RHODE ISLAND COASTLINE
COAST STORM RISK MANAGEMENT
Final Feasibility Study

Appendix D: Engineering and Design

January 2023

US Army Corps
of Engineers®
New England District

RHODE ISLAND COASTLINE
COASTAL STORM RISK MANAGEMENT

DRAFT FEASIBILITY REPORT
APPENDIX D: ENGINEERING AND DESIGN

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

BGS	Below Ground Surface
CSO	Combined Sewer Overflow
FEMA	Federal Emergency Management Agency
FNP	Federal Navigation Project
HSS	Heavy Steel tube
LIDAR	Light Detection and Ranging
MHHW	Mean Higher High Water
NAVD88	North American Vertical Datum 1988
NFIP	National Flood Insurance Program
PDT	Project Delivery Team
RIDOT	Rhode Island Department of Transportation
RIGIS	Rhode Island Geographic Information System
SF	Square Foot
TWAE	Temporary Work Area Easements
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Service

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1.0 INTRODUCTION

1.1 Study Area and Overview

The study is focused on reducing coastal storm risks of several communities located along the greater Narragansett Bay coastline. By analyzing historical and existing conditions, flood mapping models and other sources of data, various opportunities and alternatives were developed and considered with the objective of arriving at a readily implementable solution to mitigate coastal flooding to residential, commercial, and industrial structures.

As shown in **Figure 1**, the study area included locations along the Narragansett Bay coastline from Point Judith to Massachusetts border and Block Island. Approximately 457 miles of coastline was considered in the study area. Progressive analysis and research narrowed the list of impacted communities through several iterations and select communities were ultimately looked into further for possible alternatives based upon the identified problems and available opportunities.

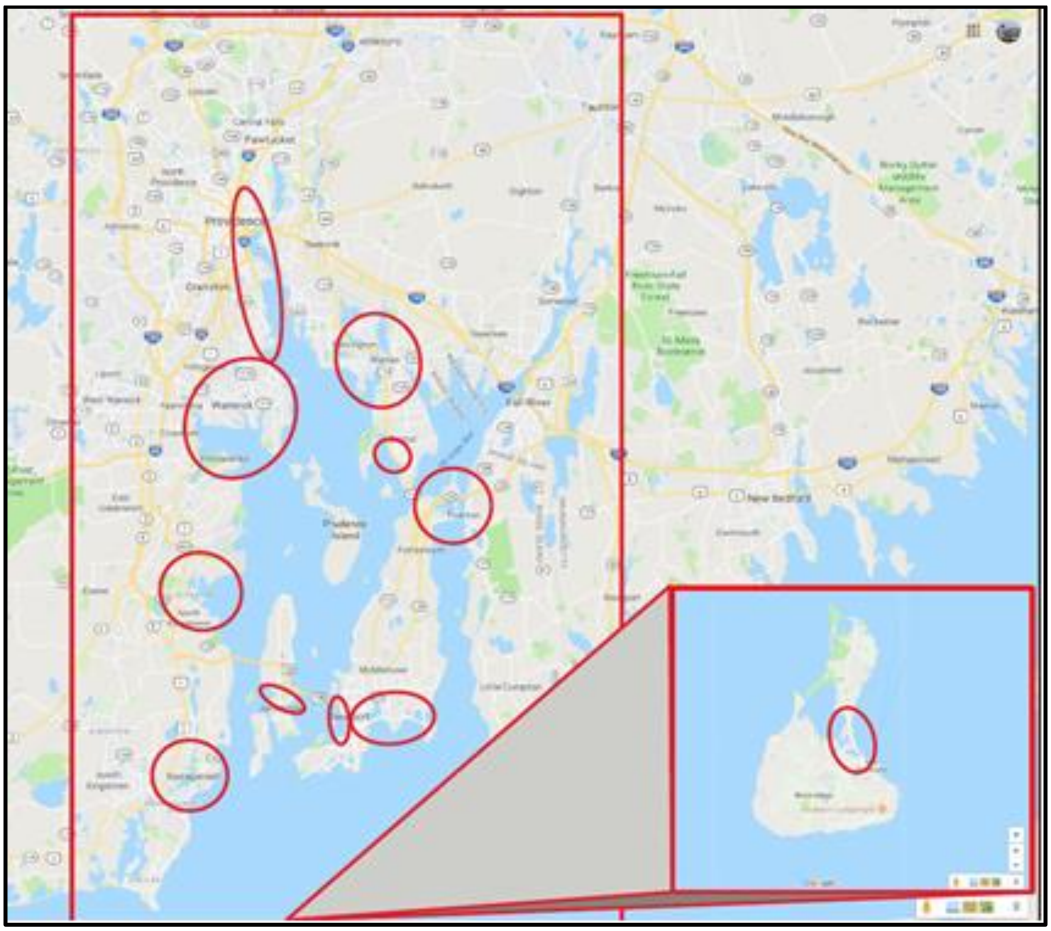


Figure 1: Location of municipalities that were looked into further for alternatives.

2.0 EXISTING CONDITIONS

2.1 Topographic and Subsurface Data

Elevation measurements and topography (contours) for civil & site design activities were established from aerial survey data made available from public resources. The following Lidar data sets were used depending on the coverage area: 2018 U.S. Army Corps of Engineers (USACE) NCMP (Joint Airborne Light Detection and Ranging [Lidar] Bathymetry Technical Center of Expertise) and 2011 U.S. Geological Survey (USGS) Lidar. Geotechnical soil information was found using the USGS Surficial Soil Quadrangles, and boring logs from Middle Bridge No. 14, Warren Bridge No. 124, and Barrington Bridge No. 123 provided by the Rhode Island Department of Transportation (RIDOT).

2.2 Public Records

Parcel mapping data, which includes property lines and ownership rights, was collected from the Rhode Island Geographic Information System (RIGIS) database, as well as the individual municipalities databases. GIS data (i.e. .SHP) was imported into the civil design model for determination of real estate impacts, easement requirements and development of real estate plans. Ownership and parcel IDs of individual properties was obtained from municipal tax maps and matched with the GIS property lines. Additional GIS features that were incorporated into the model include utility locations (electric, sewer, storm, water) and existing building footprints to assist in identifying potential interferences and/or obstructions during the development of alternatives.

2.3 CAD & GIS

A three-dimensional CAD model of existing site conditions for each study area was created by compiling topographic data, public records data, and external referencing of aerial imagery. In addition, targeted contour lines were established using tidal gauge readings (mean high water, mean low water) and historical records (flood inundation levels) to precisely plan the alignments of proposed alternatives. Proposed structural alternatives were designed in plan view to analyze spatial extents with respect to existing conditions and then reviewed in profile view to determine to the required height of structures needed to provide specific levels of storm protection (i.e., 100-Year Storm, 500-Year Storm).

3.0 DESIGN PROCESS

As part of the alternatives development and analysis, the project delivery team (PDT) considered various alternatives to reduce coastal storm risks within the entire project area. This section describes the alternatives carried forward and analyzed in detail with the goal of arriving at the Recommended Plan. The processes included the consideration of structural, non-structural and natural and nature-based alternatives. Structural alternatives would use “Active” or “Passive” barriers. An Active barrier is a barrier that is physically employed before the flood event by means of erecting non-mechanical gates or barriers to stop or divert the flood to another area. An example of a passive barrier would be a flood wall that is permanently in place, or the activation of a mechanically operated gate. Passive barriers usually have less operations and maintenance costs when compared to the “Active” systems. Passive barriers can be more costly to construct than active systems. To conclude, structural barriers stop flood movement and create a pool by holding back the water.

Non-structural alternatives allow water to move in the projected path, but in a way so infrastructure is not affected. Municipalities should be aware that the methods to provide a non-structural solution do require structural work to be done on the protected structure. For example, the raising of a home would have break-away walls or vents with hinges to allow water to pass under the structure. The initial activities begin with raising the home or building which involves structural analysis and some construction. The end result is the protection of the structure without stopping flow or holding water back from following the flood plain.

3.1 No Action

Analysis was performed for all project areas and considered the option of not deploying any type of implementable alternative and the impacts which would result. Models were developed by others to project coastline impacts and concluded that several communities would be severely impacted if no action is taken. No engineering design input was considered as this alternative implies no change to the present conditions.

3.2 Wellington Avenue Floodwall & Levee (Newport)

Historical records and models indicate major flooding concerns in the Fifth Ward residential neighborhood of Newport from coastal storms due to low-lying structures. Wellington Avenue, which runs east to west, was the existing infrastructure used to plan structural measures around to protect this area. Models showed that flood waters come in from Newport Harbor and inundate the region to the south of Wellington Avenue. Kings Park, which is a public recreational area and includes ball fields, two (2) beaches, and public meeting areas borders Wellington Avenue to the north. A structural measure for the area consists of a concrete floodwall and earthen levee system located along the westbound side of Wellington Avenue. The structure would extend from Thames Street on the east to Columbus Avenue on the west. A vehicle barrier would be required across Wellington Avenue in order to continue the structure onto Columbus Avenue and reach the target ground elevation. The target elevation for the structure was determined to be 12.4 Ft North American Vertical Datum 1988 (NAVD88). This is the 100-year water level and includes storm surge and sea level change for the year 2080 (the end of the 50-year period of economic analysis). The elevation does not include a wave runup height which would incorporate the effects of waves, as the elevation will be refined during future design activities.

