notes Sheet No. WD-2, the design appears to be based on a Factor of Safety (FS) equal to 1.25. Taylor Engineering typically uses a FS of 1.6 for sheet pile flexure and 2.0 for the deadman soil pullout capacity. In addition, we usually add a temporary live load of 200 psf to account for potential construction loads.

Steel Reinforcement: All steel reinforcement shown in the City’s details include the use of mild, low-carbon chromium steel (MMFX) rebar or epoxy coated rebar, except for the tie-backs.

Tie-back System: The City is currently using rebar tie-backs that are specified as epoxy coated or steel with PVC encasement. The use of epoxy coated reinforcement has had mixed results in marine applications. At one point, the FDOT stopped using epoxy coated rebar due to performance concerns. Considering both potential loading and corrosion rates in the marine environment, the #5 rebar for the anchor rods as shown in Figure 6.2, is undersized, particularly where site conditions require greater sheet pile lengths. Notably, the size and spacing of the anchor rods typically change/increase with increasing wall height. The current design allows for welding of new anchor rods to the existing ones. The welds can present an area of metal with a significantly reduced cross section, thereby making the welds very susceptible to loss of strength due to corrosion.

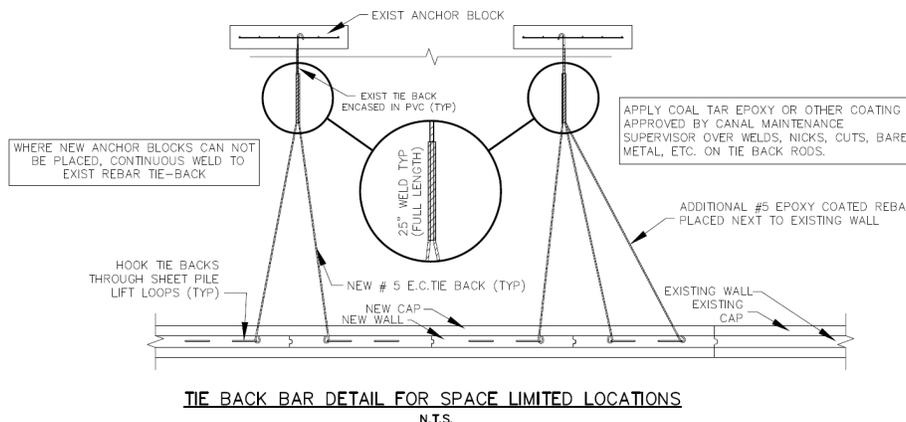


Figure 6.2 Tie-back Detail

The City indicated that existing tie-rods and deadmen at a wall replacement location may be reused if they provide 'resistance' when pulled using the contractor's equipment. In such a case, new tie-rods are typically welded to the old anchor system. However, the specific remaining pullout capacity of the modified system is unknown/undetermined. If the anchor system pulls free when the load is applied by the contractor, then a new deadman and tie-rods are installed.

Concrete Mix: The concrete mix design used for panel forming includes a high strength 5,500 psi concrete with silica fume admixture, used to reduce shrinkage cracking. The panels are typically manufactured at the Public Works Facility, where they are formed and cast, and then plastic sheeting is placed on top of the panel. Due to a lack of available space, the next manufactured panel is formed and cast on-top of the previously manufactured panel. Each new panel is cast on top of the prior panel the following workday until the panels are stacked 7 panels high in consecutive days. Although the top panel is treated with a curing compound, no added moisture is used to properly wet cure the panels.

Installation: During construction, the City has been using vacant lots as staging areas. The staging areas are used for delivery of materials, loading and offloading of barges, and material storage. Once at the project site, the Contractor excavates behind the existing bulkhead and then demolishes the wall. Excavated earth fill is stored on the respective upland project site or staging area. Demolished bulkhead material is placed on the barge and transported to the nearest staging area for transport to a landfill. New sheet piles are loaded onto the barge at the staging area and delivered to the project site where they are installed. Concrete sheet pile panels are installed by jetting. All cap forms, jacks, rebar, etc. are delivered to the project site from the road adjacent to the property. From correspondence with City staff, all concrete for the cap and deadmen is pumped from the road adjacent to the property. Transport of demolished bulkheads and excavated earth is done via barge. The rate and duration of construction is highly dependent on the distance from the project site to the staging area.

7.0 ALTERNATIVES ANALYSIS

Taylor Engineering performed a review of seawall alternatives to assist in determining if alternative materials or methods might benefit the City's ongoing seawall replacement program. The goal was to identify appropriate cost-effective sheet pile materials and installation technologies that the City might consider for seawall repair, replacement, and rehabilitation. A range of seawall and shoreline stabilization alternatives were summarized and evaluated, as outlined in Table 7.1. and discussed in more detail in sections following. The alternatives presented herein are viable, cost-effective, options to improve the seawall design or are technologies that the City has expressed an interest in reviewing.

Table 7.1 Seawall Panel Alternative Materials

Material	Type	Advantages	Disadvantages	Typical Failure Modes	Site Condition Requirements	Installation Technique	Access Requirements	Construction Equipment Requirements
Concrete	Precast slabs Cast-in-place Cap	Excellent longevity Common and durable Precast slabs reduce cost	Weight makes transport difficult Sheets suitable for sand installation only If concrete cracks chlorides have a direct path to reinforcement	Corrosion of steel reinforcement and degradation of concrete Panel joint deterioration	Used for exposure heights up to 15 ft Shallow water depth Loose granular soil	Excavation Jetting	Small excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Landside excavator
Steel	Corrugated sheets	High strength Excellent for hard driving conditions Used for large exposure height No need for anchors for small exposure height	Not aesthetically appealing; Expensive Subject to Corrosion Typically coated to extend service life Requires maintenance to maintain aesthetic appeal and maximize service life	Surface and localized corrosion	Used for exposure heights up to 60 ft and greater Loose to dense soils	Vibration Impact driving (dense soils) Press-in	Medium excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Landside crane/excavator
FRP	Fiber-reinforced polymer corrugated sheets	Medium to high strength Corrosion resistant material Light sheets	Less durable for hard driving Brittle	Creep UV exposure Water absorption	Used for exposure heights up to 20 ft Loose-medium soil	Vibration Jetting	Small excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Backhoe loader or similar
Vinyl	PVC corrugated sheets	Cost effective Medium strength Excellent longevity Light sheets	Strength limitations Less durable for hard driving High deflections, even when max moment is not exceeded	Creep UV exposure	Used for exposure heights up to 15 ft Loose-medium soil	Vibration Jetting	Small excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Backhoe loader or similar
Truline	Double Sheets of Vinyl filled with Concrete	Medium strength Excellent longevity Light sheets Addition of concrete strengthens flexural capacity of wall (but must be added below the mudline to be effective).	Additional construction sequence appears costly The addition of concrete results in extra costs when compared to a vinyl-only sheet pile wall The addition of concrete does not provide additional flexural capacity unless the concrete is installed below the mudline - which incurs additional costs to remove soil within the sheet pile before placing the concrete	Creep UV exposure Corrosion of steel reinforcement	Used for exposure heights up to 20 ft Loose-medium granular soil	Jetting Vibration	Medium excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Backhoe loader or similar
Aluminum	Corrugated sheets	Medium strength High strength to weight ratio	Less durable for hard driving Increasingly expensive Prone to corrosion below the waterline in salt water - not recommended for salt water		Used for exposure heights up to 20 ft Loose-medium soil	Press-in Vibration Jetting	Small excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Backhoe loader or similar
Timber	Soldier pile and lagging wall	Lightweight materials Aesthetic appeal	Lower strength Less longevity Not economically competitive given life cycle costs in marine environment	Physical deterioration biological deterioration	Used for exposure heights up to 10 ft Shallow water depth	Jetting Impact driving	Medium excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Landside crane/excavator
Segmental Block	Concrete blocks Pavers Rock blocks	Aesthetics Lighter equipment demands Easier contouring Excellent longevity	Foundation challenges in marine environment - requires dewatering of foundation area to compact foundation grade and install cast-in-place concrete foundation	Foundation failure - undermining Degradation of geosynthetic tie-backs	Used for exposure heights up to about 30 ft Dense soil	Excavation	Small excavator clearance from road to wall Waterside through a canal	Crane/Excavator barge Backhoe loader or similar
Living Shorelines	Combination of: Rip Rap Oyster bags or reef Local plants	Resilient Environmental Benefits	Typically sloped (rather than vertical) grade change	Erosion and Scour Unanticipated coastal conditions	Used mainly on sloped shorelines	Dumping from a barge Manual hand placement Small equipment	Small excavator clearance from road to shoreline Waterside through a canal	Excavator barge

7.1 Alternative Seawall Systems and Shoreline Stabilization

Taylor Engineering looked at a broad spectrum of seawall alternatives and presented these alternatives in a table format (Table 7.1). A summary description of these alternatives is outlined as follows.

Vinyl Sheet Pile

Vinyl sheet pile is a common material used for walls with small exposure heights. This material is considered cost effective due to its relatively low cost, corrosion resistance and longevity but does not work in all situations. The sheets maintain good aesthetics since they do not rust. Typical vinyl sheets are manufactured from polyvinyl chloride (PVC) infused with a UV inhibitor to resist degradation from sunlight. Since they are non-corrosive, they are ideally suited for saltwater conditions. Although many vinyl sheet pile manufacturers predict a service life of 50 plus years, we believe a predicted service life of 40 years is more accurate in a marine environment.

The lighter sheets can be carried by laborers and cut easily using hand tools. Commonly used installation techniques include vibration and jetting. Disadvantages of vinyl sheet pile include strength limitations and a low modulus of elasticity that can result in excessive deflections even when strength criteria are satisfied. Another problem is the material is susceptible to creep, meaning that the material stretches over time when subjected to a constant load. These limitations can usually be overcome by selection of the proper sheet size for the project. Another problem with vinyl sheet pile is it cannot be driven through hard soil strata without damage unless a mandrel is used. Although a mandrel can be used for installation in hard soils, it is usually cost prohibitive.

Fiber Reinforced Polymer (FRP) Sheet Pile

Fiber Reinforced Polymer (FRP) is used for walls with small to medium exposure heights. It offers superior strength compared to vinyl but is not as strong as steel. Advantages of this material include corrosion resistance, a higher strength than vinyl, and a much lighter weight than steel. Disadvantages include documented water absorption and a low modulus of elasticity. As with vinyl, these limitations can be overcome by selection of the proper sheet size, thereby limiting design stresses to recommended maximums for the FRP material.

The lighter sheets can be carried by laborers if needed. Commonly used installation techniques include vibration and jetting. Just like vinyl, FRP sheet pile is susceptible to impact damage when driving through hard soil strata.

Steel Sheet Pile

Steel sheet pile are used for walls with medium to large exposure heights. Advantages include superior strength both in flexure and compression, making them well suited for installation in hard soil strata. For low wall heights, they can be used as a cantilever wall, thereby omitting the need for a tie-back anchor system. Disadvantages include cost and aesthetics as they rust quickly in a marine environment. To overcome metal loss due to corrosion, engineers typically over-design the sheet pile and select pilings with additional sheet thickness. Although this design technique can often provide a 50 year service life in a marine environment, it increases cost substantially. Due to cost, steel sheet piling is rarely used in a marine environment for walls with low exposure heights.

Truline™ Sheet Pile

Truline™ is a proprietary technology which consist of rectangular vinyl sheet modules filled with concrete. This composite type structure attempts to combine the longevity and low maintenance of the vinyl material with the strength of the reinforced concrete. However, the additional flexural capacity from the concrete is only achieved if the soils below the mudline are pumped out of the modules and replaced with concrete. This increases the cost and complexity of construction.

Given the requirement to remove soil from the sheet modules and replace it with reinforced concrete, this type of wall would require more labor and materials for installation. Therefore, we assume this type of wall would not be as cost effective as a vinyl sheet pile wall.

Living Shoreline

Living shorelines are a great way to add habitat to the estuary ecosystem and reinforce a shoreline. However, living shoreline projects generally incorporate a sloped design which would require a reduction of upland space and/or a reduction in channel width. Therefore, living shorelines might be a solution for a limited number of locations, on a case-by-case basis but are not considered a viable option for this general canal-fronting application.

7.2 Alternative Anchor Systems

There are a number of anchoring system technologies available. Taylor Engineering provides a brief summary of the anchoring system types evaluated as part of this study, summarized in Table 7.2. However, the most cost-effective anchoring system usually consist of tie-rods and concrete deadmen similar to what the City is using now. This system is so widely and commonly used, we refer to it as a traditional deadman system.

Helical anchors may be a feasible alternative for site conditions where limited upland space prevents excavation and burial of concrete deadmen. Essentially, helical anchors consist of steel shafts with helical plates that are screwed into the soil at an angle. The advantages of this method are the rapid installation, immediate load caring capacity, and minimal site disturbance. This method is widely used when structures near the seawall prevent excavation and installation of traditional deadmen. However, they are not suitable for gravel or cobble soils and they need special equipment for installation. This technology would be more expensive than the traditional cast-in-place concrete deadmen currently used by the City.

Several other types of anchor systems are available for tied back (anchored) walls. Some of these types include proprietary soil anchors, sheet pile anchor systems, and various reaction piles (e.g. king piles, batter piles). In general, these anchor types are either not considered cost effective and/or in our experience do not have an adequate design life.

Table 7.2 Anchoring Alternatives

Anchor Type	Description	Advantages	Disadvantages
Concrete Deadman	Cast-in-place concrete block that mass and surface area support lateral load of wall	Built in place, any size, and requires minimal working space. Can be poured at the same time as the cap.	Form installation and concrete curing time and labor Requires significant upland excavation
Sheet Pile Deadman	Sheet pile sheets driven vertical into the soil to support lateral load of wall	Same seawall materials and similar driving method More suitable for temporary construction	Requires more upland working space area
Pile Anchor Deadman	Pile driven vertical into the soil to support lateral load of wall	Fast and cheaper to construct Easily adjusted in the field Simple construction techniques	Requires more upland working space area May require different installation method than seawall
Helical Anchors	Shaft with helical plate at the end that gets screwed at an angle to the ground	Rapid installation Immediate load carrying capability Minimal site disturbance	Not suitable for gravel or cobble soils Special equipment needed for installation
Grouted Soil Anchors	Structural element installed in soil or rock that is used to transmit an applied tensile load into the ground.	Rapid installation Minimal site disturbance	Waterside installation only Special equipment needed for installation
Manta Anchor	Shaft with tipping plate vibrated at an angle to the ground to create anchorage	Rapid installation Minimal site disturbance	Drilled hole required to install Holding capacity limited by soil failure Not recommended for loose soils

7.3 Alternatives Analysis Conclusions

Upon review of the City's waterfront development design standards and completion of the alternative's analysis, the section below outlines 3 alternatives for the City's consideration based on our experience and engineering standards of practice. These recommendations are also intended to address City staff's request to consider alternative construction methodologies.

7.3.1 Option 1 – Modify Existing Concrete Panel Design and use MMFX

The City's current concrete sheet pile design has many merits and continuing it may be the most viable option based on the City's needs and capabilities. However, Taylor Engineering has identified areas where the design could be improved. These areas include structural capacity, detailing, and field quality control described in further detail below.

Structural Capacity

We consider the current structural design to be 'unconservative' because many aspects of the design do not provide any additional safety margin (i.e., extra load resisting capacity) for extreme loading conditions such as coastal storms or upland surcharges. Review of the existing wall design indicated that the concrete sheet pile reinforcement, panel toe embedment, deadmen anchor rods, and the deadmen soil capacity are probably insufficient for any loading conditions other than day-to-day conditions. Unusual loading conditions arising from coastal storms or unforeseen circumstances could result in an overload that would cause excessive cracking, reduced service life, movement, or even failure. Suggestions for increasing the structural capacity include:

- Provide additional flexural reinforcement in the concrete sheet pile. Preliminary analysis indicates that the 10 ft concrete sheet pile design used by the City would benefit from additional steel reinforcement. Additional steel reinforcement would provide extra flexural capacity for extreme loading conditions and could help control some sources of concrete cracking. Cracking allows chlorides to penetrate the concrete and reach the steel reinforcement, thereby initiating the corrosion process. Once the reinforcement begins corroding; concrete cracking, rust staining, spalling, and failure can occur very quickly.
- Upsize the tie-rods diameters to a minimum of at least #8 rebar in order to allow for an additional safety factor. Corrosion rates should be considered for the chosen material and the loss of section included in the final design. A tied back wall is substantially dependent on the tie-rods for stability. Given the design life expectancy, we suggest increasing the diameter of the tie-rods to allow for additional residual capacity even after long-term corrosion occurs.
- Use a more corrosion resistant material such as MMFX reinforcement for all structural elements. While MMFX rebar are not totally immune to corrosion in a marine environment (as stated above); studies have produced mixed results and sometimes indicate very poor performance for epoxy coated rebar. Any nicks in the coating due to field installation techniques can cause accelerated corrosion at the damaged area since the corrosion tends to concentrate on a smaller area. Taylor Engineering recommends the use of MMFX or stainless steel (316 or Duplex 2205) for anchor tie-rods for consistency in metal usage throughout the designed system.

- Increase the amount of reinforcement in the current design to provide better crack control in the concrete.
- For use in combination with MMFX reinforcement, the City's appropriate choice in using a high strength marine grade concrete mix (5,500 PSI) design is still recommended. However, the casting and curing techniques for the silica fume concrete should be improved to conform to manufacturers recommendations. Silica fume must be properly cured to control shrinkage cracking. The relatively dense impermeable mix characteristics that slow the migration of chlorides through the concrete matrix are defeated if the concrete has shrinkage cracks. To help prevent such plastic shrinkage cracking, immediately following placement and during finishing/troweling of the fresh concrete surface, silica fume concrete should be kept moistened by fogging or misting. After surface finishing is complete, concrete should be covered with plastic sheeting or burlap and continuous moisture applied for 3 days additional using sprinklers or soaker hoses. After 3 days of continuously applied moisture, concrete should be kept moist for an additional 4 days by covering with burlap or plastic sheeting and applying moisture 2-3 times each day as necessary to keep the concrete surface damp. This process also presumes that the concrete panels are not moved or otherwise stressed during the curing process. The concrete manufacturer should be consulted for further details on the necessary procedures for proper curing.
- Replace all concrete deadmen when replacing seawall panel segments. To increase capacity, we recommend to upsize the concrete deadmen or decrease deadmen spacing to allow for unusual loading conditions.
- Consider moving the lower weep hole to a lower elevation on the concrete sheet pile. This will reduce hydrostatic forces on the sheet pile and other components if the ground behind the sheet pile is saturated by rainfall or flooding.

7.3.2 Option 2 – Modify Existing Concrete Panel Design and use Stainless Steel Reinforcement

Alternatively, in addition to the recommendations outlined in Option 1, we recommend that the City consider replacing MMFX reinforcement with stainless steel reinforcement. This option includes the use of 316 stainless steel or duplex stainless steel for all concrete reinforcement. Although more expensive than MMFX, duplex and 316 stainless steel rebar have much greater corrosion resistance. Although MMFX is much more corrosion resistant than carbon steel, it may not be best suited in this application. The relative thin sheet pile section (6 inches) does not provide enough strength to prevent concrete cracking during handling and installation. The potential for cracking is exacerbated by the use of improper curing techniques. Cracking allows chlorides to penetrate through the cracks to the rebar, quickly reaching the material corrosion threshold. Based on our experience and limited research, MMFX requires relatively uncracked concrete cover to serve as a protecting barrier against chloride penetration, similar to that of carbon steel. As a result, the basis for the projected 90 year design life that the City is currently using for the seawall replacement program is skeptical.

If the City switches to stainless steel reinforcement, we recommend the silica fume concrete be discontinued to help offset the cost. The City could use a standard concrete mix design, with a 4,000

PSI strength. The long-term structural strength would depend more on the corrosion resistance of the stainless steel reinforcement and less on the protective cover of the concrete. The cost savings from omitting silica fume would partially offset the increased cost of the stainless steel. However, proper curing techniques still are required to prevent cracking of the panels. Though somewhat subject to conditions at the casting site and water availability, curing for the standard concrete mix design may require potentially less water consumption during the initial curing process.

7.3.3 Option 3 – Vinyl Sheet pile

Should the City wish to consider a new material for wall construction, the most viable material alternative for consideration is vinyl sheet piles. Vinyl sheet piling can withstand the existing design loads and does not require internal reinforcing and therefore does not corrode in saltwater. Vinyl's light weight would allow the City to deliver the sheets to the project sites by truck and have them carried by hand from the street to the waterfront for installation. This delivery method may decrease the number of trips made by the installation barge from the staging area to the project site.

The vinyl sheet pile design still would utilize a concrete cap and cast-in-place concrete deadmen anchors similar to what the City is using now. As stated previously for Options 1 and 2, Taylor Engineering would recommend the City increase the amount of reinforcement in the cap to control concrete cracking, consider the use of stainless steel rebar, improve concrete curing procedures, and increase the size of the concrete deadmen and tie-rods.

7.3.4 Issues Related to Construction and Site Access

Barge Accessibility and Mobilization Cost

Based on Taylor Engineering's understanding of the current construction methodology, it seems that a major cost for these projects is the demolition of the existing wall. The current demolition process entails excavation behind the existing wall, extraction of the existing concrete sheet pile panels, barge transport of those panels to a staging area, and truck transport to a final disposal area. If permit conditions allow, installing the new wall just in front of the old wall could alleviate the need to demolish the existing wall in many cases/sites, thereby providing a cost savings to the City.

The existing bulkhead's concrete cap would likely still have to be demolished and portions of the wall would have to be 'chipped' out in order to install the new tie-rods. But the main body of the existing sheet pile would stay in place. The void between the two walls would require analysis to either structurally connect the two walls or structurally isolate the two wall sections; structural fill of some type may be required. At the ends, the design would require a structural corner connection to the adjacent existing wall. We would not recommend this methodology for areas where the City planned on replacing only a short section of seawall as this could result in a patch work of dissimilar wall material and variations in alignment. The feasibility of this approach should be evaluated on a case by case basis where existing docks are structurally connected to a wall that requires replacement. A determination from the City Attorney may be required as to whether the property owner or the City (CMD) would be responsible for incremental additional costs associated with temporary anchoring/supporting the dock.

Loss of Staging Areas

The City has expressed concerns regarding the future loss of vacant lots available for construction staging due to increased development. We understand that the City has already considered purchasing strategically located vacant lots within the PGI and BSI communities to use as staging areas. Based on review of prior correspondence from the City attorney, there is concern that use of such vacant lots for construction staging could produce complaints from nearby homeowners and even result in eventual legal challenges because these lots are not zoned for commercial use. In light of this expressed concern, Taylor Engineering recommends the City consider the following alternative options for further evaluation:

- Purchase strategically located existing residential lots and pursue rezoning them for an appropriate government/public use,
- Potential purchase of commercial waterfront property with barge access that is as near to the canal system as practical,
- Pursue potential partnership agreement with the Punta Gorda commercial marina for temporary use of the property and barge access,
- Evaluate the use of the City owned parcel located at Colony Point for manufacturing, staging and barge access to adjacent communities. This site is located inland adjacent to the waterway, which is separated by a densely populated mangrove conservation area. The City might consider performing a conceptual evaluation to gain barge access to the site via coordination pre-application meetings with regulatory agencies.

The City would want to further involve legal counsel before considering the purchase of any land and/or use agreements intended for long term use as construction staging areas.

8.0 ENVIRONMENTAL AND REGULATORY CONSIDERATIONS

The City of Punta Gorda currently operates its seawall maintenance program under permits from the U.S. Army Corps of Engineers and an exemption from required authorization by the Florida Department of Environmental Protection due to the maintenance nature of the program. Based on the recommendations provided under Section 7, we have identified some potential environmental and regulatory considerations for future operation of the City's maintenance program.

One of the recommendations for future seawall program management is that the City pursue a permit that authorizes other possible seawall replacement approaches (e.g. putting a new wall waterward within 18 inches of the existing wall) in addition to the current exemption.

Such alternatives would require revision of the permit and consultation required under the Endangered Species Act (ESA) with NOAA Fisheries (National Marine Fisheries Service), because the project occurs in the critical habitat footprint for the Smalltooth Sawfish (*Pristis pectinate*), a federally Endangered Species with a declining population (critically endangered). In addition, Charlotte Harbor is an important nursery area for the species. The city seawalls line canals that are almost all created from upland dredge cuts and range from about five feet to over 15 ft deep. These upland-cut canals, lined with seawalls, contain little nursery habitat for young sawfish – shallow (less than 3 ft deep) estuarine habitat fringed with vegetation, especially red mangrove. However, the federal consultation between USACE and NOAA Fisheries is required as part of written policy when a project or significant project modification is proposed in the critical habitat of a federally listed species.

The City may also consider including a range of other construction options/methods for which a plan to obtain authorizations for alternative construction approaches in an effort to allow for flexibility as site conditions and potential staging areas change over time. Given the time left before expiration of the current permit, such modifications should be possible and certainly pursued as part of the reapplication process following expiration. Such permit modifications should qualify for a similar maintenance exemption for which the project is currently authorized.

9.0 SEAWALL REPLACEMENT PROJECTIONS

Taylor Engineering relied on the City's historic inspection and replacement records to estimate the remaining service life for all 109 miles of wall. This section describes the analysis used to develop the estimated remaining service life and subsequent calculations for future replacement projects. The City currently budgets for replacement of 8,000 linear feet of wall annually. The purpose of this analysis section is to assist the City in proactive planning for future seawall replacements by identifying if the current production/replacement rate is sufficient or requires an increase.

As summarized in Section 5.0, the most recent 2017 condition rating assessment was utilized to estimate a reasonable design service life for each era of wall. Table 9.1 represents the number of walls evaluated by the City in 2017 but excluding those walls that subsequently failed during Hurricane Irma. It is assumed that all walls that failed and were later replaced as a result of Irma were installed in 2018/2019 using MMFX rebar. Although the City has indicated that newly installed MMFX walls have a 90-year design life, based on observations identified in Sections 6.0 and 7.0, that predicted design life could be overly optimistic. For a more conservative budgeting plan, a potential design life of 60 years has been assigned for all MMFX rebar reinforced walls. However, these projections are intended to be a planning level estimate. The actual remaining service life of the seawalls will vary from location to location. The structural capacity of structures relies heavily on proper design, manufacturing, installation, and construction of each structural element.

Review of Table 5.5 reveals a pattern wherein the greatest number of walls with a favorable rating (0, 1, or 2) was assigned to the original walls, typically installed between the 1960's to 1980's. The second greatest occurrence of walls with favorable ratings are observed in walls that have epoxy coated rebar, representing the second oldest generation of walls. The most recently installed walls constructed with MMFX rebar have the lowest instance of favorable ratings. Notably, 65,955 LF of MMFX rebar reinforced wall rated in 2017 did not fail during Hurricane Irma; wherein a total of 55,748 LF of wall failed during Irma and was subsequently replaced. Therefore, a total of 121,703 ft of MMFX rebar reinforced wall is currently in place with ratings ranging from 0 to 4. There are several factors that might contribute to the comparatively more unfavorable ratings for seemingly newer walls and we outlined these factors in previous interim reports to the City. To account for the variability in concrete types, curing methods, rebar types, installation techniques and other variabilities between seawall eras, an adjustment factor was developed using the 2017 conditions assessment. Table 9.1 illustrates how those adjustment factors were applied to the identified design life for each era in order to project out the potential remaining service life in years.

Table 9.1 Design Life and Adjustment Factor Summary

Estimated Effective Service Life (ESL)		Original Walls Adjustment Factor (1960s-1980s)		Epoxy Rebar Wall Adjustment Factor (1981-2002) (2002-2009)		MMFX Rebar Wall Adjustment Factor (2010-Present)
			40 Yrs	50 Yrs	50 Yrs	60 Yrs
2017 Conditions Rating	0 = Excellent	Add 50% to DL	1.5	1.4		1.1
	1 = Good	Add 45% to DL	1.45	1.3		1.1
	2 = Fair	Add 40% to DL	1.4	1.2		1
	3 = Moderate	No Change	1	1		1
	4 = Serious	Replace by 2025	1	1		1
	5 = Failure	Replace by 2025	1	1		1

Nearly 61% of the originally installed walls are still in place with remaining service life estimated to be 39 to 51 years; 98% of those walls were rated excellent, good or fair. Therefore, we have assumed that those walls were installed using good quality concrete, proper rebar cover and curing methods, acceptable rebar material/treatment, and additional safety factors. At the outset, the intended design life for original, epoxy, and MMFX walls are 40, 50, and 60 years, respectively. The adjustment factor allows for a reasonable projected effective service life based on local performance records pulled from the GIS database. For example, original walls that had a 2017 condition rating of 0, 1, or 2, an adjustment factor of 50%, 45%, or 40% (respectively) was applied to the design life in order to calculate the remaining estimated ‘effective’ service life. A slightly lower rated adjustment factor was applied to the epoxy coated rebar reinforced era of walls at 40%, 30%, and 20%.

No adjustment factors were applied to walls that did not have location information associated with the data. Specifically, the 85,917 feet of epoxy coated rebar reinforced walls accounted for in the City’s historic budget records.

Figures 9.1 and 9.2 summarize in graphical format Taylor Engineering’s estimate of the linear footage of seawall that will reach the end of its service life each year up to the year 2087. These figures do not include approximately 35,374 linear ft of epoxy wall where no installation date was identified from the 2017 conditions assessment records or historic budget records.

Due to the lack of data, inconsistent records, and the difficulty in accurately predicting the service life of existing seawalls, the graph should not be taken by itself as a yearly planning tool, but as a general estimate of how much seawall may need replacement over a 10-20 year span.

