MARINA RE-DEVELOPMENT VULNERABILITY ASSESSMENT

November 2021

JUAN DE JESUS ORTEGA-ROSALES
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PROFESSIONAL ENGINEER

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TASK ORDER NO. 19-07-GP/ENV(S)
ENVIRONMENTAL SERVICES PROJECTS
PROJECT NO. 21077-119

PREPARED BY: GPI

PREPARED FOR: CITY OF ST. PETERSBURG

st.petersburg

LAND&WATER
ENGINEERING SCIENCE

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Introduction

In advance of anticipated redevelopment of the St. Petersburg Municipal Marina, the City of St. Petersburg contracted Greenman-Pedersen, Inc. (GPI), and subconsultant Land & Water Engineering Science, Inc. (LWES), to assess the feasibility of incorporating into redevelopment activities a series of improvements to associated bulkhead and seawalls. GPI assembled and reviewed existing plans and inspection reports provided by the City of St. Petersburg and performed a field assessment on July 23, 2021. The purpose of the field assessment was to visually verify existing conditions against the most recent inspection reports and identify potential constructability issues for the proposed improvements. This assessment was performed entirely from land and was limited to that which was visible by the naked eye at the time of the assessment. LWES developed sea level rise (SLR) inundation maps for the marina area based on potential SLR estimates for a design year of 2070. Data provided by LWES, in conjunction with information gathered by GPI through the document review and field assessment, were utilized to assess the feasibility of the following improvements:

- Central Basin (Pier) – Bulkhead replacement with 2-foot raise.
- Central Basin (West Quay Wall / East Pier) – Repairs to bulkhead with no raise.
- Central Basin (Demens) – Installation of new bulkhead in front of existing quay wall with 1.2-foot raise from existing.
- South Basin – Riprap installation at existing bulkhead with replacement of fill behind bulkhead.

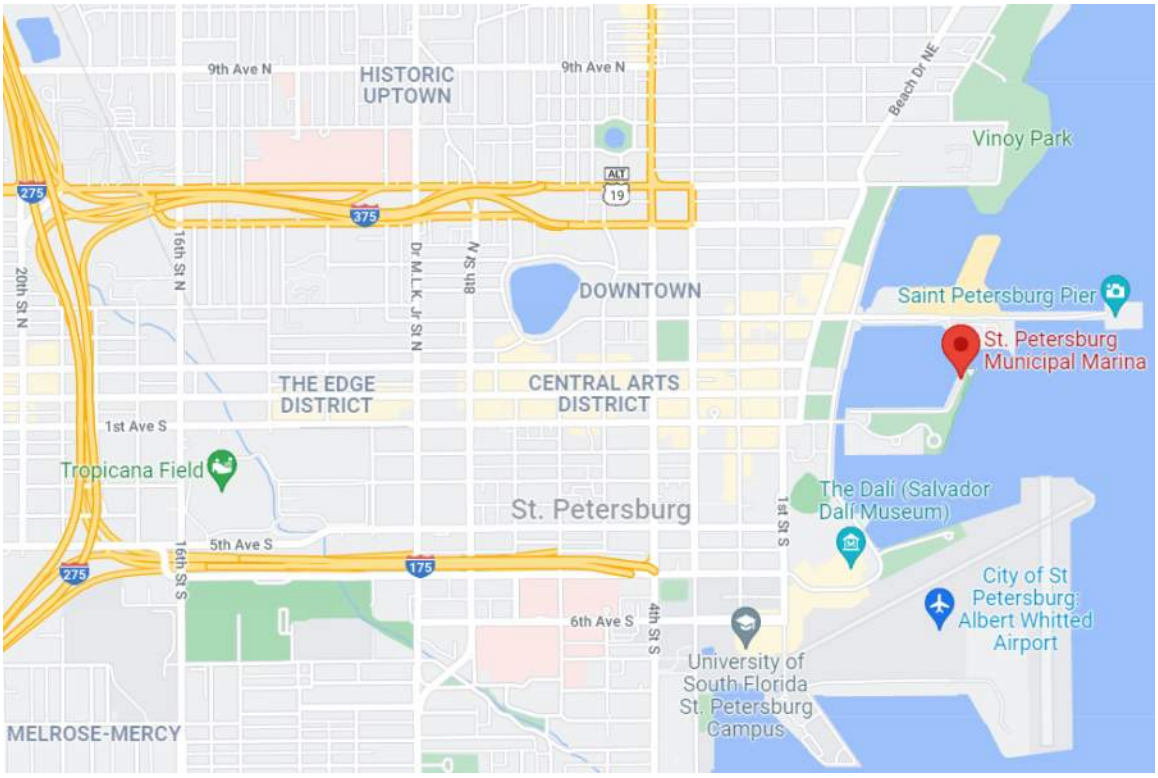


Figure 1: Location Map (Google Maps)