The concrete floodwall will range in height of 5 to 8 ft above ground with the majority of the earthen levee having a crest 8 ft above ground. In addition to the structure, there will be various personnel and vehicle access points which will require barriers to maintain access. A vehicle barrier crossing Wellington Avenue will consist of a 40 ft wide span with a deployable steel flood gate manually installed ahead of a storm. There will also be two (2) pedestrian access points integrated into the levee and will consist of built-in staircases. A 5 ft wide paved walking path will be located at the crest of the levee and serve as a recreational walkway for views of Newport Harbor. In order to maintain access for service vehicles to the Newport Combined Sewer Overflow (CSO) building, a 15 ft wide stop-log barrier will be integrated into the floodwall structure. Similar stop-log barriers will be integrated into the floodwall crossing the driveways for two (2) private properties along the east end of the structure

In order to remove rainwater which would accumulate behind the wall (dry side) during a storm event with all barriers closed (i.e., vehicle closure structure, stop logs deployed, etc.), a pump station will be integrated into the flood protection system. The pump station will be sized to accommodate the volume of water anticipated to collect behind the wall and levee system. Based upon the existing topography of the Wellington Avenue area, the pump station will be located underground at a localized low point at Spencer Park. Existing stormwater drainage piping will require modifications and relocations as well. There are currently two (2) stormwater outfalls located within the project area and both flow into Newport Harbor near the CSO building. Installation of a box culvert leading to the pump station may be required in order to maintain flow as well as capacity requirements during a storm event. The existing 18-inch storm drain piping running west to east along Wellington Avenue beneath the sidewalk will be re-located into the right-of-way in order to avoid interferences with earthwork for the levee during construction and also remain in an accessible and dry location once the levee is complete for future maintenance and/or repairs.

3.2.1 Real Estate Requirements

By layering the project footprint with the parcel mapping data, real estate impacts were determined by identifying the interferences with private and publicly owned land parcels. GIS files were obtained from the RIGIS database, which included the property lines for each parcel within the project area. This data was verified with the City of Newport GIS database, which provided the parcel ID and ownership rights as depicted on the Real Estate Plan (See Sheet RE-001). As identified between the interferences with property lines and the proposed alignment for the wall and levee system, the majority of work would take place on City of Newport property. A permanent easement would be required for the entire footprint of the earthen levee, which encompasses city property on King Park. The dry side toe of the levee would be aligned with the existing curb line of Wellington Avenue. East extents, which includes a concrete floodwall, would be aligned with the existing centerline of the public sidewalk. The west tie-in of the floodwall would require a permanent easement along the shoulder of Columbus Avenue, which is a private way. The below ground pump station would be located on Spencer Park, which is a public park located to the south of Wellington Avenue. There are three (3) construction staging and stockpiling areas identified for temporary work area easements (TWAE) all located on city property. In addition, a TWAE would be required to either side of the floodwall and levee during construction. Currently there is a row of street parking located along the westbound lane of Wellington Avenue. This row would be utilized during construction for heavy equipment to haul and place materials. A similar area would be established along the north (wet side) toe and include 15 ft. of clearance to allow heavy equipment to travel back and forth for material placement. For the segments where a concrete floodwall is being constructed, a 10 ft. clearance would be required for TWAE to either side of the wall. It is intended that all work take place on city property, with the exception of construction along Columbus Avenue, which is a private way.

3.2.2 Construction Plans

The floodwall and levee would both require all new materials be hauled to the project area and staged at designated locations. There are three (3) areas identified for the staging of equipment, setup of temporary facilities (i.e., trailers, sanitation, etc.), and stockpiling of new materials. An ~11,000 square foot (SF) area located in the gravel driveway for the CSO building would be utilized for constructing portions of the east extents of the wall and levee. An ~13,000 SF area located adjacent to King Park Beach would be utilized for constructing portions of the west extents and a ~6,000 SF area located to the south of Wellington Avenue on Spencer Park would be utilized for construction of the pump station. It is anticipated that there would be only short durations of lane closures of Wellington Avenue during floodwall or levee construction. The on-street parking row would be utilized for construction work and traffic control would be required to ensure safe conditions. Lane closures would be required during the installation of the vehicle closure barrier across Wellington Avenue. The relocation of storm drain piping would require a lane closure of Wellington Avenue, since the piping would be trenched beneath the westbound lane.

The USGS surficial soil quadrangle for Newport was never finalized, but draft copies indicated the soil in the south region of Newburyport near Wellington Avenue. is primarily sand with silt. There are no anticipated geotechnical issues constructing the soil levee portions of the protection structure. The floodwall portion has sandy soils in this area that can cause seepage and uplift concerns. Therefore, a 10-foot vinyl sheet was included along the centerline as a seepage cutoff.

3.2.3 Structural

A T-wall section was selected for the concrete floodwall. The T-wall employs a minimum 18-inch-thick reinforced wall to withstand the elements including substantial weight to resist overturning and sliding forces. Reinforced concrete is economical and has been used successfully on other USACE projects for storm barriers. Soil can be placed above the footing for added stability. If needed, larger stones can be added above the landside portion of the stem to help counteract overturning forces. A shear key at the bottom of the footing would help resist sliding forces. If a key is placed at the heel, the design could benefit from eliminating the uplift forces. There may be flexibility to move the location of the stem towards the land side to take advantage of water weight above the base on the watered side of the wall. This may help to reduce the thickness requirements of the footing.

Any reductions would need to be carefully considered since there are no piles, the T-wall needs to behave as a mass-gravity structure. It is preferred that the design to remain as robust as possible, to keep the kern within the middle third of the base. In addition, have the ability to deflect recreational vessel and impact debris loads.

The concrete footing and the stem wall were designed to provide rotational stability against wave action. Some portions of the base footing were up to 3 ft-thick reinforced concrete. Significant benefits to reducing concrete volume on this wall could affect longevity.

The concrete wall selected for this and other alternatives were based on the criteria found in the Engineering Manuals:

- EM-1110-2-2100 - Stability Analysis of Concrete Structures
- EM-1110-2-2502 - Floodwalls and Other Hydraulic Retaining Walls
- EM-1110-2-2105 - Design of Hydraulic Steel Structures

3.3 Barrington & Warren Hurricane Barrier – Upper

Utilizing a combination of existing infrastructure and constructing new structures, a hurricane barrier system was looked into for the upper reach of the Warren River. Route 114 is the primary infrastructure in concern as this is an evacuation route and major thru way for the community. Significant portions of the road located in Warren and Barrington experiences inundation during storm events and persistent maintenance needs due to flooding. The area is also thickly settled with both residential and commercial properties. Overflow from the Warren River and Belcher Cove are the main sources for flooding in the area during storm events.

Alignments were investigated for scenarios that provided protection from a 100-year storm (1% chance) and 500-year storm (0.2% chance). Providing protection for a 500-year storm would result in a hurricane barrier that would extend for 6,350 ft. (1.2 miles) between Barrington and Warren. Both alignments utilize the East Bay Bike Path for the majority of the length. The west limit of the barrier system would require building up the bike path to the required elevation, which is ~16.5 Ft NAVD88 for the 500-year water levels. The elevated bike path would consist of a concrete floodwall to either side of the existing path built up with gravel fill material between both walls until the target elevation. A new asphalt pavement bike path would be installed at the crest for continued recreational use of the East Bay Bike Path. A similar structure would be built between the two (2) pedestrian bridges. One (1) bridge crosses the Warren River and the other crosses the inlet to Belcher Cover. A closure structure consisting of operable gates across the river would be integrated into the elevated bike path structure and incorporate the existing bridges. The crest of the closure structures would also contain a paved bike path. On the Warren side of the structure, the alignment would run predominately north to south and consist of a concrete floodwall running along the riverside of the Tourister Mill property. The east tie into higher ground would utilize Company Street in Warren. Overall, the hurricane barrier system would consist of elevating the existing East Bay Bike Path, installing operable flood gates on the pedestrian bridges, and constructing a flood wall along the Warren River front. Structure heights would range between 10 to 16 ft above ground.

3.3.1 Real Estate Requirements

A preliminary look into the real estate requirements to implement this alternative indicate substantial work would occur on private property and construction crews would progressively build the flood protection system from the beginning station to the end. Temporary closure of the East Bay Bike Path would be required during construction, as well as Route 114 during installation of the vehicle barrier. There would be no impact to boating and marine traffic as the existing pedestrian bridges being utilized for closure gates do not currently permit marine traffic to pass through.