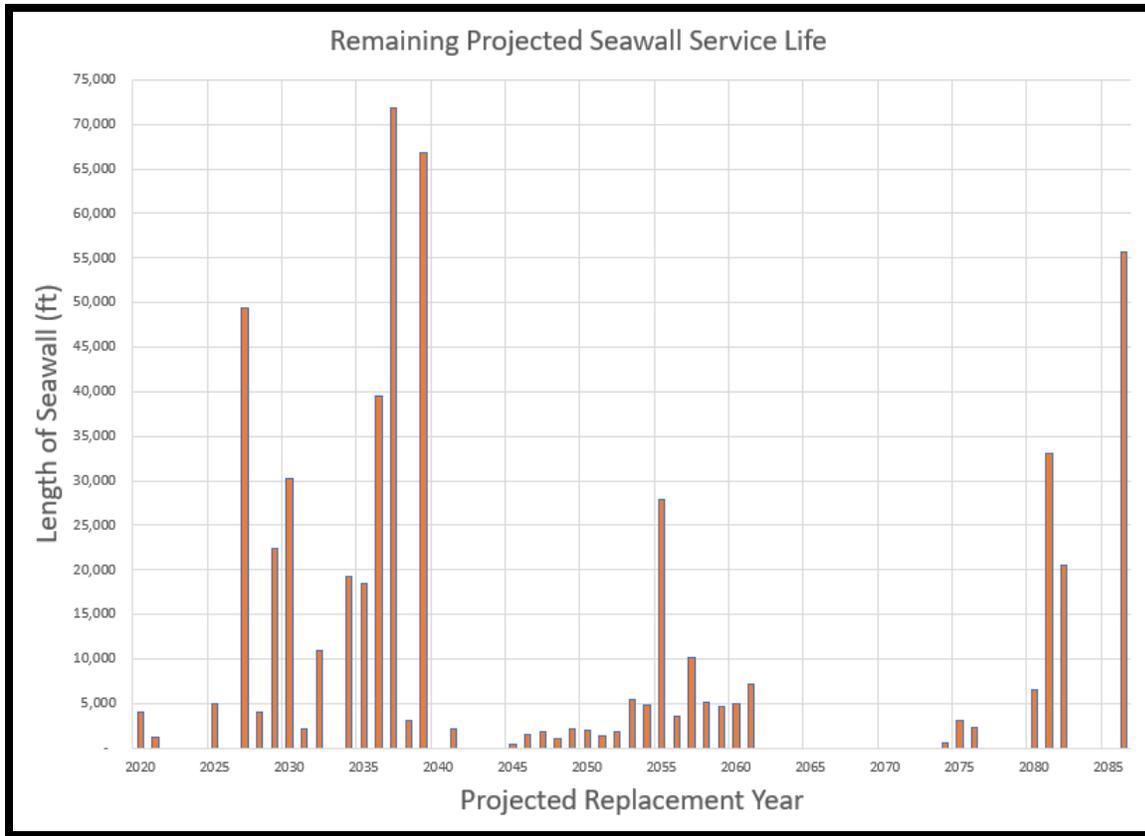


Figure 9.1 Remaining Projected Seawall Replacement by Year

Examination of Figure 9.1 indicates that the City should anticipate that a large portion of the total seawall length (about 350,000 linear ft) will reach the end of its’ service life in the next 20 years. If production rates were to remain unchanged (at 8,000 linear feet per year), the City should anticipate significant and irregular spikes in the required replacement linear footage (as evidence by the large spikes observed between the years 2025 and approximately 2040). Beyond 2040, the replacement needs significantly drop off to less than 2,000 linear feet per year until approximately year 2050. Notably, these replacement rates do not include additional anticipated wall failures due to storms or other unforeseen events. However, this need not be done immediately or in one calendar year.

Figure 9.2 is a cumulative plot illustrating the linear feet of future replacement projections by year up to year 2040, which would result in replacement of nearly 61% of the City’s priority seawalls. The year 2040 was selected by the City as a reasonable planning level timeframe for budget and program management. In order for the City to replace all 109 miles of seawall at least one time based on the calculated remaining service life, the replacement projection carries out to the year 2087. Detailed tables summarizing the calculation of the remaining service life projections by zone and seawall era can be found in Appendix D.

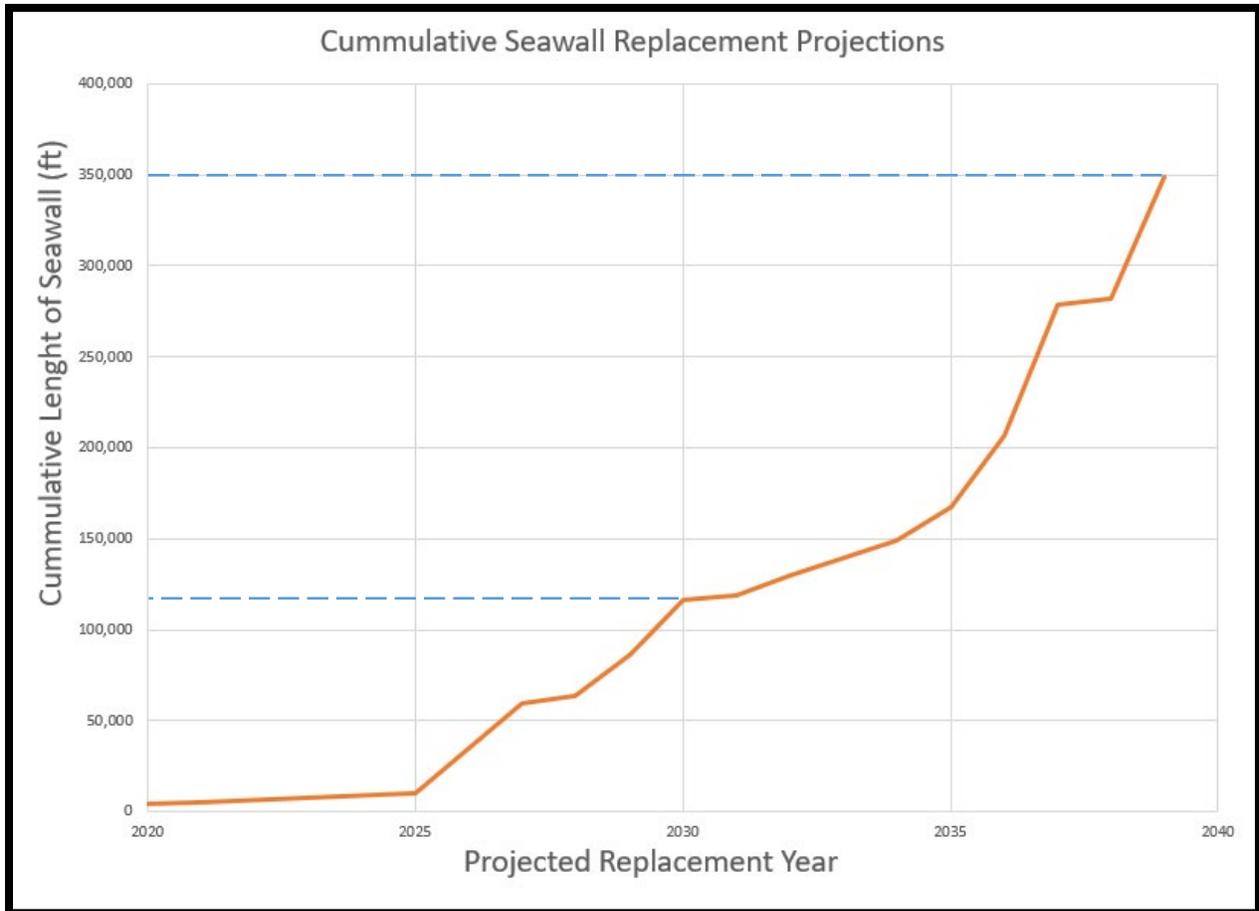


Figure 9.2 Cumulative Seawall Replacement Projections

Potential Replacement Planning Projections: We recommend a more proactive approach for long range planning of the seawall maintenance program as the City will not be able to keep up with the demand using the current production rate of 8,000 linear feet per year. While there are a number of planning level scenarios to consider for future funding on increased production, we have identified two potential replacement projection scenarios for consideration, below:

- Linear Approach: Based on Figure 9.2, approximately 350,000 linear feet of wall must be replaced within the next 20 years (by 2040). If the City were able to implement budget changes over the next fiscal year with a preference to maintain the same length of wall per year over the 20 year period, a 219% increase in production to nearly 17,500 feet/year may be necessary (between FY2020 and FY2040).
 - Year 2020 to 2040: 17,500 feet per year (over 20 years)
- Stepped Approach: To avoid a sudden increase in production rates, the City might consider a phased approach. For example, based on Figure 9.2, a peak in production requirements can be observed in the year 2030, wherein nearly 125,000 feet of wall must be replaced. An additional 225,000 feet of wall must be replaced between years 2030 and 2040. If the City were to

implement budget changes over the next fiscal year while maintaining some near-term flexibility, an initial 10 year projection would require a 56% production increase from 8,000 feet/year to nearly 12,500 feet/year over the next 10 years. However, production would ramp up between years 2030 and 2040, requiring a 281% increase from 8,000 feet/year to 22,500 feet/year.

- Year 2020 to 2030: 12,500 feet per year (56% increase over the 1st 10 years)
- Year 2030 to 2040: 22,500 feet per year (281% increase for a period of 10 years, starting in 2030)

10.0 COST ANALYSIS

Taylor Engineering performed a cost analysis for each of the alternatives identified under Section 7.0, to include consideration of materials and installation. The three alternatives were: 1) modification of the existing design use MMFX rebar, 2) modification of the existing design combined with the use of stainless steel reinforcement and 3) use vinyl sheets in place of concrete.

10.1 Existing Seawall Construction Cost

To provide a benchmark for comparison of the three alternatives, this section summarizes the City's current manufacturing and installations costs. The existing seawall design consists of concrete sheet pile topped with a concrete cap. Concrete deadmen are utilized as tie-back anchors connected to the cap using steel rods. The sheet pile panels are manufactured at the City's Public Works Facility using marine grade 5,500 psi concrete and MMFX rebar. There are four design panel lengths available, however the cost provided by the City was for the 10 ft panel only (discussed herein). The cost for all materials required to manufacture the 10 ft long concrete sheet piles is \$43.98/LF, which includes the cost of labor (at \$12.33/LF) associated with casting the panels.

Upon completion of the panel manufacturing, the City contracts with marine contractors to transport the panels from the City's Public Works facility to a staging area located adjacent to the active construction area (usually an empty lot near the project site). Based on review of City invoice records, the unit cost for transport and installation (including removal of the existing backfill and deteriorated panels, installation of the new panels, form and pour the concrete cap and install the tie-rods) is approximately \$261.25/LF. Hence, the City's current total cost for replacement of the seawall structure is \$317.56/LF. This unit price is used in comparison with the alternatives below. Note that this baseline unit price does not reflect the higher costs associated with replacement of the Hurricane Irma walls.

Additional site-specific items are not included in this cost and may vary. Sod for example is installed at a cost of \$0.75/SF and depends on the area damaged by the construction equipment (as identified by City staff). Additional construction line items such as rip rap installation for toe protection, deadmen replacement, outfall drainage rework, and davit removal and disposal are purchased as needed and presented in Table. 10.1 for reference only. Currently, only about 30% of the existing deadmen are replaced as part of a year's seawall projects.

Table 10.1 City of Punta Gorda Current Operating Installed Cost

Material	Main Items	Cost/LF	Date of Records
Reinforced Concrete	City's Panel Material Cost	\$ 43.98	Oct 2017
	City's Labor and Overhead Costs	\$ 12.33	Mar 2019
	Contractor Installed Cost	\$ 261.25	FY 2019
	Total	\$ 317.56	
	Additional Items (for reference only)	Cost	Date of Records
	Rip Rap Toe Protection Installation	\$ 100.00/LF	FY 2019
	Deadmen Replacement	\$ 200.00/EA	FY 2019
	Outfall Drainage Rework	\$ 750.00/EA	FY 2019
Davit Removal & Disposal	\$ 250.00/EA	FY 2019	

For comparison to the existing costs, Taylor Engineering developed a simplified 'order of magnitude' cost estimate for three alternatives using the City's current materials, labor and installation costs as a basis for the estimate. However, the cost of materials and installation is market driven and therefore subject to change. Cost associated with these proposed improvements are presented below.

10.2 Alternatives 1 and 2 - Cost to Modify Existing Design using MMFX and Stainless Steel Reinforcement

The proposed changes in the current design and construction method identified as Alternatives 1 and 2 do not significantly increase cost. However, the structural design life is estimated to increase if these recommendations are implemented. Below is a summary of design criteria and assumptions used to evaluate potential order of magnitude costs for Alternatives 1 and 2:

- Increase steel reinforcement within the concrete panels by 30% to account for additional safety factor due to construction installation and additional loading due to storm conditions. As outlined in Section 7.0, preliminary calculations of the existing design show that the panel flexural reinforcement maybe adequate for the basic service loads but does not provide a sufficient safety factor for episodic events. or to help prevent concrete cracking during curing, transport and installation.
- Upsize tie-rods assuming use of #8 MMFX rebar. The cost was included in the cost per linear foot by dividing the cost by an assumed spacing for the larger tie-rods.
- Replace all concrete deadmen with larger deadmen
 - The presented cost assumed a 50% increase in deadmen size. Preliminary calculation of existing design reflects that the deadmen are inadequate for soil resistance and require an increase in their size to meet minimum load requirements and to increase safety factors.
 - It was assumed that all deadmen will be replaced. Their cost was included in the cost per linear foot by dividing the cost by the spacing of the deadmen.
- Move the lower weep hole to an even lower elevation on the concrete sheet pile

- The presented cost assumed no change in cost for this task. The weep hole should be placed 1 foot below MLW to prevent excessive pressure differences during ‘king’ tides or coastal storms.
- Omit the use of epoxy coated rebar altogether, use all MMFX rebar within the seawall system
 - The presented cost assumed MMFX rebar used throughout the design including the concrete panel, cap, deadmen and tie-rods.
- Maintain the use of high strength marine grade concrete (5,500 PSI) with implementation of proper curing techniques necessary for marine grade concrete using silica fume.
 - The presented cost includes additional labor time and an estimated cost of water needed to properly wet-cure the concrete panels.
 - Recommended process to cure panels using silica fume concrete is as follows:
 - Stagger the fabricated panels within the casting yard for the first week. With properly planned panel layout and placement, no new land acquisition is necessary.
 - Wet cure all of the panels using continuously applied moisture (sprinklers or soaker hoses) for the first 3 days.
 - For days 4-7, cover with plastic sheeting and maintain moisture under plastic sheets. Apply moisture 2-3 times a day as necessary depending on weather conditions.
 - After 7 days of moist curing, additional fabricated panels may be stacked on top of previously cured panels or all cured panels may be moved to a convenient storage location and stacked as needed. Repeat process.

Table 10.2 shows the cost to modify the existing design with the recommendations provided.

Table 10.2 Estimated Cost to Modify Existing Design using MMFX (Alternative 1)

Material	Main Items	Add/Sub	Cost/LF
MMFX Reinforced Concrete	City’s Current Panel Materials Cost		\$ 43.98
	Current City Labor Costs		\$ 12.33
	Contractor Installation Cost		\$ 261.25
	Add 30% More Steel Reinforcement	(+)	\$ 6.07
	Upsize the Tie-rods using MMFX Rebar	(+)	\$ 7.77
	50% Size Increase & Replace All Concrete Deadmen	(+)	\$ 8.33
	Use all MMFX Rebar in Cap and Deadmen	(+)	\$ 0.82
	Additional Labor for Implementation of Concrete Curing Techniques for 5500 PSI Concrete	(+)	\$ 18.12
	Estimated Unit Cost		

Alternative 2 includes the use of stainless steel rebar in place of the MMFX rebar currently used in order to increase the overall design life. With the use of stainless steel rebar, a standard concrete mix

design can be used in place of the more costly current marine grade (silica fume) concrete mix design; this change also would provide some minor cost savings related to the curing process. The substitution of stainless steel rebar increases the overall panel design life from approximately 65 years to approximately 90 years. The estimated costs associated with the use of stainless steel (SS) rebar and a standard concrete mix design is outlined in Table 10.3 below.

Table 10.3 Estimated Cost for Stainless Steel Reinforced Concrete Panels (Alternative 2)

Material	Items	Add/Sub	Cost/LF
Stainless Steel Reinforced Concrete	City's Current Panel Materials Cost		\$ 43.98
	Current City Labor Costs		\$ 12.33
	Contractor Installation Cost		\$ 261.25
	Add 30% More SS Reinforcement	(+)	\$ 55.10
	Upsize the Tie-rods using SS Rebar	(+)	\$ 29.48
	50% Size Increase & Replace All Concrete Deadmen	(+)	\$ 8.33
	Use all SS Rebar in Cap and Deadmen	(+)	\$ 11.28
	4000 PSI Concrete Mix Design	(-)	\$ 11.85
	Additional Labor for Implementation of Concrete Curing Techniques	(+)	\$ 18.12
		Estimated Unit Cost	

Notably, the recommended modifications associated with each option (MMFX vs. stainless steel reinforcement) are added or subtracted to the City's current overall base unit price for manufacturing and installation of 10 ft concrete panels. For the stainless steel reinforced option, the cost associated with the concrete curing process is conservatively assumed to be the same unit cost identified for the MMFX/high strength silica fume concrete mix design option (reflected in Table 10.2). However, due to the nature of the curing requirements within the initial first three days of curing, the standard concrete mix design may require potentially less water consumption.

10.3 Alternative 3 - Cost of Using Vinyl Sheet Pile

The third alternative for consideration includes vinyl sheet pile panels. The sheet thickness and lengths must be designed according to the soil and loads conditions. Based on design assumptions, the estimated cost for vinyl sheets is approximately \$96.00/LF. From discussions with marine contractors, the installation costs for use of vinyl vs. concrete sheets are comparable assuming that similar staging area and site conditions are provided. Vinyl material is much lighter weight than concrete panels and can therefore be handled more easily/efficiently. This component may provide cost savings when access to proximal staging areas is no longer available. However, the vinyl installation process will still require the demolition of the existing seawall structure and sheets are driven using similar methods to the concrete panels. Therefore, the installation cost of the vinyl sheets is \$261.25/LF. Significant savings in installation cost could be achieved if contractor is allowed to install the new sheets in front of the old concrete panels.

Similar recommendations outlined in Alternatives 1 and 2 were applied to the vinyl sheet pile alternative as well in order to increase service life to all the structural members including the vinyl panels. However, the system's service life was limited by the vinyl, which was estimated to be 40 years in a marine

environment. The cost to change the epoxy coated rebar to all MMFX rebar into the design, including the cap, deadmen, and tie-rods is \$8.58/LF. Table 10.4 summarizes the estimated costs using vinyl sheets.

Table 10.4 Estimated Cost of Vinyl Sheet pile

Material	Main Items	Add/Sub	Cost/LF
Vinyl	Vinyl Panel Cost		\$ 96.00
	Contractor Installation Cost		\$ 261.25
	Upsize and Use of MMFX Rebar in Cap, Deadmen and Tie-rods	(+)	\$ 8.58
	Total		\$ 365.83

Both the unit cost and the estimate service life of each alternative – considering MMFX and stainless steel rebar for each – varies considerably. For example, the City’s current concrete panel design has an estimated design service life of 50 years. The estimated design service life for the other alternatives are outlined below:

1. Modified Concrete Panel Design using MMFX Rebar and High Strength 5,500 PSI Concrete – approximately 65 years
2. Modified Concrete Panel Design using Stainless Steel Reinforcement and Standard 4,000 PSI Concrete – approximately 90 years
3. Vinyl Panels with MMFX Tie-rods and Tie-back Modifications – approximately 40 years.

Although not a rigorous financial analysis, Table 10.5 provides insight into the overall cost comparison over a projected equivalent design life. However, material and installation costs do not escalate uniformly or proportionally for the various seawall materials.

Table 10.5 Cost Summary

Material	Cost/LF	Service Life	Cost/LF/Year	Equivalent 90 Year Cost/LF
Current Concrete Design*	\$ 317.56	50 yr	\$6.35	\$571.07
Modified Concrete Design	\$ 358.67	65 yr	\$5.52	\$496.62
Modified Concrete Design with SS Reinforcement**	\$ 428.03	90 yr	\$4.76	\$428.03
Vinyl Alternative	\$ 365.83	40 yr	\$9.15	\$823.12

*Sheet pile panels are estimated at 60 yr life but overall structure life estimated at 50 years

**Stainless steel reinforcement used in sheet pile, cap, and deadmen

10.4 Barge Transport Costs and Material Considerations

As outlined in Table 10.5, vinyl sheet pile is estimated to cost approximately \$365.83 per foot with a design life estimated at 40 years in a marine environment. This equates to a life cycle cost of \$9.15/ft/year. When multiplied over a 90 year life cycle, this results in a cost of \$823.12 per ft. Concrete sheet pile with 316 or duplex stainless steel reinforcement is estimated to cost \$428.03, with a design life

of 90 years. When life cycle cost is considered, vinyl sheet pile costs 1.92 times more than concrete with stainless steel reinforcement. However, the vinyl sheet pile panel was evaluated as an alternative early in the project due to its light weight which would allow for potential installation of the system from the upland once availability of vacant lots is diminished.

To validate this consideration, we evaluated the potential barge transport costs in comparison to the vinyl sheet pile cost. Once all the vacant lots currently being used for staging are developed, the Contractor will have to transport the old demolished concrete sheet pile by barge to an offloading point much further away. Using vinyl sheet pile instead of concrete may save extra barge trips required to transport new sheet pile since vinyl sheet pile can be offloaded and carried by workman directly at the project site. This assumes that one barge trip is required to offload demolished concrete sheet pile and a separate barge trip is required to obtain new concrete sheet pile. Under that assumption, one barge trip is saved for each load of demolished concrete sheet pile if utilizing vinyl sheet pile.

To determine a comparative cost estimate, we identified a series of assumptions based on City provided data. Using an assumed barge cost rate of \$265 per hour, carrying an average of 10 panels per barge trip at a barge speed of 2 mph, an estimated one way barge distance of 96 miles would be required before savings for extra barge travel would equate to the extra life cycle cost associated with the use of vinyl. If we assume that for each barge trip, the barge is fully loaded - with demolished debris on the initial trip and with new concrete sheet pile on the return trip - then no cost savings can be calculated in barge trips; resulting in no cost savings offered by use of vinyl sheet piles. Given the long travel distance of 96 miles required to recoup the cost of vinyl for the first assumption and the second assumption presents the possibility that there may be no cost savings at all to using vinyl, Taylor Engineering recommends the City continue using concrete sheet pile as the preferred alternative (as identified in Alternatives 1 or 2).

Once all the vacant lots are developed, Contractors will have to barge new and demolished material over greater distances. Assuming a 10-mile one-way barge trip to the closest staging area, Taylor Engineering estimates an increase in installation cost of \$44.00 per linear ft. This assumes a \$265 per hour barge cost and that a barge will hold 10 concrete sheet panels. If a 20 or 30 mile distance is utilized, the cost per linear ft increases to \$88.00 and \$132.00 per ft, respectively. We recommend the City work with the Contractors to locate new staging areas and plan their future budgets to accommodate increases in sheet pile cost once vacant lots are no longer available for use as staging areas.

11.0 SUMMARY RECOMMENDATIONS AND CONCLUSIONS

As a result of this feasibility study, Taylor Engineering has provided a range of recommendations for City consideration in an effort to improve the City's overall seawall maintenance program. The recommendations include four primary components: a) structural design modifications, b) seawall production and replacement rates, c) standardized seawall inspection process, and d) consideration of future construction staging and barge transport access. We offer the following recommendations and conclusions for each component for City consideration:

Structural Design Modifications: Upon review of the City's current waterfront design standards, manufacturing process, and installation techniques, we propose that the design life and structural integrity of the current seawall design could be improved with the following recommendations:

- To minimize the long-term costs of seawall replacement, recommend continue using concrete sheet pile but switch to stainless steel reinforcement (316L or Duplex 2205) in the panels. In addition, use stainless reinforcement in the cap and deadmen. If stainless steel reinforcement is used, silica fume should be omitted from the concrete mix design.
- As previously outlined, due to lifecycle cost analysis, switching to vinyl may not be desired/feasible.
- Recommend replacing and upsizing all deadmen when replacing seawall panels. Do not re-use deadmen.
- Recommend upsizing tie-rods and using MMFX or stainless steel.
- Recommend increasing the amount of flexural reinforcement in the concrete sheet pile.
- Recommend discontinuing the use of epoxy coated reinforcement.
- Recommend discontinuing the use of welding in any capacity as related to repair or replacement. If a situation arises where welding cannot be avoided, use stainless steel filler metal.
- Until such time as stainless steel reinforcement is utilized, recommend proper curing of silica fume concrete as described in report.
- Recommend lowering the weep hole on the concrete panel.
- Recommend the City engage an Engineer to design a new standard concrete sheet pile design that would accommodate and quantify the recommendations above.

Seawall Production and Replacement Rates: Although extremely difficult to predict, Taylor Engineering evaluated the remaining service life for all 109 miles of wall using the City's inspection and replacement records. Based on these calculations, that the City's average annual seawall replacement rate of 8,000 linear feet is not sufficient to maintain the seawalls prior to reaching the end of their projected service life. We recommend that the City begin to plan for increased production and seawall replacement rates. The intent of this study is to provide the data necessary for the City to made planning level financial decisions in collaboration with the residents. Therefore, it is not the intent of this study for provide financial recommendations. There are several ways in which the City may approach an increased seawall production/replacement rate two (2) planning level budget example scenarios are described below for as possible considerations:

- Linear Approach: Based on Figure 9.2, approximately 350,000 linear feet of wall must be replaced within the next 20 years (by 2040). If the City were able to implement budget changes over the next fiscal year with a preference to maintain the same length of wall per year over the entire 20 year period, a 219% increase in production to nearly 17,500 feet/year would be necessary (between FY2020 and FY2040).
 - Year 2020 to 2040: 17,500 feet per year (219% increase over 20 years)
- Stepped Approach: To avoid a sudden increase in production rates, the City might consider a phased approach. For example, based on Figure 9.2, a peak in production requirements can be observed in the year 2030, wherein nearly 125,000 feet of wall must be replaced. An additional 225,000 feet of wall must be replaced between years 2030 and 2040. If the City were to implement budget changes over the next fiscal year while maintaining some near-term flexibility, an initial 10 year projection would require a 156% production increase from 8,000 feet/year to

nearly 12,500 feet/year over the next 10 years. However, production would ramp up between years 2030 and 2040, requiring a 281% increase from 8,000 feet/year to 22,500 feet/year.

- Year 2020 to 2030: 12,500 feet per year (156% increase over the 1st 10 years)
- Year 2030 to 2040: 22,500 feet per year (281% increase for a period of 10 years, starting in 2030)

Future Seawall Inspections: The City has done a great job in performing annual visual inspections for all 109 miles of seawall. Such data was instrumental in development of the service life projections. To streamline the overall seawall management program and improve the consistency in inspection process (including data collection and record keeping), we offer the following suggestions for consideration:

- Reduce the frequency of inspections. The City indicated that annual inspections cost the City on the order of 700+ labor hours per year to inspect all 109 miles of wall. With improvements to the overall structural design as outlined above, the frequency of inspections can be reduced to a period of 3 to 5 years and following major storm events. For example, the US Coast Guard performs inspections on their marine facilities every 4 to 5 years, typically. This reduction in inspection frequency may help to offset the costs associated with potential seawall design improvements.
- Consider implementing inspection methods as outlined in the ASCE Waterfront Facilities Inspection Manual, which provides detailed guidance and a standard of practice for inspecting existing waterfront facilities, including seawalls and bulkheads. Taylor Engineering recommends that the City consider the use of this manual for subsequent inspections to allow for increased inspection rating consistency. On off years where inspections are not scheduled, consider sending staff to a week-long ASCE Waterfront Facilities Inspection training (budgeting for 40 labor hours plus per diem). The quality of this data is significant in order to more accurately predict and project future replacement scenarios for proper budget planning. Applying a well-known and standard methodology for such inspections will help to reduce subjectivity and inconsistency in data collection from year to year.

Future Construction Staging/Barge Transport Access: Due to the concern regarding decreased vacant lot availability for use as construction staging, Taylor Engineering has provided a range of recommendations for City consideration:

- Once all the vacant lots currently being used for staging are developed, recommend planning on a budget increase of approximately \$44 to \$120 per linear ft of sheet pile replaced to account for increased barge travel distance in Contractor's bids.
- Consider acquisition of an on-water commercial facility. A priority site should be as centrally located to the canal system as practical, for use as a manufacturing facility and potential staging area for seawall construction.
- In the event that such purchase is not a viable option for the City, we recommend that the City consider a partnership agreement with a commercially available waterfront facility, such as the

Punta Gorda Marina located off Highway US17. See Section 10.4 for the estimated costs associated with barge transport once vacant lots are no longer available.

- Finally, consider pursuing a feasibility study to consider the regulatory, design, and construction costs associated with dredging an access channel to the City-owned Colony Point site for potential future use as a manufacturing and staging area.

These detailed recommendations are intended to offer feasible, cost effective alternative solutions to the City's concerns as part of a Phase I effort. Upon City selection of the preferred alternative, additional analysis may be warranted to perform structural analysis, update the seawall system design and refine associated costs as part of a Phase II effort.

We would like to take the time to compliment the City of Punta Gorda on its comprehensive management program through its commitment to replace approximately 8,000 linear feet of seawall per year and their well-thought selection of seawall type and structural details for the City's residents. It is clear that the City has been guided by good decision making as the seawall program has evolved. We hope the suggestions and recommendations outlined herein will help to improve the overall program efficiency, increase seawall structural integrity, and ensure that City residents will continue to enjoy their waterfront properties in the decades to come.

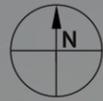
12.0 REFERENCES

Heffron, R.E. (2015). *Waterfront Facilities Inspection and Assessment*. Coasts, Oceans, Ports and Rivers Institute. American Society of Civil Engineers.

Holland T.C. (2005). *Silica Fume User's Manual*. US Department of Transportation. Report No. FHWA-IF-05-016

APPENDIX A

Figures and Maps



Harborwalk

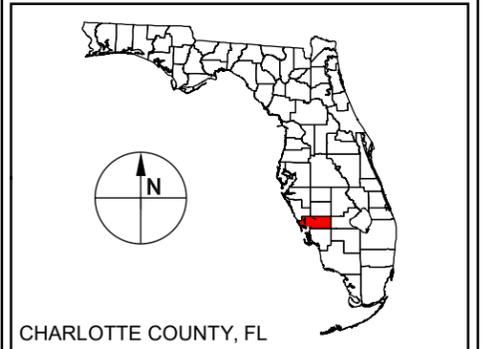
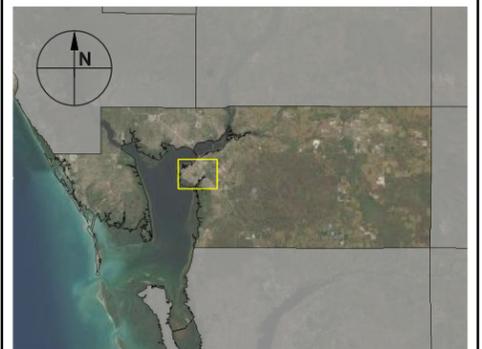


Taylor Engineering, Inc.