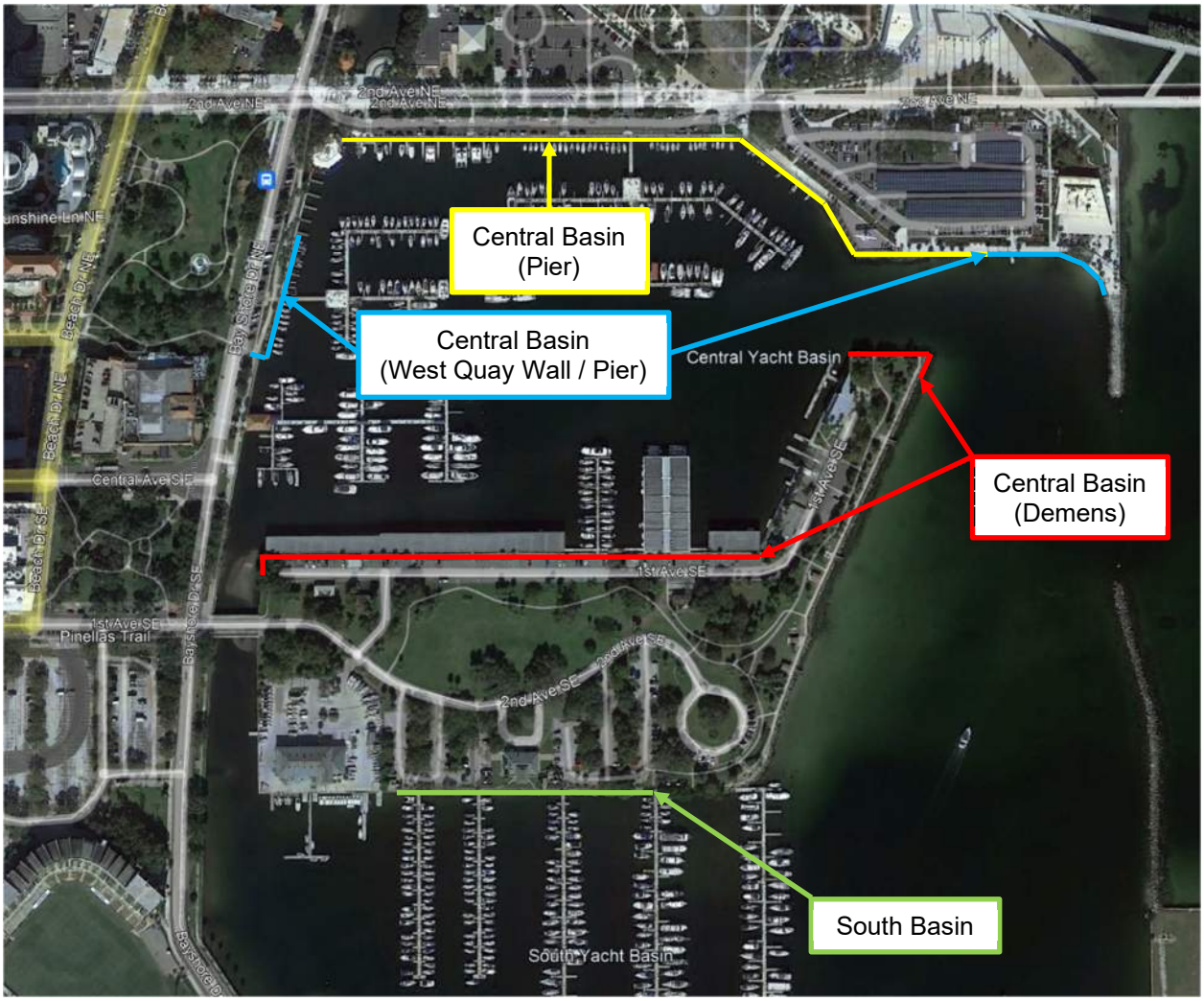


Figure 2: Site Map of St. Petersburg Municipal Marina

Assessment Criteria

A service life of 75 years has been selected by the City for the structural design of improvements. This sets end of life for these structures near the year 2100. As can be seen in Figure 3, from the Technical Memorandum prepared by LWES, projections that far out result in significantly higher uncertainty. Through discussions with the City and LWES, a SLR criteria based on the year 2070 will be utilized for this assessment. Within the design year of 2070, several other factors affect the degree of SLR to consider: NOAA models predicting intermediate low, intermediate, or high SLR; tide levels of mean high water (MHW), mean higher high water (MHHW), or perigean spring tide (PST or “king tide”).

The importance of the facility in question is a vital component in selection of the appropriate NOAA model. For the marina, the intermediate or high models would be appropriate; however, review of the inundation maps shows the high model resulting in significant flooding throughout the marina, extending well into the city. As this level of flooding presents significant considerations for the city beyond the marina, it is considered a higher investment than is

reasonable without being part of a holistic approach to protecting the entire waterfront of St. Petersburg. As such, the intermediate model was determined the most appropriate for the evaluation at hand.

Tide level was also considered to determine the most appropriate evaluation criteria. The difference between MHW and MHHW, as shown in Table 1, is under 4 inches, and the intermediate SLR inundation map (see appendix) shows minimal difference between the two. The PST on the other hand, increases over 7 inches beyond the MHHW and results in significantly more flooding, especially at the interior of Demens Landing Park. Over the course of a year, PST flooding will amount to a few hours of nuisance flooding as opposed to a consistent issue. For this reason, the MHHW tide level was selected.

See the full Technical Memorandum prepared by LWES, included at the end of this report, for inundation maps and additional information on the criteria discussed within this section.

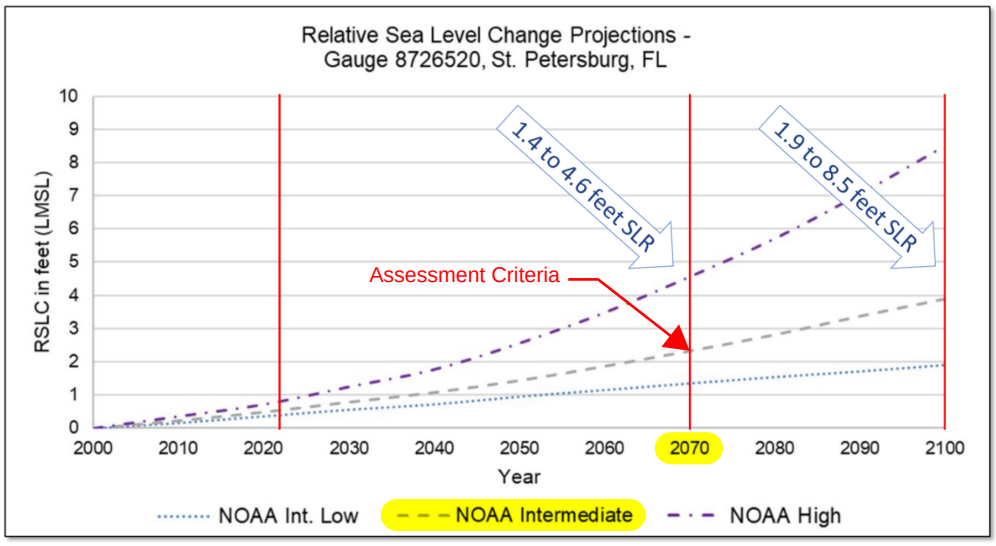


Figure 3: SLR Projections in the Tampa Bay Region

Tide	Water Surface Elevation for Various 2070 SLR Scenarios					
	Intermediate Low		Intermediate		High	
	Feet, NAVD88	Feet, City Datum	Feet, NAVD88	Feet, City Datum	Feet, NAVD88	Feet, City Datum
MHW	1.88	99.75	2.86	100.73	5.09	102.96
MHHW	2.18	100.05	3.16	101.03	5.39	103.26
Perigean Spring Tide	2.78	100.65	3.76	101.63	5.99	103.86