3.3.2 Construction Plans

The Warren and Barrington Upper Hurricane Barriers were designed as two (2) separate system, each located by the respective Warren and Barrington Bridges.

For the Barrington Bridge location, the USGS surficial soil quadrangle data and the RIDOT Barrington Bridge No. 123 drawings indicate soft organic silt soils between 10 and 20 ft below ground surface (BGS). Bedrock depth varied, but was decomposed bedrock was typically encountered between 30 and 50 feet BGS). Because of the soft soils and relatively shallow bedrock, the team opted to use 35-foot long 24-inch inboard and outboard HP piles (or driven to refusal on rock). The pile spacing was determined to be 10 feet on center. Where a gate structure is required, piles of no more than 15 degrees batter were allowed. In addition, the sandy soils in this area cause seepage and uplift concerns.

For the Warren Bridge location, the USGS surficial soil quadrangle data and the RIDOT Warren Bridge No. 124 drawings indicate soft organic silt soils between 0 and 5 ft BGS. Bedrock depth varied, but was decomposed bedrock was typically encountered between 15 and 35 ft BSG. Because of the soft soils and relatively shallow bedrock, the team opted to use 30-ft long 24-inch inboard and outboard HP piles (or driven to refusal on rock). The pile spacing was determined to be 10 ft on center. Where a gate structure is required, piles of no more than 15 degrees batter were allowed. In addition, the sandy soils in this area cause seepage and uplift concerns. Therefore, a 10-foot vinyl sheet was included along the centerline as a seepage cutoff.

3.3.3 Structural

The hurricane protection barrier selected for this alternative are composed of steel bulkhead roller gates and concrete T- walls. The steel gate structures would be built in the waterway channels supported by concrete piers on deep piles into rock. One (1) section of the barrier would utilize heavy steel tube (HSS) sections. This is the portion of the barrier that would allow the daily passing of recreational vessels. At the time when protection is needed, a barge would install the stoplog sections to provide storm protection. The steel bulkhead roller gates are operated by a mobile crane. The crane would access the gates via concrete bridge deck supported by concrete piers that also serve as the supports for the gates. The deck would also allow for pedestrians to cross the channel to gain access to the other side.

The land (dry) portion of the barrier would utilize T-walls. The T-walls in this portion of this barrier are 2-sided. This was done to create a wall that was wide enough to allow a path at the top of the wall friendly for pedestrians and cyclists. A brick or stone facade would be attached to the face of the wall for aesthetics. To achieve flood protection at road crossings, removable steel panel gates supported by steel strut arms will be employed. Levy alternatives on the land portions of the proposed barrier were not considered due to limited real-estate and the existing of utilities that would have need relocation.

3.4 Barrington & Warren Hurricane Barrier – Lower

A hurricane barrier similar in function and design as the New Bedford, Massachusetts Hurricane Barrier was investigated by the engineering team for the lower reach of the Warren River. A larger acreage of protection would be provided by the lower barrier than the upper barrier which includes protection of several riverfront properties, as well as Route 114. The west wingwall would utilize Bourne Lane in Barrington and the east wingwall for the hurricane barrier would run along Water Street and then turn onto Campbell Street in Warren. This portion of the Warren River is located within the USACE's federal navigation project (FNP) limits and water depths are around 16 ft mean lower low water (MLLW) in the proposed location for the hurricane barrier. The barrier would extend across the Warren River and contain a 150 ft wide gated opening to maintain commercial and recreational navigation. Earth fill levees would be constructed within the river to either side of the gate and then tie into floodwalls built upon the landsides of the river. Vehicle barriers would need to be integrated into each floodwall in Barrington and Warren and remain open during non-storm events. The floodwall along Bourne Lane would also need to integrate a tide gate to maintain tidal flows as this area is a wetland. A maintenance road along the crest of the levees out to the gates would be required in order for crews to maintain and operate the hurricane barrier. The alignment was analyzed for a 500 Year storm and the target elevation was determined to be 16.47 ft NAVD88.

4.4.1. Real Estate Requirements

A preliminary look into real estate requirements to implement this alternative would have substantial impacts to marine traffic during construction. The gate opening would be located along the existing navigation channel; however, construction would require a cofferdam be utilized. The west wingwall built along Bourne Lane would have significant impacts to private properties during construction and an area along the waterfront would be required as a laydown area for materials and equipment. The east wingwall would utilize the public park adjacent to Warren Town Beach for a construction laydown area. Tying into higher ground at Burrs Hill Park was avoided due to historical and preservation constraints. The floodwall would run along the Water Street sidewalk and then turn on the Campbell St and utilize private property for higher ground.

3.4.1. Construction Plans

No geotechnical borings were located for the lower Barrington and Warren. Therefore, the soil conditions for Barrington were assumed on the west side and Warren was assume for the east half of the hurricane barrier. The structural engineer requested to use timber piles. Timber piles shall be driven to refusal in the bedrock or decomposed bedrock.

3.4.2. Structural

The barrier chosen for this section will utilize steel sector gates. A large portion of these double-leaf gates are used by USACE as lock systems. The construction methods are proven, and these gates have the ability to be opened and closed rapidly. They also have low short-term maintenance costs. One (1) advantage is there is no need for overhead clearance consideration. A disadvantage is that they cannot be closed in an emergency with high velocity water passing the channel. These gates need to be closed before the storm event proceeds to the protected area. On the contrary**,** construction of sector gates is very complex and costly requiring significant excavation, dewatering cofferdams, etc. and maintenance (including operations and inspections) are also very costly. For example, every five (5) years a detailed inspection should be conducted, but access and coordination to the structure could be challenging. A typical smaller municipality may find O&M tasks challenging for a sector gate.

Additionally, while the gates are in the open position, they are stored in their own respective cavities for storage. This allows for an open channel with minimal obstructions. Furthermore, there are no overhead obstructions such as overhead walkways or hanging gates during the non-storm conditions that could hinder vessel passage. The arch shape created by the leaf gates when closed divert the hydrostatic forces to the lock walls. This makes the sector gates very efficient for spanning long distances. This proposed alternative would be similar to the New Bedford Sector Gates which are in use in New Bedford, MA (**Figure 2**).

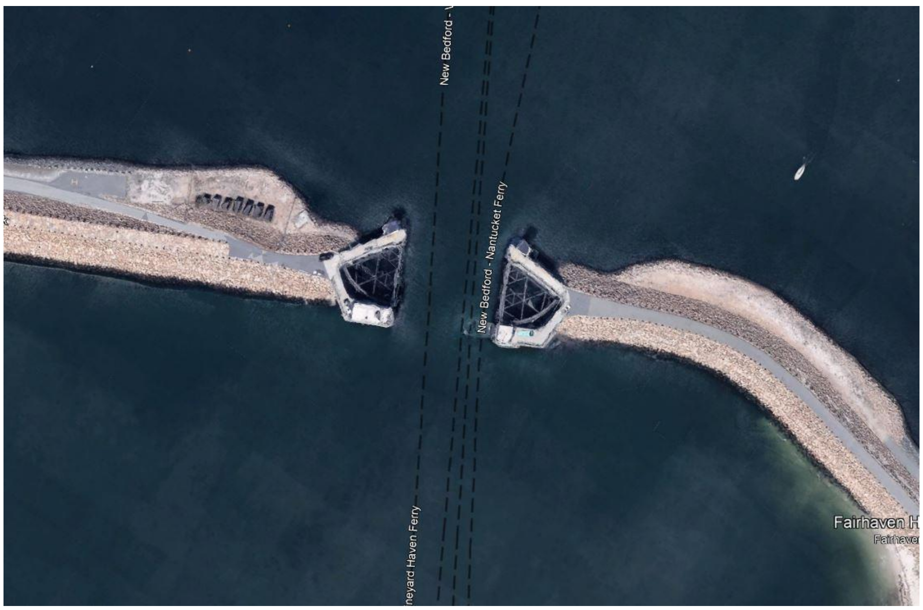


Figure 2: New Bedford Hurricane Barrier

3.5 Middlebridge Hurricane Barrier

Historical records and past flood damages have occurred along the Narrow River which is fed from waters in Narragansett Bay. The Narrow River is a tidal inlet between the towns of North Kingstown, South Kingstown and Narragansett and includes several properties along the waterfront susceptible to flooding and inundation during storm events. Middlebridge Road runs parallel to the Narrow River in South Kingstown and then crosses over a bridge to Narragansett where Middlebridge Road leads to Route 1A. A flood protection system for the area would consist of a floodwall to either side of the Narrow River Bridge and integrate a stop log structure underneath the existing bridge. The existing bridge was built to withstand 100-year storm water elevation levels but not 500-year levels and therefore the proposed hurricane barrier was designed for target elevations of 10.13 ft NAVD88. The existing clearance beneath the bridge only permits small recreational vessels such as kayaks as the water depth is minimal (approximately.