1800 2nd Street, Suite 714
Sarasota, FL 34236

CERTIFICATE OF AUTHORIZATION # 4815

**CITY OF PUNTA GORDA
SEAWALL REPLACEMENT STUDY
POST IRMA AS BUILT DATA
AS OF MAY 16, 2019**



CHARLOTTE COUNTY, FL

**HURRICANE
IRMA
FAILURES**

 Failed During Irma (55,314 LF)

1:24,000

0 1,000 2,000 4,000

One Inch = 2,000 Feet

PROJECT C2019-018

DRAWN BY PL

DATE 12/19/2019

Image source: FDOT 2017

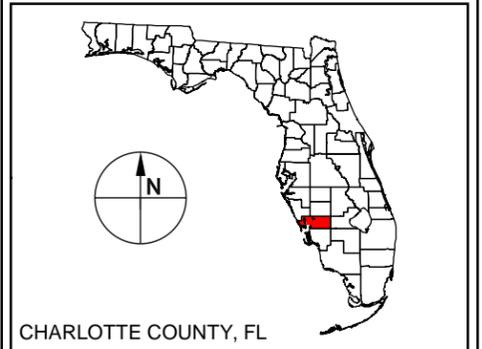
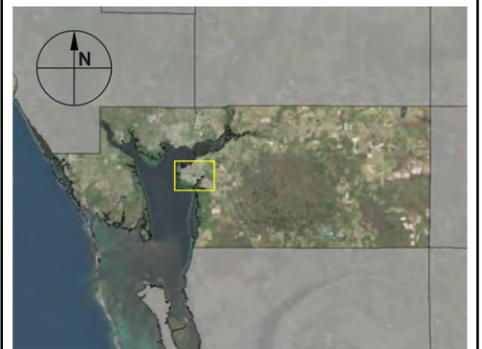


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**CITY OF PUNTA GORDA
SEAWALL REPLACEMENT STUDY
IRMA FAILURES VS. CONDITIONS
AS OF MARCH 2017**



CHARLOTTE COUNTY, FL

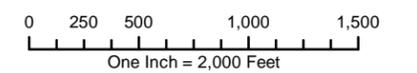
**HURRICANE IRMA FAILURES SUPERIMPOSED
OVER MARCH 2017 CONDITIONS**

-  No Failure During Irma
-  Failed During Irma

**WALL CONDITION
AS OF MARCH 2017**

-  Excellent
-  Fair
-  Good
-  Moderate
-  Serious
-  Failure

1:10,000

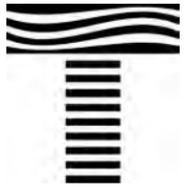
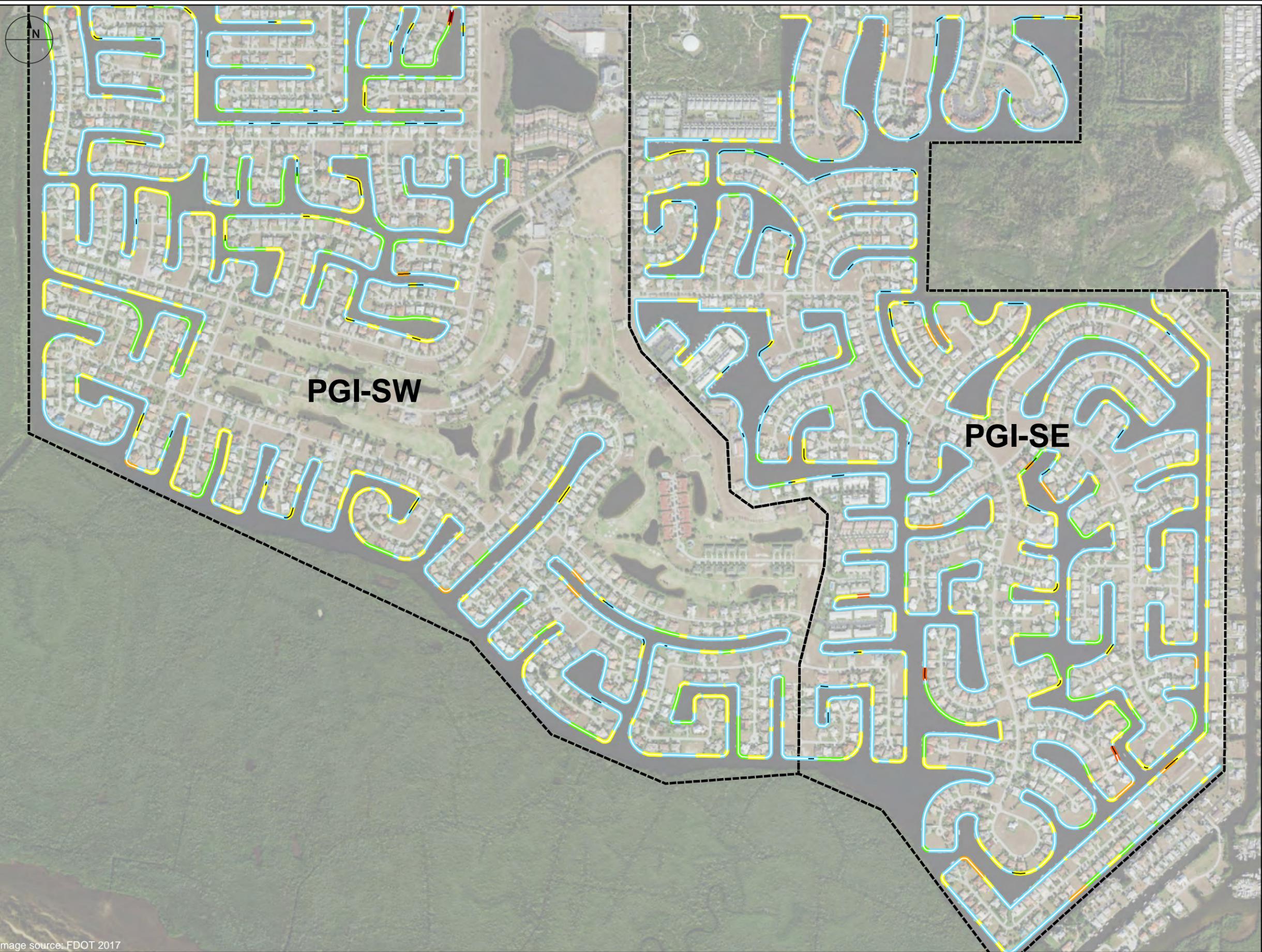


PROJECT C2019-018

DRAWN BY PL

DATE 6/18/2019

Image source: FOOT 2017



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**CITY OF PUNTA GORDA
SEAWALL REPLACEMENT STUDY
IRMA FAILURES VS. CONDITIONS
AS OF MARCH 2017**



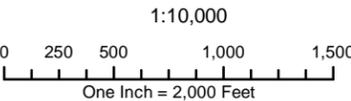
CHARLOTTE COUNTY, FL

**HURRICANE IRMA FAILURES SUPERIMPOSED
OVER MARCH 2017 CONDITIONS**

- No Failure During Irma
- - Failed During Irma

**WALL CONDITION
AS OF MARCH 2017**

- Excellent
- Moderate
- Good
- Serious
- Fair
- Failure



PROJECT	C2019-018
DRAWN BY	PL
DATE	6/18/2019

Image source: FDOT 2017

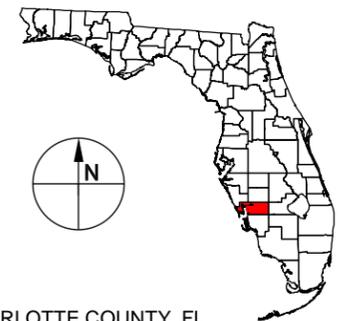
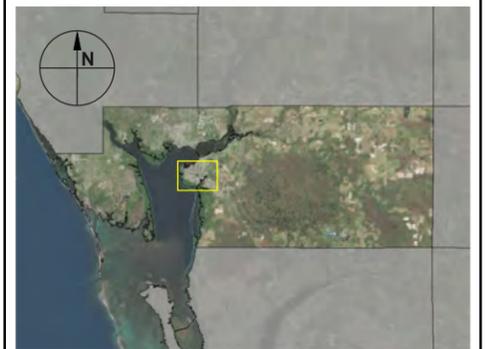


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CERTIFICATE OF AUTHORIZATION # 4815

CITY OF PUNTA GORDA
SEAWALL REPLACEMENT STUDY
IRMA FAILURES VS. CONDITIONS
AS OF MARCH 2017



CHARLOTTE COUNTY, FL

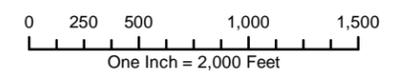
**HURRICANE IRMA FAILURES SUPERIMPOSED
OVER MARCH 2017 CONDITIONS**

- No Failure During Irma
- Failed During Irma

**WALL CONDITION
AS OF MARCH 2017**

- Excellent
- Good
- Fair
- Moderate
- Serious
- Failure

1:10,000



PROJECT C2019-018

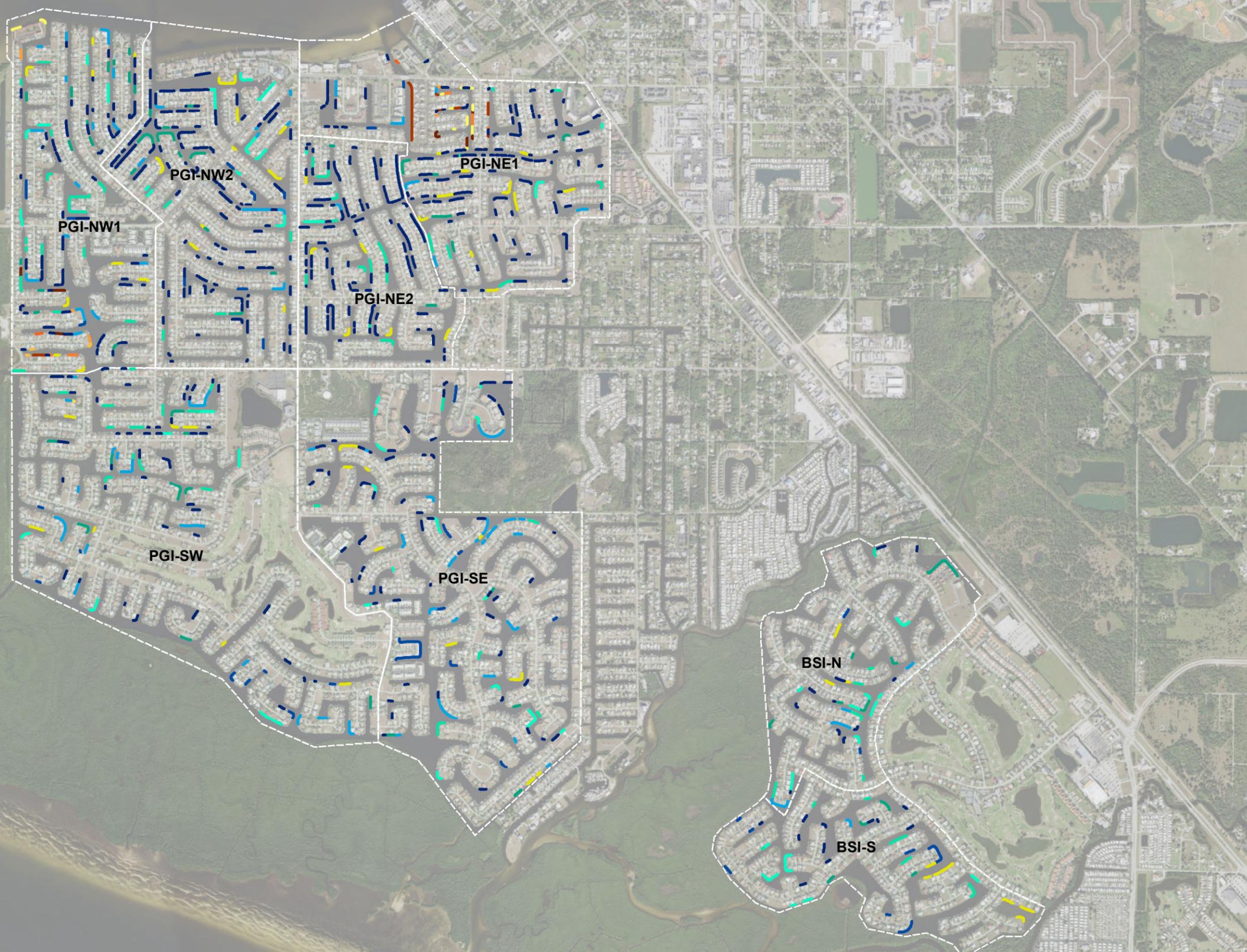
DRAWN BY PL

DATE 6/18/2019

Image source: FDOT 2017



Harborwalk

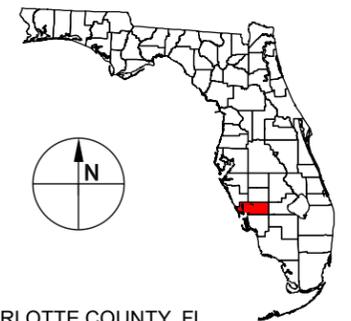


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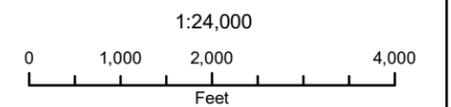
CITY OF PUNTA GORDA
SEAWALL REPLACEMENT STUDY
SEAWALL REPLACEMENT YEARS



CHARLOTTE COUNTY, FL

YEAR WALL REPLACED

2003	2012
2004	2013
2005	2014
2006	2015
2007	2016
2009	2017
2010	2018
2011	



PROJECT C2019-018

DRAWN BY PL

DATE 6/18/2019

APPENDIX B

Site Evaluation Notes and Photos



City of Punta Gorda - Seawall Materials & Methods Project

TASK 3 – SITE EVALUATION

SUMMARY MEMO

Date: July 24, 2019
Participants: Gary Disher, Todd Helt, and Gary Koska - City of Punta Gorda
Omar L. Lopez – Taylor Engineering

General: This memo describes the site visit performed on June 28, 2019 by Taylor Engineering under the Task 3 of this project. City and Taylor Engineering staff conducted a City-guided tour of the seawalls located within the two canal maintenance districts (PGI and BSI) to observe the different types of seawalls, their general conditions, and ongoing installation processes.

Summary of Site Evaluation: Below is a summary of the site visit:

On June 28, 2019 Taylor staff joined City staff to conduct a one day City-guided site visit; arriving at the Ponce de Leon Boat Ramp in Punta Gorda at 7:30am to meet with the City. According to the NOAA Tide Predictions for the Fishermen's Village pier, low tide occurred at 5:59 AM with high tide at 12:06 AM (Figure 1).

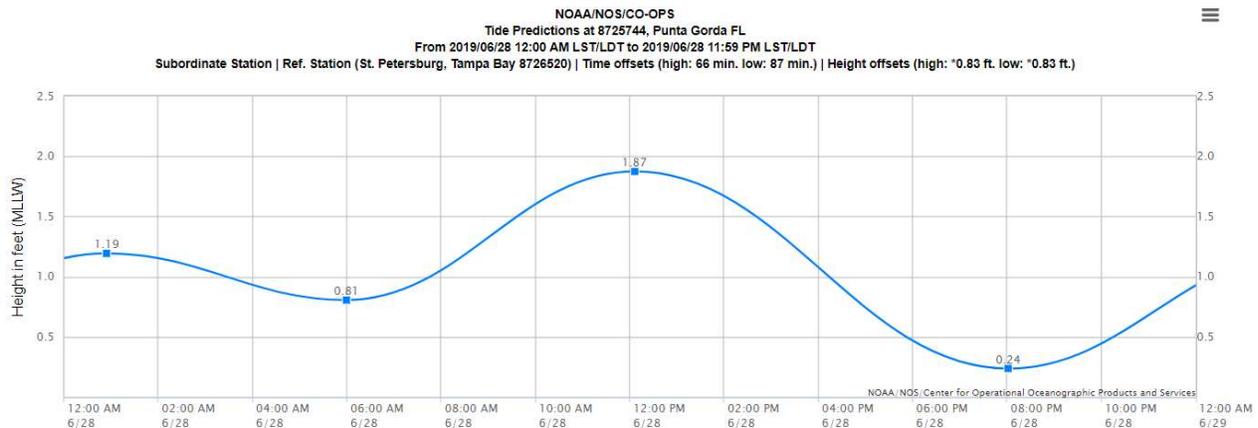


Figure 1 – NOAA Tide Predictions in Punta Gorda Station 8725744

The site visit included observations within the residential canals on the subdivisions PGI-NW1, PGI-NW2, and PGI-NE1 to observe and photo document the four different types of seawall systems in Punta Gorda, as summarized below:

- Original walls not yet replaced
• Walls replaced using epoxy coated rebar (replaced prior to 2010)

- Walls replaced between 2010 and 2017 using MMFX rebar (Before Hurricane Irma)
- Walls replaced using MMFX rebar following Hurricane Irma

During this site visit, three bridges were also observed to identify available maneuver space and vertical clearances available for construction equipment over barges.

Using the 2017 Condition Assessment and specific seawall locations, we observed walls rated as Moderate, Serious and Failed seawalls according to the City's rating system. Three active staging areas were observed along with the construction equipment used on each one. Two ongoing seawall construction sites were observed and described below. At the first site visited, panels and part of the cap were installed. The cap form was being removed from the one finished section of the seawall and installed on another to continue the concrete pour. At the second construction site, the concrete was ready to be poured on all the cap form and deadmen excavation holes. After completion of the PGI site visit, Taylor Engineering staff visited the Burnt Store Isles lock.

Different Types of Seawalls

Four different seawall types were observed in the field, described as follows:

1 - Original Seawalls:

Initially installed between 1965 and the 1980s, the City indicated that their goal is to replace all of the original seawalls since they are close to the end of their service life. It was found that the majority of these seawalls were repaired with an oversized cap using epoxy coated rebar, before 2009/2010. In some locations like 257 Lido Dr. (location 6), the panels were found in better condition than expected but most of them show abrasion and some type of deterioration. At the time of the site visit, City staff noted that during typical condition assessments, for walls where abrasion is present, such as observed at 410 Medici Ct (location 23), the rating severity is typically increased. The City stated that they would like Taylor to assist with improving the rating system, specifically as it applies to abrasion on the panel. There are locations in the system where many panel unions and weep holes have been patched along the original seawall installations. City staff indicated that the practice of patching was modified in 2009 due to the significant hydrostatic pressure and stress exerted on the panels for extended periods of time. The modifications include patching from the berm up to the oyster line and leaving the seams open from that point to the cap. The weep holes are left open as well.

Minor longitudinal cracks on the panel were observed, typically below the cap. Moderate to serious cracks were found on the panels below the oyster line, as observed at 7 Hibiscus Dr. (location 10). A limited amount of these cracked panels are scheduled for replacement during the next fiscal year based on budget constraints.

2 - Seawalls with Epoxy Coated Rebar:

The seawall repair program in Punta Gorda started around 1986. From 1986 to 2009, seawalls were repaired by installing an oversized epoxy coated rebar reinforced cap. Otherwise, both panels and the cap were replaced with epoxy coated rebar. As a result, new cap installations often extended beyond the limits of the panel replacement sections, terminating in the middle of older adjacent panels. The City

indicated that panel breakage often occurred at these locations due to the differential loading of different caps sizes. The City also noted that panel cracks below the new cap connection were observed at almost every location. An example of this condition was observed at 2800 Via Paloma Dr. (location 4) and 2001 W Marion Ave (location 14).

Many locations were observed where a new seawall system was installed along a majority of the property but discontinued in a few areas where residential docks are present, such as shown at 2803 Via Paloma Dr. (location 3). As a convenience to the homeowner; this typically occurred where the original dock had been pinned to the seawall for support and the dock would have had to be removed if the seawall panels were removed. Taylor staff also noted that only a few panels were replaced at a time in several locations. There are many locations where a seawall was replaced then at a later date an adjacent seawall was replaced and a couple/few original panels were left in place between the two replacement locations.

3 - Seawalls with MMFX Rebar:

The first generation of seawalls with MMFX rebar were installed between 2010 and 2017. During this time, the City started using a better corrosion resistant rebar for the construction of the cap and panels. An example of this type of installation was observed at 2803 Sancho Panza Ct. (location 1), replaced in 2012. Weep holes were placed at a lower elevation than those on the original seawall design in this location and others replaced during this period.

Some of the walls that were replaced between 2010 and 2017 have since been replaced again as have some of the 1986 to 2009 replacements. For example, the seawall on 2131 Bayou Rd. (location 18) [*this exhibit on pages 35 and 36 is labeled as Epoxy Coated and should be revised*] was replaced during this era but recently failed with the top of the wall leaning seaward. Based on this failure mode, it is evident that either the deadmen connection failed or the tie rods broke. As expected, several large depressions were observed at this location. At the time of the site visit the City was waiting on FWC to give them authorization to replace this wall after a few birds finish their nesting on a cypress tree near the seawall.

4 – New era of MMFX after Irma

Hurricane Irma passed in September 2017, resulting in excessive rainfall combined with an extreme negative tide which caused widespread damage and failure to the aging seawalls in Punta Gorda. Following the storm, the City hired a company to assist with manufacturing seawall panels to help keep up the storm recovery production demands. The most common failure type observed following the storm was a ‘toe kick-out’, indicative of poor soil penetration/embedment. An example of this failure mode was observed at 185 Gulfview Rd (location 19). The City noted that the seawalls installed post-Irma to the present are referred to as the ‘new era of MMFX’ seawalls; wherein refined installation techniques and methods have been employed. A replacement site was observed at 260 Lido Drive (location 5) in which Duncan Seawall Inc. utilized an expansive foam to seal the gap between cap formwork and panel. Other contractors such as Marine Contracting Group Inc. have used a piece of cloth to cover the gap before pouring the concrete.

Seawalls that did not Fail During Irma

Prior to the site visit, Taylor Engineering prepared GIS maps using data collated from the City provided GIS database and Excel spreadsheet records. Based on the 2016-2017 Conditions Assessment dated March

2017, Taylor staff prepared a plan view color coded map of the City's 2016-2017 ratings, zero through 5. For purposes of the field visit, we identified walls that were previously identified as moderate, serious or failed during the 2016-2017 Assessment and compared them to the walls that failed during Hurricane Irma. Specifically, we prepared a map of walls that did not fail during Irma that were rated moderate, serious or failed in the March 2017 conditions survey. An example of each scenario was observed at the time of the site visit, with specific examples identified below:

- A moderate condition seawall with an overall rating of 3 was observed on 2813 Coral Way (location 8). Several panels exhibited longitudinal cracking below the cap. On each end of the wall segment fronting this property, a larger cap from a more recent installation was placed over the last original panel. Chips and spalls were observed on the cap as well.
- Walls with an overall rating of 4 (serious condition) were also observed at 29 Ocean Dr. (location 11) and 7 Hibiscus Dr. (location 10). Both seawalls have wide cracks near the waterline, which the City indicated is the reason those walls were rated as serious. Another serious condition rated wall was observed at 1793 Belle Ct. (location 15), where large spalls were present along the cap exposing the rebar. All of the panels along this particular property are original, though the panels located on the east side of the property appeared to be in better condition than the ones facing south.
- Failed seawalls were found at 2096 El Cerito Ct (location 16) [*2096 El Cerito is rated a 3 and should be moved up two bullet points*] 325 Belvedere Ct (location 17) and 185 Gulfview Rd (location 19). The City noted that the wall at Belvedere Ct was rated as failed due to 75% water line cracking with a severity rating of 4. The seawall has not collapsed yet, but loss of fill and depressions are visible behind the cap. The wall located at Gulfview Rd. was assigned a failure rating due to toe kick-out. The City has not been able to repair this section of wall due to the presence of protected bird nesting in the area. Once cleared, FWC will provide authorization to proceed with the work.

Active Construction

Two active construction sites were observed at the time of the site visit. At 704 Vía Formia (location 26) all the panels were installed and the cap construction was ongoing. Based on the orientation of the house, it was noted that some of the deadmen may be located below the foundation of the house along the north end of the property. The City indicated that helical tieback anchors may be necessary to anchor the wall in this location if the original deadmen and tiebacks can't be reused.

At 2227 Magdalena Dr. (location 28) the concrete was ready to be poured for a new cap. The contractor (Marine Contracting Group) was not visible on site at the time. The cap forms were in place, but the deadmen forms were not. Some contractors do not use forms for deadmen. It appeared that epoxy coated rebar was used at a corner section in the cap, as well as on one of the panel's lift loops though this is not included in the City's approved design and specifications. A low elevation outflow pipe was observed in this location. The pipe was designed to rest on top of a 10 foot long panel driven to the elevation of the bottom of the pipe with a box form placed around and above the pipe for concrete pouring. The City noted that the contractors were waiting for a low tide to be able to complete the work in this location.

Staging Areas

Three active staging areas were observed along with the construction equipment used on each one. At 2289 Gulfview Rd. (location 12) Duncan Seawall Inc. was staged on the lot with a stockpile of soil, a stack of panels, and other materials. The equipment observed at the time of the visit included one excavator, a front-end loader, a dumpster trailer, and several pick-up trucks. In the water, there were three barges with two excavators, one bobcat, one crawler crane, and one small work boat.

A second staging area observed was at 126 Gulfview Rd. (location 13), which stored only four storage trailers. The site was observed to be well organized and clean. The third active staging area visited was located at 245 Freeport Ct. (location 27) where a front-end loader was observed working on a soil stockpile. City staff mentioned the desire to use the end of the right of way for staging at 1200 Columbian Dr. (location 22). However, the overhead power lines make this difficult to implement.

Bridges and Lock

Three bridges were observed on W Marion Ave. The first one is located at the west end of the subdivision PGI-NW1 (location 7). At 8:10 AM the tide was about 1.2-ft above MLLW and the water mark at the rod level indicate an approximate vertical clearance of 13-ft during the normal high tide. The bridge substructure was observed to be in good shape. City staff warned about the strong currents that occur due to the narrower section just below the bridge. At this location, the maximum water depth reaches about 26-ft, and the City indicated that 16-ft long panels were installed in this segment of canal. Newer panels were installed in front of the old ones and a “super cap” with dimensions of 18-in tall and 24-in was constructed over both new and old panels. The City noted that at the time of installation, not enough penetration was achieved. Therefore, the City and its contractor implemented a solution to drive shorter panels in front of the 16-ft long panels for added support.

A second bridge is located near the north end of the PGI-NW2 subdivision and has a vertical clearance of approximately 12-ft during the normal high tide. Taylor staff noted that some of the panels near the bridge abutment were about 2-ft wide. City staff stated that those panels were possibly installed by FDOT at the time of the bridge construction. Minor chips and spalls were observed on the prestressed concrete piles.

The third bridge observed serves as the only water access to both Zones within PGI-NE. There is a turn approaching the bridge from the north side. All the piles in the middle of the canal were protected around the splash zone with timber boards. Large spalls were observed at multiple different elevations along many of the prestressed concrete piles, presumably due to repeated vessel impacts. The vertical clearance around the normal high tide is also in the 12-ft. However, maneuverability of construction barges below the bridge at this location combined with strong currents and a sharp turn is a likely challenge.

Around the bridges, the newer seawalls were installed in front of the old panels, encapsulated with a “super cap”. On the southwest side of the bridge, the newer seawall construction stopped before an outflow pipe and continued after it, leaving a panel gap and cap discontinuity.

Following completion of the site visit by boat, Taylor staff visited the entrance lock located in BSI. Several photos were taken from the lot located at 3713 Candia Dr, which is owned by the City. The lock system is not operating anymore, but part of the structure is still present, making the only entrance to BSI canals very narrow. It is presumed that only one boat at a time could use this access entrance. Once in use, the vessels must signal other boats before doing a sharp right or left turn right after entering the BSI canal system.

Rip Rap

Rip rap was observed in a few sporadic sections on the northwestern canal of PGI-NW1 and on the north side of PGI facing the bay during the morning mid-incoming tide. The majority of the panels facing the bay (such as the ones located at 4 Sabal Dr.) are still the original installations. The City indicated that even with the exposure to wind generated waves and boat wakes, the rip rap helps to provide scour protection to the panels. For this reason, the City is considering pursuing regulatory authorizations to install rip rap on the majority of the seawall system damaged during Hurricane Irma using potentially available FEMA mitigation funding.

Docks

Per City ordinance, all residential docks within the districts must be built using concrete. Dock slabs and stairs are usually left intact during the new seawall installation. Several docks were found to be pinned to the seawall panels and supported by three piles along the seaward end of the slab. City staff indicated that in the past, during seawall replacement, homeowners were often reluctant to have their docks removed, compelling the City to leave those panels behind the dock in place after the installation was completed. The City also noted observations that a portion of the lateral vessel berthing load from davit lifts is being absorbed by the panels; a condition that the panels are not designed for. Another type of damage observed by the City included damage to the dock slabs, particularly observed in some dock locations along the eastern PGI-NW2 canal. The seaward end of the slab appears to be lifted a few inches above that of the adjacent slab sections. Further investigation should be performed to understand what causes this type of damage and how to avoid adding stress to the panels.

Trees, landscape, and pools

City staff noted that in accordance with the City's ordinance, large landscape within 10-ft of the seawall are not allowed. However, several residences were observed with landscaping and trees in close proximity to the seawalls, such as observed at the corner property located at 2790 Rio Ct. Similarly, several palm trees and other large trees (including an orange poinciana) were observed close to the seawall on the northwestern PGI-NW1 canal. Another large cypress tree was observed close to the wall at 2131 Bayou Rd (location 18). The roots of these trees add lateral pressure to the seawalls and could damage the tieback system.

Pools in close proximity to seawalls is also of concern for the City. One example was observed at 2290 Gulfview Rd., where an old seawall could not be removed due to a large pool and elevated patio in close proximity to the seawall. In this case, the City opted to leave the cracked seawall in place after meeting with the homeowner. The homeowner had a contractor remove the paver patio, excavate below the berm elevation, and backfill the area along the seawall with flowable fill. Many homeowners are reluctant to work with City staff around pools in fear that the pool would be damaged.

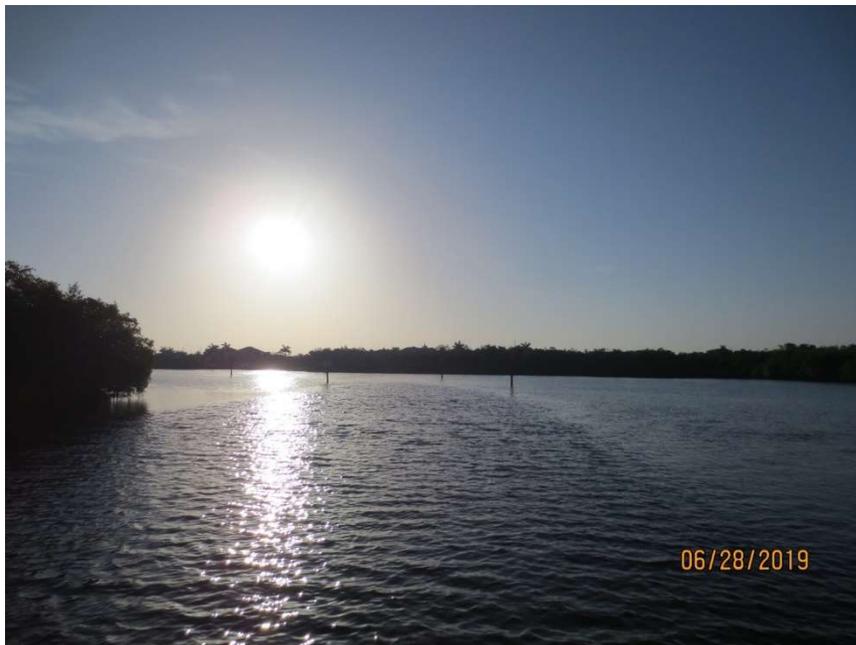
In some cases, most typically on older established home sites, seawall deadmen are located beneath patios or structural foundations. This creates a problem when a new tieback system must be installed. Extra caution must be taken by the contractor so that the structure is not compromised.