Table 1: 2070 Water Surface Elevations for Various Tides and SLR Scenarios

Central Basin (Pier)

Existing Conditions

This area consists of two different wall types. At the east end, the wall is a concrete seawall of unknown construction. Heading toward the west, the wall turns towards the north and changes to a concrete sheet pile wall at the next bend point. Original construction plans are not available for either section of wall.

Figure 4: East end of wall

Figure 5: West end of wall

The east end of the wall appears to be of similar construction to the wall at Central Basin (Demens). Repair details for that section of wall (Figure 6) are part of rehabilitation plans prepared by Moffatt & Nichol. It is unknown how the construction of the wall was verified for creation of this detail. Another possible construction detail for the wall is shown in Figure 7. This detail was developed by the St. Petersburg Department of Public Works in 1926 for an adjacent area. Due to the similar time of construction, it is likely Figure 7 reflects the actual construction of the wall.

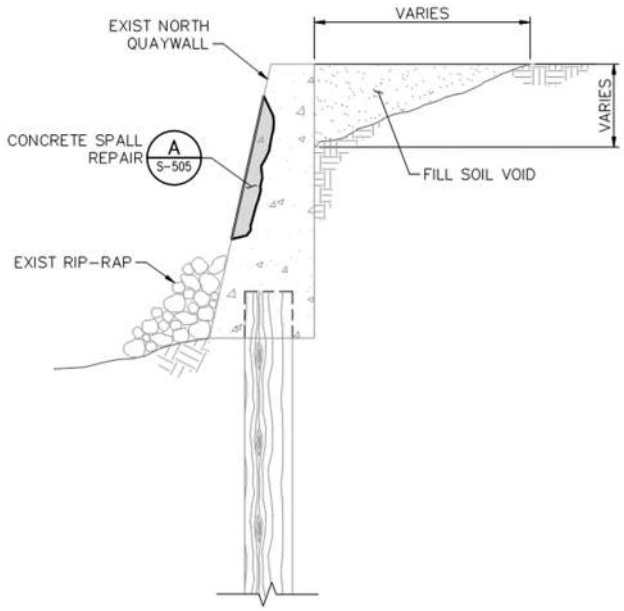


Figure 6: Wall detail from Marina Rehabilitation
(St. Petersburg Municipal Marina South & Central Yacht Basins Structural Rehabilitation, Rev. 1, Moffatt & Nichol, 06/20/2018, Project No. 16111-119R)

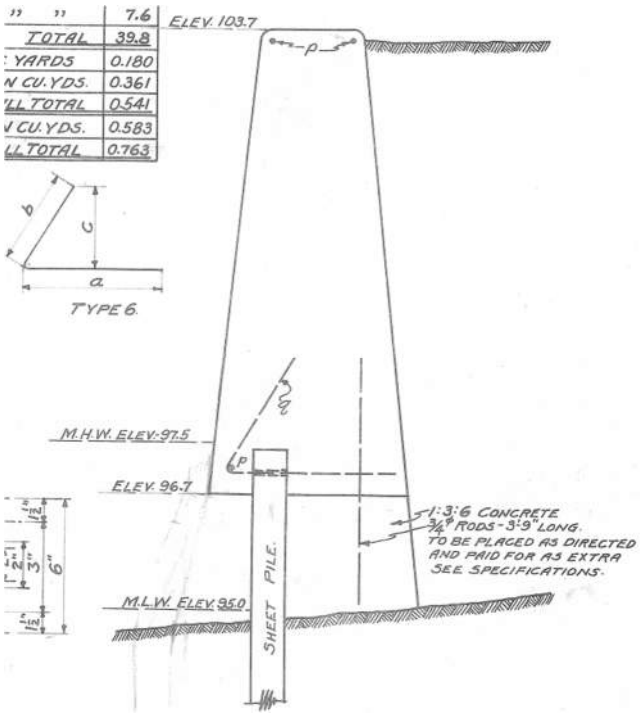


Figure 7: Wall detail from 1926 Plans for Concrete Seawall

Figure 8 shows the believed construction of the western section of the wall. This detail was developed as part of a March 2018 technical memorandum by Moffatt & Nichol and is based on test pits, water jet probes, and additional exploration performed at that time.

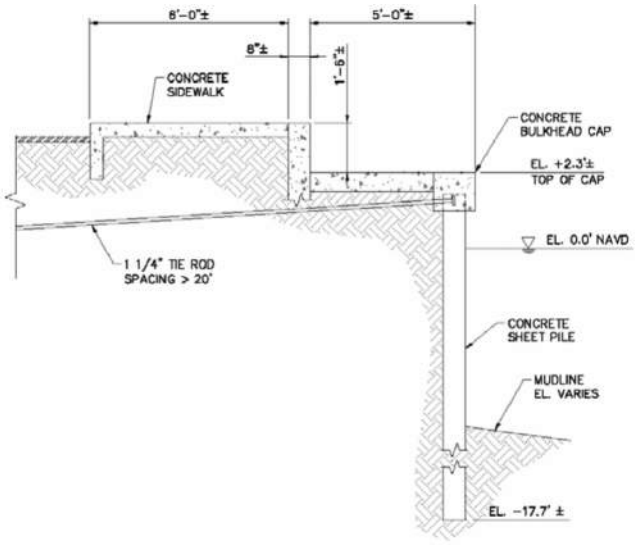


Figure 8: Concrete sheet pile wall detail
(St. Petersburg Bulkheads at Pier Approach, Moffatt & Nichol, 03/30/2018)

The 2021 Annual Marina Structures Inspection Condition Assessment Report (Project No. 21070-119), prepared by Moffatt & Nichol, includes assessments of the walls throughout the Central Basin. The east end of the Central Basin (Pier) is assessed as being in "poor" condition with patches and exposed reinforcement. The report assesses the west side of the wall as having the concrete cap in "poor" condition (due to cracking, spalling, and exposed reinforcement) and the concrete sheet piles in "fair" condition. This was confirmed during our site visit. Both sections of wall appear to be stable without significant signs of movement.