2 to 3 ft). A structure would be built into the existing bridge and contain slots to install stop logs during storm events. The width of opening would be approximately 30 ft in order to maintain marine traffic. The west wingwall would utilize an existing cleared pathway along the shoulder of Middlebridge Road in South Kingstown and the east wingwall would be constructed along the shoulder of Middlebridge Road in Narragansett.

3.5.1 Real Estate Requirements

Future design and planning activities would need to address real estate concerns such as a possible interference with a historical landmark in the construction of the floodwall in South Kingstown. There are private properties at either end of the bridge and coordination would be required during construction to ensure access. The floodwall for the east wingwall will be located along the shoulder of Middlebridge Road in Narragansett.

3.5.2 Construction Plans

For the Middle Bridge location, the USGS surficial soil quadrangle data and the RIDOT Middle Bridge No. 14 drawings indicate soft organic silt soils between 0 and 10 ft BGS. Below the organic silt is sandy silt typically between 10 ft and 50 ft. Bedrock was not encountered by the boring logs at this site. Because of the soft soils and relatively shallow bedrock, the team opted to use 35-ft long 24-inch inboard and outboard HP piles. The pile spacing was determined to be 10-ft on center. Where a gate structure is required, piles of no more than 15 degrees batter were allowed. In addition, the sandy soils in this area cause seepage and uplift concerns. Therefore, a 10-ft vinyl sheet was included along the centerline as a seepage cutoff.

3.5.3 Structural

A concrete T-wall was proposed to be constructed on the land portion of the barrier. This T-wall would continue along the upstream side of the bridge. There would be a stoplog structure integrated into the T-wall to allow stoplogs to be inserted in a high flood event. Marine traffic at this site is limited and only recreational kayaks and canoes pass under the bridge. The stoplog structure proposed was reinforced concrete with 6- HSS 22X22X5/8 sections that would be installed by a work barge ahead of a storm.

3.6 Non-Structural (Floodproofing & House Elevations)

The Recommended Plan includes 290 residential structures were identified for elevating. Those homes which do not have a basement, including mobile homes, will be elevated using lifting jacks and supported on temporary cribbing while temporary utilities are provided until the existing or new utilities are hooked up. A new concrete foundation (CMU or similar) will be constructed to the desired elevation, in addition to, any utility equipment located outside the home or basement (heating, ventilation, air conditioning, electrical, fuel etc.) will require individual raised mounting platforms or be re-located to the first floor. Houses which contain basements will require additional measures to ensure all living space is floodproofed per local building codes. Existing basement walls will need to be evaluated for structural integrity and impermeability, as well as any openings (windows, vents, other utilities) will need to be removed and/or re-routed. It may be necessary to add structural bracing to basement walls to improve stability while the structure is raised. National Flood Insurance Program (NFIP) regulations specify several requirements regarding the foundation and basement walls such as structural analysis for buoyant and hydrostatic forces, which would be further examined during final design activities.

State and local building regulations provide additional guidance on the methods and requirements for elevating residential structures, including those with basements. Many of these regulations provide protection to the homeowners in the preservation of their existing homes such as continuity of utility service, permitting, and compliancy with building codes. Accessory buildings such as garages and sheds are considered low value by the NFIP and therefore are not included in the floodproofing efforts of residential structures.

A variety of non-residential structures were identified for floodproofing efforts including municipal buildings (fire, town, education, and utility), commercial use, restaurants, retail stores, and fuel stations. The Recommended Plan identified approximately 171 non-residential structures and 36 Critical Infrastructure facilities to receive floodproofing measures. As part of final design activities, the NFIP (FEMA P-936) recommends a structure-by-structure evaluation of floodproofing options including an assessment of the existing structure and associated utilities. In addition to, it should be expected that any dry floodproofing measure cannot be completely effective without human intervention to deploy and include proactive flood warning systems.

Dry floodproofing measures typically include the retrofit of an existing structure and can include measures such as continuous impermeable walls, sealing openings, backflow valves, flood shields and internal drainage systems. All measures require ongoing maintenance and human intervention to deploy during flood events. Typically, the retrofitting of existing exterior walls is only performed up to a height of 3 ft from the first-floor elevation due to structural concerns such as the buildup of hydrostatic loads from flood waters. A variety of materials and methods can be implemented to create a substantially impermeable wall such as applying a waterproof coating. Various other alternatives exist for impermeable walls and are to be considered during final design activities. Openings such as windows should be considered for filling in while exterior doors will require removable flood shields to be deployed during flood events. Protecting the water supply is also critical during flood events and backflow valves can be installed on both potable and non-potable water systems. Non-potable, gravity fed systems such as sewer and drainage piping can be sources for water infiltration when those systems are surcharged during floods and backflow valves will prevent both the flood and health hazard.

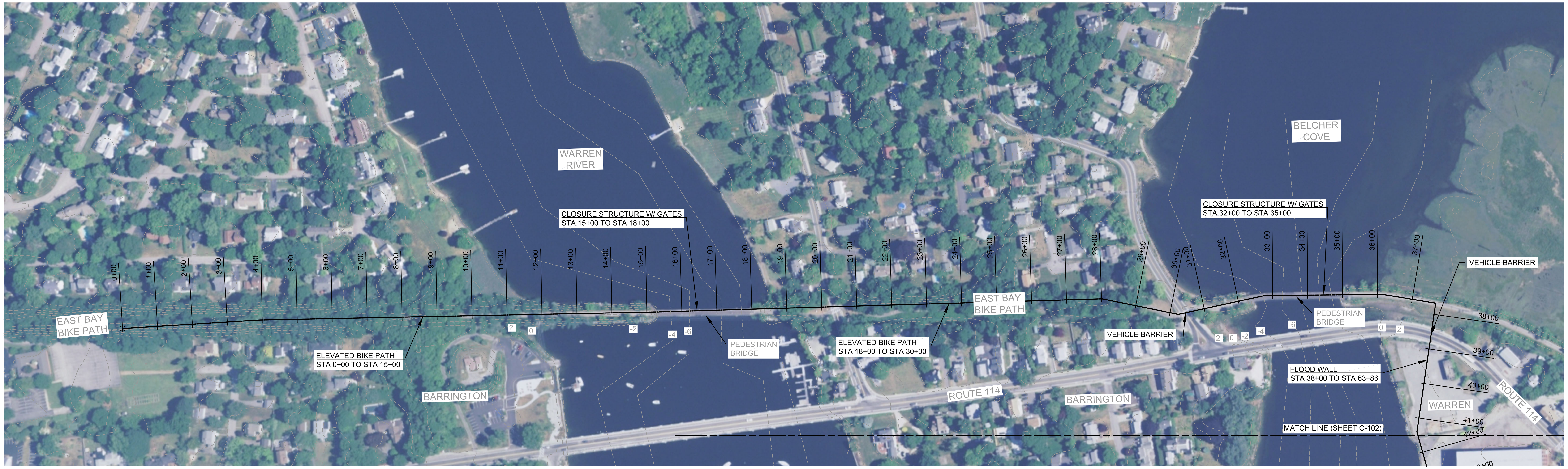
Various measures have potential to be implemented in order to obtain a cost-effective dry floodproofed structure. It is important to note, however, that every structure must maintain a Flood Emergency Operations Plan to include an Inspection and Maintenance Plan. Ultimately, the buildings' structure and functional use will determine the complexity of the measures and resulting operations plan. Efforts will also need to be done to ensure that floodproofing measures do not create any adverse effects or negative impacts on the surrounding areas and environment.

4.0 DESIGN SUMMARY

The most readily implementable and cost effective alternative to mitigate coastal storm risk for the study area was determined to be nonstructural improvements consisting of home elevations and floodproofing measures. Approximately 12,000 structures were included in the 100-yr floodplain for the 19 towns considered. During the pre-construction, engineering and design phase of the Recommended Plan, engineering activities will begin with a structure by structure assessment to determine appropiate measures. Design activies will consist of identifying the most efficient and cost effective methods to flood proof and/or elevate a structure. Impact to adjacent structures will be avoided by limiting construction work to within each property's boundaries, however, local municipality coordination will be required in order to plan material haul routes, utility connections, and miscellaneous work.

