Memo

GEI Consultants

To: Mr. Samuel J.P. Jensen, P.E.
From: Stephen T. Hennessy, EIT, Russell Titmuss, PE
Date: 4/12/2019
Re: Sandwich Boardwalk
GEI Project 1802840

Purpose

The Town of Sandwich is proposing to reconstruct the Sandwich boardwalk and is seeking to improve the boardwalk resiliency. The existing boardwalk has suffered repeated damage over the years and the Town is seeking a more durable replacement with lower maintenance requirements. The purpose of this memorandum is to provide a review of a number of different conceptual design options for the boardwalk together with their estimated construction costs, constructability, environmental impacts, and permitting requirements. Information included in this memo includes a review of different boardwalk widths and elevations, alternative railing types and details, and different foundation type details. The goal of this study is to identify a recommended alternative for construction.

Project Background

GEI Consultants Inc., was retained through the Town of Sandwich engineering department to develop a conceptual design to rebuild the 1,500-foot-long Sandwich Boardwalk which would improve its resistance to repeated flood damage while maintaining the historic look and character. On February 6, 2018, ***GEI*** personnel performed a condition inspection of the timber boardwalk including the boardwalk extension to the Town Neck Beach Parking Lot and the Dune Walkway. The purpose of the inspection was to determine the existing condition of the boardwalk *(refer to the previous report of February 26, 2018 for the full existing conditions of the boardwalk).* On June 22, 2018, ***GEI*** personnel performed a topographic Drone Survey to confirm elevations and layout, of existing boardwalk and salt marsh area. This survey was performed using a DJI Phantom 4 Pro drone, and a Trimble GPS unit.

An initial review of potential improvements was also performed which included evaluation of uplift and lateral forces on the boardwalk during storm events where the surrounding marsh is flooded *(refer to the previous report of April 12, 2018 for the resiliency study of the boardwalk).* The resiliency review identified the current deck elevation varies between +7 and +10 NAVD88. Raising the deck elevation of the boardwalk between 5 to 8 feet would help prevent wind and wave damage to the superstructure in future storm events.

Design Criteria

Dimensions

Alignment: The proposed boardwalk is to follow the existing alignment along the boardwalk from Boardwalk Road and Wood Avenue towards Town Neck Beach.

Width: The proposed width is to be reviewed. The existing width of 5 feet is adequate for safe access by pedestrians only, but the boardwalk is very long, and Town safety personnel have identified the need for improved and faster access in the event of an emergency. Use of a Polaris vehicle weighing approximately 3600 lbs. would require an increased total clear width of 6 feet for safe passage of the vehicle. In addition to the wider deck, a turn-around area would be located approximately mid-length of the main boardwalk and would serve as an area for the vehicle to reverse directions safely as well as an additional overlook station for

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pedestrians. A number of overlooks will also be included in each of the options, which locally increase the width by 2 feet to allow people to stand and enjoy the view or for slower moving pedestrians to step to one side.

Slope, etc.: MAAB and ADA guidelines are to be followed for boardwalk slope, railing, and decking options *(refer to April 12, 2018 Resiliency report for general code compliance).* General criteria are as follows:

- No vertical change greater than ¼ inch
- Width – minimum 48 inches
- Slopes 1:20 or less can be unlimited length
- Slopes steeper than 1:20 are ramps and are limited to 30 inch rise between landings and require grab rails
- Minimum landing length is 60 inches
- Edge protection is required on all ramps

Deck Elevation

Current FEMA mapping shows that the boardwalk is located in an AE zone with a base flood elevation of +15 NAVD. The existing salt marsh elevation for the majority of the site is between +4 NAVD and +5 NAVD but the ground elevations rise at the existing dunes to an elevation of approximately +19 NAVD. Existing boardwalk deck elevations vary between +7 and +8 NAVD for the majority of the length but start rising from the northern bridge crossing to elevation +10 NAVD and, then, over the dunes.

For protection against future storms, it would be desirable to raise the deck fully above the FEMA base flood elevation, but this would require raising the structure by 7 to 8 feet and would significantly change user access and the "feel" of the boardwalk. Future sea level rise should also be considered for the life of the structure and a reconstructed timber structure would be expected to have a design life of 30 years. Sea level rise over this period is estimated to be between 0.5 to 2.0 feet based on intermediate and high rates from both NOAA and USACE prediction curves. If this additional amount is included, the deck would be raised 8 to 10 feet higher than the existing deck. However, raising the deck by this amount would result in a structure 10 to 12 feet above the marsh which would have a number of impacts:

- Much longer ramps for ADA compliance.
- The ramp section below the FEMA elevation by the Boardwalk Beach parking lot would be up to 200 feet long and would remain susceptible to damage.
- It would significantly change the "feel" of the boardwalk for users.
- It would be very difficult to provide an accessible route from the boardwalk to the salt marsh and Mill Creek.
- The structure would be much more obtrusive.