Proposed Modifications

The proposed modifications to this area are shown in Figure 9. This detail, provided to GPI by the City, is similar to a proposed replacement alternative included in the March 30, 2018 technical memorandum by Moffatt & Nichol (St. Petersburg Bulkheads at Pier Approach). The original detail shows a new sheet pile wall installed in front of the existing concrete sheet pile wall, which is to be abandoned. This concept raised the top of the wall from EL +2.3' to EL +3.8' with the cap and adjacent sidewalk raised to the same elevation as the upper sidewalk to the left. Overlayed onto the original detail is the current concept of further raising to top of the cap to 2 ft above the sidewalk to EL +6.0.

There are few physical conflicts present that would prevent construction of the proposed modifications. No overhead obstructions were noted that would prevent driving sheet piles. Portions of the North Docks in proximity to the wall will need to be removed, and any utilities extending from land to the docks will need to be relocated during construction (Figure 10). Pile driving can be accomplished with equipment positioned along 2nd Ave NE, or from barges to keep the pier fully available to the public.

Design of the new steel sheet pile wall will need to consider the ramifications of using anchors or dead men. Retaining approximately 13 ft of soil, a sheet pile wall designed without an anchor will require a relatively large section. Potential cost savings could be achieved by designing the wall with an anchor in order to reduce the sheet pile section and required embedment. However, use of a tie rod and dead man, as in the existing construction, would require excavation of numerous sections of 2nd Ave NE. Alternatively, tie backs could be drilled from the front face of the wall and anchored with concrete grouted from the same location. This would require thorough utility coordination to ensure no existing facilities are damaged.

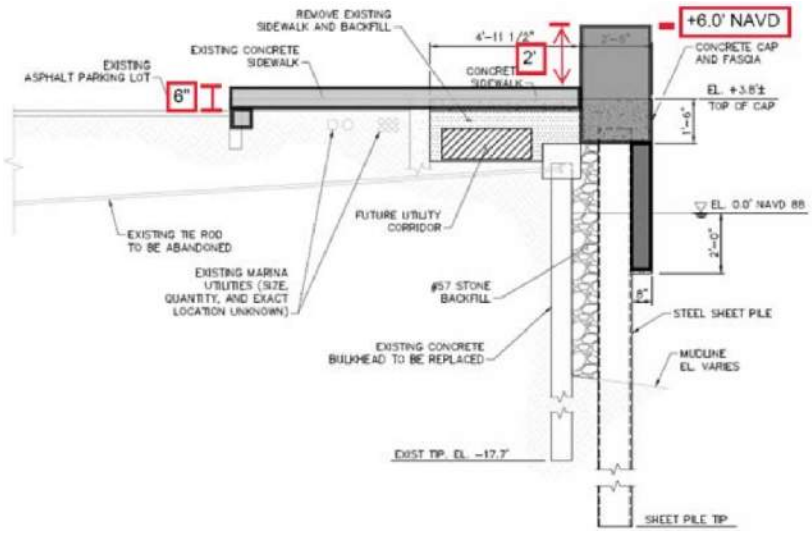


Figure 9: Proposed modifications to Central Basin (Pier)

Figure 10: North Docks at the Central Basin (Pier) Wall

Proposed modifications to the east end of the wall were not provided. It is anticipated that modifications similar to those proposed at Central Basin (Demens) will be applied at this location as well. As with the west end of the wall, there are

few conflicts to driving sheet piles in front of the existing wall. It is anticipated that pile driving from barges will be more desirable in this area due to the presence of sidewalks and landscaping along this entire length of wall that would require restoration after pile driving is completed. There may be large rubble riprap that will need to be moved to allow for pile driving. Additionally, there are three drainage pipe outlets at the end of the wall, where wall type changes to concrete sheet piles, that will need to be accommodated by the new wall (Figure 11).

Figure 11: Pipe outlets at end of concrete seawall

Central Basin (West Quay Wall / East Pier)

Existing Conditions

The West Quay Wall and East Pier areas are both concrete sheet pile bulkhead walls with concrete caps and tie rods or beams extending back to deadmen. Original construction plans are only available for the pier area (Plans for Breakwater and Bulkheads by Parsons, Brinkerhoff, Hall & Macdonald, 1958, see Figure 12). It is believed construction of the West Quay Wall is similar to that of the Central Basin (Pier) concrete sheet pile wall.

The 2021 Annual Marina Structures Inspection Condition Assessment Report assessed the West Quay Wall as having the concrete cap in “poor” condition due to cracking, spalling, and exposed reinforcement and the concrete sheet piles in “fair” condition. The report does not assess the pier area. The stated condition of the West Quay Wall cap was confirmed during our site visit, and the pier area was found to be in similar condition. Both sections of wall appear to be stable without significant signs of movement.