Memo Attachment A – Site Visit Photos



Ponce de Leon Canal Entrance A



Ponce de Leon Canal Entrance B



Ponce de Leon Canal Entrance C



Location 1: 2803 Sancho Panza Ct

Left: Original Panels with Epoxy Coated Rebar Cap Replacement

Right: 1st Generation MMFX, 2012 (lower weep hole, prior Irma)



Location 1: 2803 Sancho Panza Ct



Location 2: 2803 Don Quixote Dr

Left: Original Panels with Epoxy Coated Rebar Cap Replacement

Right: Epoxy Coated Rebar seawall



Location 2: 2803 Don Quixote Dr

Left: Original Panels with Epoxy Coated Rebar Cap Replacement

Right: Epoxy Coated Rebar seawall, 5 Panels left out Original, then more Replacements

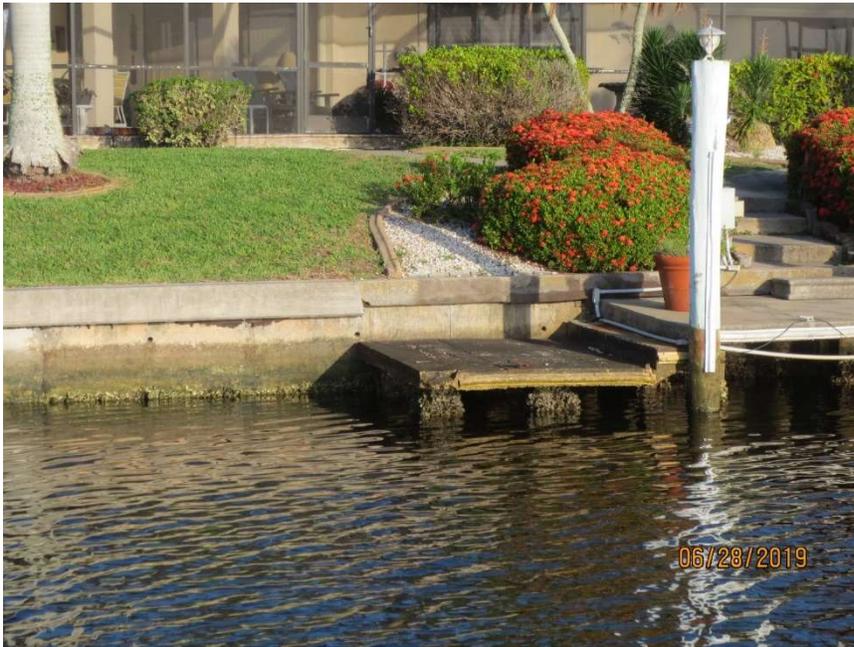


Location 3: 2803 Via Paloma Dr

Left: Epoxy Coated Rebar Seawall 2012;

Middle: Original Seawalls Behind Dock

Right: 2 Panels of Epoxy Coated Rebar Seawall 2012



Location 3: 2803 Via Paloma Dr

Left: Epoxy Coated Rebar Cap (larger cap)

Right: Original Seawalls (smaller cap)



Location 3: 2803 Via Paloma Dr

Far Right: Original Seawall with Newer Cap



Location 4: 2800 Via Paloma Dr

Left: Original Panels with Newer Cap

Center: Original Panels and Cap

Right: Newer Panel and Cap



Location 4: 2800 Via Paloma Dr

Larger Caps used to stop in the middle of an old panel. Typical panel breakage occurred at these locations because differential loading. Now new Cap installation ends where new installation ends to avoid further damage to the panel.

Right: Panel union void below grout patch



Location 5: 260 Lido Dr

Irma walls installed by Duncan Seawall



Location 5: 260 Lido Dr

Irma walls installed by Duncan Seawall

Note the expansive foam used between cap and form



Location 6: 257 Lido Dr

Original 1971 wall in good shape



Location 6: 257 Lido Dr

Original 1971 wall in good shape



Location: West side of Divinci Dr Canal

Left: Original walls with lower elevation than newer installed walls on right



Location 7: West Marion Bridge on PGI-NW1 facing north

Deep spot about 26 feet.

Walls were installed in front of old walls.



Panels are 16-ft long and do not have enough penetration.



Location 7: West Marion Bridge on PGI-NW

Super Cap holding both walls together

Piles were driven in front of 16-ft panels for support.



Location 7: West Marion Bridge on PGI-NW

About 12-ft of clearance during normal high tide





Location 7: West Marion Bridge on PGI-NW

Right: Super Cap holding both walls together

Left: Shorter panel driven in front of original wall for support.



Location 8: 2813 Coral Way

Left: Original panel with Overall Rating of 3 (Moderate)



Right: Newer installation with Cap ending on half width of older panel cracking it



Location 8: 2813 Coral Way



Location 8: 2813 Coral Way



Location 9: 158 Colony Point Dr

New house construction with original wall left in place.



Location: Northwestern canal of PGI-NW1

Mangroves grow usually 18-inches a year. PGI mangroves grow faster than that, possibly due to nutrients in the water.

The City trims mangroves under an exemption provision of Statute FS403.9326 Exemptions (d).



Location: Northwestern canal of PGI-NW1

Large Poinciana tree within 10-ft of the seawall



Location: 2790 Rio Ct

Large landscape within 10 -ft of the seawall is not allowed by City ordinance



Location 10: 7 Hibiscus Dr

Newer Cap with Epoxy Coated Rebar built on original panels

Severe Rating, Crack by waterline, Panel unions grouted to waterline



Location 10: 7 Hibiscus Dr

Longitudinal cracks below Cap



Location 10: 7 Hibiscus Dr

Severe Rating, Crack by waterline



Location 10: 7 Hibiscus Dr

Severe Rating, Crack by waterline



Location 10: 7 Hibiscus Dr

Old and newer panel separation

Cap end spall



Location: 2 Tropicana Dr

Original panels with Epoxy Coated Rebar facing the Peace River bay



Location: 4 Sabal Dr

Rip Rap exposed and submerged along the seawall



Location: 4 Sabal Dr

Rip Rap exposed in front of wall



Location 11: 29 Ocean Dr

Right: Newer construction in 2015 with MMFX Rebar. Cap extends to old seawall and crack the panel below.

Left: Original seawall with overall condition 4 and waterline cracking.



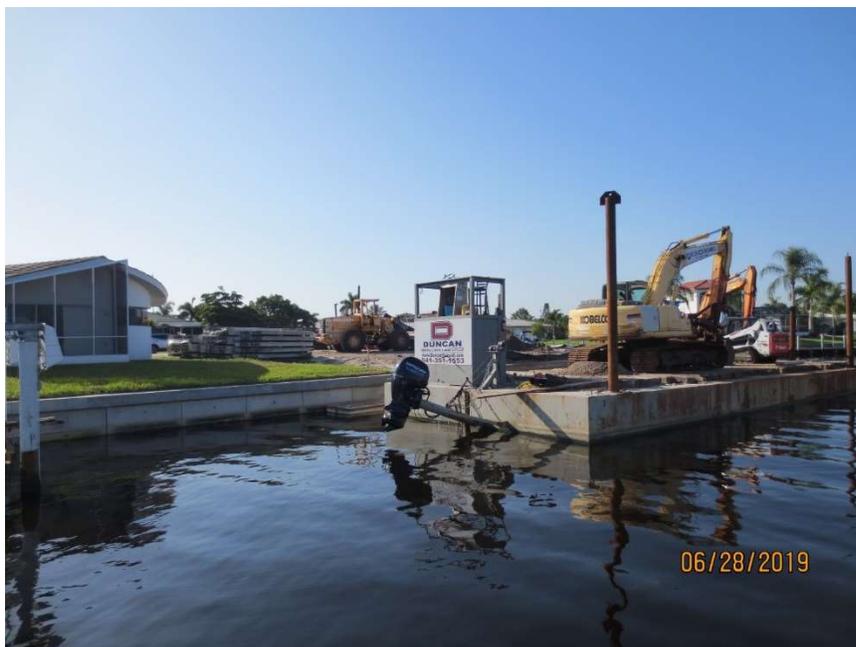
Location 11: 29 Ocean Dr

Original seawall with overall condition 4 and waterline cracking.



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd



Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 12: 2289 Gulfview Rd

Current Duncan Seawall Staging Area



Location 13: 126 Gulfview Rd

Current Duncan Seawall Storage Trailers Staging Area



Location 14: West Marion Ave Bridge on PGI-NW2 facing southeast.



Location 14: West Marion Ave Bridge on PGI-NW2 facing south.

Small width panels possibly installed by FDOT



Location 14: 2001 W Marion Ave

Left: Original Seawall



Right: Epoxy Coated Rebar seawall with cap extending over old wall cracking panel below.



Location 15: 1793 Belle Ct

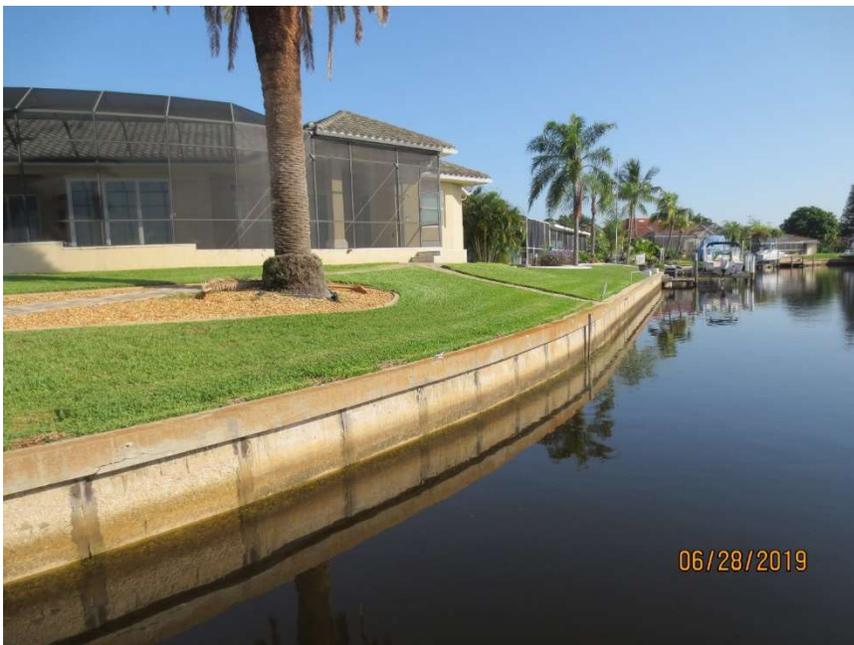
Left: Original Seawall with lower elevation

Right: Cap rebar exposed most of the seawall on the south and west end of the property.



Location 15: 1793 Belle Ct

Cap rebar exposed on south end of property.



Location 15: 1793 Belle Ct

East side of the wall in better condition.



Location 15: 1793 Belle Ct

East side of the wall in better condition and cap patched with grout.



Location 16: 2096 El Cerito Ct

Waterline cracking almost failure condition



Location 16: 2096 El Cerito Ct

Waterline cracking almost failure condition



Location 17: 325 Belvedere Ct

Overall Condition 4, 75% cracks, below waterline.



Location 17: 325 Belvedere Ct

Overall Condition 4, 75% cracks, below waterline.



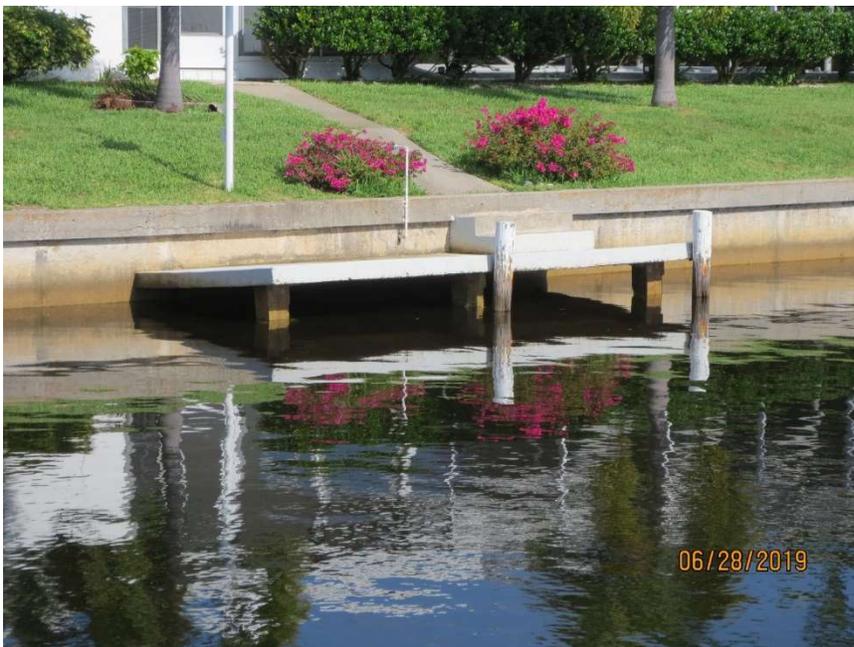
Location 17: 325 Belvedere Ct

Overall Condition 4, 75% cracks, below waterline.



Location: Eastern canal on PGI-NW2

Dock supported by 3 squared concrete piles. Slab pinned to wall panels.



Location: Eastern canal on PGI-NW2

Dock supported by 3 squared concrete piles. Slab pinned to wall panels. Typical damage condition of this design is an inclined slab.



Location 18: 2131 Bayou Rd

Left: MMFX Rebar seawall installed around 2012 to be replaced again.

Right: Bird nest of blue heron and other birds on cypress tree. Tree needs to come out, too close to the seawall.



Location 18: 2131 Bayou Rd

Left: MMFX Rebar seawall installed around 2012 to be replaced again.



Wall leaning waterward, depressions, tie back rods possibly broken.



Location 19: 185 Gulfview Rd

Right: Original seawall north side of the property.



Location 19: 185 Gulfview Rd

Right: Seawall typical Irma failure (toe kicked out) to be replaced.



Location 19: 185 Gulfview Rd

Right: Seawall typical Irma failure (toe kicked out) to be replaced.



Location 19: 185 Gulfview Rd

Right: Seawall typical Irma failure (toe kicked out) to be replaced.

Large depression behind wall.



Location 19: 185 Gulfview Rd

Right: Seawall typical Irma failure (toe kicked out) to be replaced.

Large depression behind wall.



Location 19: 197 Gulfview Rd

Right: Large depression behind wall, panel crack and exposed rebar on cap.



Location 19: 197 Gulfview Rd

Right: Large depression behind wall, panel crack and exposed rebar on cap.

Location 20: 2299 Gulfview Rd

Lot just north of Duncan staging area at the time of the site visit. No picture. Neighbor said walls had failed and been replaced 3 times.

Location 20: 2290 Gulfview Rd

Corner house north of Duncan staging area at the time of the site visit. No picture. Pool next to seawall, no tiebacks, but homeowner cooperative.



Location 21: West Marion Ave Bridge on PGI-NE1

Approaching the bridge looking south



Location 21: West Marion Ave Bridge on PGI-NE1

Mangrove growth and super cap on original seawall



Location 21: West Marion Ave Bridge on PGI-NE1

Approaching the bridge looking south



Location 21: West Marion Ave Bridge on PGI-NE1

Timber to protect piles from vessels.

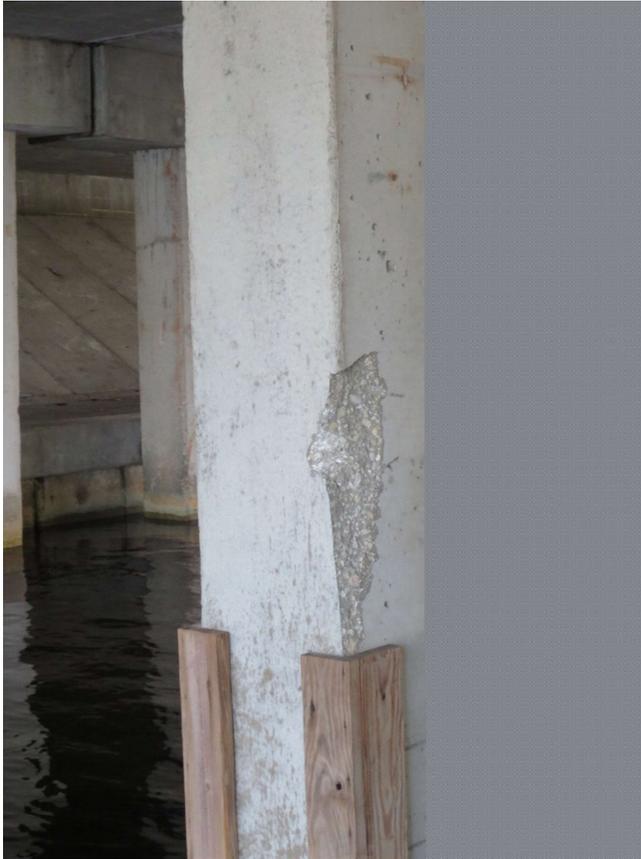






Location 21: West Marion Ave Bridge on PGI-NE1

Large spall on pile











Location 21: West Marion Ave Bridge on PGI-NE1

New wall in front of the old wall, missing section on outflow pipe location

Punta Gorda Seawall Study - Task 3 Site Visit Memo

Page 49 of 74



Location 21: West Marion Ave Bridge on PGI-NE1

Super cap on newer wall



Location 22: 1200 Columbian Dr

City owned right of way at the end of the street for possible staging area, but there are power lines above.



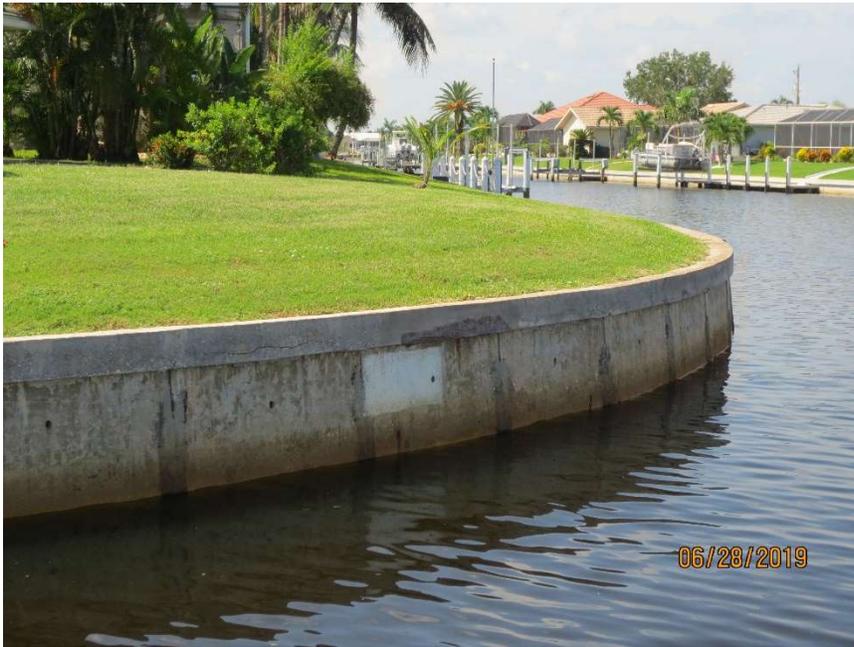
Location 23: 410 Medici Ct

Surface abrasion sets the overall condition to fair.



Location 24: 1036 Francesca Ct

Seawall with Moderate Rating since wall is leaning landward. It might have been built that way since it is a corner lot.



Location 24: 1036 Francesca Ct

Seawall with Moderate Rating since wall is leaning landward. It might have been built that way since it is a corner lot.



Location 24: 1036 Francesca Ct

Location 25: 1123 Lucia Dr

Moderate wall that got replaced only on corner radius. No photos

Punta Gorda Seawall Study - Task 3 Site Visit Memo



Location 26: 704 Vía Formia

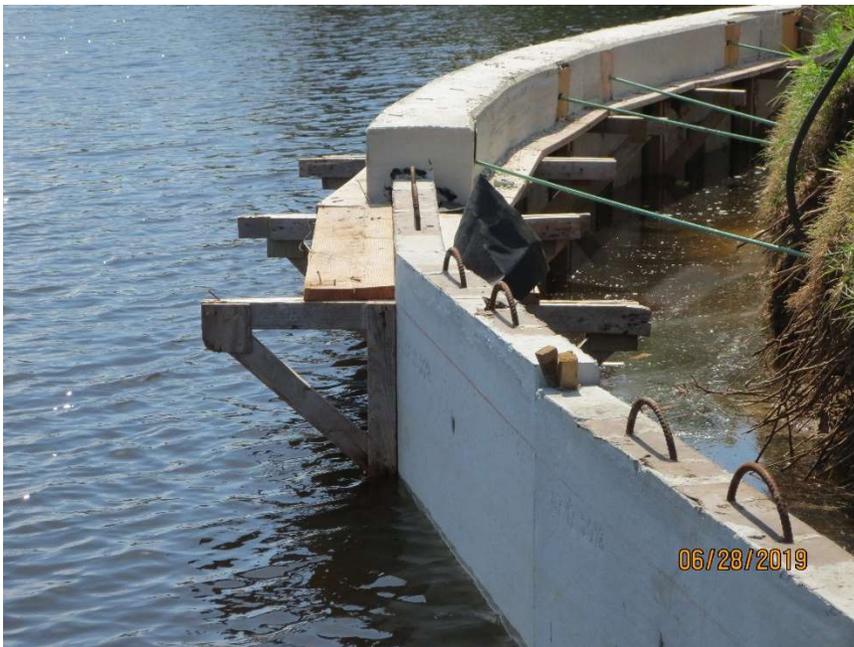
Seawall construction. Panels

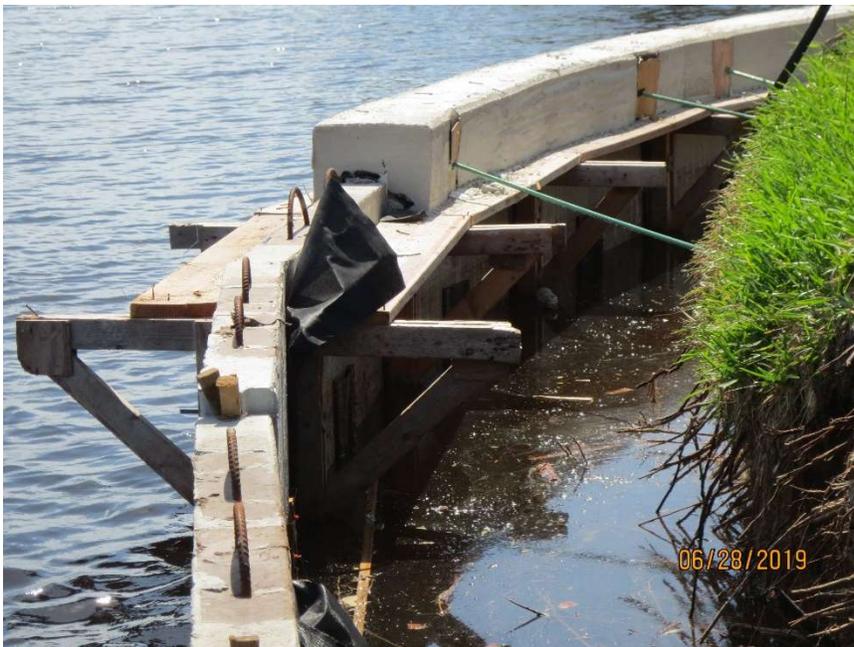
















Location 26: 704 Vía Formia

Some old deadmen are possibly under the house foundation.







Location 27: 245 Freeport Ct

Staging Area



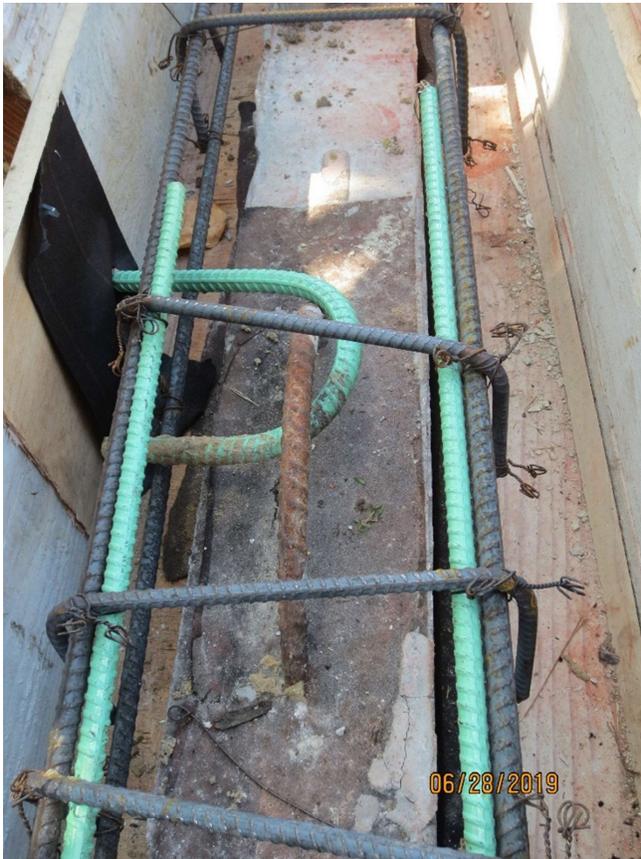


Location 28: 2227 Magdalena Dr

New construction, few new deadmen, outflow pipe set on top of over driven panel and form around and on top for concrete pour.





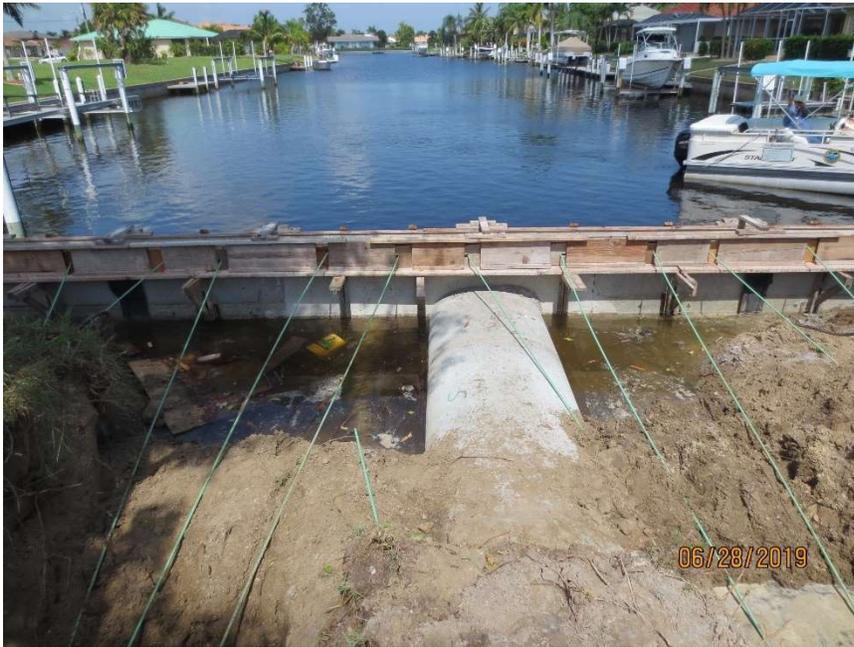




Location 28: 2227 Magdalena Dr

Concrete ready to be poured, no form placed.







Location 28: 2227 Magdalena Dr

Concrete ready to be poured, dam created with soil.









Location: 3713 Candia Dr

Looking at the BSI entrance lock (not in use).

Mirrors to see incoming boats. One boat at the time.

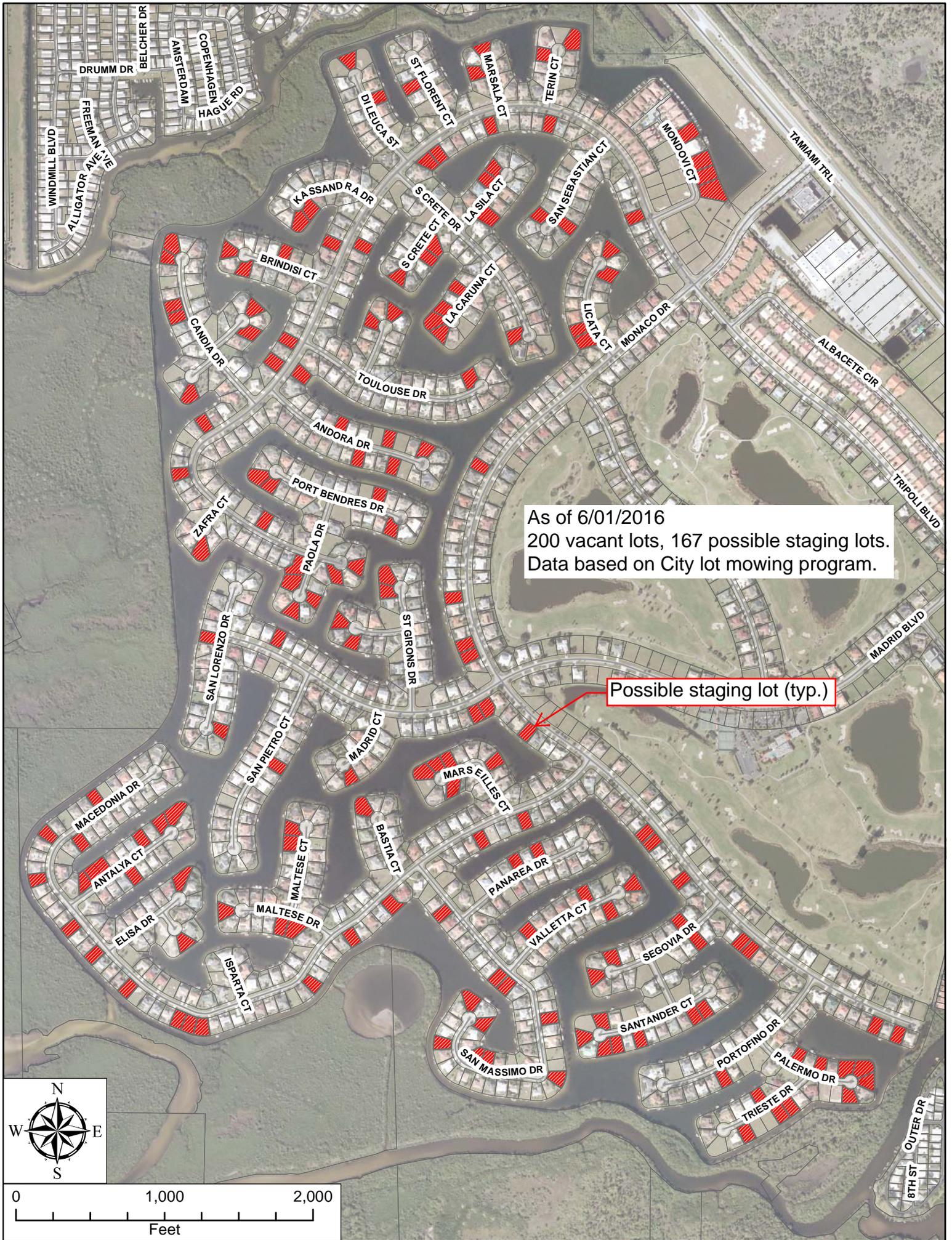






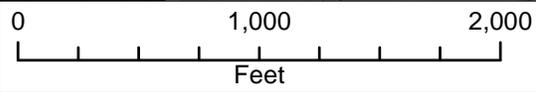
APPENDIX C

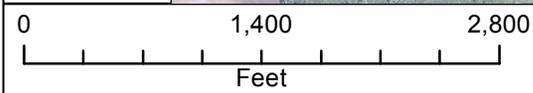
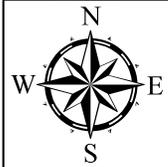
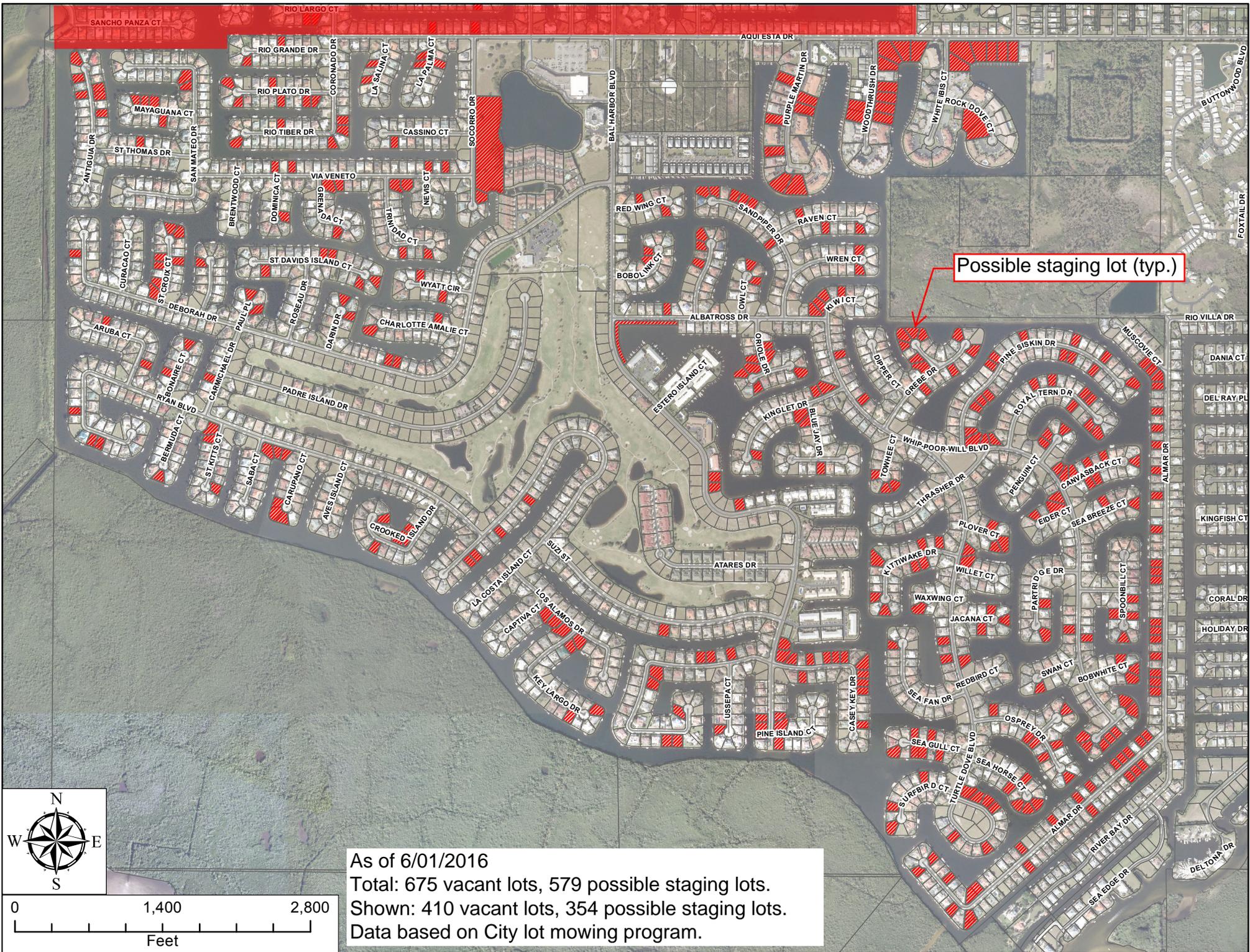
Vacant Lot Location and Staging Area Maps



As of 6/01/2016
200 vacant lots, 167 possible staging lots.
Data based on City lot mowing program.