A lower deck elevation could be considered using a higher probability flood elevation. The FEMA flood insurance study publishes data for 1% annual chance, 2% annual chance and 10% annual chance still water elevations. FEMA base flood elevations are established using the 1% annual chance still water elevation and include the effects of wave setup which further increases water elevations. The FEMA transect line for the area of Sandwich boardwalk shows a 10% annual chance still water elevation of +8.4 NAVD compared to a +13.5 NAVD 1% water elevation. Estimated wave heights from the 1.5 Mile Fetch are conservatively expected to be up to 2.7 feet total with a top of crest approximately 2 feet above the still water elevation. Top of wave crest elevation is estimated to be +10.4 NAVD. If an allowance for sea level rise is included, a proposed deck elevation of +12 NAVD would significantly reduce the risk of future storm damage.

Live Load

The boardwalk should be designed for 100 pounds per square foot (PSF) live loading for pedestrian use to comply with MA State Building code. Use of a Polaris vehicle (Fire Dept. Emergency Vehicle) weighing 3600 lbs. distributed over its wheelbase, has also been considered in the alternatives reviewed below.

Wave loads on the structure have been previously estimated based on the assumption that the deck will be partially submerged during severe storm events. Uplift loads of 2000 lbs. per pile foundation, and horizontal loads of 40 pounds per linear foot on the superstructure should be considered but re-evaluated when the final deck elevation has been confirmed.

Miscellaneous

The existing engraved planks will be removed and preserved for use as railing or similar option if deemed structurally intact for re-use. The Town can elect to retain the boards and distribute them back to the families who had paid for them previously if they are not to be incorporated into the new design.

Foundation Options and Recommendations:

A limited geotechnical investigation has been performed consisting of two soil borings and three geoprobes. A geotechnical report has been prepared and a copy is attached. The investigation found that the majority of the existing boardwalk has very soft organic soils down to a depth of 30 feet or more below grade with a thin layer of sand at the surface. The thin layer of sand has functioned as a bearing layer for the existing boardwalk but will not provide the additional support necessary to improve long term resilience. The existing timber posts provide very limited lateral and uplift load capacity and a stronger foundation is required. The two alternatives to be considered are timber piles or helical piles.

Timber Pile Foundation:

Timber piles would be treated softwood or greenheart piles with an approximate 12-inch diameter driven to capacity using a crane mounted pile hammer. The estimated required tip depth would be over 40 feet below grade to provide the capacity necessary for applied loads and uplift forces. This would require piles approximately 55 feet in length. They are an effective option for the boardwalk foundation and would provide a durable foundation. Estimated construction cost is $4000 per pile. Potential advantages and disadvantages of pile foundations are as follows:

Advantages	Disadvantages
• Durable foundation • Higher vertical and horizontal load capacity • Potential for longer spans up to 12 feet	• Difficult to construct in intertidal environment over salt marsh • Higher cost per pile

Helical Pile Foundation:

Helical piles would be a steel shaft (tube or square bar) with a series of helical vanes near the bottom tip. They can be installed with lightweight equipment consisting of a torque motor mounted on a Bobcat or similar skid steer. The estimated length of each helical pile is assumed to be approximately 35 feet. As discussed in the geotechnical report, a pilot program should be considered to determine if shorter helical piles could be used for the relatively low loads. Estimated construction cost is $1500 per helical.

Advantages	Disadvantages
• Durable foundation • High vertical load capacity including increased uplift capacity • Potential for longer spans up to 10 feet • Smaller equipment required for installation easier to construct over salt marsh • Lower cost per pile	• Lower lateral load capacity due to post connection at mudline • Additional cross bracing may be required for stability • Steel components in salt water environment subject to corrosion

The geotechnical report summarizes the ground conditions and provides recommendations for foundation type. The majority of the site has a very thick layer of soft organic soils underneath a thin capping layer of sand. The report recommends the use of helical piles.

Railing Options:

Railings should be provided where the boardwalk deck will be more than 30 inches above the existing adjacent grade to provide fall protection. Timber railings have been recommended as the preferred option to the aluminum and glass alternatives in maintaining the existing boardwalk look.