SECTION 5.0: DESIGN DRAWINGS

1. **BARRINGTON WARREN BARRIER (UPPER) –** *ID NUMBER C-101 & C-102*
2. **BARRINGTON WARREN BARRIER (LOWER) –** *ID NUMBER C-101*
3. **MIDDLEBRIDGE BARRIER -** *ID NUMBER C-101*
4. **NEWPORT LEVEE/FLOODWALL PLAN AND PROFILE VIEW -** *ID NUMBER C-101*
5. **NEWPORT LEVEE/FLOODWALL REAL ESTATE PLAN -** *ID NUMBER RE-001*
6. **NEWPORT HURRICANE BARRIER (LEVY AND T-WALL) -** *ID NUMBER S-101*
7. **NEW BEDFORD-HAIRHAVEN BARRIER (SECTOR-GATE)**

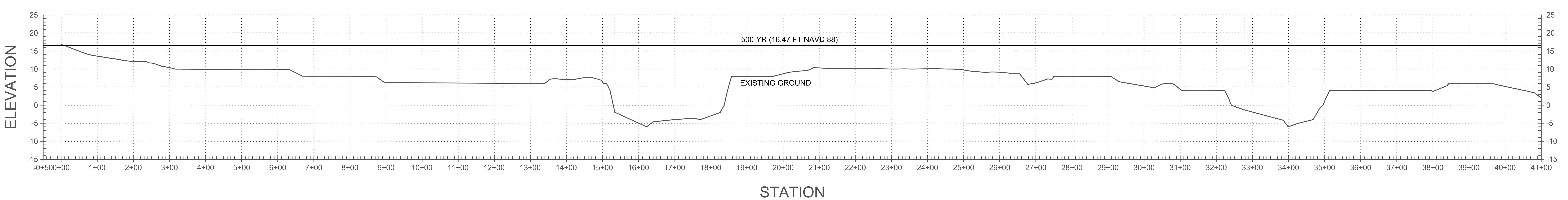


G1 UPPER WARREN RIVER HURRICANE BARRIER - SITE PLAN (STA 0+00 TO STA 41+00)

SCALE: 1" = 150'

GENERAL NOTES:

1. THE RHODE ISLAND STATE COORDINATE SYSTEM IS USED (HORIZONTAL DATUM: NAD83, VERTICAL DATUM: NAVD88).
2. SEE STRUCTURAL DRAWINGS FOR TYPICAL CROSS SECTIONS OF ELEVATED BIKE PATH, VEHICLE BARRIER, FLOOD WALL, AND CLOSURE STRUCTURE WITH GATES.



A1 PROFILE VIEW OF EXISTING GROUND (STA 0+00 TO STA 41+00)

SCALE: 1" = 15' (VERTICAL), 1" = 150' (HORIZONTAL)

US Army Corps of Engineers

MARK	DESCRIPTION	DATE

ISSUE DATE: JULY 2021
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
SHEET 1 OF 2

DESIGNED BY: ECR
DRAWN BY: ECR
CHECKED BY:
SUBMITTED BY:
SIZE: ANSI D
SCALE: VARIES

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

RHODE ISLAND COASTAL STORM RISK MANAGEMENT
FEASABILITY STUDY
WARREN & BARRINGTON, RHODE ISLAND

UPPER WARREN RIVER HURRICANE BARRIER
SITE PLAN
STA 0+00 TO STA 41+00

SHEET ID
C-101

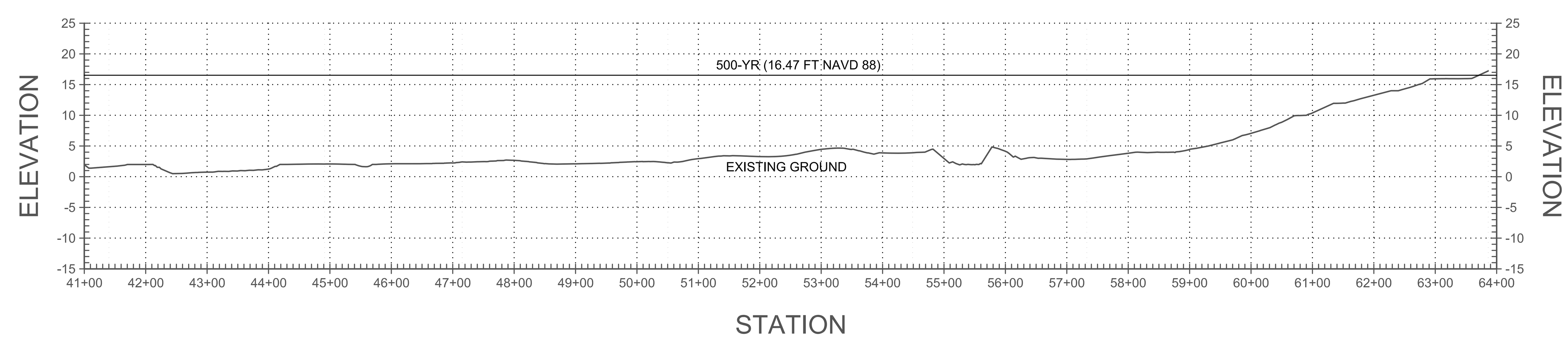
PLAN NORTH

F1 UPPER WARREN RIVER HURRICANE BARRIER - SITE PLAN (STA 41+00 TO STA 64+00)

SCALE: 1" = 150'

GENERAL NOTES:

1. THE RHODE ISLAND STATE COORDINATE SYSTEM IS USED (HORIZONTAL DATUM: NAD83, VERTICAL DATUM: NAVD88).
2. SEE STRUCTURAL DRAWINGS FOR TYPICAL CROSS SECTIONS OF ELEVATED BIKE PATH, VEHICLE BARRIER, FLOOD WALL, AND CLOSURE STRUCTURE WITH GATES.



A1 PROFILE VIEW OF EXISTING GROUND (STA 41+00 TO STA 64+00)

SCALE: 1" = 15' (VERTICAL), 1" = 150' (HORIZONTAL)

US Army Corps of Engineers

MARK	DESCRIPTION	DATE

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

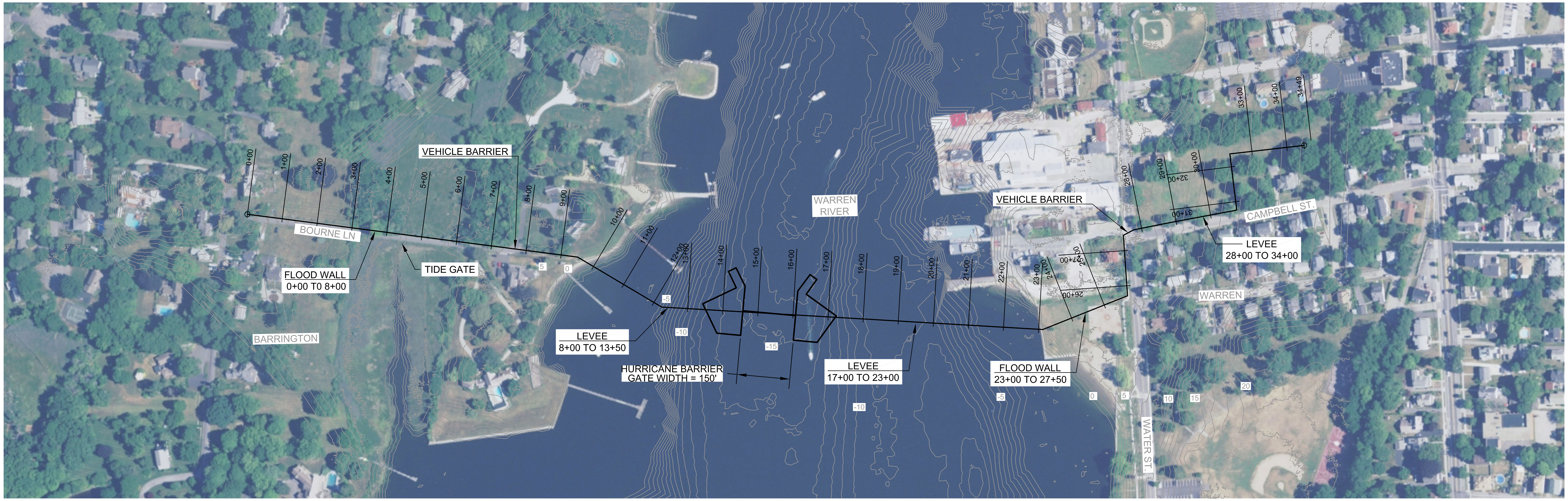
DESIGNED BY: ECR	ISSUE DATE: JULY 2021
DRAWN BY: ECR	SOLICITATION NO.:
CHECKED BY:	CONTRACT NO.:
SUBMITTED BY:	DRAWING CODE:
SIZE: ANSI 'D' / SCALE: VARIES	SHEET 2 OF 2