Possible staging lot (typ.)

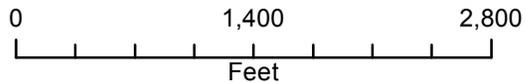
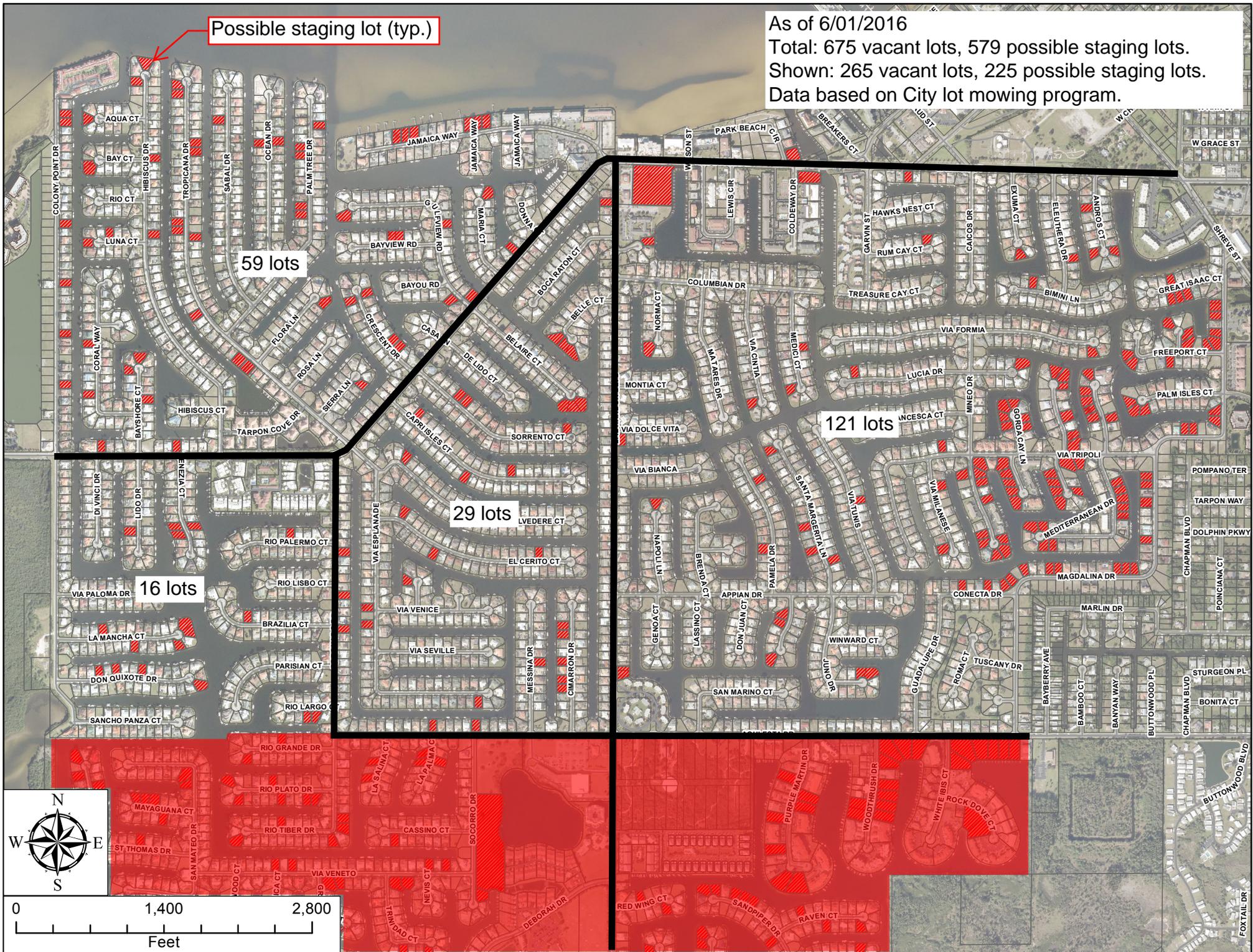


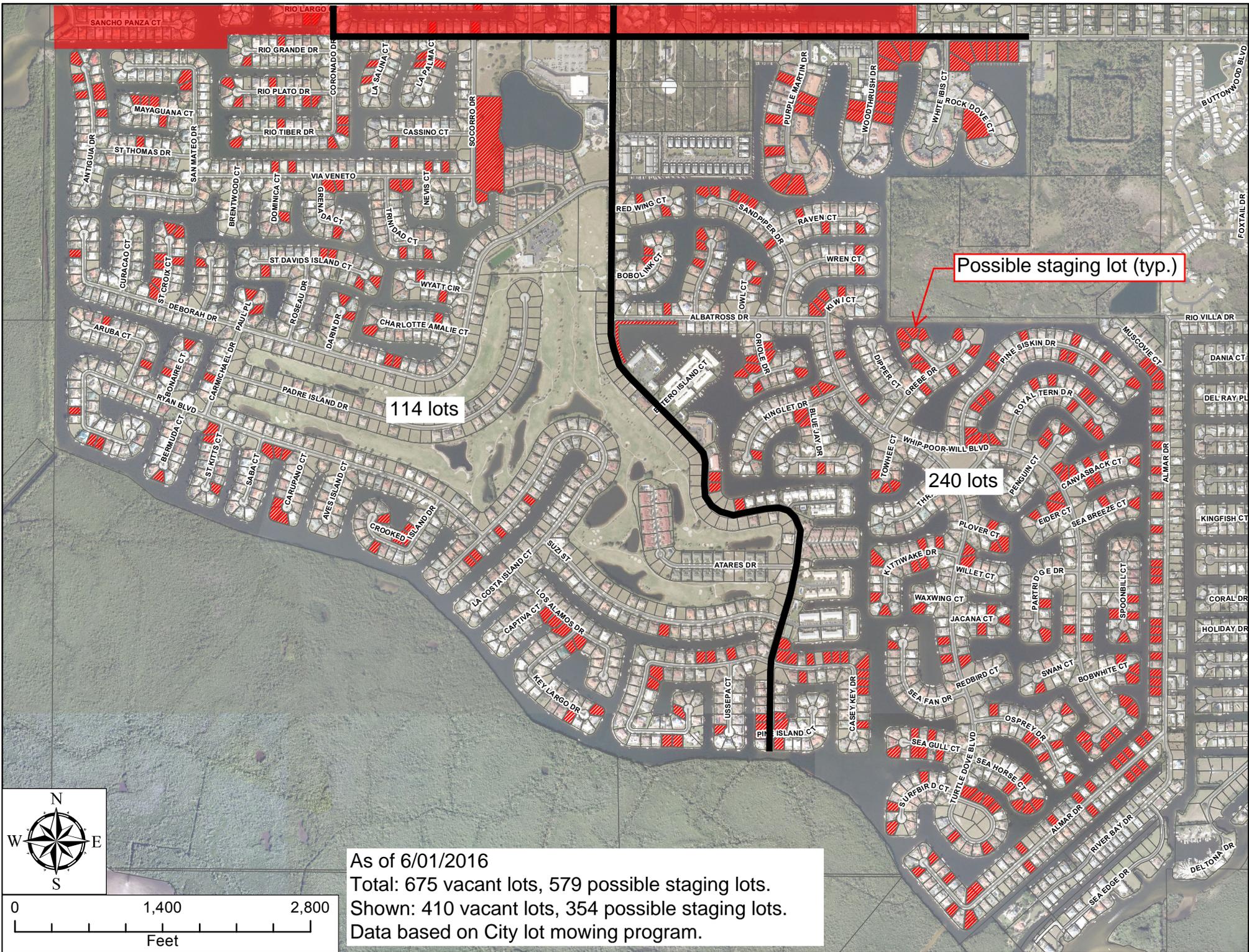


Possible staging lot (typ.)

As of 6/01/2016

Total: 675 vacant lots, 579 possible staging lots.
Shown: 265 vacant lots, 225 possible staging lots.
Data based on City lot mowing program.

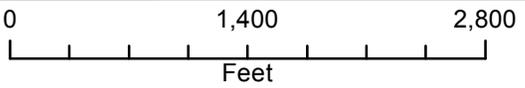




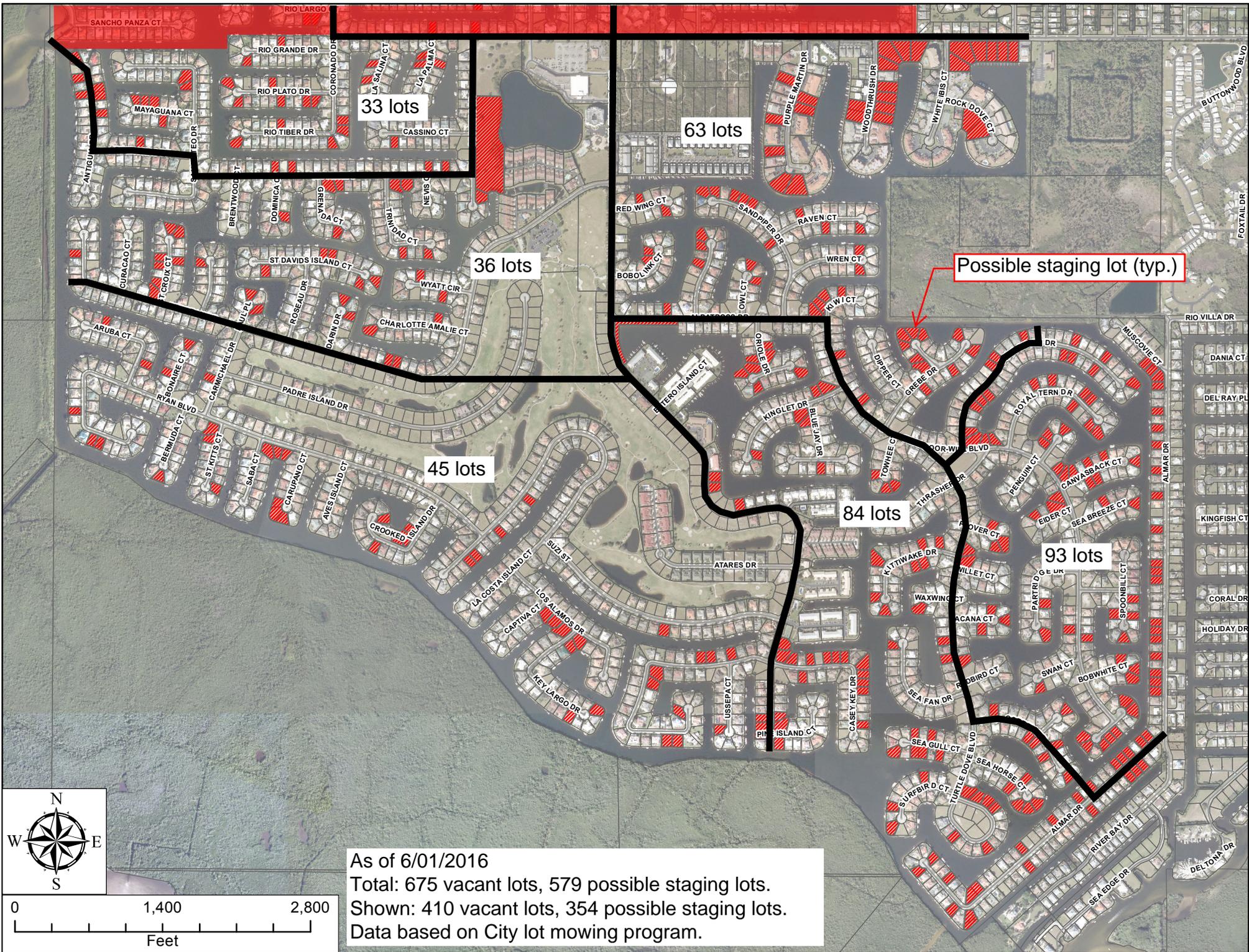
Possible staging lot (typ.)

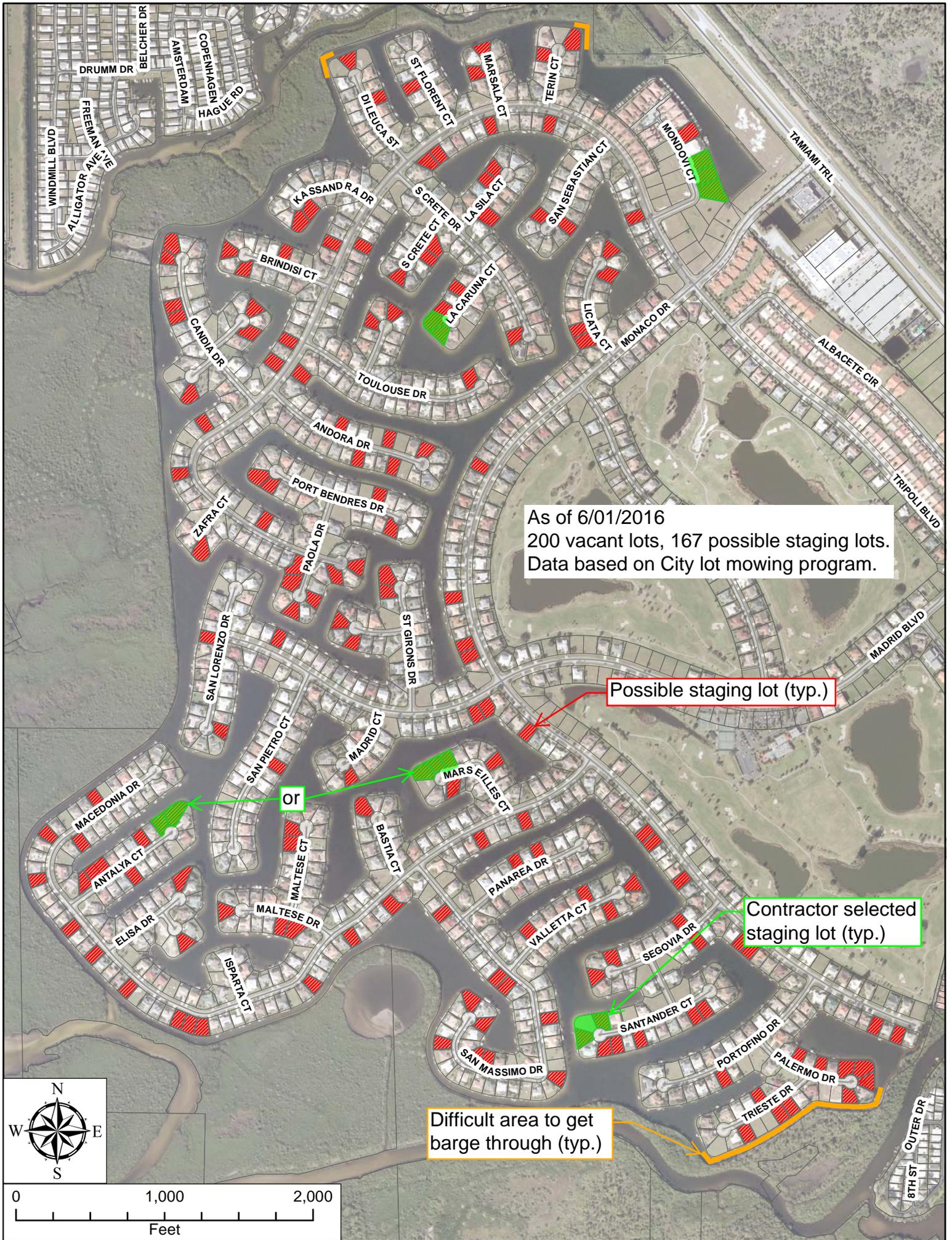
114 lots

240 lots



As of 6/01/2016
 Total: 675 vacant lots, 579 possible staging lots.
 Shown: 410 vacant lots, 354 possible staging lots.
 Data based on City lot mowing program.







18500 Murdock Circle



Project location



City of Punta Gorda

0.4mi

26° 56' 12" N 82° 01' 19" W



18500 Murdock Circle



Ownership

Existing spoil site

City of Punta Gorda

City of Punta Gorda

Punta Gorda Isles Inc

Trustees of the Internal Improvement Trust Fund / Department of Natural Resources - State Lands

Punta Gorda Isles Sales Inc

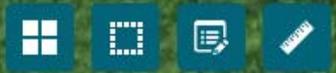
Right-of-Way



200ft 26° 54' 38" N 82° 05' 06" W



18500 Murdock Circle



City Zoning

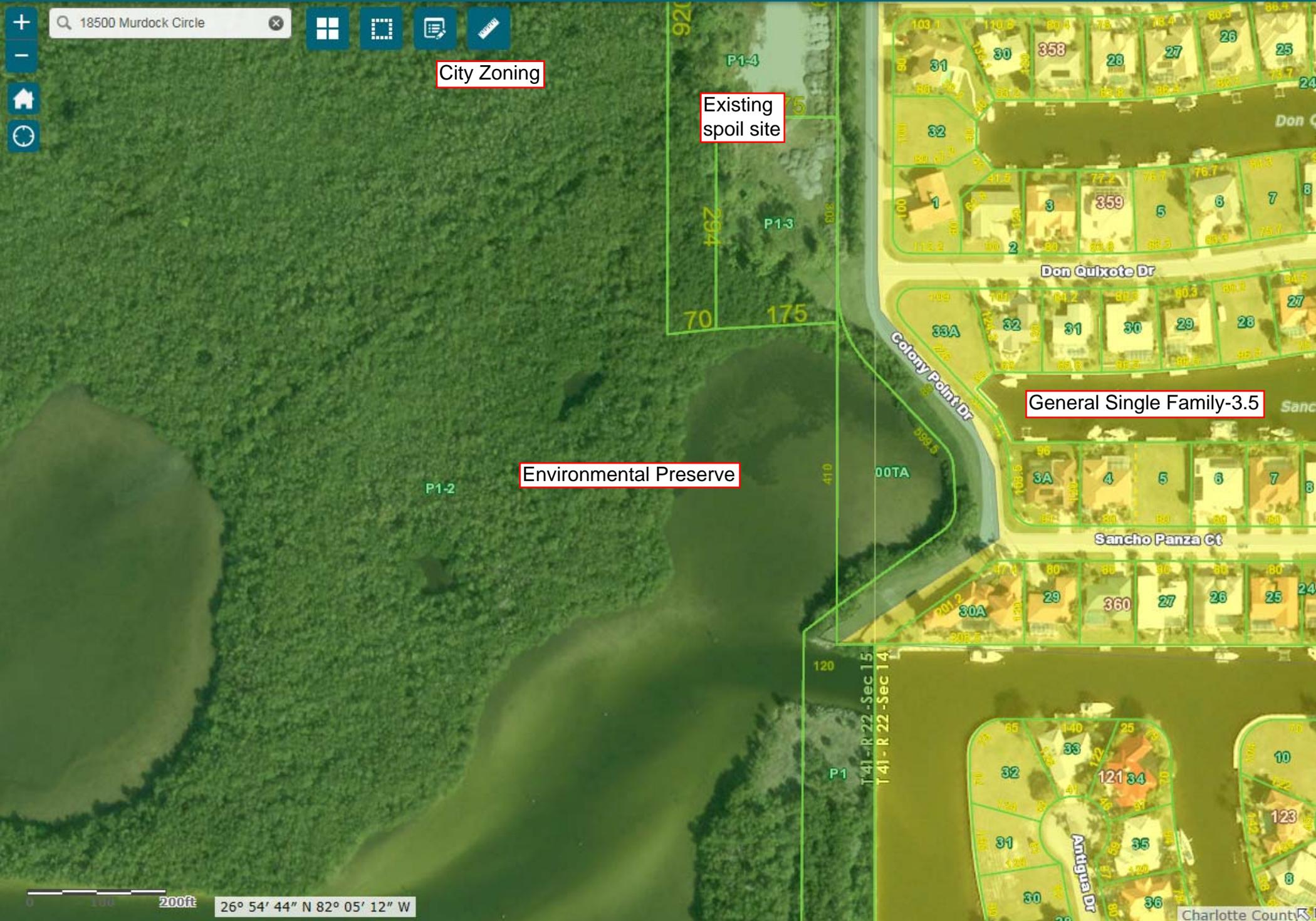
Existing spoil site

Environmental Preserve

General Single Family-3.5

0 100 200ft

26° 54' 44" N 82° 05' 12" W





18500 Murdock Circle



Existing spoil site

60' x 525' proposed channel, depth of 6' below MLW.

100ft

26° 54' 41" N 82° 05' 05" W

APPENDIX D

Seawall Service Life and Replacement Projections Data

Appendix D

Table D.1 - Service Life for Original Walls (w/No Irma Failure)

Assigned Design Life (Yrs):		40				
Effective Service Life (Yrs):		60				
Zone	Installation Year (range)	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 0 Rating	LF	Remaining Service Life (Yrs)
BSI-N	1980-1980	1980	39	2%	1,046	21
BSI-S	1980-1980	1980	39	2%	1,115	21
PGI-NE1	1968-1997	1973	46	5%	3,563	14
PGI-NE2	1971-1978	1971	48	1%	516	12
PGI-NW1	1965-1978	1970	49	3%	2,110	11
PGI-NW2	1965-1971	1968	51	2%	1,504	9
PGI-SE	1978-1978	1978	41	2%	2,550	19
PGI-SW	1971-1978	1977	42	3%	3,091	18
Total LF:					15,494	

Effective Service Life (Yrs):		58				
Zone	Installation Year (range)	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 1 Rating	LF	Remaining Service Life (Yrs)
BSI-N	1980-1980	1980	39	69%	33,706	19
BSI-S	1980-1980	1980	39	67%	30,538	19
PGI-NE1	1968-1997	1973	46	15%	10,432	12
PGI-NE2	1971-1978	1971	48	47%	22,946	10
PGI-NW1	1965-1978	1970	49	30%	20,957	9
PGI-NW2	1965-1971	1968	51	50%	40,022	7
PGI-SE	1978-1978	1978	41	54%	61,618	17
PGI-SW	1971-1978	1977	42	42%	39,563	16
Total LF:					259,782	

Effective Service Life (Yrs):		56				
Zone	Installation Year (range)	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 2 Rating	LF	Remaining Service Life (Yrs)
BSI-N	1980-1980	1980	39	11%	5,238	17
BSI-S	1980-1980	1980	39	11%	4,975	17
PGI-NE1	1968-1997	1973	46	10%	7,295	10
PGI-NE2	1971-1978	1971	48	8%	4,095	8
PGI-NW1	1965-1978	1970	49	13%	9,445	7
PGI-NW2	1965-1971	1968	51	6%	4,954	5
PGI-SE	1978-1978	1978	41	16%	18,490	15
PGI-SW	1971-1978	1977	42	17%	15,680	14
Total LF:					70,172	

Effective Service Life (Yrs):		40				
Zone	Installation Year (range)	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 3 Rating	LF	Remaining Service Life (Yrs)
BSI-N	1980-1980	1980	39	2%	938	1
BSI-S	1980-1980	1980	39	1%	232	1
PGI-NE1	1968-1997	1973	46	0%	156	-6
PGI-NE2	1971-1978	1971	48	0%	-	-8
PGI-NW1	1965-1978	1970	49	2%	1,150	-9
PGI-NW2	1965-1971	1968	51	1%	472	-11
PGI-SE	1978-1978	1978	41	1%	1,569	-1
PGI-SW	1971-1978	1977	42	0%	437	-2
Total LF:					4,953	

Effective Service Life (Yrs):		40				
Zone	Installation Year (range)	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 4 Rating	LF	Remaining Service Life (Yrs)
BSI-N	1980-1980	1980	39	0%	-	1
BSI-S	1980-1980	1980	39	0	-	1
PGI-NE1	1968-1997	1973	46	0%	47	-6
PGI-NE2	1971-1978	1971	48	0%	-	-8
PGI-NW1	1965-1978	1970	49	0%	21	-9
PGI-NW2	1965-1971	1968	51	0%	110	-11
PGI-SE	1978-1978	1978	41	0%	73	-1
PGI-SW	1971-1978	1977	42	0%	-	-2
Total LF:					250	

Effective Service Life (Yrs):		40				
Zone	Installation Year (range)	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 5 Rating	LF	Remaining Service Life (Yrs)
BSI-N	1980-1980	1980	39	0%	-	1
BSI-S	1980-1980	1980	39	0%	-	1
PGI-NE1	1968-1997	1973	46	0%	-	-6
PGI-NE2	1971-1978	1971	48	0%	-	-8
PGI-NW1	1965-1978	1970	49	0%	-	-9
PGI-NW2	1965-1971	1968	51	0%	-	-11
PGI-SE	1978-1978	1978	41	0%	-	-1
PGI-SW	1971-1978	1977	42	0%	25	-2
Total LF:					25	

Total Length Assessed:

350,676

Appendix D

Table D.2 - Service Life for Epoxy Rebar Walls from (w/No Irma Failure)

NOTE: Data provided from GIS records; does not include City budget data provided Oct. 2019

Assigned Design Life (Yrs):		50								
Effective Service Life (Yrs):		70								
Zones	Known Installation Date (YR)	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002	Average Age of Replaced Epoxy Wall (Yrs)	% of Walls with 0 Rating	LF	Remaining Service Life (Yrs)	
BSI-N		1,446	3%	6,829	14%	-	0.02%	8	-	
BSI-S		2,198	5%	6,776	15%	-	0.08%	39	-	
PGI-NE1	2004	32,667	46%	16,306	23%	15	0.92%	650	55	
PGI-NE2		6,467	13%	15,199	31%	-	0.14%	70	-	
PGI-NW1	2005	20,439	29%	16,556	23%	14	0.24%	169	56	
PGI-NW2		15,879	20%	17,702	22%	-	0.27%	221	-	
PGI-SE		14,801	13%	15,648	14%	-	0.11%	123	-	
PGI-SW		21,529	23%	13,758	15%	-	0.71%	669	-	
				108,773			Total LF:	1,948		

Effective Service Life (Yrs):		65								
Zones	Installation Date (YR)	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002	Average Age of Replaced Epoxy Wall (Yrs)	% of Walls with 1 Rating	LF	Remaining Service Life (Yrs)	
BSI-N		1,446	3%	6,829	14%	-	2%	984	-	
BSI-S		2,198	5%	6,776	15%	-	4%	1,916	-	
PGI-NE1	2004	32,667	46%	16,306	23%	15	37%	26,510	50	
PGI-NE2		6,467	13%	15,199	31%	-	10%	5,029	-	
PGI-NW1	2005	20,439	29%	16,556	23%	14	26%	18,083	51	
PGI-NW2		15,879	20%	17,702	22%	-	14%	11,027	-	
PGI-SE		14,801	13%	15,648	14%	-	11%	12,454	-	
PGI-SW		21,529	23%	13,758	15%	-	19%	17,994	-	
				108,773			Total LF:	93,999		

Effective Service Life (Yrs):		60								
Zones	Installation Date (YR)	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002	Average Age of Replaced Epoxy Wall (Yrs)	% of Walls with 2 Rating	LF	Remaining Service Life (Yrs)	
BSI-N		1,446	3%	6,829	14%	-	0.30%	150	-	
BSI-S		2,198	5%	6,776	15%	-	0.05%	24	-	
PGI-NE1	2004	32,667	46%	16,306	23%	15	5.75%	4,075	45	
PGI-NE2		6,467	13%	15,199	31%	-	0.12%	61	-	
PGI-NW1	2005	20,439	29%	16,556	23%	14	1.59%	1,127	46	
PGI-NW2		15,879	20%	17,702	22%	-	0.26%	210	-	
PGI-SE		14,801	13%	15,648	14%	-	0.41%	474	-	
PGI-SW		21,529	23%	13,758	15%	-	0.76%	718	-	
							Total LF:	6,838		