Existing railing over Mill Creek bridge will be part of new construction and installed to match the deck elevation. A concern of the town is that the railings will provide pedestrians with a higher platform to jump from above creek crossings. The railings should be designed to limit potential falls from the boardwalk, as well as to prevent anyone from climbing over them.

Vertical Railing:

Horizontal Rails: Traditional horizontal timber rails between vertical posts along the length of boardwalk with appropriate edge and toe protection meeting MAAB and ADA guidelines. This type of rail is relatively simple to climb. Costs associated with the vertical timber railings are estimated to be approximately ($200/LF).

Vertical Picket infills: Vertical posts with horizontal bottom rail and top rail with vertical infill between along the length of boardwalk with appropriate edge and toe protection meeting MAAB and ADA guidelines. This type of rail is slightly harder to climb but timber infill has a smaller cross section and is more easily vandalized. Costs associated with the vertical timber railings are estimated to be approximately ($200/LF).

Steel Mesh infill: Vertical posts with horizontal bottom rail and top rail and the use of galvanized steel mesh as infill is also possible. The mesh grid spacing should be small to limit the ability to climb the railing and a narrow or pointed triangular cap could also be used. Appropriate edge and toe protection meeting MAAB and ADA guidelines would also be incorporated. Costs associated with the vertical timber railings are estimated to be approximately ($200/LF).

Sloped Railings:

Sloping posts and horizontal rails along the length of boardwalk with appropriate edge and toe protection meeting MAAB and ADA guidelines. The sloping posts will provide approximately 2 to 3 feet greater width at the top rail elevation. This larger width at the top of railing will provide users with an "open feel" along the length of the boardwalk, similar to the existing boardwalk without railings. This type of railing is very easily climbed. Costs associated with the sloped timber railings are estimated to be approximately ($250/LF).

Boardwalk Conceptual Design Alternatives

Options A, B, C, and D listed below provide combinations of deck elevation and widths based on previous discussions with the Town of Sandwich. Each option includes a summary list of advantages and disadvantages and a matrix of construction cost estimates is provided at the end for each Option with either a piled or helical foundation.

Option A: Match Existing Boardwalk Profile and Width

Option A provides replacement of the existing boardwalk to match existing with the addition of railings. Bent spacing will be increased to 10 feet for helical foundations and 12 feet for piled foundations. Keeping the existing deck width will not allow for use by emergency or maintenance vehicles. A boardwalk constructed to match elevation is at risk of frequent damage from storm events. This option includes installing a railing although some lower height areas may not require a railing.

Advantages	Disadvantages
• Lower cost per bent (less width) • Historical "low profile" look • Easier access to Mill Creek from bridge	• High risk of storm damage • Does not consider future sea level rise • Higher cost of maintenance (deck elevation within flood and wave zone) • No access for emergency vehicles

Option B: Match Existing Boardwalk Profile and Increase Width

Option B provides replacement of the existing boardwalk matching existing deck elevation but, with a widened deck. The deck will increase from the existing 5' width, to a 6' width. Bent spacing will be increased to 10 feet for helical foundations and 12 feet for piled foundations. Widening the deck profile allows access for emergency and maintenance vehicles and a turnaround should be included mid-length. This option includes installing a railing although some lower height areas may not require a railing.

Advantages	Disadvantages
• Increased width allows for access by emergency vehicles • Historical "low profile" look • Widened deck profile improves lateral stability • Easier access to Mill Creek from bridge • Turnaround provides observation platform mid-boardwalk	• High risk of storm damage • Does not consider future sea level rise • Higher cost of maintenance (deck elevation within flood and wave zone)

Option C: Increase Boardwalk Elevation and Maintain Existing Width

Option C provides replacement of the existing boardwalk with an increased deck elevation of approximately +12 NAVD, while matching the existing deck width. Ramps will be provided from the existing parking lot elevations at the Boardwalk Beach parking lot and Town Neck Beach parking lot. Bent spacing will be increased to 10 feet for helical foundations and 12 feet for piled foundations. Keeping the existing deck width will not allow for emergency or maintenance vehicles. The increase in boardwalk elevation will reduce the risk of storm damage to the superstructure. Lower maintenance costs would be expected as a result, but some deck board replacement should be planned after major storm events.