RHODE ISLAND COASTAL STORM RISK MANAGEMENT
FEASABILITY STUDY
WARREN & BARRINGTON, RHODE ISLAND

UPPER WARREN RIVER HURRICANE BARRIER
SITE PLAN
STA 41+00 TO STA 63+00

SHEET ID
C-102

%PRODUCTION DATA 1%
%PRODUCTION DATA 4%
%PRODUCTION DATA 3%
%PRODUCTION DATA 2%



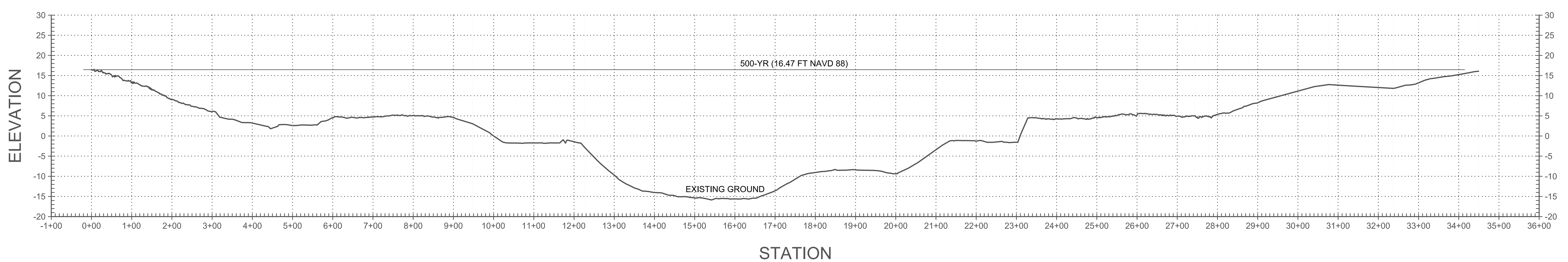
PLAN
NORTH

G1 LOWER WARREN RIVER HURRICANE BARRIER - SITE PLAN (STA 0+00 TO STA 34+00)

SCALE: 1" = 150'

GENERAL NOTES:

1. THE RHODE ISLAND STATE COORDINATE SYSTEM IS USED (HORIZONTAL DATUM: NAD83, VERTICAL DATUM: NAVD88).
2. SEE STRUCTURAL DRAWINGS FOR TYPICAL CROSS SECTIONS OF FLOOD WALL, VEHICLE BARRIER, LEVEE AND HURRICANE BARRIER.



A1 PROFILE VIEW OF EXISTING GROUND (STA 0+00 TO STA 34+00)

SCALE: 1" = 15' (VERTICAL), 1" = 150' (HORIZONTAL)

US Army Corps of Engineers®

MARK | DESCRIPTION | DATE

ISSUE DATE: JULY 2021
SOLICITATION NO.:
CONTRACT NO.:
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SHEET 1 OF 1
DESIGNED BY: ECR
DRAWN BY: ECR
CHECKED BY:
SUBMITTED BY:
SIZE: ANSI 'D'
SCALE: VARIES

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

RHODE ISLAND COASTAL STORM RISK MANAGEMENT
FEASABILITY STUDY
WARREN & BARRINGTON, RHODE ISLAND

LOWER WARREN RIVER HURRICANE BARRIER
SITE PLAN
STA 0+00 TO STA 34+00

SHEET ID
C-101

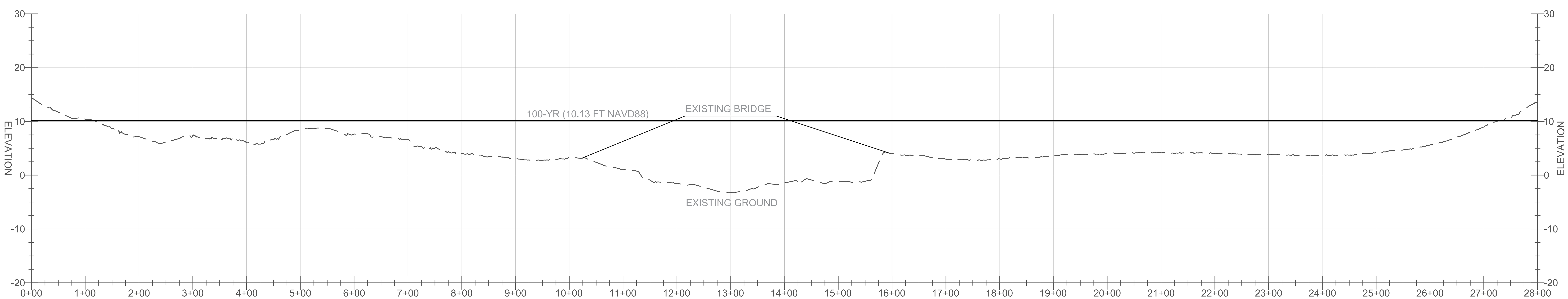
%PRODUCTION DATA 1%
%PRODUCTION DATA 4%
%PRODUCTION DATA 3%
%PRODUCTION DATA 2%

G1 MIDDLEBRIDGE HURRICANE BARRIER - SITE PLAN (STA 0+00 TO STA 28+20)

SCALE: 1" = 100'

GENERAL NOTES:

1. THE RHODE ISLAND STATE COORDINATE SYSTEM IS USED (HORIZONTAL DATUM: NAD83, VERTICAL DATUM: NAVD88).
2. SEE STRUCTURAL DRAWINGS FOR TYPICAL CROSS SECTIONS OF FLOOD WALL AND CLOSURE STRUCTURE WITH STOP LOGS.



A1 PROFILE VIEW OF EXISTING GROUND (STA 0+00 TO STA 28+20)

SCALE: 1" = 10' (VERTICAL), 1" = 100' (HORIZONTAL)

0 100' 200'

0 10' 20'

US Army Corps of Engineers

MARK | DESCRIPTION | DATE

DESIGNED BY: ECR
DRAWN BY: ECR
CHECKED BY:
SUBMITTED BY:
SIZE: ANSI D
ISSUE DATE: JULY 2021
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
SHEET 1 OF 1
SCALE: VARIES

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

RHODE ISLAND COASTAL STORM RISK MANAGEMENT
FEASABILITY STUDY
SOUTH KINGSTOWN & NARRAGANSETT, RHODE ISLAND

MIDDLEBRIDGE HURRICANE BARRIER
SITE PLAN
STA 0+00 TO STA 28+20

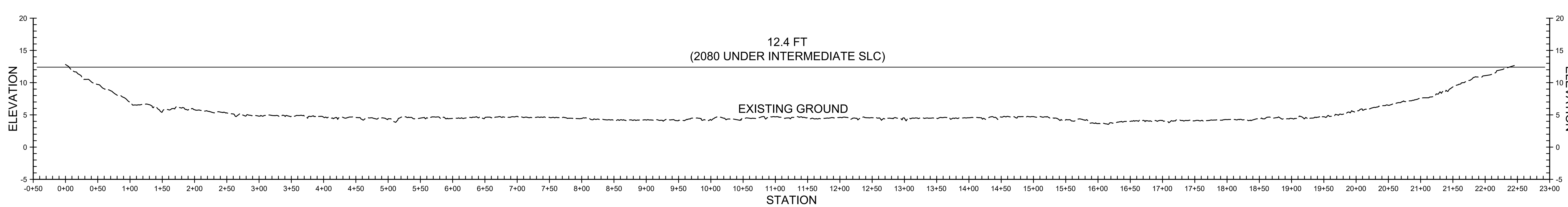
SHEET ID
C-101

%PRODUCTION DATA 1%
%PRODUCTION DATA 4%
%PRODUCTION DATA 3%
%PRODUCTION DATA 2%

GENERAL NOTES:

1. THE RHODE ISLAND STATE COORDINATE SYSTEM IS USED (HORIZONTAL DATUM: NAD83, VERTICAL DATUM: NAVD88)
2. RE-LOCATE APPROX. 1,300 LF OF STORMWATER PIPING (18" DIA.) INTO WELLINGTON AVE RIGHT-OF-WAY. RE-LOCATION WILL REQUIRE TRENCHING AND PATCHING OF PAVEMENT.
3. CONSTRUCT BELOW GROUND PUMP STATION (480 CFS).

C1 **SITE PLAN**
SCALE: 1" = 100'



A1 **PROFILE**
SCALE: HORIZONTAL 1" = 50'
VERTICAL 1" = 5'

0 50' 100'
0 5' 10'

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE

ISSUE DATE: APRIL 2021
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
SHEET 1 OF 1

DESIGNED BY: E.ROSENBERG
DRAWN BY: E.ROSENBERG
CHECKED BY:
SUBMITTED BY:
SIZE: ANSI D
SCALE: 1"=100'

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

RHODE ISLAND COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY
NEWPORT, RHODE ISLAND

PLAN & PROFILE VIEW
WELLINGTON AVE.
ALIGNMENT W/ VEHICLE CLOSURE BARRIER

SHEET ID
C-101

PLANNING PHASE

GENERAL NOTES:

1. THE PARCEL MAPPING DATA (PARCEL ID, OWNERSHIP, AND PROPERTY LINES) SHOWN ON THE SITE PLAN WAS OBTAINED FROM THE CITY OF NEWPORT, RI GIS MAPPING DATABASE.
2. A PERMANENT EASEMENT IS REQUIRED FOR THE ENTIRE FOOTPRINT OF THE PROPOSED LEVEE AND FLOOD WALL.
3. A TEMPORARY EASEMENT IS REQUIRED DURING CONSTRUCTION FOR THE EXTENTS SHOWN IN ORDER TO CONDUCT CONSTRUCTION OPERATIONS, MOBILIZE HEAVY EQUIPMENT, AND PROVIDE SAFE SETBACKS FROM THE WELLINGTON AVE. RIGHT-OF-WAY. REPAIR AND MAINTENANCE ACTIVITIES WILL UTILIZE THE SAME EXTENTS DURING FUTURE WORK.
4. CONSTRUCTION STAGING AND STOCKPILING AREAS SHOWN AS INDICATED WILL REQUIRE A TEMPORARY EASEMENT THROUGHOUT THE CONSTRUCTION PROCESS.