Effective Service Life (Yrs):		50								
Zones	Installation Date (YR)	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002	Average Age of Replaced Epoxy Wall (Yrs)	% of Walls with 3 Rating	LF	Remaining Service Life (Yrs)	
BSI-N		1,446	3%	6,829	14%	-	-	-	-	
BSI-S		2,198	5%	6,776	15%	-	-	-	-	
PGI-NE1	2004	32,667	46%	16,306	23%	15	0.01%	4	35	
PGI-NE2		6,467	13%	15,199	31%	-	-	-	-	
PGI-NW1	2005	20,439	29%	16,556	23%	14	0.00%	2	36	
PGI-NW2		15,879	20%	17,702	22%	-	0.01%	5	-	
PGI-SE		14,801	13%	15,648	14%	-	0.00%	2	-	
PGI-SW		21,529	23%	13,758	15%	-	0.10%	97	-	
							Total LF:	111		

Effective Service Life (Yrs):		50								
Zones	Installation Date (YR)	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002	Average Age of Replaced Epoxy Wall (Yrs)	% of Walls with 4 Rating	LF	Remaining Service Life (Yrs)	
BSI-N		1,446	3%	6,829	14%	-	-	-	-	
BSI-S		2,198	5%	6,776	15%	-	-	-	-	
PGI-NE1	2004	32,667	46%	16,306	23%	15	-	-	35	
PGI-NE2		6,467	13%	15,199	31%	-	-	-	-	
PGI-NW1	2005	20,439	29%	16,556	23%	14	-	-	36	
PGI-NW2		15,879	20%	17,702	22%	-	0.02%	14	-	
PGI-SE		14,801	13%	15,648	14%	-	-	-	-	
PGI-SW		21,529	23%	13,758	15%	-	-	-	-	
							Total LF:	14		

Effective Service Life (Yrs):		50								
Zones	Installation Date (YR)	LF of walls replaced between 1981 & 2002 (Epoxy Coated)	% of Walls Replaced between 1981 & 2002 (Epoxy Coated)	LF of walls replaced one time after 2002	% of Walls Replaced Once after 2002	Average Age of Replaced Epoxy Wall (Yrs)	% of Walls with 5 Rating	LF	Remaining Service Life (Yrs)	
BSI-N		1,446	3%	6,829	14%	-	-	-	-	
BSI-S		2,198	5%	6,776	15%	-	-	-	-	
PGI-NE1	2004	32,667	46%	16,306	23%	15	-	-	35	
PGI-NE2		6,467	13%	15,199	31%	-	-	-	-	
PGI-NW1	2005	20,439	29%	16,556	23%	14	-	-	36	
PGI-NW2		15,879	20%	17,702	22%	-	-	-	-	
PGI-SE		14,801	13%	15,648	14%	-	-	-	-	
PGI-SW		21,529	23%	13,758	15%	-	-	-	-	
							Total LF:	-		

Total Length Assessed: 96,071

Appendix D

Table D-3: Epoxy Rebar Wall Replacement Dates from City Historic Budget Data

Invoiced Fiscal Year	Replacement Yr	Seawall Replaced (ft)		Combined	Avg Age	Remaining
		BSI (ft)	PGI (ft)	Seawall Replaced Length (ft))	of Walls (Yrs)	Service Life (Yrs)
Oct 1, 2009 - Sept. 30, 2010	2010	694	6,484	7,178	9	41
Oct 1, 2008 - Sept. 30, 2009	2009	750	4,221	4,971	10	40
Oct 1, 2007 - Sept. 30, 2008	2008	474	4,248	4,722	11	39
Oct 1, 2006 - Sept. 30, 2007	2007	312	4,740	5,052	12	38
Oct 1, 2005 - Sept. 30, 2006	2006	598	9,612	10,210	13	37
Oct 1, 2004 - Sept. 30, 2005	2005	154	3,384	3,538	14	36
Oct 1, 2003 - Sept. 30, 2004	2004	93	27,776	27,869	15	35
Oct 1, 2002 - Sept. 30, 2003	2003	89	4,671	4,760	16	34
Oct 1, 2001 - Sept. 30, 2002	2002	38	5,377	5,415	17	33
Oct 1, 2000 - Sept. 30, 2001	2001	39	1,790	1,829	18	32
Oct 1, 1999 - Sept. 30, 2000	2000	59	1,367	1,426	19	31
Oct 1, 1998 - Sept. 30, 1999	1999	16	1,991	2,007	20	30
Oct 1, 1997 - Sept. 30, 1998	1998	0	2,133	2,133	21	29
Oct 1, 1996 - Sept. 30, 1997	1997	0	983	983	22	28
Oct 1, 1995 - Sept. 30, 1996	1996	0	1,831	1,831	23	27
Oct 1, 1994 - Sept. 30, 1995	1995	60	1,467	1,527	24	26
Oct 1, 1993 - Sept. 30, 1994	1994	66	400	466	25	25
		3,442	82,475			

Total Feet of Wall (ft): 85,917

Epoxy Assigned Design Life (Yrs): 50

Appendix D

Table D.4 - Service Life for MMFX Rebar Walls from (w/No Irma Failure)

Assigned Design Life (Yrs):		60				
Effective Service Life (Yrs):		66				
Zone	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 0 Rating	LF	Remaining Service Life (Yrs)	Total LF in Zone
BSI-N	2014	5	7%	3,661	61	49,204
BSI-S	2014	5	7%	3,160	61	45,834
PGI-NE1	2013	6	6%	4,450	60	70,846
PGI-NE2	2014	5	6%	2,809	61	49,256
PGI-NW1	2014	5	10%	6,989	61	70,677
PGI-NW2	2014	5	7%	5,375	61	80,643
PGI-SE	2015	4	5%	5,684	62	114,748
PGI-SW	2015	4	8%	7,548	62	94,082
Total LF:				39,676		

Effective Service Life (Yrs):		66				
Zone	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 1 Rating	LF	Remaining Service Life (Yrs)	Total LF in Zone
BSI-N	2014	5	4%	1,922	61	49,204
BSI-S	2014	5	5%	2,125	61	45,834
PGI-NE1	2013	6	3%	2,072	60	70,846
PGI-NE2	2014	5	2%	1,182	61	49,256
PGI-NW1	2014	5	4%	2,671	61	70,677
PGI-NW2	2014	5	4%	3,174	61	80,643
PGI-SE	2015	4	4%	4,339	62	114,748
PGI-SW	2015	4	3%	3,010	62	94,082
Total LF:				20,495		

Effective Service Life (Yrs):		60				
Zone	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 2 Rating	LF	Remaining Service Life (Yrs)	Total LF in Zone
BSI-N	2014	5	1%	392	55	49,204
BSI-S	2014	5	1%	337	55	45,834
PGI-NE1	2013	6	1%	546	54	70,846
PGI-NE2	2014	5	0%	101	55	49,256
PGI-NW1	2014	5	1%	816	55	70,677
PGI-NW2	2014	5	1%	670	55	80,643
PGI-SE	2015	4	1%	1,277	56	114,748
PGI-SW	2015	4	1%	707	56	94,082
Total LF:				4,847		

Effective Service Life (Yrs):		60				
Zone	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 3 Rating	LF	Remaining Service Life (Yrs)	Total LF in Zone
BSI-N	2014	5	0%	37	55	49,204
BSI-S	2014	5	1%	323	55	45,834
PGI-NE1	2013	6	0%	-	54	70,846
PGI-NE2	2014	5	0%	-	55	49,256
PGI-NW1	2014	5	0%	198	55	70,677
PGI-NW2	2014	5	0%	16	55	80,643
PGI-SE	2015	4	0%	244	56	114,748
PGI-SW	2015	4	0%	-	56	94,082
Total LF:				818		

Effective Service Life (Yrs):		60				
Zone	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 4 Rating	LF	Remaining Service Life (Yrs)	Total LF in Zone
BSI-N	2014	5	0%	-	-	49,204
BSI-S	2014	5	0	-	-	45,834
PGI-NE1	2013	6	0%	-	-	70,846
PGI-NE2	2014	5	0%	-	-	49,256
PGI-NW1	2014	5	0%	-	-	70,677
PGI-NW2	2014	5	0%	118	55	80,643
PGI-SE	2015	4	0%	-	-	114,748
PGI-SW	2015	4	0%	-	-	94,082
Total LF:				118		

Effective Service Life (Yrs):		60				
Zone	Year Installed Weighted Average (based on LF)	Average Age of Original Walls (Yrs)	% of Walls with 5 Rating	LF	Remaining Service Life (Yrs)	Total LF in Zone
BSI-N	2014	5	0%	-	-	49,204
BSI-S	2014	5	0%	-	-	45,834
PGI-NE1	2013	6	0%	-	-	70,846
PGI-NE2	2014	5	0%	-	-	49,256
PGI-NW1	2014	5	0%	-	-	70,677
PGI-NW2	2014	5	0%	-	-	80,643
PGI-SE	2015	4	0%	-	-	114,748
PGI-SW	2015	4	0%	-	-	94,082
Total LF:				-		

Total Length Assessed: 65,955

APPENDIX E

City of Punta Gorda Waterfront Design Standards

TABLE OF CONTENTS

WATERFRONT DEVELOPMENT STANDARDS

WD-1	TABLE OF CONTENTS—WATERFRONT DEVELOPMENT
WD-2	GENERAL NOTES
WD-3	REBAR DETAILS
WD-4	SEAWALL CAP AND FILTER FABRIC DETAILS
WD-5	THICKENED SEAWALL CAP DETAIL (SPECIAL USE)
WD-6	EXPANSION JOINT AND LOAD TRANSFER DETAILS
WD-7	CONTRACTION JOINT DETAILS / JOINT LAYOUT
WD-8	TIE BACK DETAILS
WD-9	ROCK ANCHOR TIE BACK DETAIL
WD-10	EXCAVATION DETAILS
WD-11	10'-0" PRECAST SEAWALL PANEL DETAILS
WD-12	12'-6" PRECAST SEAWALL PANEL DETAILS
WD-13	14'-0" PRECAST SEAWALL PANEL DETAILS
WD-14	16'-0" PRECAST SEAWALL PANEL DETAILS
WD-15	STANDARD DOCKSIDE DREDGING DETAIL
WD-16	STANDARD CONCRETE DOCK AND OUT PILE DETAIL
WD-17	RIP-RAP STABILIZATION DETAIL
WD-18	OUTFALL STABILIZATION DETAIL

CITY OF PUNTA GORDA

326 WEST MARION AVENUE
PUNTA GORDA, FL. 33950
(941) 575-5050

WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

TABLE OF CONTENTS

SHEET NO. WD-1

AUGUST 2019

GENERAL NOTES:

1. CONSTRUCTION SPECIFICATIONS: FLORIDA DEPARTMENT OF TRANSPORTATION "STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION", CURRENT EDITION (FDOT SPECIFICATIONS)
2. DESIGN SPECIFICATIONS: DESIGN SHALL BE IN ACCORDANCE WITH THE FOLLOWING SPECIFICATIONS:
 - A. DESIGN SPECIFICATIONS: AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO) LRFD BRIDGE DESIGN SPECIFICATIONS CURRENT EDITION
 - B. DESIGN METHOD: LIMIT STATES DESIGN METHOD (LOAD AND RESISTANCE FACTOR DESIGN).
 - C. U.S. ARMY CORPS OF ENGINEERS ENGINEERING MANUAL EM 1110-2-2504, CURRENT EDITION
 - D. AMERICAN CONCRETE INSTITUTE 318-05
3. MATERIAL STRESSES: ALL ALLOWABLE STRESSES ARE IN ACCORDANCE WITH THE AASHTO SPECIFICATIONS FOR THE MATERIALS SHOWN ON THE PLANS.
 - A. ALL CONCRETE SHALL CONFORM TO SECTION 346 OF FDOT SPECIFICATIONS AND SHALL BE CLASS IV, WITH A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 5,500 PSI.
 - B. ALL REINFORCEMENT SHOWN IN DETAILS EXCEPT FOR TIE-BACKS SHALL BE LOW-CARBON, CORROSION-RESISTENT CHROMIUM STEEL REBAR, WHICH SHALL MEET THE SPECIFICATIONS AND STANDARD OF ASTM A1035 (LABELED IN DETAILS AS "CHROMX 9100") TIE-BACKS CAN BE EITHER CHROMX 9100 (WHICH NEEDS TO BE ENCASED IN PVC FROM CONCRETE CAP TO DEADMAN) OR EPOXY COATED REBAR. EPOXY COATING SHALL BE "SCOTCHKOTE" BRAND EPOXY COATING RESIN #413 ASTM A775, ASTM A934, AND AASHTO M284.
4. PRECAST SEAWALL PANEL DESIGN CRITERIA:
 - A. THE PRECAST SEAWALL PANEL WAS DESIGNED FOR THE CRITERIA SHOWN IN THE WATERFRONT DEVELOPMENT STANDARDS. SHOULD THE WALL HEIGHT EXCEED THE MAXIMUM VALUE SHOWN IN THESE DETAILS OR IF THE BERM WIDTH IS LESS THAN THAT SHOWN IN THESE DETAILS, AN INDEPENDENT VERIFICATION OF WALL DETAILS WILL BE PERFORMED BY THE CITY.
 - B. NO SURCHARGE LIVE LOAD WAS CONSIDERED IN THE DESIGN OF THE SEAWALL PANEL. NO SURCHARGE SHALL BE APPLIED TO THE BACKSIDE OF THE WALL EITHER DURING CONSTRUCTION OR IN THE FINAL CONDITION. STRUCTURES CONSTRUCTED BEHIND THE BULKHEAD WALL SHALL BE FOUNDED ON SEPARATE DEEP FOUNDATIONS
 - C. THE SEAWALL SYSTEM WAS DESIGNED FOR THE FOLLOWING MINIMUM SOIL VALUES. FIELD VERIFICATION OF THESE VALUES SHOULD BE PERFORMED FOR EACH WALL LOCATION. IF THE CITY'S ENGINEER CONSIDERS THE SOIL TYPES AT A SPECIFIC LOCATION TO BE OF LESSER STRENGTH PROPERTIES THAN THE VALUE SHOWN IN THESE NOTES, AN INDEPENDENT VERIFICATION OF WALL DETAILS WILL NEED TO BE PERFORMED BY THE CITY'S ENGINEER.

SATURATED UNIT WEIGHT = 115 pcf
 MOIST UNIT WEIGHT = 105 pcf
 ANGLE OF INTERNAL FRICTION = 28 DEGREES
 ANGLE OF WALL FRICTION = 21 DEGREES
5. ENVIRONMENT: HIGHLY AGGRESSIVE.
6. SEAWALL PANEL PENETRATION: IT IS EXPECTED THAT HARD MATERIALS MAY BE ENCOUNTERED WITHIN THE EMBANKMENT. THE CONTRACTOR WILL BE REQUIRED TO ACHIEVE THE MINIMUM PENETRATIONS REQUIRED IN THE PLANS, AND IF NECESSARY, USE SPECIAL EQUIPMENT AND/OR METHODS TO FACILITATE THE PENETRATION AT NO ADDITIONAL COST TO THE CITY. THE CONTRACTOR SHALL CONTACT THE CANAL MAINTENANCE DIVISION AS SOON AS HARD MATERIALS ARE ENCOUNTERED.
7. CONSTRUCTION: THE CONTRACTOR SHALL VERIFY LOCATIONS OF ALL UNDERGROUND UTILITIES BEFORE ANY EXCAVATION OR INSTALLATION OF ANY SEAWALL PANEL. ANY DISTURBANCE OR DAMAGE TO EXISTING STRUCTURES, UTILITIES OR OTHER PROPERTY, CAUSED BY THE CONTRACTORS OPERATION, SHALL BE REPAIRED BY THE CONTRACTOR IN A MANNER SATISFACTORY TO THE CITY AT NO ADDITIONAL COST TO THE CITY. THE CONTRACTOR SHALL BE RESPONSIBLE FOR DETERMINING THE APPROPRIATE EQUIPMENT NECESSARY TO INSTALL THE SEAWALL PANEL TO THE PENETRATION DEPTH AS SPECIFIED ON THE PLANS. THE SEAWALL PANEL SHALL BE INSTALLED, A MINIMUM, TO THE TIP ELEVATION(S) SPECIFIED, PRIOR TO COMMENCING ANY RELATED CONSTRUCTION. IF UNABLE TO REACH THE MINIMUM TIP ELEVATION, THE ADEQUACY OF THE SEAWALL PANEL DESIGN WILL REQUIRE RE-EVALUATION BY THE CITY'S ENGINEER.
8. COVER: CONCRETE COVER SHOWN IN THE PLANS DOES NOT INCLUDE REINFORCEMENT PLACEMENT AND FABRICATION TOLERANCES, UNLESS SHOWN AS "MINIMUM COVER". THE FOLLOWING MINIMUM CONCRETE COVER SHOULD BE PROVIDED:

PRECAST SEAWALL PANELS = 2 1/2"
 CAST IN PLACE SEAWALL CAP = 2 1/2" FOR EXTERNAL SURFACES
9. APPLIED FINISH: A SMOOTH TROWEL FINISH SHALL BE APPLIED TO THE WATER SIDE FACE OF THE CONCRETE SEAWALL PANEL. A BROOM FINISH SHALL BE APPLIED TO THE SURFACES OF THE SEAWALL CAP IN ACCORDANCE WITH SECTION 400 OF THE FDOT SPECIFICATIONS.
10. THE CONTRACTOR SHALL MAINTAIN THE INTEGRITY OF THE SEAWALL PANELS DURING INSTALLATION UNTIL FILL IS PLACED TO FINAL GRADE. FILL SHALL BE PLACED IN AREAS AWAY FROM THE WALL PRIOR TO PLACING AGAINST THE SEAWALL PANELS.
11. FLOATING TURBIDITY BARRIER AND/OR SILT FENCE SHALL BE REQUIRED DURING THE CONSTRUCTION OF THE SEAWALLS, CAP REPLACEMENT AND STAGING AREAS.
12. EXPANSION, LOAD TRANSFER, AND CONTRACTION JOINTS SHALL BE INSTALLED AS SHOWN IN THE WATERFRONT DEVELOPMENT STANDARDS.
13. SEAWALL PANELS ARE TONGUE AND GROOVE. ANY GAPS BETWEEN SEAWALL PANELS OF ONE INCH (1") TO THREE INCHES (3") SHALL BE PATCHED WITH MARINE GRADE HYDRAULIC CEMENT FROM THE BOTTOM OF THE CAP TO TWELVE INCHES (12") BELOW THE MUD LINE ON BOTH SIDES OF THE WALL, LANDSIDE AND WATERSIDE. ANY GAPS BETWEEN SEAWALL PANELS THAT ARE THREE INCHES (3") TO TWELVE INCHES (12") SHALL REQUIRE A BOX POUR FROM THE TOP OF SEAWALL PANEL TO TWELVE INCHES (12") BELOW THE MUD LINE WITH REINFORCED STEEL.

WHEN CONNECTING A NEW SEAWALL PANEL TO AN EXISTING SEAWALL PANEL, AND THE CONTRACTOR IS UNABLE TO UTILIZE THE TONGUE AND GROOVE, THE CONTRACTOR SHALL POUR A CONCRETE BOX FROM THE TOP OF SEAWALL PANEL TO TWELVE INCHES (12") BELOW THE MUD LINE. THE CONTRACTOR MUST INSTALL A REBAR CAGE AND CONNECT IT TO THE CAP REBAR CAGE. CONCRETE MUST BE 5500 PSI MARINE GRADE READY MIX CONCRETE FOR ALL BOX POURS. ALL WOOD FORMS SHALL BE REMOVED PRIOR TO FINAL INSPECTION. MAXIMUM ACCEPTABLE GAP BETWEEN EXISTING AND REPLACED SEAWALL PANELS IS TWELVE INCHES (12").
14. SWALE RESTORATION: REGRADE ROADSIDE SWALE TO CITY SPECIFICATIONS AND SOD ENTIRE LIMITS OF DISTURBED AREAS. INCLUDES REPLACEMENT LOCATIONS AND STAGING SITES.
15. SOD REQUIREMENTS AT VACANT LOTS AND EXISTING RESIDENCE:
 - A. VACANT LOTS - THE DISTURBED PORTIONS OF A VACANT LOT OR PROPERTY SHALL BE SODDED WITH ARGENTINE BAHIA. NO EXPOSED SOILS SHALL BE PERMITTED, INCLUDING ALL RIGHTS-OF-WAY AND DRAINAGE AREAS.
 - B. EXISTING RESIDENCE - ALL DISTURBED AREAS SHALL BE COMPLETELY SODDED WITH SOD THAT MATCHES EXISTING.

CITY OF PUNTA GORDA
 326 WEST MARION AVENUE
 PUNTA GORDA, FL. 33950
 (941) 575-5050

WATERFRONT
 DEVELOPMENT
 STANDARDS

STANDARD DETAIL

GENERAL NOTES

SHEET NO. WD-2

AUGUST 2019

REBAR SCHEDULE FOR 10' SEAWALL PANEL

QTY	LENGTH (FT)	SIZE	SHAPE	WEIGHT (LBS)
10	5.5	#4	STRAIGHT	36.74
2	9.75	#4	STRAIGHT	13.03
2	20.60	#5	HAIRPIN (12" DIA.)	42.97

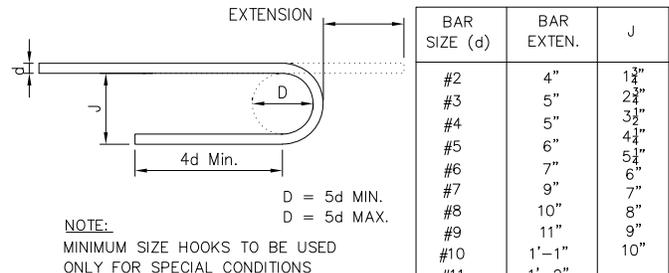
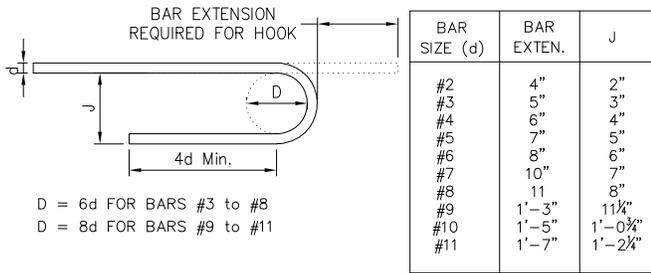
REBAR SCHEDULE FOR 12.5' SEAWALL PANEL

QTY	LENGTH (FT)	SIZE	SHAPE	WEIGHT (LBS)
13	5.5	#4	STRAIGHT	47.76
5	12.25	#4	STRAIGHT	40.92
2	25.55	#5	HAIRPIN (7.5" DIA.)	53.30

REBAR SCHEDULE FOR 14' SEAWALL PANEL

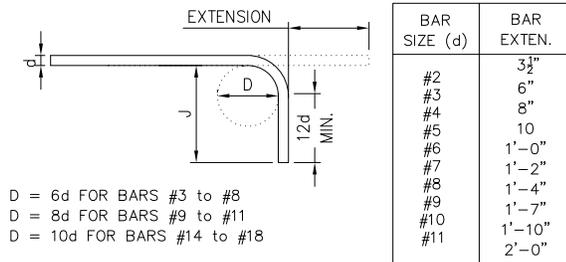
QTY	LENGTH (FT)	SIZE	SHAPE	WEIGHT (LBS)
14	5.5	#4	STRAIGHT	51.44
8	13.67	#4	STRAIGHT	73.05
2	28.31	#5	HAIRPIN (5.75" DIA.)	59.05

REBAR SCHEDULE

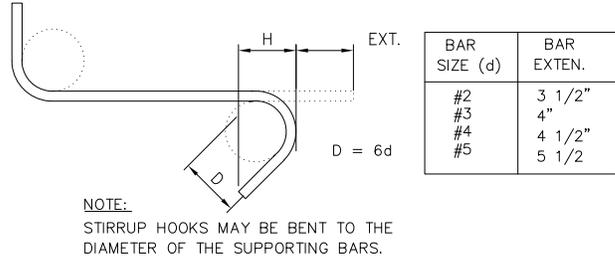


RECOMMENDED SIZES - 180° HOOK

MINIMUM SIZES - 180° HOOK



RECOMMENDED MINIMUM SIZES - 90° HOOK



RECOMMENDED SIZES - 135° HOOK

STANDARD HOOK DETAILS

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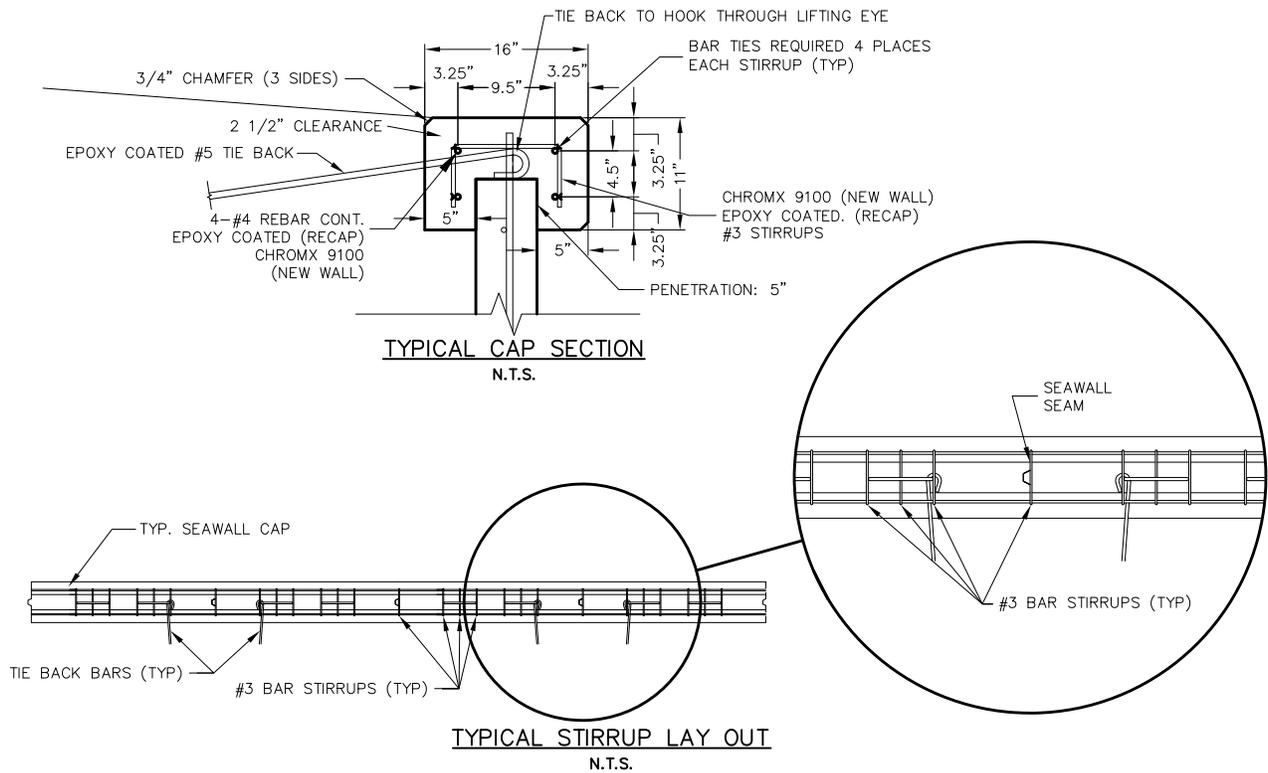
WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

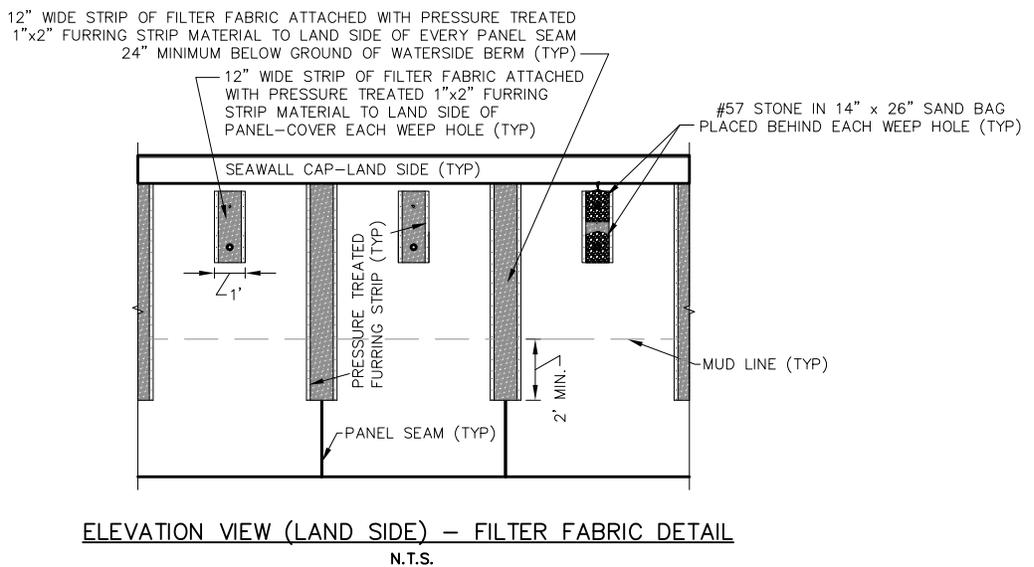
REBAR DETAILS

SHEET NO. WD-3

AUGUST 2019



NOTE:
 MAXIMUM 1 FOOT SPACING. 1 STIRRUP OVER EACH SEAM; 1 STIRRUP OVER EACH LIFTING EYE; 1 STIRRUP ON THE RIGHT AND 1 STIRRUP ON THE LEFT OF THE LIFTING EYE. 15 STIRRUPS MINIMUM IN A 12 FOOT SECTION (2 SEAWALL PANELS)



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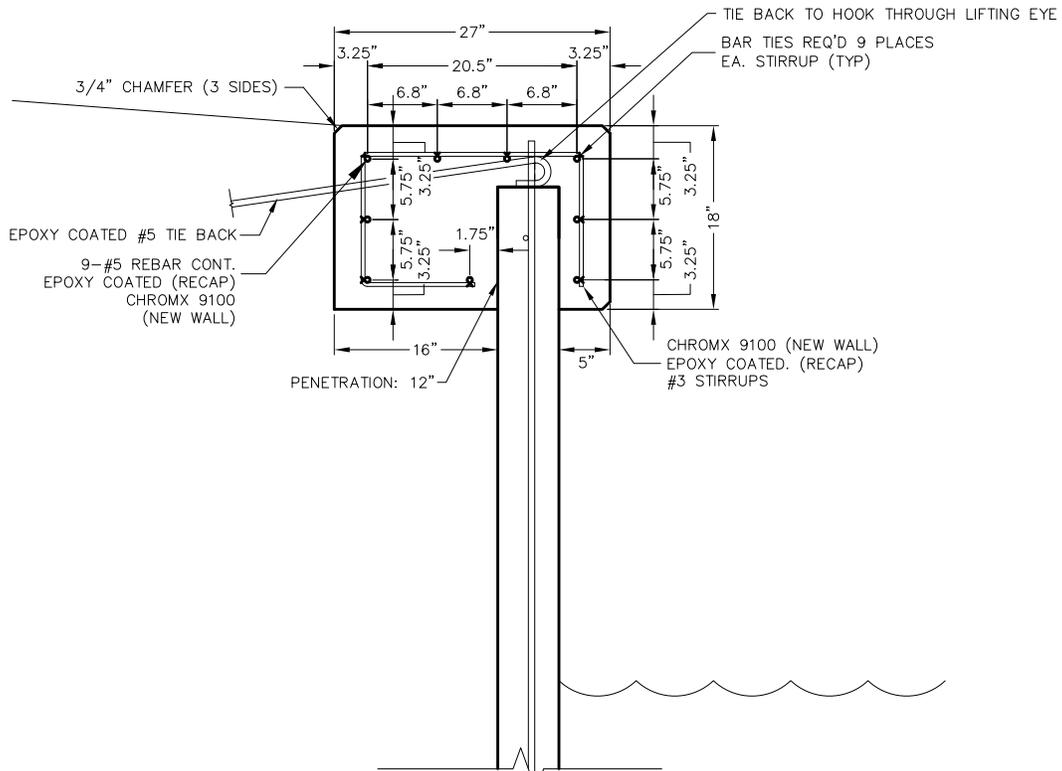
WATERFRONT
 DEVELOPMENT
 STANDARDS

STANDARD DETAIL

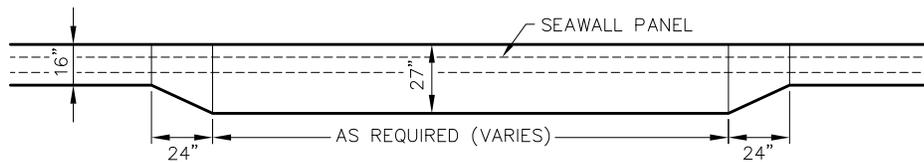
SEAWALL CAP AND
 FILTER FABRIC DETAILS

SHEET NO. WD-4

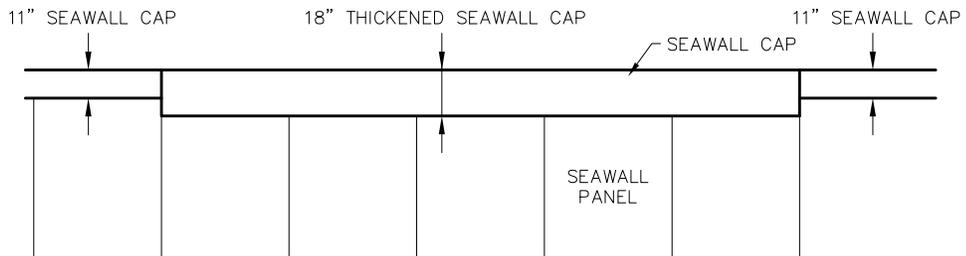
AUGUST 2019



TYPICAL CAP SECTION
N.T.S.