Advantages	Disadvantages
• Increased elevation provides improved resiliency and includes an allowance for sea level rise • Less frequent maintenance schedule • Decreased sun-shading to salt marsh • Higher vantage points for observation of surrounding area	• Fall distance from railing is increased (higher deck elevation) • Limited access to salt marsh and Mill Creek • No access for emergency vehicles • Does not maintain historic "low profile" look

Option D: Increase Boardwalk Elevation and Width

Option D provides replacement of the existing boardwalk with an increased deck elevation of approximately +12 NAVD, while increasing the deck width from 5' to 6' wide. Ramps will be provided from the existing parking lot elevations at the Boardwalk Beach parking lot and Town Neck Beach parking lot. Bent spacing will be increased to 10 feet for helical foundations and 12 feet for piled foundations. This option will reduce the risk of storm damage to the superstructure, as well as provide access for emergency and maintenance vehicles. As for Option C, lower maintenance costs would be expected as a result of raising the deck, but some deck board replacement should be planned after major storm events.

Advantages	Disadvantages
• Increased elevation provides improved resiliency and includes an allowance for sea level rise • Increased width allows for access by maintenance and emergency vehicles • Less frequent maintenance schedule • Decreased sun-shading to salt marsh • Higher vantage points for observation of surrounding area • Observation platform mid-boardwalk	• Fall distance from railing is increased (higher deck elevation) • Limited access to salt marsh and Mill Creek • Does not maintain historic "low profile" look

Boardwalk Cost Estimates:

Cost estimates listed in the table below have been estimated based on the four conceptual design boardwalk alternatives. Each option includes the demolition and removal of the existing boardwalk, reconstruction of the timber boardwalk, and installation of foundations, and the railing options.

The foundation costs for these estimates assume the use of 35-foot helical piles for 10 foot bent spacing, and 60-foot helical piles for 12 foot bent spacing as recommended by the draft geotechnical engineering report *(refer to attached geotechnical engineering report)*.

Sloped railing costs are approximately 25-30% more per linear foot than the vertical railings, due to the increased labor and material costs associated with the angle of railings.

Demolition and removal efforts are expected to be approximately $200,000. Reconstruction of the foot bridges are expected to be approximately $200,000. For the widened deck profile, the turn-around location is proposed to be approximately an additional $70,000.

An allowance of 10% has been included for engineering and permitting all options and a 20% contingency has also been included.

	10' Bent Spacing - Vertical Railing	10' Bent Spacing - Sloped Railing	12' Bent Spacing - Vertical Railing	12' Bent Spacing - Sloped Railing
Option A - Existing Elevation & Existing Deck Width	$1,932,152	$2,018,852	$2,556,684	$2,643,384
Option B - Existing Elevation & Widened Deck Width	$2,071,672	$2,157,372	$2,682,340	$2,768,040
Option C - Increased Elevation & Existing Deck Width	$2,005,432	$2,091,132	$2,604,896	$2,690,596
Option D - Increased Elevation & Widened Deck Width	$2,143,952	$2,231,652	$2,742,380	$2,830,080

Permitting Considerations:

All four options are anticipated to require similar permit applications. Option A may be more straightforward because it is essentially reconstruction of existing. Anticipated permit applications include:

- US Army Corps of Engineers Pre-Construction Notification (GP3).
- MEPA Environmental Notification Form
- Chapter 91 License
- Town of Sandwich Conservation Commission Notice of Intent

A pre-application meeting with agencies should be considered to confirm regulatory concerns prior to filing applications. A shore bird time of year restriction on construction (April 1-August 31) may be imposed.

Recommendations:

Deck Elevation: (+12 NAVD88)

Although a higher deck elevation will reduce the risk of damage, an assessment of storm surge elevations and sea-level rise has been performed and it is recommended that the deck elevation be increased to a minimum elevation of +12 NAVD88. This elevation will provide a combination of resiliency and function, while maintaining some of the historic look. The reduced maintenance schedule will result in a lower cost over the lifespan of the structure which has been an ongoing problem in past years.