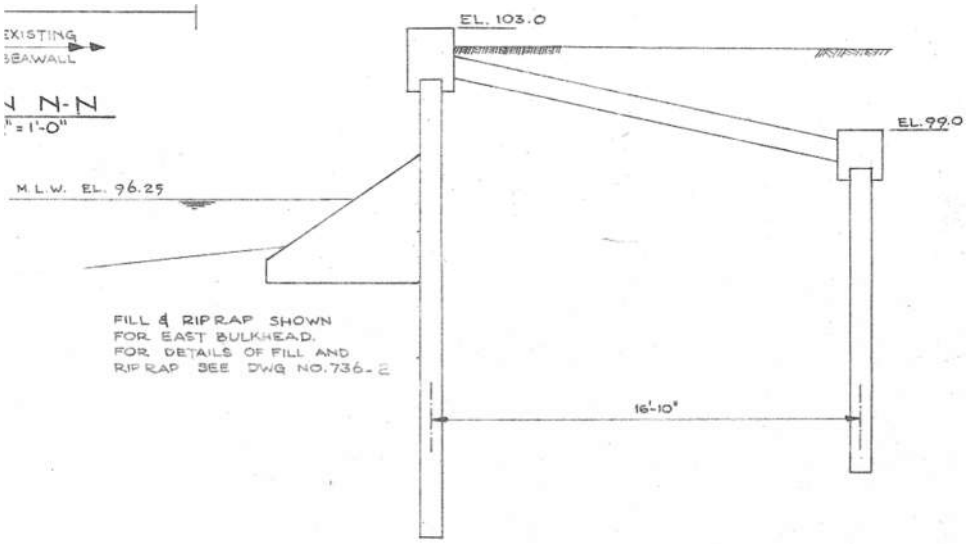


Figure 12: Typical bulkhead section from 1958 plans for Pier section of wall

Figure 13: Central Basin (West Quay Wall)

Proposed Modifications

The proposed modifications to these areas consist solely of repairs to the existing bulkhead caps. Based on the assessment in the 2021 inspection report, this appears to be an acceptable approach at this time. While the concrete sheet piles are in “fair” condition, the concrete caps display cracks, spalls, and corrosion stains at existing patch repairs (Figure 14). These are signs of advanced corrosion in the cap reinforcement.

Figure 14: Multiple patch repairs and corrosion stains at Central Basin (East Pier) wall

Based on the condition of the concrete caps, it is recommended that repairs should consist of full cap replacement as opposed to localized repairs. The signs of corrosion indicate high chloride concentrations in the cap concrete, and localized repairs will likely result in accelerated corrosion in areas surrounding the patches, referred to as the "halo effect". This effect is the result of high pH concrete in a repair passivating the reinforcement within the repair while the reinforcement within the adjacent, lower pH concrete remains unaffected. The large difference in the corrosion potential of the reinforcement and the presence of the chloride contamination accelerates corrosion around the patch area. While the halo effect can be mitigated by installing galvanic anodes in patch repairs, this will only protect the area of the patch and areas in proximity. Galvanic anodes placed in patches will not sufficiently polarize the steel to establish cathodic protection and will only slow the progress of corrosion in areas where corrosion has already begun.

Replacement of the concrete cap should consider several additional factors. Both sections of wall are believed to have either tie rods or concrete beams that extend to deadmen that provide support to the top of the walls. These must be protected during demolition / construction and appropriate limits to activities along the wall must be established to maintain its structural stability. Just as corrosion is present in the caps, it may be discovered during demolition that the tie rods / beams are similarly corroded or damaged. Repair details for these components should be prepared during design to prevent delays during construction.

Design of the cap replacements should consider reinforcement with Fiberglass Reinforced Polymer (FRP) rebar in lieu of carbon steel. Utilizing FRP, the service life of the caps will be extended considerably by removing the possibility of future corrosion. FDOT and GPI have implemented FRP reinforcement in several bulkhead cap replacements throughout the State with excellent outcomes and relatively low additional cost.

The wall directly to the north of the West Quay Wall was repaired approximately 5 years ago with a cap and sidewalk replacement. During our site visit, settlement was noted in the sidewalk as was visible loss of fill behind the sheet piles (Figure 15). During construction of repairs to the concrete caps, additional mitigation measures should be implemented to seal the joints between sheets and prevent loss of fill material.

Figure 15: Sidewalk settlement and joint failure at recent repairs north of West Quay Wall due to loss of fill behind sheet piles

Central Basin (Demens)

Existing Conditions

The area that extends across the southern limits of the central basin consists of three different wall types. The sections of seawall that run east-west appear to be of similar construction to the concrete seawall at Central Basin (Pier) (Figure 16). The southern end of the section that runs north-northeast (East Quay Wall) appears to have been reconstructed relatively recently, possibly at the same time as the reconstruction of the adjacent boat ramp to the north (Figure 17). The northern end of the section that runs north-northeast is a steel sheet pile wall (Figure 18).

Original construction plans are not available for any section of wall. As discussed in the Central Basin (Pier) section, it is anticipated that construction of the concrete seawall is similar to that shown in the 1926 plans developed by the City of St. Petersburg Department of Public Works. However, it appears a rehabilitation, for which no plans are available, was constructed at some point installing a corrugated steel sheet pile toe-wall with concrete fill between it and the seawall. There is no information available on the recently reconstructed section of wall. The February 2017 Moffatt & Nichol Marine Infrastructure Condition Assessment (Project No. 16111-119) references 1985 plans prepared by Dlouhy & Associates for the steel sheet pile bulkhead, but these plans were unavailable.

Figure 16: South seawall at Central Docks

Figure 17: Reconstructed section of East Quay Wall south of boat ramp

The 2021 Annual Marina Structures Inspection Condition Assessment Report assessed the Central Basin (Demens) walls as being in “serious” to “fair” condition. The report assessed the concrete seawall as being in “poor” condition with moderate to severe abrasion, lateral movement, full depth cracking, and areas of subsidence behind the wall. The reconstructed section of wall is identified as a steel sheet pile wall and is assessed as being in “fair” condition. The northern sheet pile wall is assessed as being in “serious” condition with severe corrosion of the sheet piles. The field assessment confirmed the evaluation of each area to be accurate.

Figure 18: East Quay Wall north of boat ramp

Proposed Modifications

The proposed modifications to the concrete seawalls are shown in Figure 19. This detail, provided to GPI by the City, appears to be based on a proposed replacement alternative prepared by Moffatt & Nichol, but the document of origin could not be located. The original detail and the current overlayed concept are essentially identical, showing a new sheet pile wall installed in front of the existing corrugated sheet pile toe-wall. The existing wall is to be abandoned under fill with the top of wall elevation increased by 1.2 ft to EL +6.0'.