SEAWALL CAP TRANSITION PLAN VIEW
N.T.S.



SEAWALL CAP TRANSITION ELEVATION VIEW FROM WATER
N.T.S.

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WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

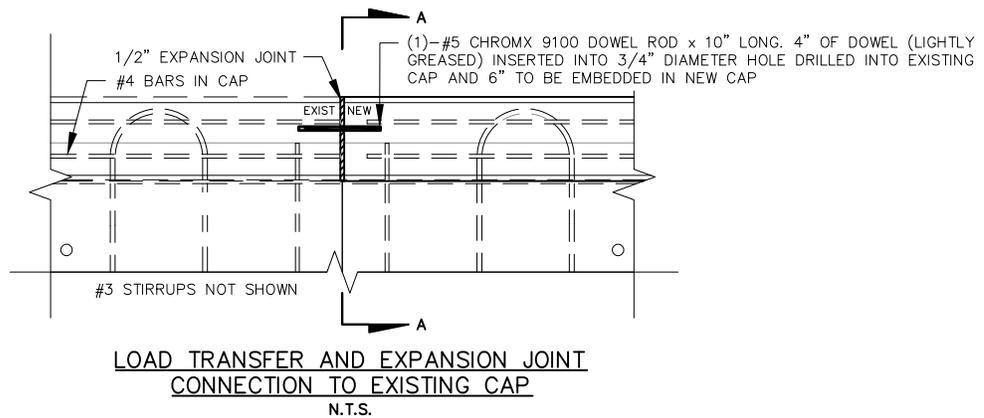
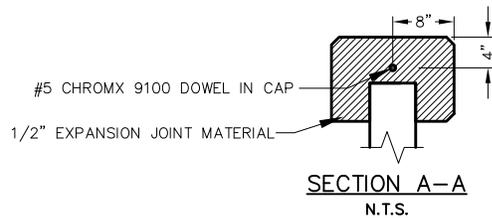
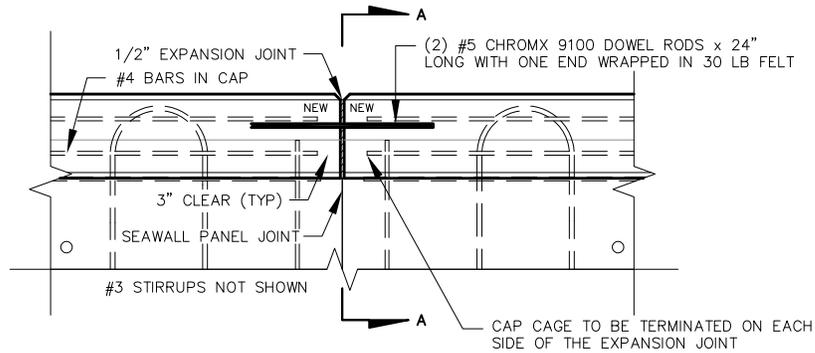
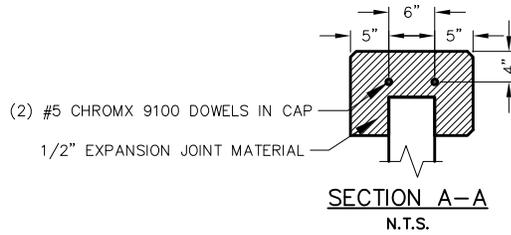
THICKENED SEAWALL CAP
(SPECIAL USE)

SHEET NO. WD-5

AUGUST 2019

NOTE:
 TO BE UTILIZED WITH NEW SEAWALL AND CAP CONSTRUCTION; AND ALL CAP REPLACEMENTS. EXPANSION JOINTS SHALL BE PLACED APPROXIMATELY 80-85 FEET ON CENTER NEAR THE PROPERTY LINE(S). CONTRACTION JOINTS TO BE PLACED MIDWAY BETWEEN EXPANSION JOINTS.

ALL EXPANSION JOINTS TO BE PLACED AT/OVER THE SEAWALL PANEL JOINT.



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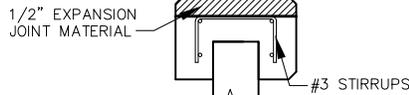
WATERFRONT
 DEVELOPMENT
 STANDARDS

STANDARD DETAIL

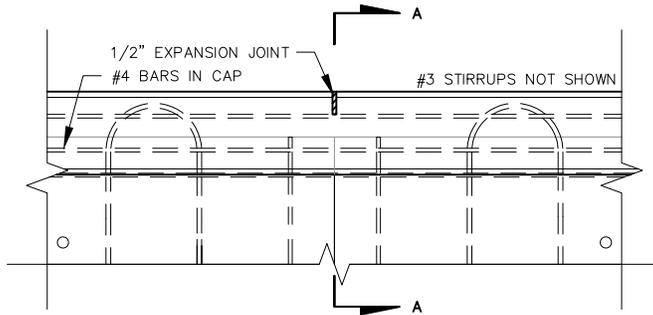
EXPANSION JOINT AND
 LOAD TRANSFER DETAILS

SHEET NO. WD-6

AUGUST 2019

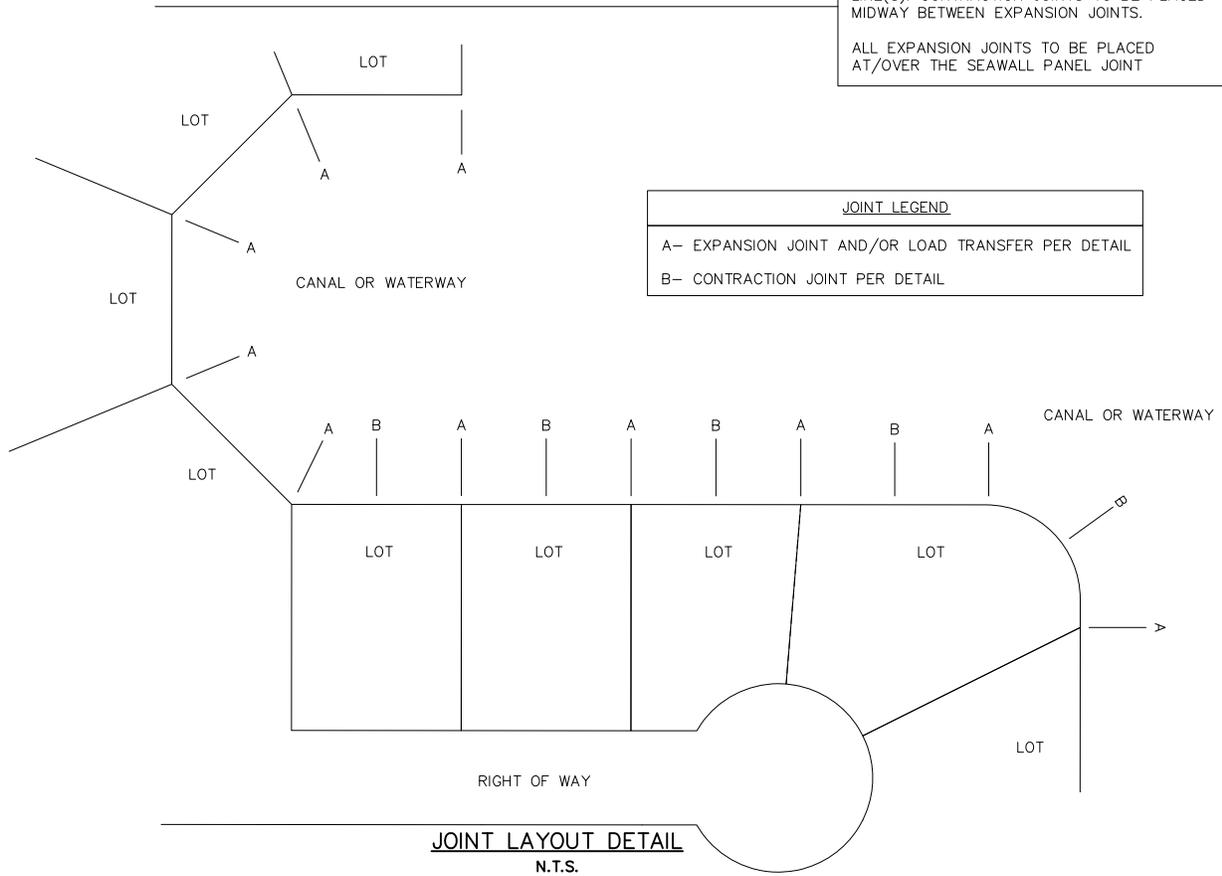


SECTION A-A
N.T.S.



CONTRACTION JOINT DETAIL
N.T.S.

NOTE:
EXPANSION JOINTS SHALL BE PLACED APPROX
80-85 FEET O.C. NEAR THE PROPERTY
LINE(S). CONTRACTION JOINTS TO BE PLACED
MIDWAY BETWEEN EXPANSION JOINTS.
ALL EXPANSION JOINTS TO BE PLACED
AT/OVER THE SEAWALL PANEL JOINT

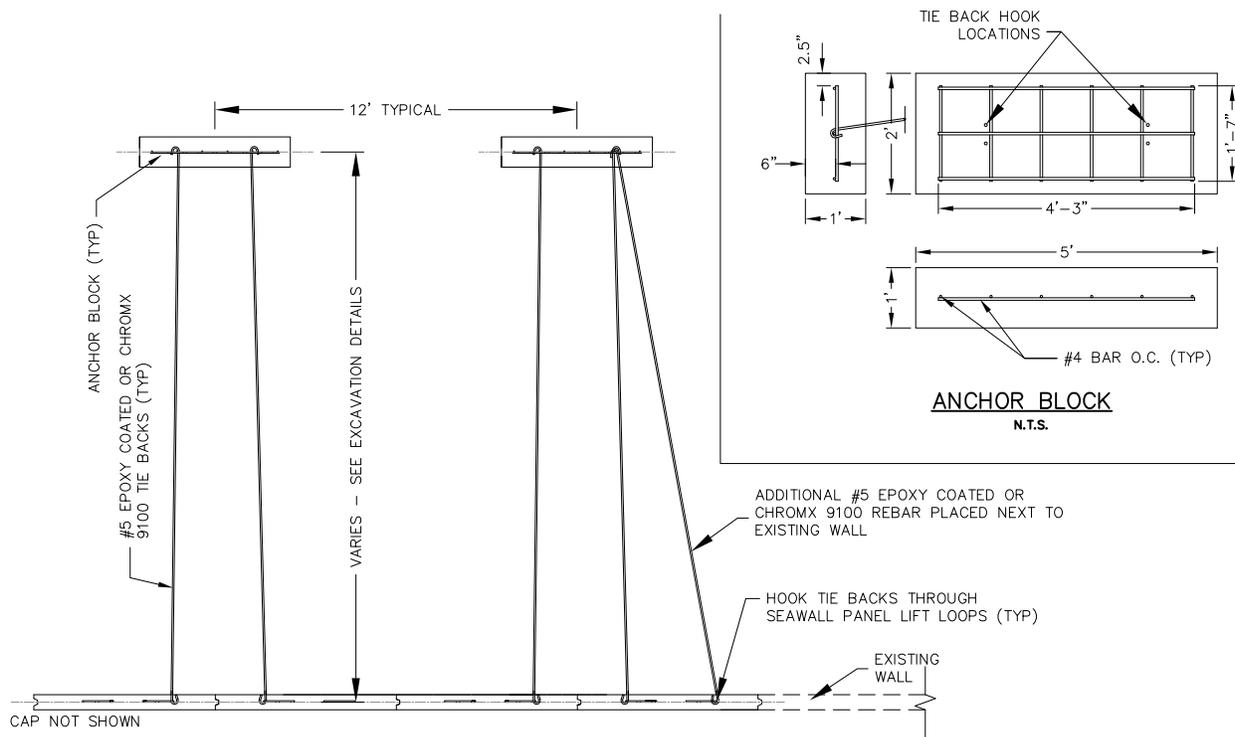


JOINT LEGEND	
A-	EXPANSION JOINT AND/OR LOAD TRANSFER PER DETAIL
B-	CONTRACTION JOINT PER DETAIL

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DEVELOPMENT
STANDARDS

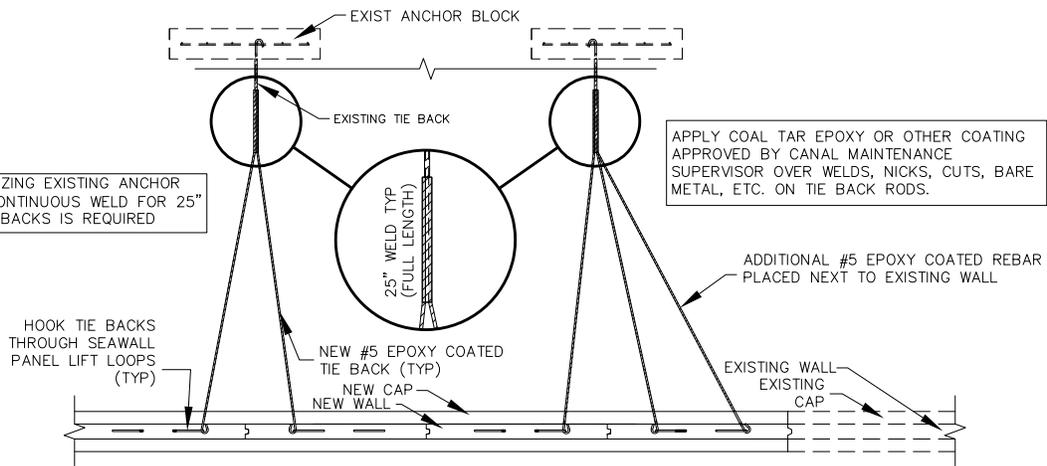
STANDARD DETAIL	
CONTRACTION JOINT DETAILS / JOINT LAYOUT	
SHEET NO. WD-7	AUGUST 2019



TYPICAL TIE BACK AND NEW ANCHOR BLOCK

N.T.S.

USE OF EXISTING ANCHOR BLOCKS AND THE LOCATION OF NEW ANCHOR BLOCKS SHALL BE APPROVED BY THE CITY.



TIE BACK BAR DETAIL FOR UTILIZING EXISTING ANCHOR BLOCK

N.T.S.

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WATERFRONT
DEVELOPMENT
STANDARDS

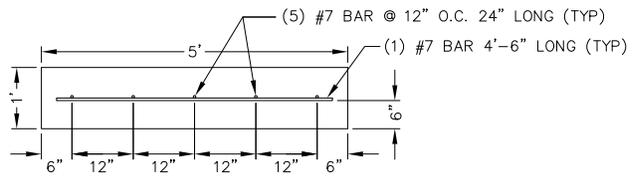
STANDARD DETAIL

TIE BACK DETAILS

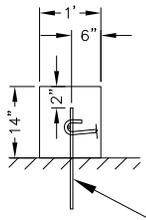
SHEET NO. WD-8

AUGUST 2019

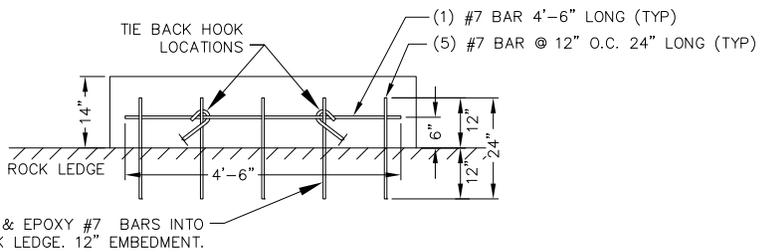
NOTE:
PLACE ROCK ANCHOR TIE BACK @ 12' O.C. USE STANDARD TIE BACK RODS WITH HOOKS



ANCHOR BLOCK – PLAN VIEW
N.T.S.

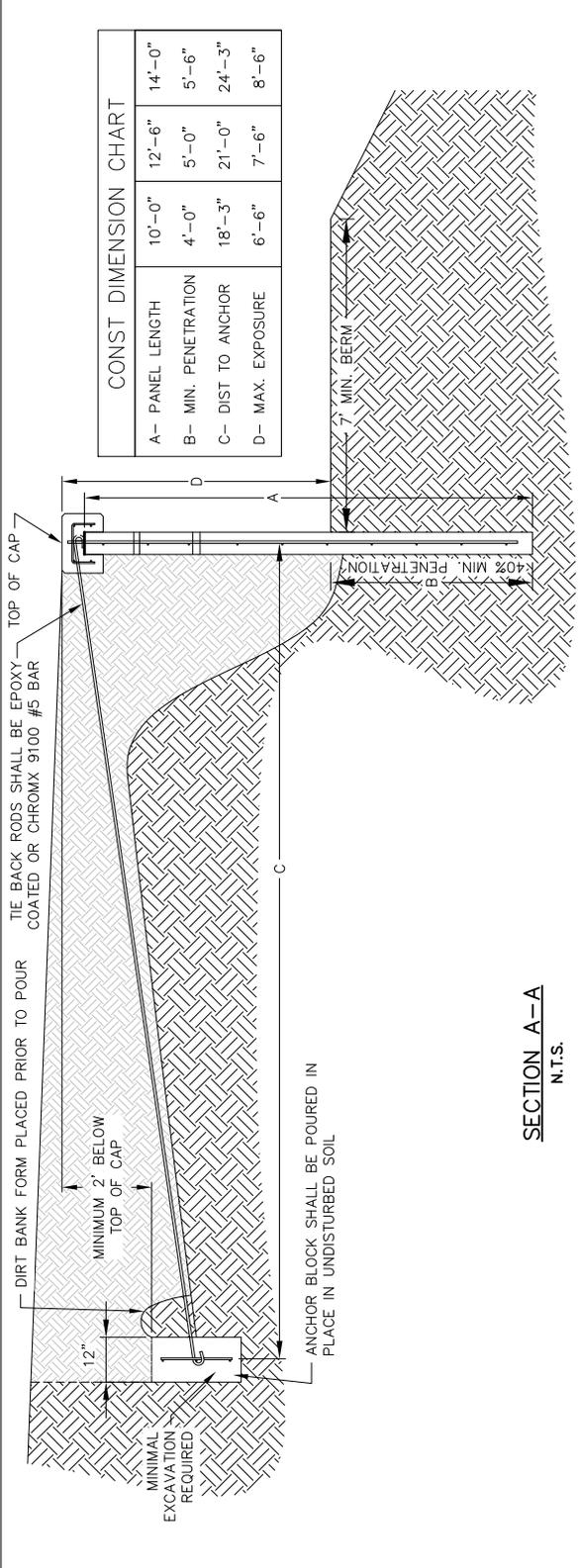


**ANCHOR BLOCK
SIDE ELEVATION VIEW**
N.T.S.



**ANCHOR BLOCK
FRONT ELEVATION VIEW**
N.T.S.

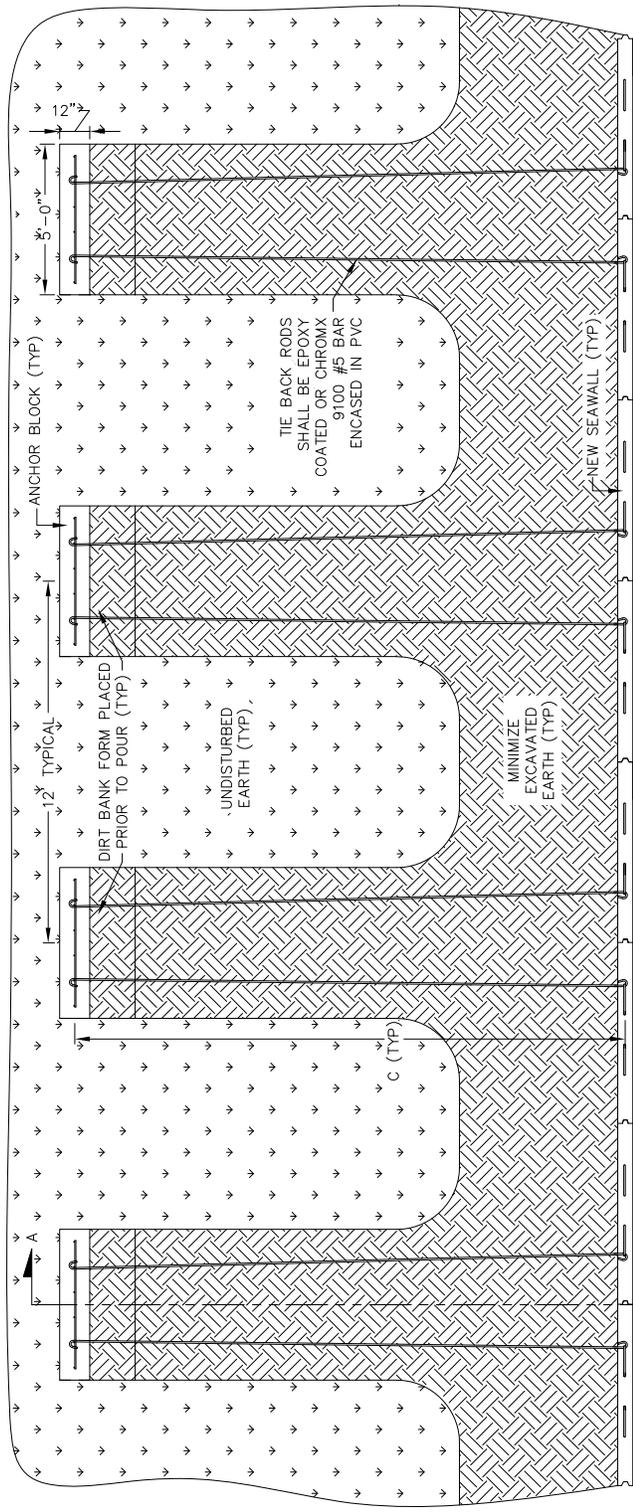
STEEL SCHEDULE	
1 EACH	- #7 BAR @ 4'-6"
5 EACH	- #7 BAR @ 2'-0"



CONST DIMENSION CHART

A- PANEL LENGTH	10'-0"	12'-6"	14'-0"
B- MIN. PENETRATION	4'-0"	5'-0"	5'-6"
C- DIST TO ANCHOR	18'-3"	21'-0"	24'-3"
D- MAX. EXPOSURE	6'-6"	7'-6"	8'-6"

SECTION A-A
N.T.S.



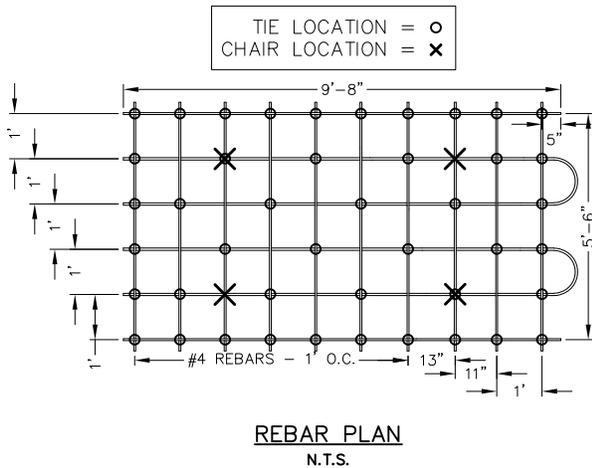
TYPICAL EXCAVATION PLAN VIEW
N.T.S.

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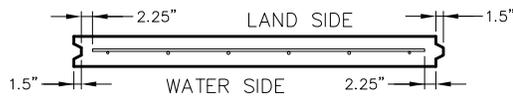
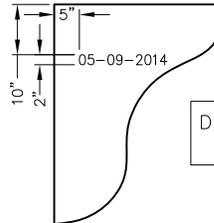
WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL	
EXCAVATION DETAILS	
SHEET NO. WD-10	AUGUST 2019

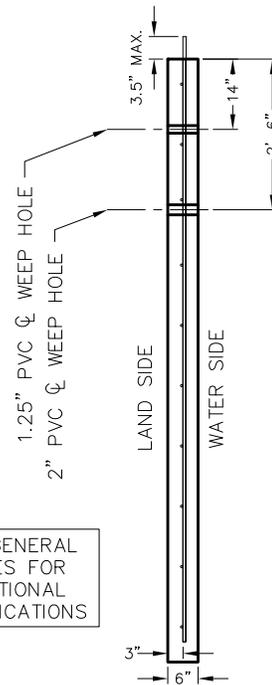
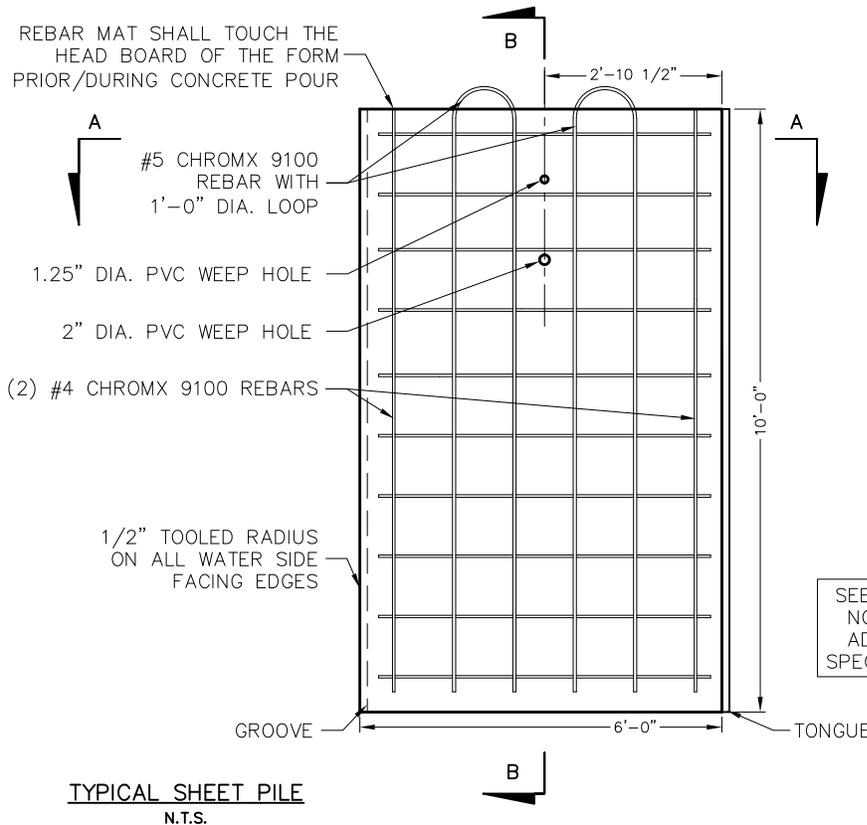
DATE STAMP DETAILS TYPICAL FOR ALL SEAWALL PANEL LENGTHS



PANELS MUST BE STAMPED AS SHOWN USING A COMMERCIALY AVAILABLE CONCRETE STAMP SYSTEM. NUMBERS ARE 2" TALL x 1/2" DEEP FONT IS ARIAL BOLD. DISPLAY = 2 DIGITS FOR DAY, 2 DIGITS FOR MONTH 4 DIGITS FOR YEAR, WITH DASH BETWEEN DATE. DATE STAMP TO BE ON WATERSIDE OF SEAWALL PANEL.