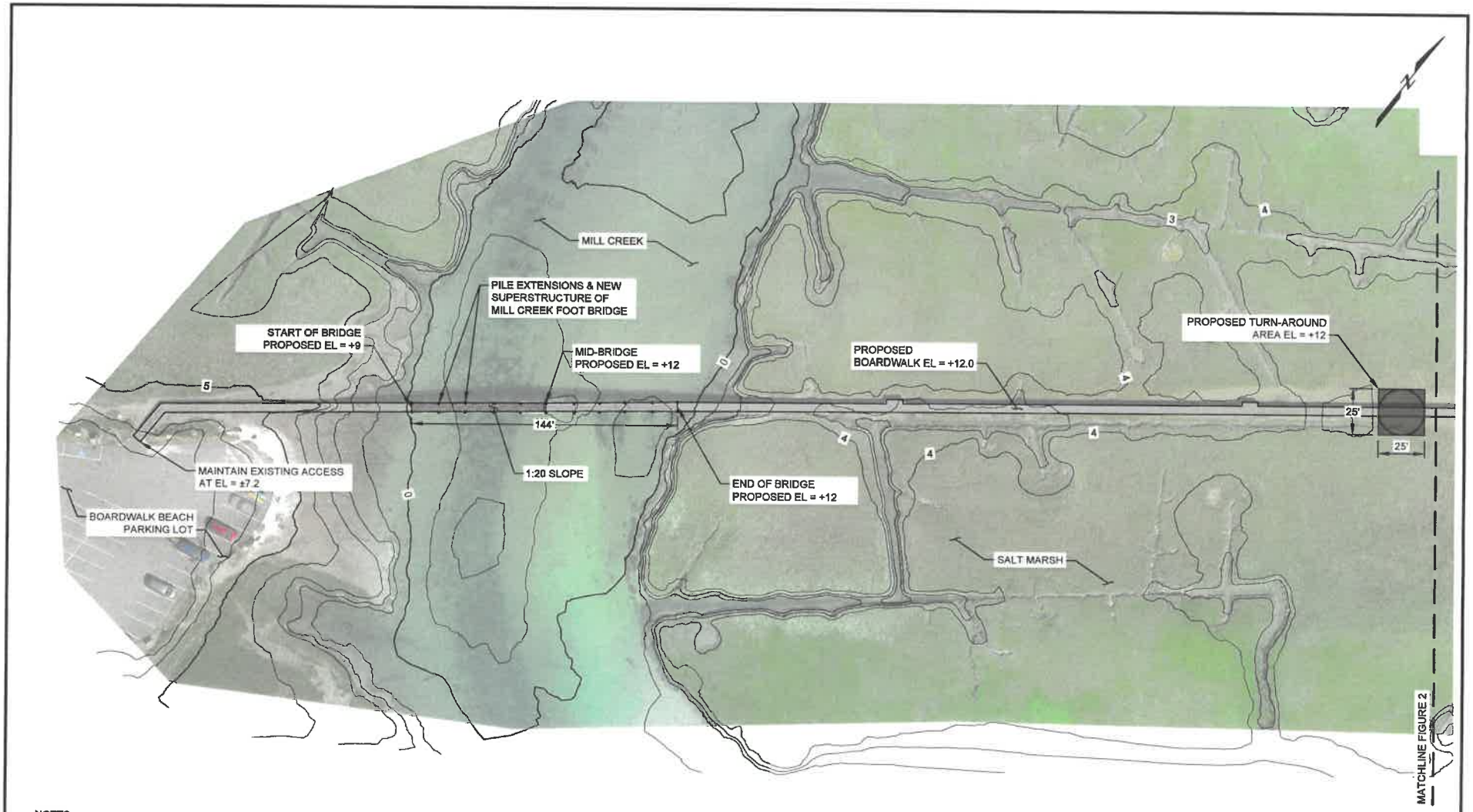
Deck Profile: (Widened 6-foot deck profile)

Widening the deck profile provides access for emergency vehicles such as the Polaris 6x6 vehicle currently in use by the Sandwich Fire Department. The 6-foot width of the boardwalk will also provide pedestrians with a more comfortable feel and functionality of passing and carrying any beach gear across the boardwalk. Included as an option in widening the deck profile is the addition of a turn-around platform for the Polaris, approximately 25 feet in diameter, to be located mid-span of the boardwalk. This platform will also serve as an observatory area for pedestrians and can incorporate historic drawings or planks from the removal of the existing boardwalk. The wider deck comes at a relatively low cost premium and is recommended.

Foundation: (Helical Piles)

The recommended foundation option is to use helical piles. It is recommended that a testing program for piles be performed along the boardwalk as noted in the geotechnical report. Helical piles will be easier to install than larger driven timber piles, as well as providing capacity against uplift, and maintaining a lower total structure cost. Installation of piles would require a large crane for installation leading to more significant construction impacts on the salt marsh.

