



**US Army Corps
of Engineers®**

Charleston District

**CHARLESTON PENINSULA, SOUTH
CAROLINA, A COASTAL FLOOD RISK
MANAGEMENT STUDY**

Charleston, South Carolina

STRUCTURAL SUB-APPENDIX

JANUARY 2020
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INTRODUCTION

The structural engineering scope of this feasibility study is to evaluate various flood wall barriers. The types of barriers considered for this study consist of earthen berms, I-walls, T-Walls and Combo Walls. Each barrier type has its own requirements, limitations and footprint requirements, which the report discusses in more detail.

REFERENCES

- EM 1110-2-2502 Retaining and Flood Walls
EM 1110-2-2906 Design of Pile Foundations
EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures
ER 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects
Coastal Storm Risk Management Feasibility Study / Environmental Impact State – NAO – July 2018

ASSUMPTIONS AND LIMITATIONS

Due to the conceptual stage of this study, assumptions had to be made and there were limitations that were used. These assumptions and limitations can be fine tuned during Preconstruction Engineering and Design (PED) Phase.

In addition, the Norfolk District (NAO) completed a similar feasibility study for the City of Norfolk in Virginia. The soil conditions in Norfolk are similar to Charleston's soils, as the soils consist of roughly 50-65 ft of soft soils, and a harder layer below that is suitable for providing reliable structural support. Therefore, similar foundation requirements for NAO's feasibility study will be used for the basis of this report.

EARTHEN BERM

Earthen Berms were ruled out as a viable option due to their large footprint requirement (i.e. 10 ft wide top, 3 to 1 slope, vegetative free zone on each side, etc.). The study is limited to the peninsula of Charleston, where the land has been heavily developed, and available land is very scarce. Therefore, if an earthen berm were to be constructed, it would result in large marsh impacts and/or seizing of many homeowners' properties. Refer to the table below for Total Width requirements for earthen berms.

Berm Height (ft) Above Existing Grade	10 ft Top Width		8 ft Top Width	
	3H : 1V	4H : 1V	3H : 1V	4H : 1V
	Total Width (ft)	Total Width (ft)	Total Width (ft)	Total Width (ft)
1	46	48	44	46
2	52	56	50	54
3	58	64	56	62
4	64	72	62	70
5	70	80	68	78
6	76	88	74	86
7	82	96	80	94
8	88	104	86	102
9	94	112	92	110
10	100	120	98	118
11	106	128	104	126
12	112	136	110	134
13	118	144	116	142
14	124	152	122	150

* Total Widths include a Vegetation Free Zone (VFZ) of 15 ft on each side of the berm

I-WALL

Due to barrier height uncertainties and unknowns at this stage of the study, I-Walls were not utilized when determining location of the barrier. I-Walls will consist of driven sheet pile walls with a concrete cap. For the purposes of this study and due to soil conditions, I-Walls will only be considered for barriers whose top elevations were 4 feet or less above the current finish grade. Due to the small footprint requirements of the I-Wall, it is more viable where space and land is limited. As stated earlier, I-Walls were not utilized at this stage of the study, but will be utilized during optimization of this study.

T-WALL

For the purposes of this study, a T-Wall was assumed to be used where the barrier needed to be constructed on land, and not in the marsh. During optimization it is anticipated that the T-Wall will be used where existing grades are at the lowest elevations. These lower elevations will primarily occur where the barrier is anticipated to be constructed within the marsh, or near the MHW line. Due to the poor nature of the soils in Charleston, it is assumed that the T-Wall will be founded on a deep pile foundation that will be embedded within the Cooper Marl stratum. This strata is roughly 50 feet below current finished grade, and consists of medium dense silty sand to firm silty clay.

COMBO WALLS

For purposes of this study, a Combo Wall was assumed to be used where the barrier is located in the marsh. A Combo Wall is a combination of a large-diameter steel pipe piles with sheet piles installed to form a surge barrier structure. Due to soil conditions and required loads, the Combo Wall will require battered piles to provide sufficient lateral support.