REBAR MAT SHALL TOUCH THE HEAD BOARD OF THE FORM PRIOR/DURING CONCRETE POUR



SEE GENERAL NOTES FOR ADDITIONAL SPECIFICATIONS

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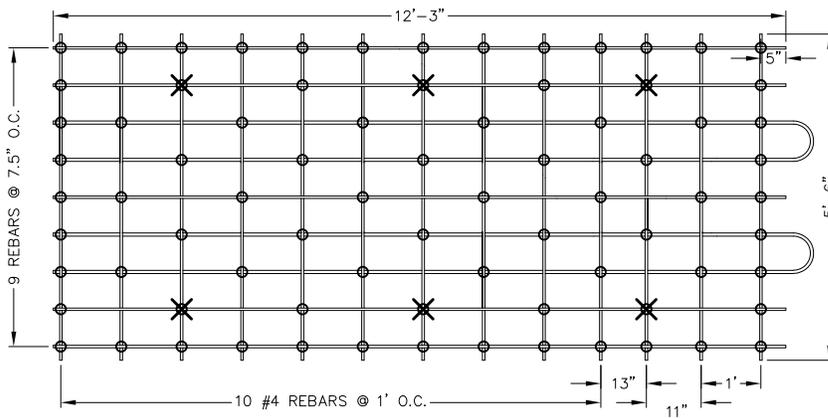
WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

10'-0" PRECAST
SEAWALL PANEL DETAILS

SHEET NO. WD-11

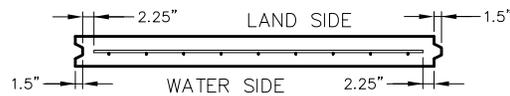
AUGUST 2019



DATE STAMP DETAILS TYPICAL FOR ALL SEAWALL PANEL LENGTHS SEE 10'-0" PRECAST SEAWALL PANEL DETAIL

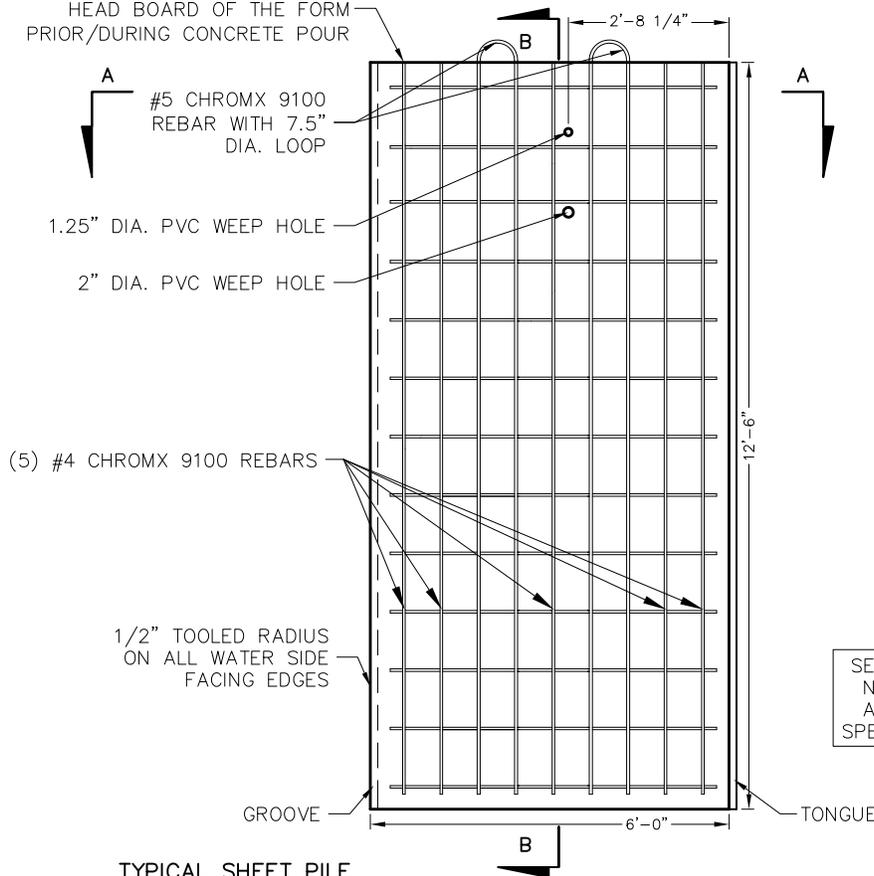
TIE LOCATION = ○
CHAIR LOCATION = ×

REBAR PLAN
N.T.S.

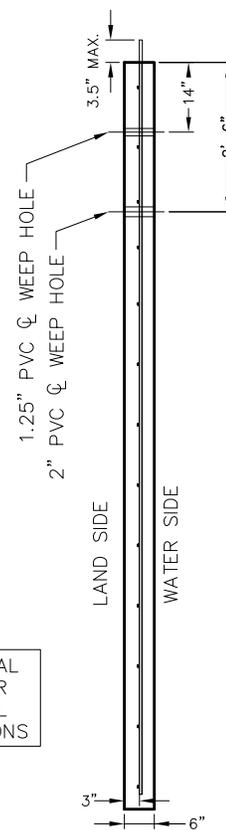


SECTION A-A
N.T.S.

REBAR MAT SHALL TOUCH THE HEAD BOARD OF THE FORM PRIOR/DURING CONCRETE POUR



TYPICAL SHEET PILE
N.T.S.



SECTION B-B
N.T.S.

SEE GENERAL NOTES FOR ADDITIONAL SPECIFICATIONS

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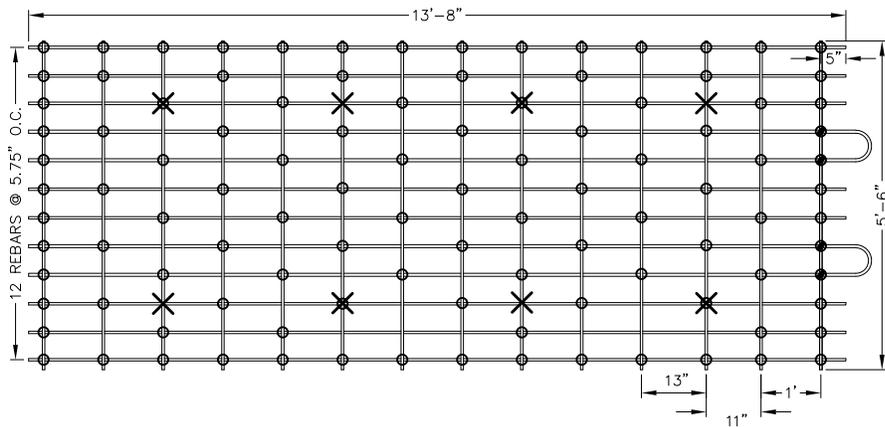
WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

12'-6" PRECAST
SEAWALL PANEL DETAILS

SHEET NO. WD-12

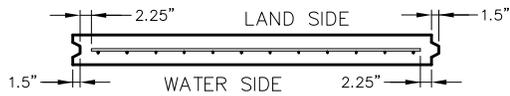
AUGUST 2019



DATE STAMP DETAILS TYPICAL FOR ALL SEAWALL PANEL LENGTHS SEE 10'-0" PRECAST SEAWALL PANEL DETAIL

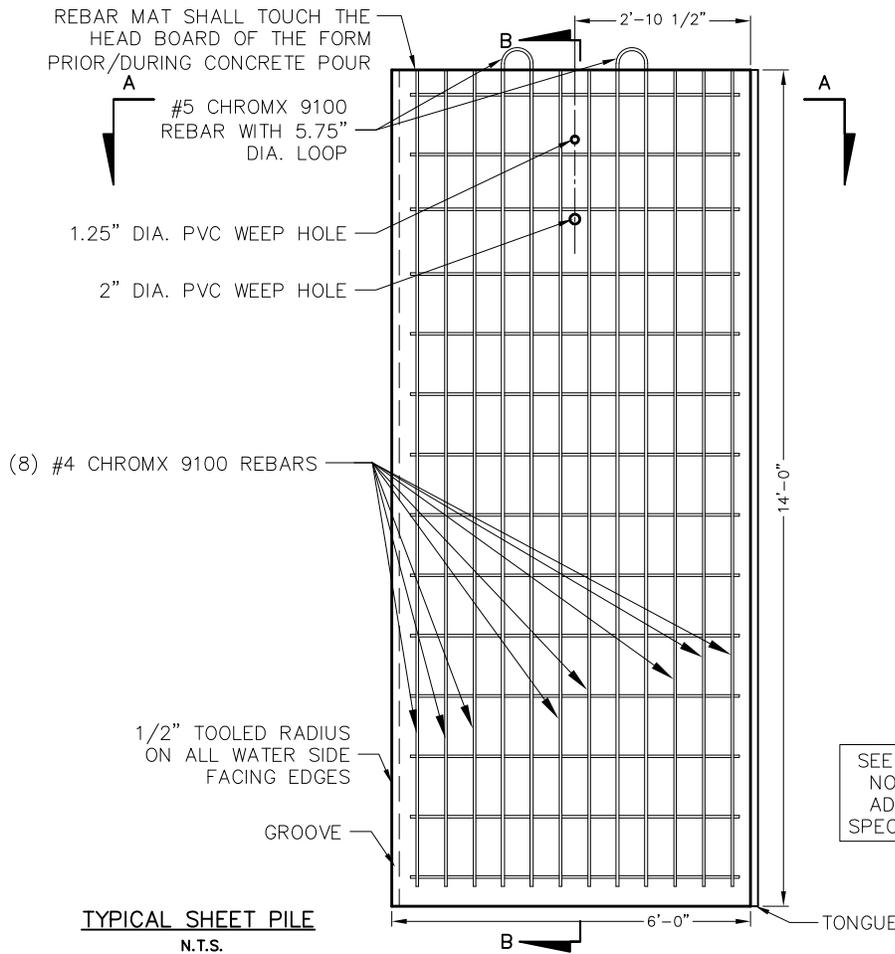
TIE LOCATION = ○
CHAIR LOCATION = X

REBAR PLAN
N.T.S.

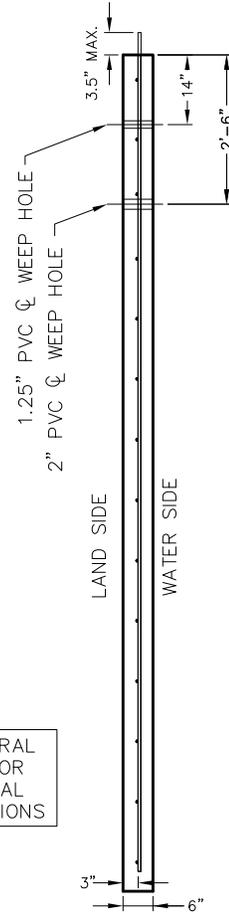


SECTION A-A
N.T.S.

REBAR MAT SHALL TOUCH THE HEAD BOARD OF THE FORM PRIOR/DURING CONCRETE POUR



TYPICAL SHEET PILE
N.T.S.



SECTION B-B
N.T.S.

SEE GENERAL NOTES FOR ADDITIONAL SPECIFICATIONS

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WATERFRONT
DEVELOPMENT
STANDARDS

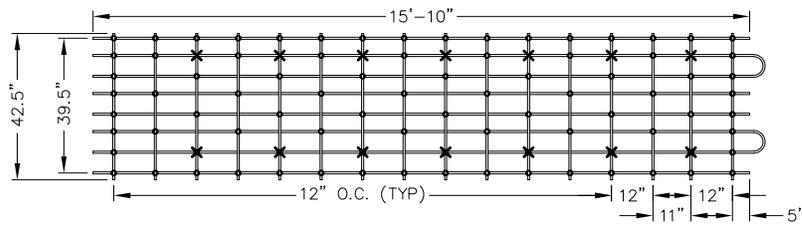
STANDARD DETAIL

14'-0" PRECAST
SEAWALL PANEL DETAILS

SHEET NO. WD-13

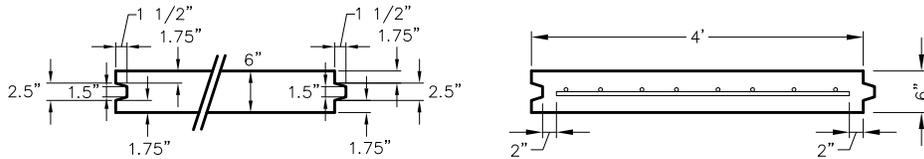
AUGUST 2019

REBAR PLAN
N.T.S.

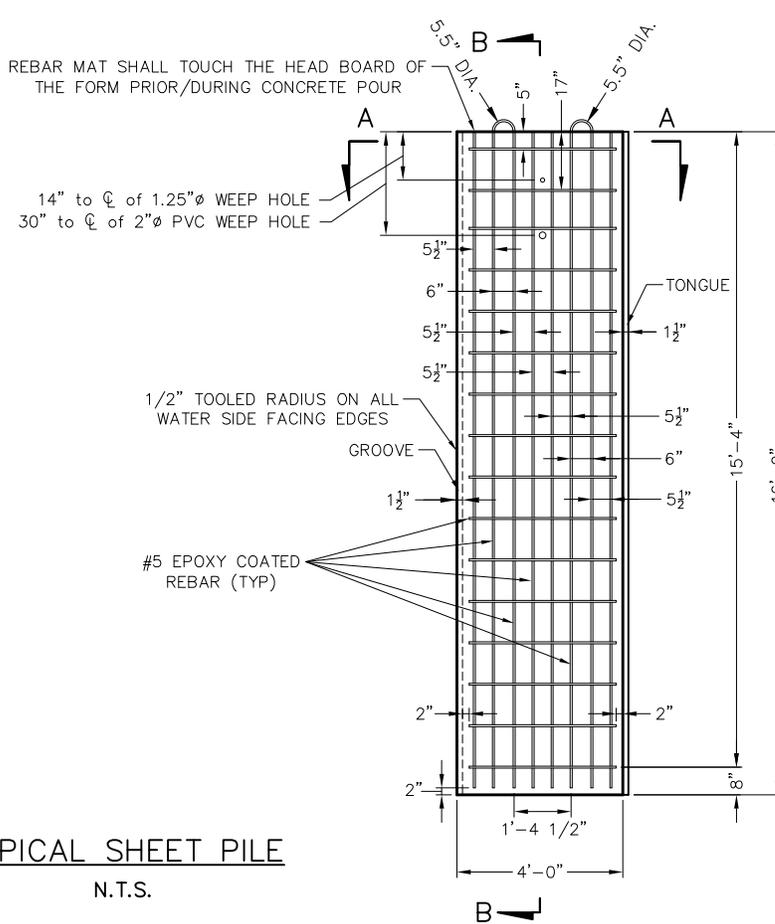


DATE STAMP DETAILS TYPICAL FOR ALL SEAWALL PANEL LENGTHS SEE 10'-0" PRECAST SEAWALL PANEL DETAIL

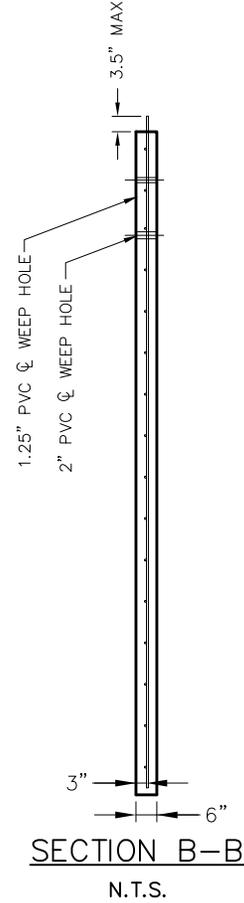
TIE LOCATION = ○
CHAIR LOCATION = X



SECTION A-A
N.T.S.



TYPICAL SHEET PILE
N.T.S.



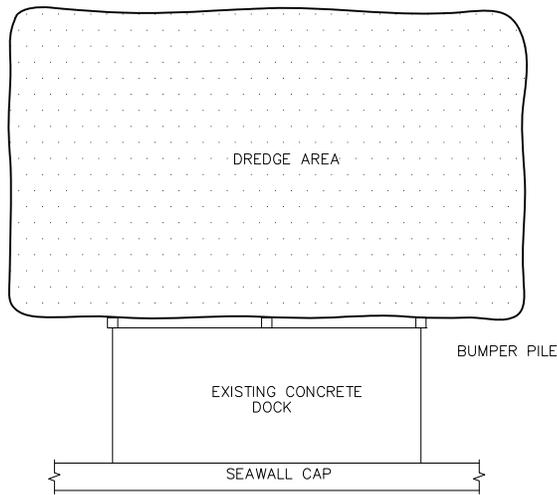
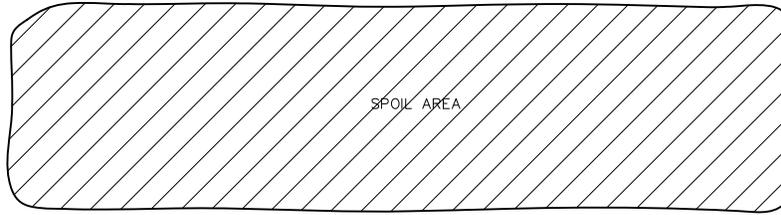
SECTION B-B
N.T.S.

SEE GENERAL NOTES FOR ADDITIONAL SPECIFICATIONS

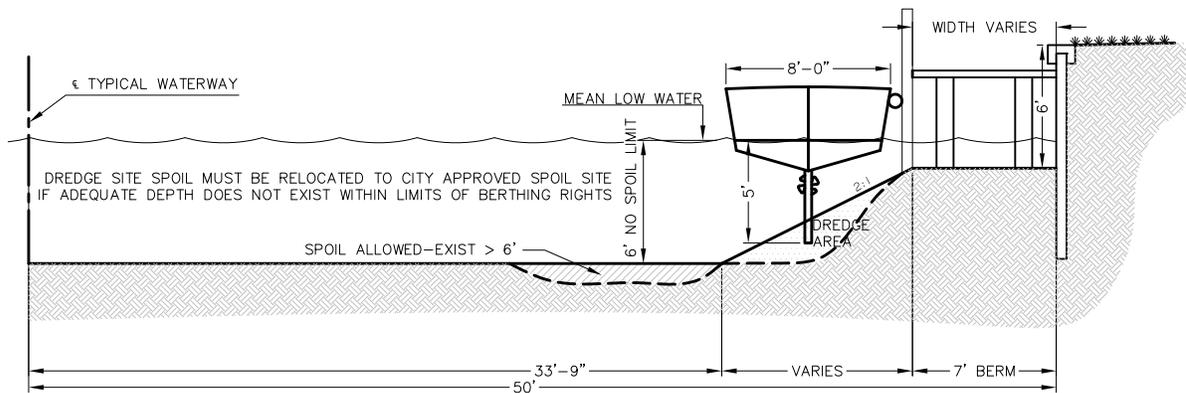
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WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL	
16'-0" PRECAST SEAWALL PANEL DETAILS	
SHEET NO. WD-14	AUGUST 2019



TYPICAL DREDGING DETAIL-PLAN VIEW
N.T.S.



TYPICAL DREDGING DETAIL-ELEVATION VIEW
N.T.S.

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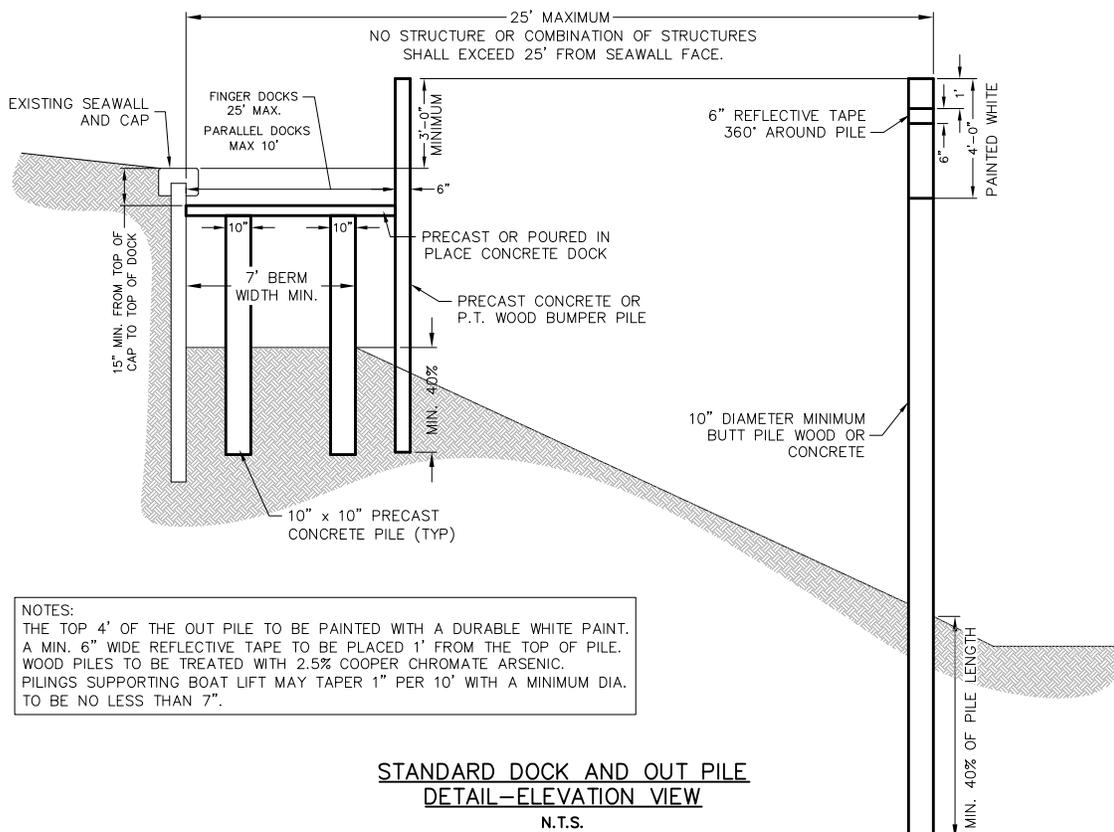
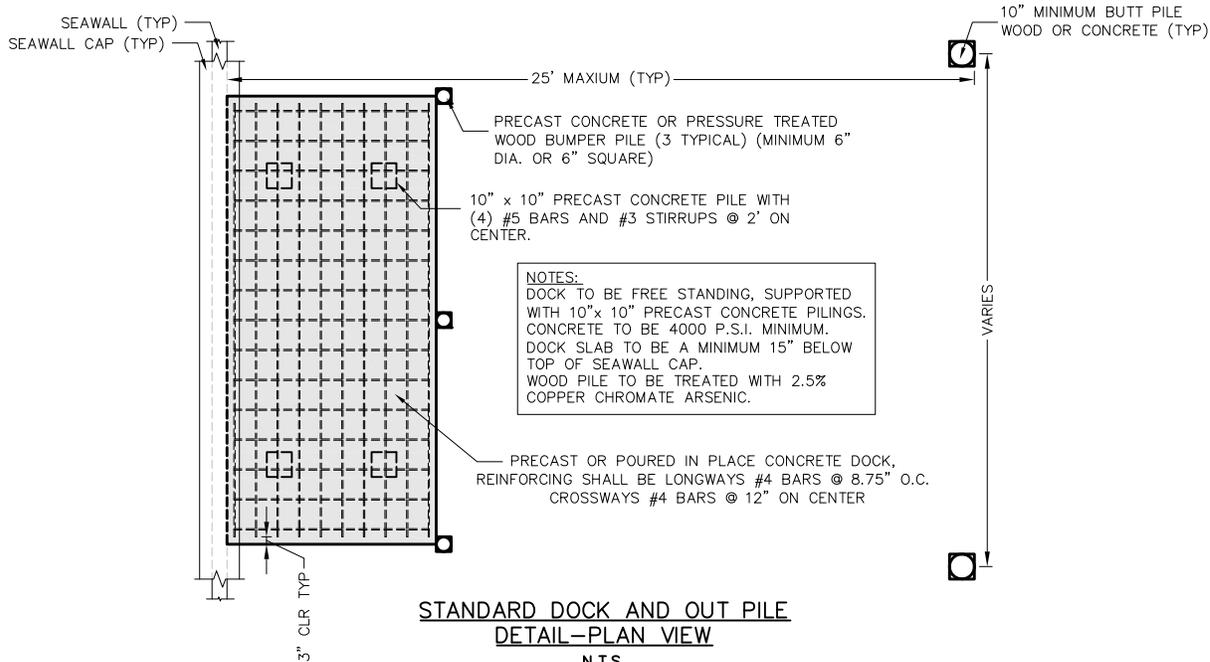
WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

STANDARD DOCKSIDE
DREDGING DETAIL

SHEET NO. WD-15

AUGUST 2019



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WATERFRONT
DEVELOPMENT
STANDARDS

STANDARD DETAIL

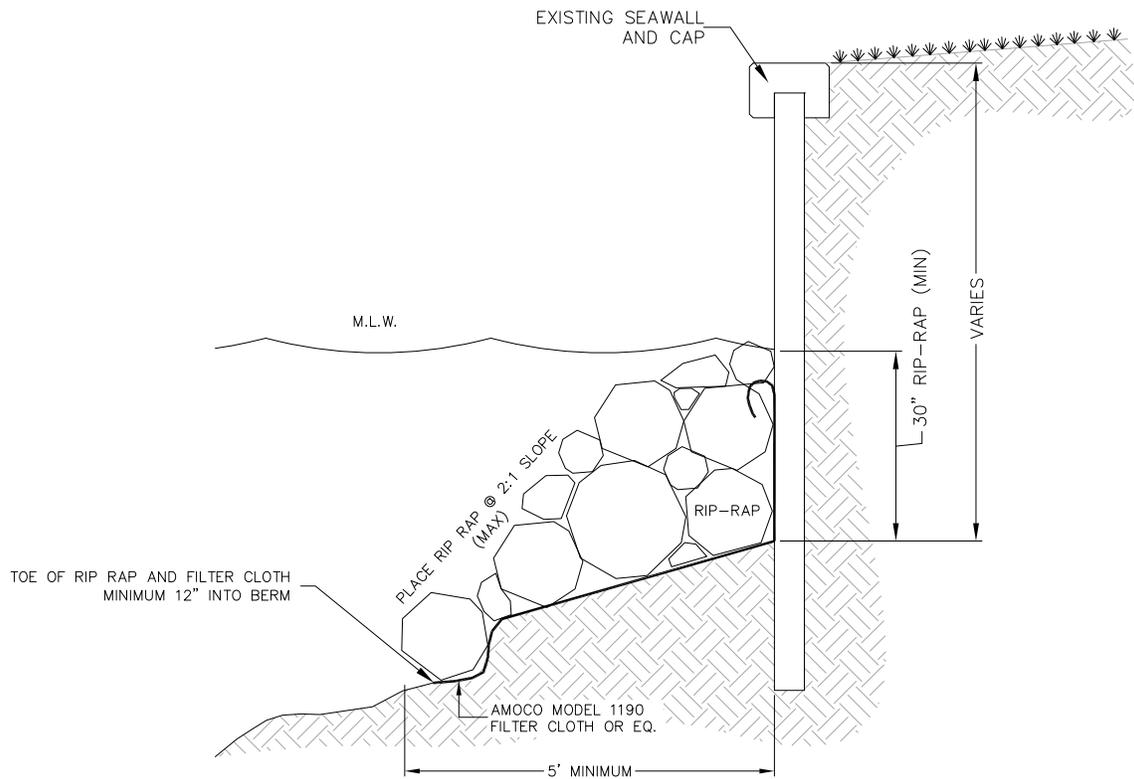
STANDARD CONCRETE DOCK
AND OUT PILE DETAIL

SHEET NO. WD-16

AUGUST 2019

NOTES:

THIS CROSS SECTION IS INTENDED TO SHOW THE ACCEPTED METHOD OF INSTALLING FILTER FABRIC. DO NOT USE THIS DRAWING TO CALCULATE MATERIAL QUANTITIES. THE SIZE OF THE ROCK RIP RAP SHALL BE 12" TO 24" . LONGITUDINAL LAPS ON FILTER CLOTH SHALL BE 18" MINIMUM.



TYPICAL CROSS SECTION
N.T.S.

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WATERFRONT
DEVELOPMENT
STANDARDS

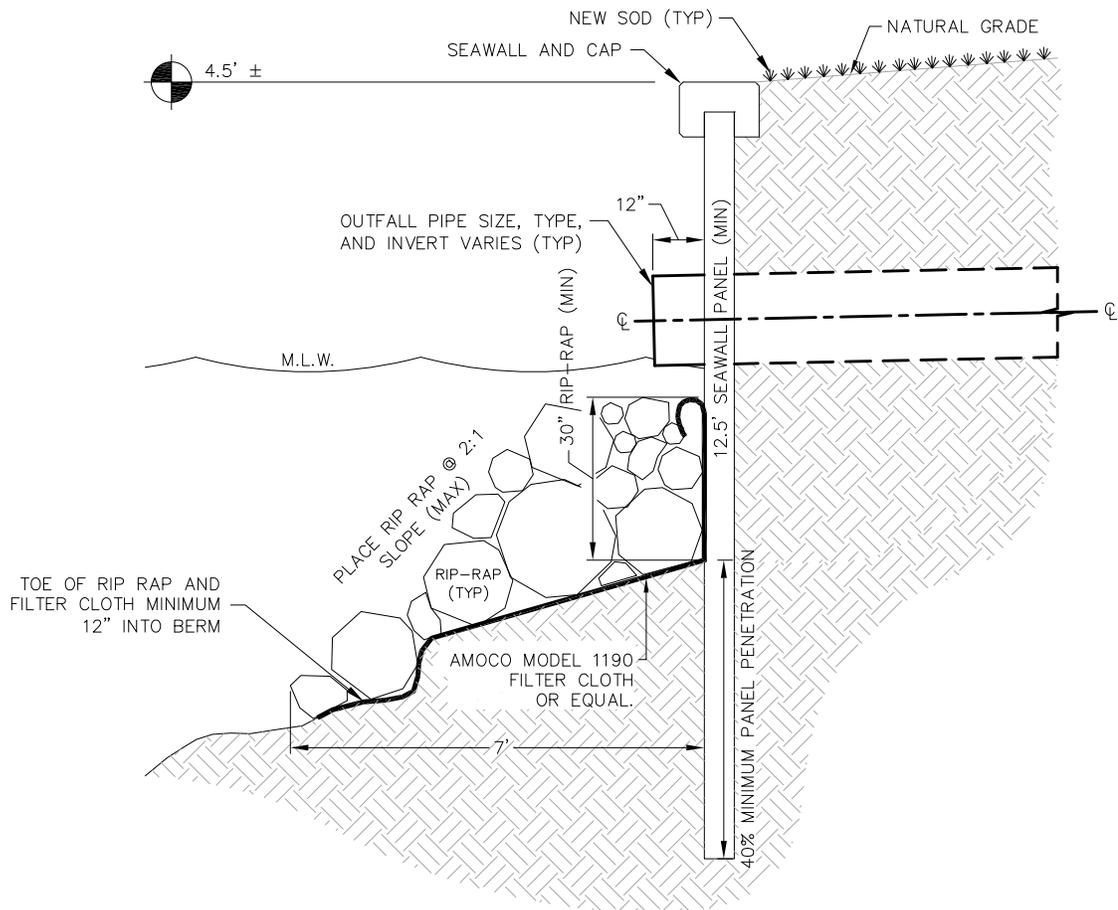
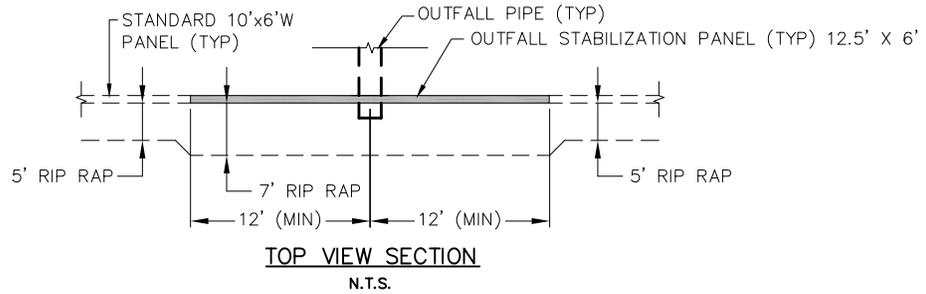
STANDARD DETAIL

RIP-RAP
STABILIZATION DETAIL

SHEET NO. WD-17

AUGUST 2019

NOTES:
 THIS CROSS SECTION IS INTENDED TO SHOW THE ACCEPTED METHOD OF INSTALLING FILTER FABRIC. DO NOT USE THIS DRAWING TO CALCULATE MATERIAL QUANTITIES. THE SIZE OF THE ROCK RIP RAP SHALL BE 12" TO 24". LONGITUDINAL LAPS ON FILTER CLOTH SHALL BE 18" MINIMUM.



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WATERFRONT
 DEVELOPMENT
 STANDARDS

STANDARD DETAIL

OUTFALL STABILIZATION DETAIL

SHEET NO. WD-18

AUGUST 2019