Given the low cost premium for the increased width, we would recommend the use of **Option D – Increase Boardwalk Elevation and Width.**



NOTES:

SURVEY DATE: JUNE 22, 2018
SURVEY DATUM: MSL
BOARDWALK LENGTHS (APPROX.)
TOTAL BOARDWALK LENGTH = 1500'
MAIN BOARDWALK LENGTH = 1334'
MILL CREEK FOOT BRIDGE = 144'
SHORT SPAN FOOT BRIDGE = 23'

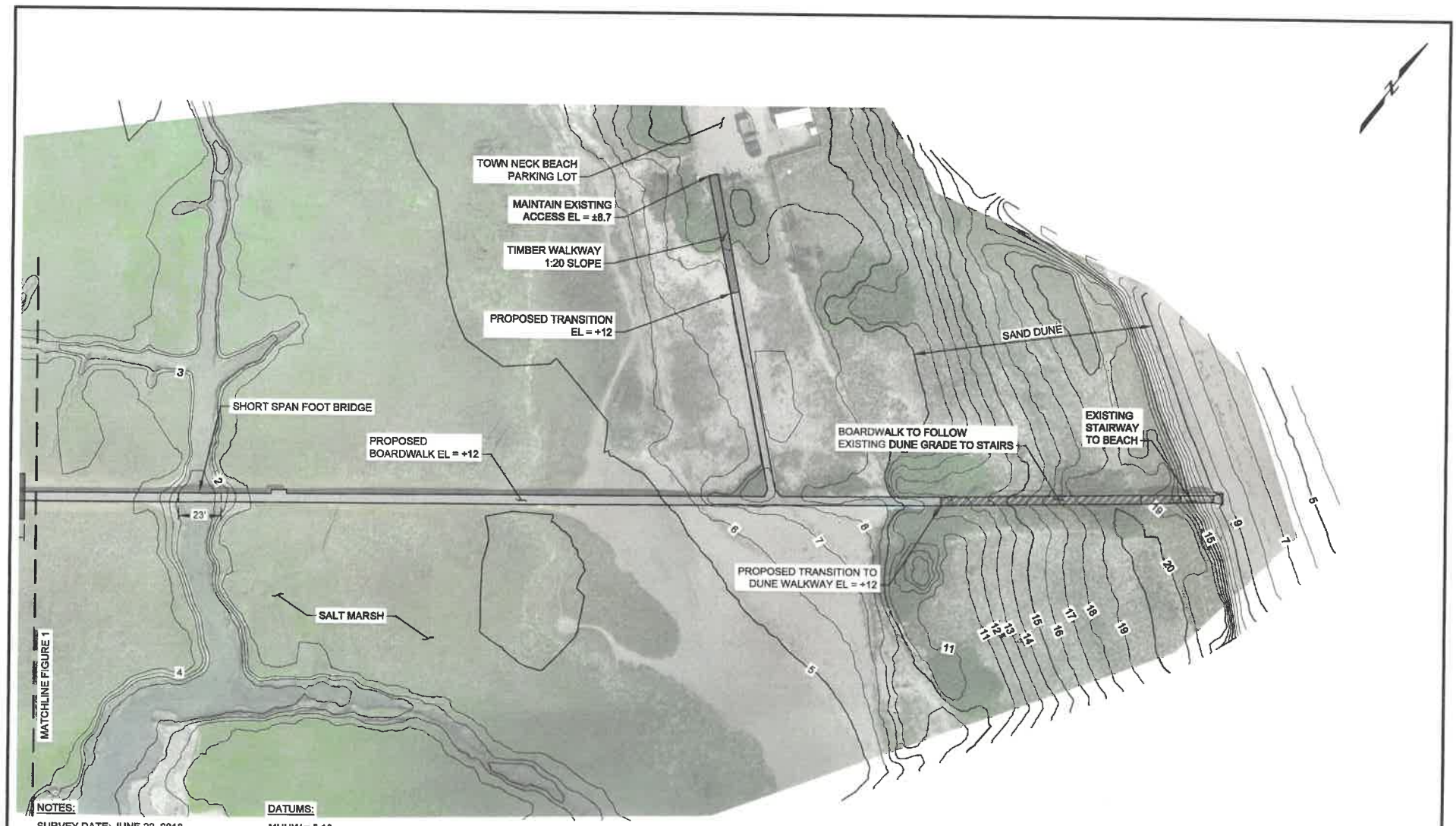
DATUMS:

MHHW = 5.18
MHW = +4.35
NAVD88 = +0.49
MSL = 0.0
MLW = -4.91
MLLW = -5.13

0 50 100
SCALE: 1" = 50'

Sandwich Boardwalk Restoration Sandwich Boardwalk Sandwich, MA	GEI Consultants	PROPOSED BOARDWALK PLAN
Town of Sandwich Sandwich, MA	Project 1802840	February 2019 Fig. 1