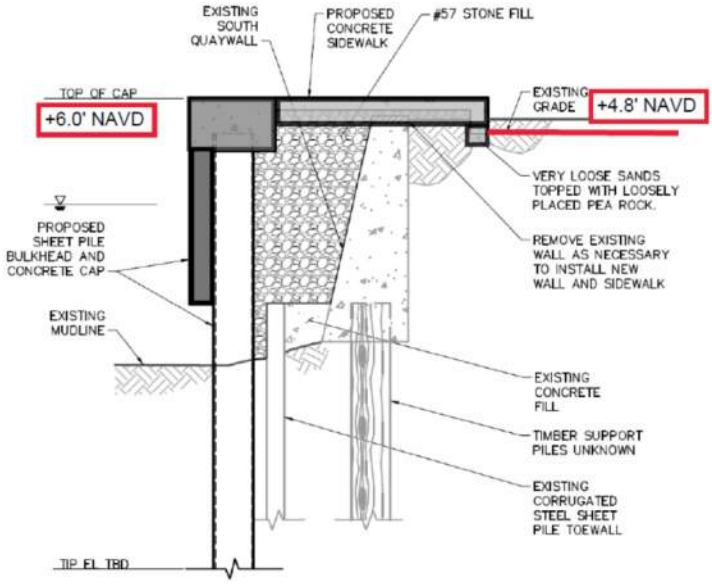


Figure 19: Proposed modifications to concrete seawall at Central Basin (Demens)

No proposed modifications were provided for the other two sections of wall. The section to the south of the boat ramp is in "fair" condition and does not require any immediate action. However, the condition of the bulkhead to the north of

the boat ramp should be addressed. Several alternatives exist for rehabilitation of the wall: spot repairs of the steel sheets by welding reinforcing plates, concrete facing installation, or encapsulation with FRP panels and placement of inert material between the panels and the wall. Selection of a rehabilitation method requires a detailed inspection and assessment of the sheet piles and is outside the scope of this report.

Numerous physical conflicts to the proposed modifications are present along the concrete seawall. Utilities and walkways extend from the seawalls to the covered Central Docks; however, the docks themselves will need to be demolished to allow for construction of the modifications. The edge of structure supporting both the walkway that is parallel to the seawall and the roof system for the docks runs directly over the corrugated steel sheet pile toe-wall (Figure 20). In addition, 12-inch piles supporting the structure are within a foot of the toe-wall. In order to drive the proposed steel sheet piles, the roof and walkway will need to be demolished and the conflicting piles will need to be removed. There is also a wooden deck, which is property of the City of St. Petersburg, at the SC bathroom and laundry room, near Slip SC-1, that extends over the wall and will need to be removed (Figure 21).

Figure 20: Conflict between dock platform and corrugated steel toe-wall

Aside from the conflicts, construction should be somewhat straightforward at the Central Docks. Pile driving can be accomplished with equipment positioned in the parking areas along 1st Ave SE or from barges to keep the park fully available to the public. Due to the short retained height, tie backs and anchors are not anticipated.

Pile driving along the seawall at the entrance to the Central Basin presents slightly more complications (Figure 22). Driving the sheet piles from land may require removal of some trees to accommodate equipment and restoration following construction. Driving sheet piles from barges will restrict the entrance to the Central Basin. Both are viable but will require close coordination with the City and the marina to determine the most desirable option. Prior to pile driving in this area, large rubble riprap will need to be relocated.

Figure 21: Wood deck at bathrooms in conflict with seawall

Figure 22: Seawall along marine vessel entrance to Central Basin

South Basin

Existing Conditions

This area consists of concrete sheet piles with concrete caps and tiebacks that extend back to deadmen. Original construction plans are not available, but details for a rehabilitation performed in 1976 were located in a 2005 Preliminary Evaluation Report prepared by the City of St. Petersburg (Figure 24). Based on these details, it appears the sheet piles had rotated and were rehabilitated by reconstructing the concrete caps to be level again and installing large rubble riprap with stones ranging from 500 to 2000 lbs.