REAL ESTATE DATA

PARCEL ID	PARCEL AREA (SF)	PERMANENT EASEMENT AREA (SF)	TEMPORARY EASEMENT AREA (SF)
39-009	218,671	33,032	23,810
42-007	73,180	18,584	22,192
35-276	5,260	910	955
39-034-4	106,284	1,600	6,572
WELLINGTON AVE.	N/A	575	32,870
COLUMBUS AVE.	N/A	892	1,020

LEGEND

PROPERTY LINE	
SETBACK LIMITS	
PERMANENT EASEMENT (SEE NOTE 2)	
TEMPORARY EASEMENT - CONSTRUCTION & REPAIRS/MAINTENANCE (SEE NOTE 3)	
TEMPORARY EASEMENT - STAGING AND STOCKPILING AREA (SEE NOTE 4)	

N

0 100' 200'

A1 REAL ESTATE SITE PLAN

SCALE: 1" = 100'

US Army Corps of Engineers®

MARK | DESCRIPTION | DATE

ISSUE DATE: MAY 2021
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
SHEET 1 OF 1

DESIGNED BY: E.ROSENBERG
DRAWN BY: E.ROSENBERG
CHECKED BY:
SUBMITTED BY:
SIZE: ANSI D
SCALE: 1"=100'

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

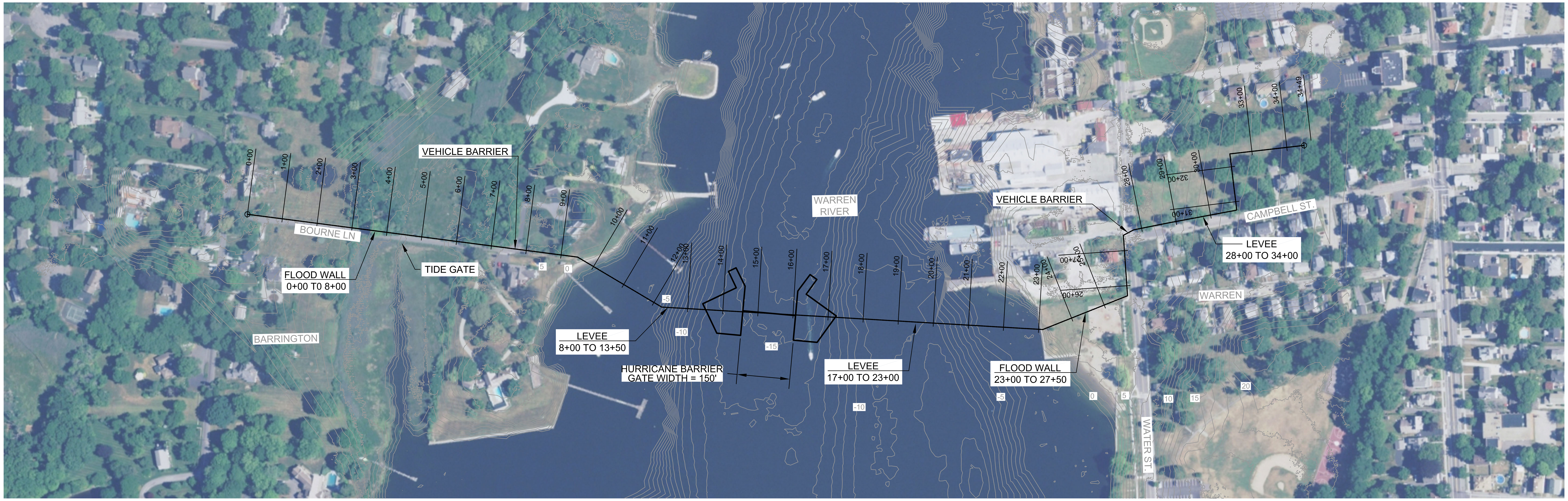
RHODE ISLAND COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY
NEWPORT, RHODE ISLAND

REAL ESTATE PLAN
CONSTRUCTION ACCESS & STAGING

SHEET ID

RE-001

PLANNING PHASE



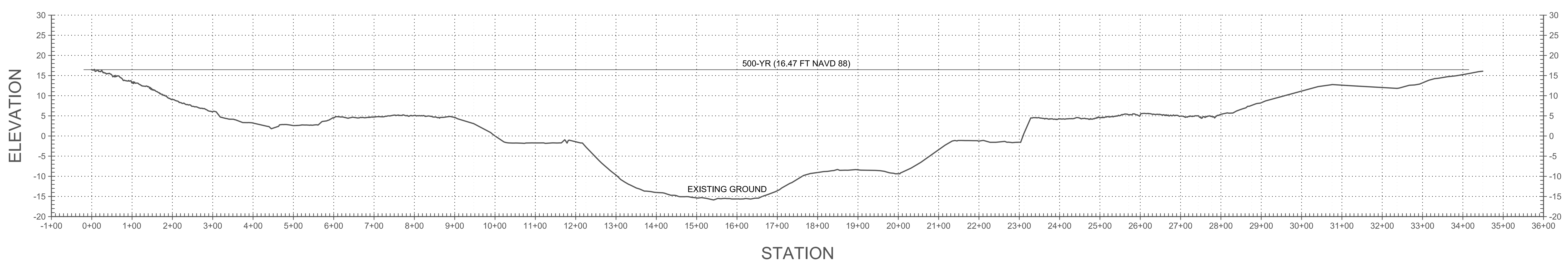
PLAN NORTH

G1 LOWER WARREN RIVER HURRICANE BARRIER - SITE PLAN (STA 0+00 TO STA 34+00)

SCALE: 1" = 150'

GENERAL NOTES:

1. THE RHODE ISLAND STATE COORDINATE SYSTEM IS USED (HORIZONTAL DATUM: NAD83, VERTICAL DATUM: NAVD88).
2. SEE STRUCTURAL DRAWINGS FOR TYPICAL CROSS SECTIONS OF FLOOD WALL, VEHICLE BARRIER, LEVEE AND HURRICANE BARRIER.



A1 PROFILE VIEW OF EXISTING GROUND (STA 0+00 TO STA 34+00)

SCALE: 1" = 15' (VERTICAL), 1" = 150' (HORIZONTAL)

US Army Corps of Engineers®

MARK | DESCRIPTION | DATE

ISSUE DATE: JULY 2021
SOLICITATION NO.:
CONTRACT NO.:
DRAWING CODE:
SHEET 1 OF 1

DESIGNED BY: ECR
DRAWN BY: ECR
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SUBMITTED BY:
SIZE: ANSI D
SCALE: VARIES

U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

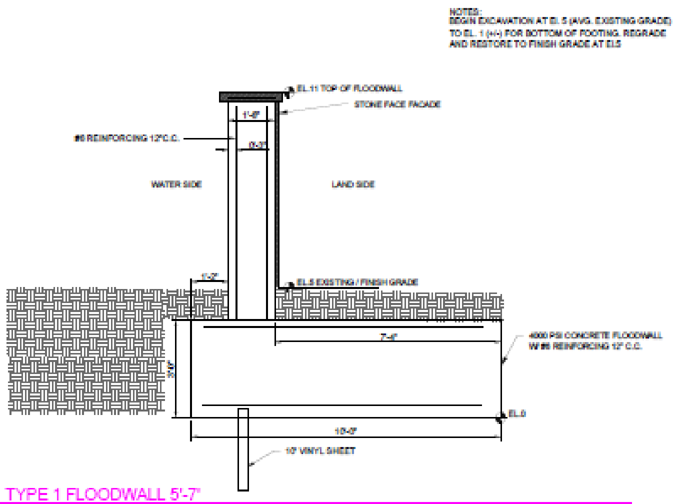
RHODE ISLAND COASTAL STORM RISK MANAGEMENT
FEASABILITY STUDY
WARREN & BARRINGTON, RHODE ISLAND