\\geiconsulta B:\Working\SANDWICH, TOWN OF\1802840 Sandwich Boardwalk Restoration\00_CAD\Figures\FIG.1-2 PROPOSED BOARDWALK ELEVATIONS.dwg - 2/19/2019



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0 50 100
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Sandwich Boardwalk Restoration
Sandwich Boardwalk
Sandwich, MA

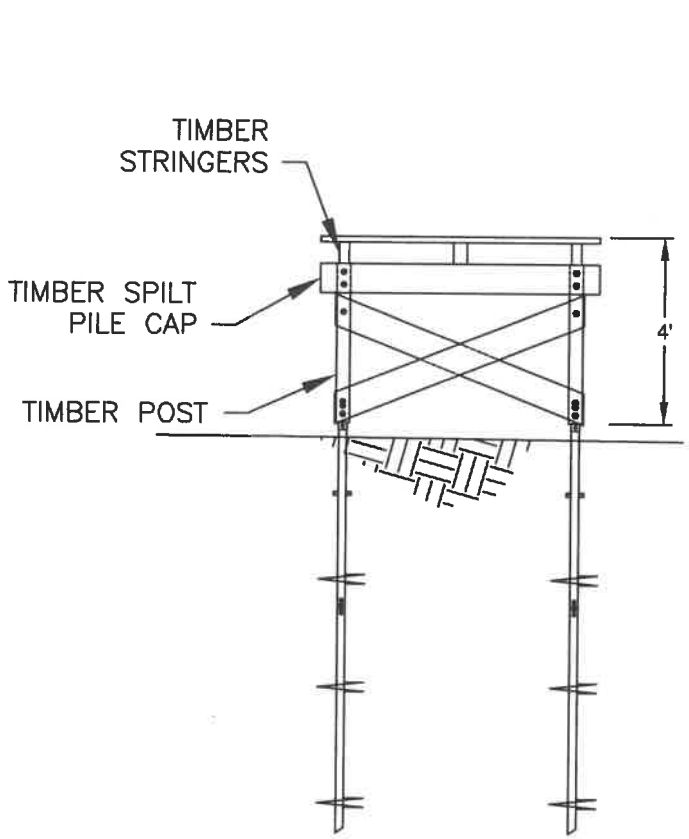
Town of Sandwich
Sandwich, MA

GEI Consultants

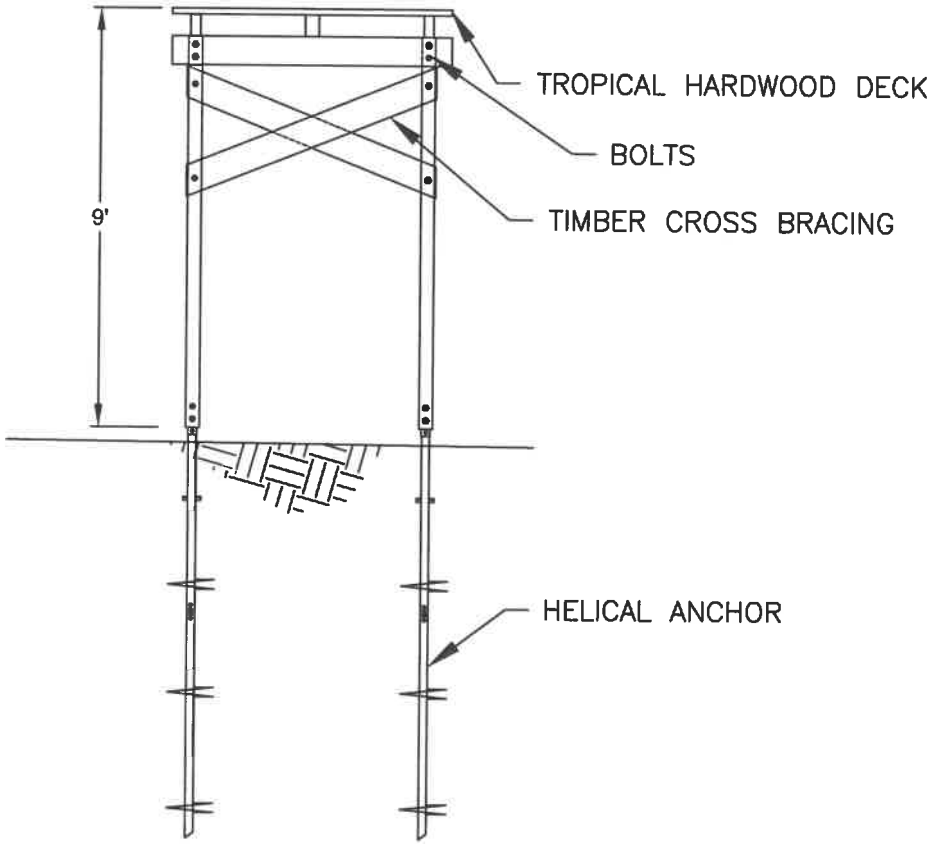
PROPOSED BOARDWALK PLAN

Project 1802840 | February 2019 | Fig. 2