Figure 23: South Basin concrete sheet pile wall

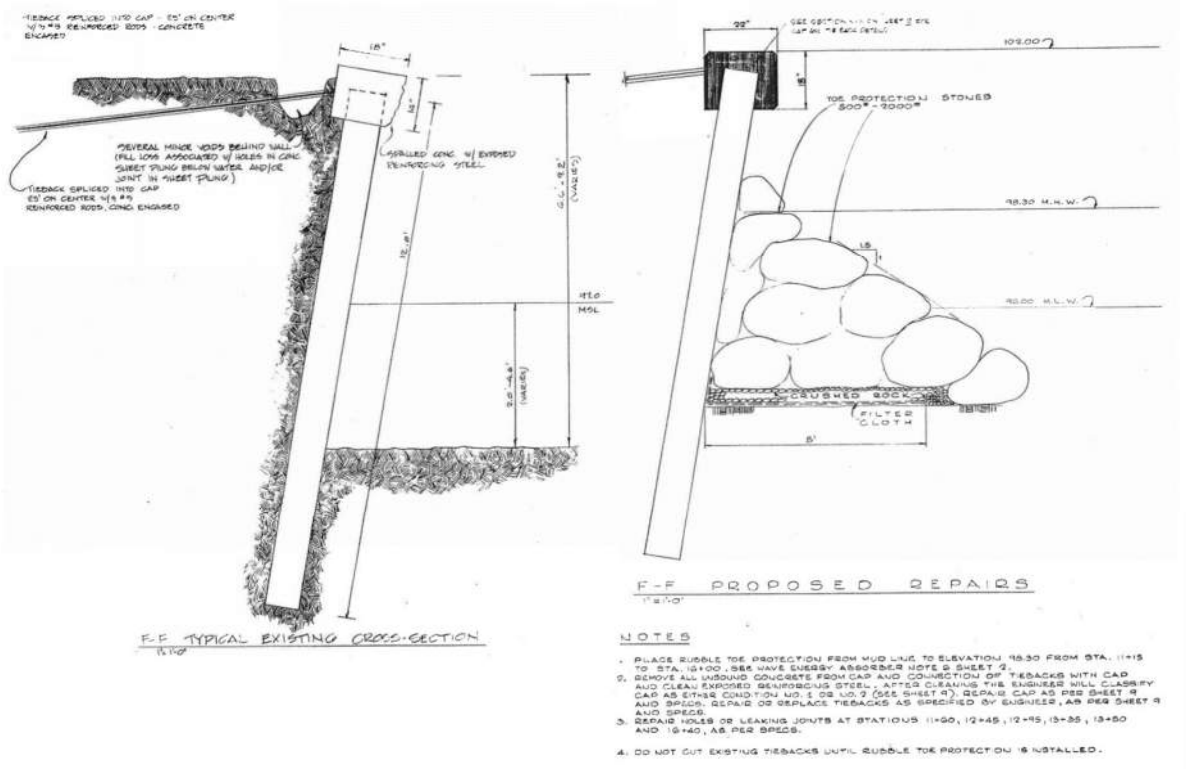


Figure 24: Details for 1976 rehabilitation of South Basin walls

The 2021 Annual Marina Structures Inspection Condition Assessment Report indicates conditions along the wall range between “fair” and “serious”. Noted conditions include cracking, spalling, delaminations, rust staining, exposed sheet pile joints, and areas of subsidence in the sidewalk behind the wall. These conditions were verified as accurate during the site visit.

Proposed Modifications

The proposed modifications to this area are shown in Figure 25. This detail, provided to GPI by the City, appears to be based on a detail in proposed rehabilitation plans prepared by Moffatt & Nichol but deleted in Revision 1 of that document. The original detail and the current concept are nearly identical, showing excavation behind the wall to install geotextile fabric and stone fill. The current concept adds rubble riprap to provide additional protection to the wall.

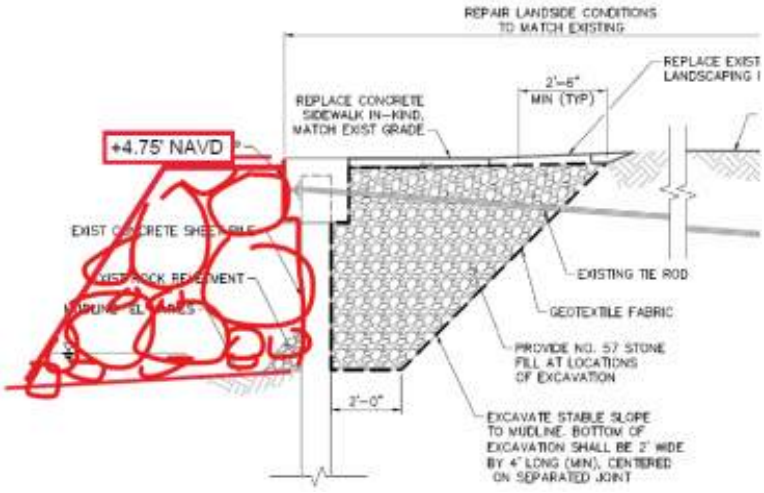


Figure 25: Proposed modifications at South Basin
(Based on St. Petersburg Municipal Marina South & Central Yacht Basins Structural Rehabilitation, Moffatt & Nichol, 06/20/2018, Project No. 16111-119R)

While the proposed modifications are feasible, they are not recommended. The condition of the concrete sheet piles, both noted in the inspection report and verified during the GPI site visit, show extensive corrosion throughout the sheet piles. Spot repairs along the sheet piles would both be too numerous to be cost effective and generally not desirable due to the "halo effect" described in the Central Basin (West Quay Wall / East Pier) section. Cathodic protection measures to halt the progression of corrosion in the wall are not advisable due to the high cost associated with protecting a wall showing advanced deterioration. It is recommended that the sheet piles wall in this area be replaced.

Figure 26: Exposed corroding reinforcement, corrosion stains, and efflorescence at the South Basin concrete sheet pile wall

Proposed Modifications Assessed Against Sea Level Rise

As noted previously, the assessment criteria utilize the 2070 Intermediate SLR model at the MHHW tide elevation. The inundation map for this criterion shows minimal flooding at Demens Landing Park or the areas surrounding the Central Basin with the walls at their current elevations. With a MHHW surface elevation of +3.16 ft NAVD88 at the 2070 Intermediate SLR model, locations where the top of wall elevation is increased to EL = +6.0 ft will be well protected. Of note, the PST elevation for the 2070 High SLR model is +5.99 ft, though less protected areas on either side of walls at EL = +6.0 ft will permit water to get around the high walls.

The inundation map shows street flooding on Bayshore Drive along the west quay wall. This flooding does not result from the overtopping of seawalls but from sea water backflowing through the stormwater system and out of inlets. The intermediate model shows this occurring at all tide levels. It is recommended that installation of check valves at the stormwater outfalls be considered in addition to the proposed modifications to the seawalls.