LOWER WARREN RIVER HURRICANE BARRIER
SITE PLAN
STA 0+00 TO STA 34+00

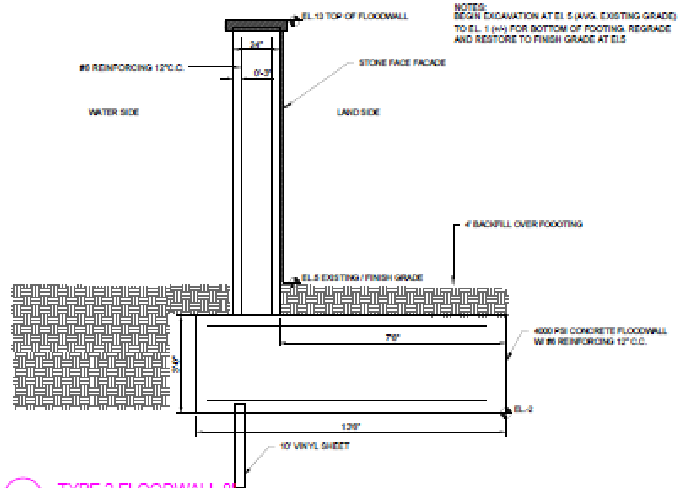
SHEET ID
C-101

%PRODUCTION DATA 1%
%PRODUCTION DATA 4%
%PRODUCTION DATA 3%
%PRODUCTION DATA 2%

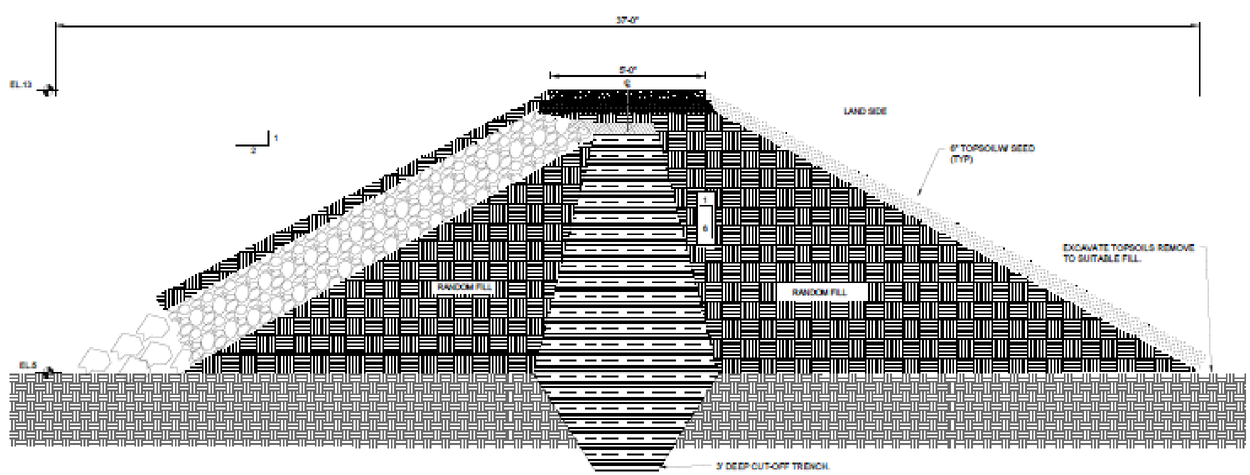
US Army Corps of Engineers



E2 TYPE 1 FLOODWALL 5'-7"
SCALE: 1/2"=1'



E2 TYPE 2 FLOODWALL 8'
SCALE: 1/2"=1'



A2 LEVY CROSS-SECTION STA.14+00-32+00
SCALE: 1/2"=1'

MARK	DESCRIPTION	DATE

DESIGNED BY: DMS	ISSUE DATE: FEB 2021
DRAWN BY: DMS	SOLICITATION NO.:
CHECKED BY:	CONTRACT NO.:
SUBMITTED BY:	DRAWING CODE:
SIZE: ANSI D / SCALE: 1/2"=1'	SHEET 1 OF 1

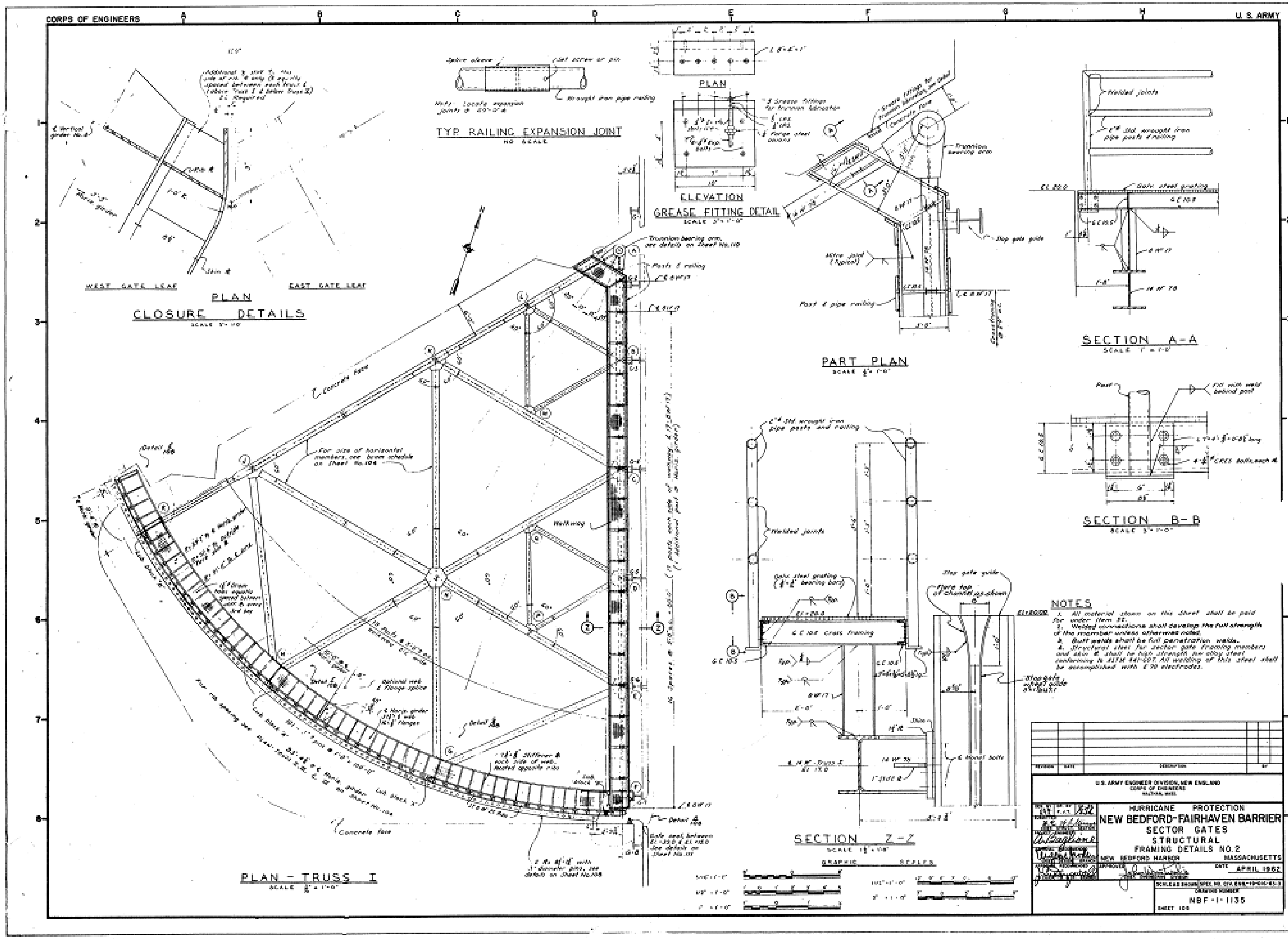
U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT
696 VIRGINIA ROAD
CONCORD, MA 01742-2751

NEWPORT, RHODE ISLAND
COASTAL STORM RISK MANAGEMENT
FEASIBILITY STUDY

STR SECTION VIEWS
NEWPORT - STREETSIDE ALIGNMENT

SHEET ID
S-101

PLANNING PHASE



CORPS OF ENGINEERS
U. S. ARMY
PLAN
CLOSURE DETAILS
WEST GATE LEAF
EAST GATE LEAF
TYP RAILING EXPANSION JOINT
NO SCALE
PLAN
ELEVATION
GREASE FITTING DETAIL
PART PLAN
SECTION A-A
SECTION B-B
SECTION Z-Z
PLAN - TRUSS I
Walkway
Concrete face
GRAPHIC SCALES
NOTES
1. All material shown on this sheet shall be paid for under item 32.
2. Welded connections shall develop the full strength of the member unless otherwise noted.
3. Butt welds shall be full penetration welds.
4. Structural steel for sector gate framing members and skin ℓ shall be high strength low alloy steel conforming to ASTM A441-60T. All welding of this steel shall be accomplished with E 70 electrodes.
REVISION
DATE
DESCRIPTION
BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
HURRICANE PROTECTION
NEW BEDFORD-FAIRHAVEN BARRIER
SECTOR GATES
STRUCTURAL
FRAMING DETAILS NO. 2
NEW BEDFORD HARBOR
MASSACHUSETTS
APPROVED
DATE
APRIL 1962
DRAWING NUMBER
NBF-1-1135
SHEET 105