BRIDGE CLEARANCES

Where the barrier goes under existing bridges, clearances for construction were taken into consideration when selecting a deep foundation system, as well as construction methods used. Micropiles will be utilized where clearance is low in the location of the T-Wall; and welding of steel sheet piles will be utilized where clearance is low for Combo Walls. Below are 2 locations where head clearance is a concern.

James Island Connector - ~35 ft clearance from MHW (Combo Wall)

Ravenel Bridge - ~25 ft clearance from existing grade in the parking lot (T-Wall)

LOADS

The load cases considered for this study were in accordance with Coastal Flood Wall requirements in EM 1110-2-2502. To date, analysis has not been completed, but engineering judgement and information from NAO's feasibility study were used at this stage. During optimization, preliminary analysis will be completed.

- C1: Surge Still Water Loading
- C2a: Nonbreaking Wave Loading
- C2b: Breaking Wave Loading
- C2c: Broken Wave Loading
- C3: Earthquake Loading
- C4: Construction Short-Duration Loading
- C5: Wind Loading

GATES

No analysis was performed. However, existing gate information from the NAO feasibility study and gate information obtained during a site visit to New Orleans, were used as a go-by at this stage.

LOW BATTERY WALL

The City of Charleston is currently completing a multi-phased construction project that consists of raising the low batter to the same elevation as the existing High Battery Wall. Upon speaking the designer of record for this design, it was determined that the new Low Battery Wall will provide a level of protection to elevation 9 ft NAVD88, and has been designed to provide a level of protection of elevation 12 ft NAVD88 upon retrofitting the structure. Therefore, if the barrier is to be above elevation 9 ft NAVD88, the Low Battery Wall will need minor construction work done, but no structural upgrades will be required.

HIGH BATTERY WALL

After reaching to multiple sources with the City of Charleston and Public Library, it was determined that we do not have accurate data about the construction of the high battery wall. In addition, given its age and assumed construction techniques used for the time period of which it was construction; it is a safe assumption that the high battery wall will not meet the criteria to be part of the Federal project.

FUTURE DETAILING AND RESILIENCY

Due to sea level rise and the harsh marine environment where the barrier is to be constructed, measures should be taken to ensure the barrier can adapt to our changing environment, as well as reduce required maintenance and ensure longevity. All of the items listed below will be considered during optimization of this study.

INCREASING BARRIER HEIGHT

Since the I-Wall does not have any battered piles or major lateral resisting elements, the I-Wall will be the most difficult to increase the height, if that needed to be done in the future. A toe on the concrete cap could be installed during initial construction, which would allow additional raising, but would add additional upfront costs.

In addition, the T-Wall and Combo Wall have battered piles which are currently assumed to be driven to the Cooper Marl stratum providing more lateral resistance. This will allow for easier retrofitting of the barrier to provide an increased level of protection without requiring structural or foundation upgrades.

INCREASING THE LOW BATTERY WALL HEIGHT

As stated earlier, per conversations with the designer of record of the raising of the low battery wall project being completed by the City of Charleston, the wall is currently being constructed to provide a

level of protection to elevation 9 ft NAVD88, and can be retrofitted to provide a level of protection to elevation 12 ft NAVD88. However, if a level of protection higher than elevation 12 ft NAVD88 is needed, then structural analysis and structural upgrades will be required. These upgrades may consist of, but are not limited to, foundation upgrades and additional lateral support. These upgrades will be very difficult to construct, and may result in major demolition and reconstruction of the low battery wall.

CORROSION PREVENTION

This project this barrier is being built in the marsh, or near the ocean in a heavy corrosive environment. Therefore, corrosion prevention measures should be taken into consideration to reduce required maintenance and ensure longevity. These measures will consist of cathodic protection, use galvanized or epoxy coated rebar, or use of fiberglass rebar. In addition, where material strengths are sufficient, vinyl sheet piles should be considered.

ATTACHMENTS

Attachment A – Drawings from Norfolk’s Feasibility Study – July 2018

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