Appendix: Land & Water Engineering Science Technical Memorandum

08.6.2021

Technical Memorandum

Revised Nov 1, 2021

To
GPI

From
Land & Water Engineering Science

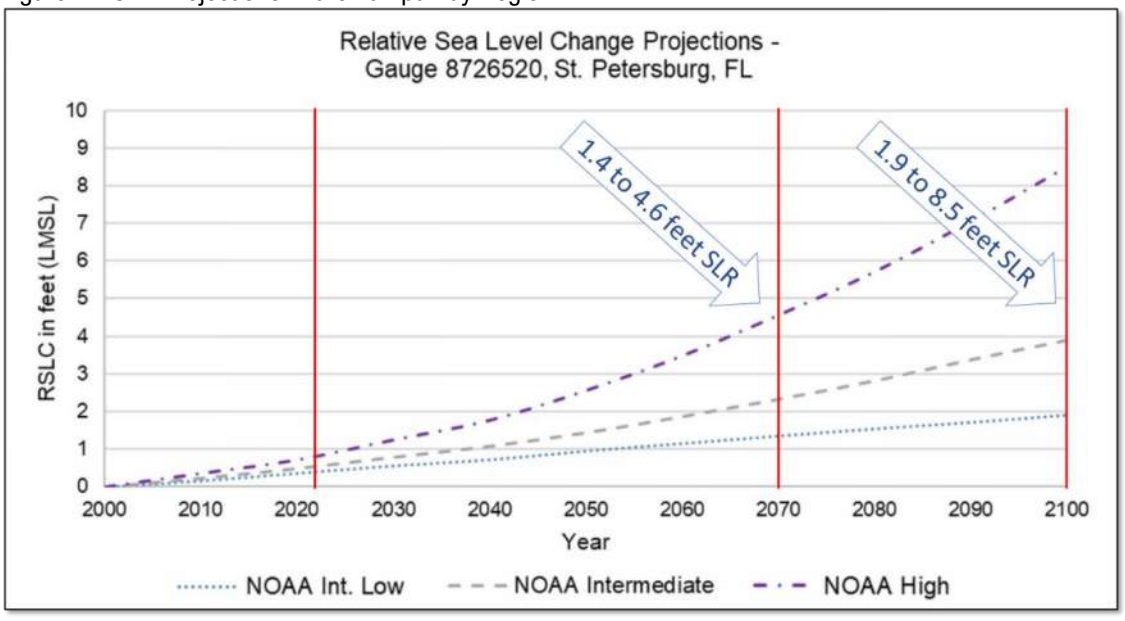
Re
St. Petersburg Marina Redevelopment Vulnerability Assessment – Sea Level Rise

Land & Water Engineering Science (LWES) was retained by GPI to identify potential sea level rise (SLR) estimates for a given time horizon and to provide SLR inundation maps for three scenarios for seawalls at the proposed St. Petersburg Marina Redevelopment Project. Recommendations for design based on SLR conditions are also provided.

Typically, the SLR planning time horizon is based on the life expectancy of an asset. In this case, concrete and steel seawalls can be expected to last 50 to 75 years, which sets a time horizon of approximately 2100. However, projections that far out have greater uncertainty. Accordingly, in consultation with City of St. Petersburg, a 75-year design life (2100 time horizon) was selected for seawalls to be designed around the 2070 SLR scenarios.

Figure 1 shows the recommended sea level rise projections in the Tampa Bay Region (Tampa Bay Climate Science Advisory Panel (TBCSAP), 2019, *Recommended Projection of Sea Level Rise in the Tampa Bay Region*). The recommendations are based on the curves developed by the National Oceanic and Atmospheric Administration (NOAA). The red vertical lines represent the time horizons (present day, 2070 and 2100) relevant to this project. For the 2070 time horizon, the three SLR scenarios are the intermediate low (+1.4 feet), the intermediate (+2.3 feet), and the high SLR (+4.6 feet) scenario.

Figure 1 - SLR Projections in the Tampa Bay Region



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For planning purposes, there are three main tide levels to consider: mean high water (MHW), mean higher high water (MHHW) and the perigean spring tide (PST or colloquially known as a "king tide"). The worst-case scenario will be flooding during a PST with the high SLR scenario. To get the future water surface elevations, the tide elevations are superimposed on top of the projected SLR for each scenario. Table 1 lists the water surface elevation expected in 2070 for various tides and SLR scenarios (WSP, 2021). Elevations in Table 1 are provided in both NAVD88 and in the City Datum (= NAVD88 + 97.87 feet).

Table 1 - 2070 Water Surface Elevations for Various Tides and SLR Scenarios

Tide	Water Surface Elevation for Various 2070 SLR Scenarios					
	Intermediate Low		Intermediate		High	
	Feet, NAVD88	Feet, City Datum	Feet, NAVD88	Feet, City Datum	Feet, NAVD88	Feet, City Datum
MHW	1.88	99.75	2.86	100.73	5.09	102.96
MHHW	2.18	100.05	3.16	101.03	5.39	103.26
Perigean Spring Tide	2.78	100.65	3.76	101.63	5.99	103.86

For reference, the flooding that the area experienced during Tropical Storm Eta in November 2020 is close to the flooding expected during the perigean spring tide and the 2070 intermediate SLR scenario. For comparison, the 2100 perigean spring tide with the high SLR scenario (i.e., the worst-case) is at elevation 10.08 feet, which puts much of the downtown St. Petersburg bayfront underwater for at least one block back from the present-day waterfront. Most of Demens Landing Park would be continuously inundated and about 5 to 6 feet under water during the PST. Protecting the marina seawalls up to this level is not practical considering the broader implications of this SLR scenario to the City of St. Petersburg. This is one reason that the 2100 scenario was not selected for seawall design.

Three aerials depicting areas inundated by the each of the SLR scenarios are included at the end of this memorandum. In the 2070 intermediate low scenario, sea water mostly remains at the fringes of the seawalls around the entire marina. In the 2070 intermediate SLR scenario, some tidal flood water can be see encroaching into the central, low areas of Demens Landing Park and overtopping the northern quay wall and into the adjacent parking areas. Also, some street flooding can be seen on Bayshore Drive along

the west quay wall and east of Al Lang Stadium. The Bayshore Drive flooding is associated with sea water backflowing through the existing stormwater system and up out of the stormwater inlets rather than overtopping of the seawall. In this case, installation of check valves at the stormwater outfalls might be an appropriate adaptation measure.

In the 2070 high SLR scenario, during mean high tide, almost all of Demens Landing Park is under water by between 0.75 feet and 1.5 feet. Similarly, all of Bayshore Drive and some of Beach Drive is flooded, as is Albert Whitted Airport (not show on the maps). Flooding along the City's bayfront is extensive. In this case, seawater overtops the seawalls in addition to backflowing through the stormwater system. In this scenario, installation of check valves in the stormwater outfalls alone is insufficient to prevent flooding. Other protective measures, such as elevating seawalls might be required.

It appears that for this area, there is a significant breakpoint in the SLR threat between the 2070 intermediate and high scenarios. In the intermediate SLR scenario, minor flooding can be expected during PST but would probably qualify as nuisance flooding. In the high SLR scenario, the extent of tidal flooding is much more significant along the City's bayfront, even during mean high tide. At this point, a much broader strategy for SLR adaptation should be implemented if the high SLR scenario is the adopted curve.

REFERENCES:

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2070, Intermediate Sea Level Rise

Aerial Source: SWFWMD, 2020

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