\\geiconsults B:\Working\SANDWICH, TOWN OF\1802840 Sandwich Boardwalk Restoration\00_CAD\Figures\FIG.1-2 PROPOSED BOARDWALK ELEVATIONS.dwg - 2/19/2019



EXISTING ELEVATION - SECTION



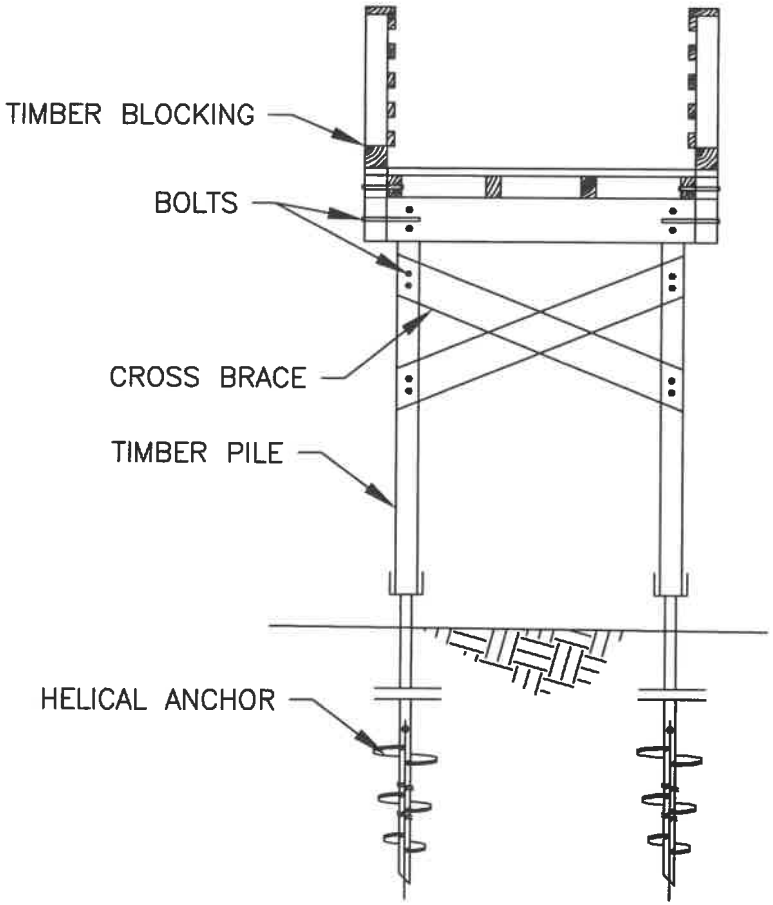
INCREASED ELEVATION - SECTION

NOTES:

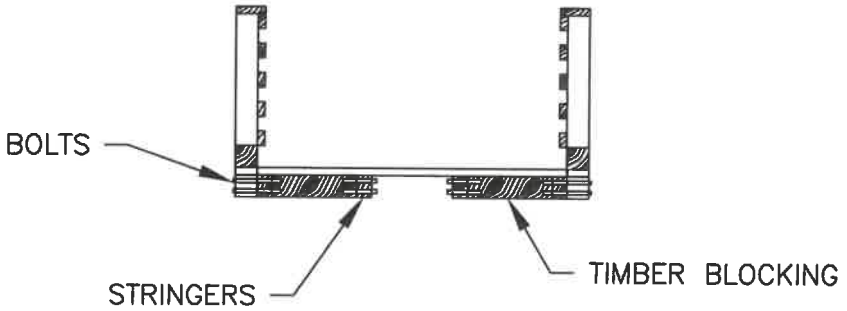
1. NOT TO SCALE

Deck Elevations Sandwich Boardwalk Sandwich, MA		GEI Consultants	Existing & Increased Deck Elevations
Town of Sandwich Sandwich, MA		Project 1802840	April 2019 Fig. 3

\\geiconsulta B:\Working\SANDWICH, TOWN OF\1802840 Sandwich Boardwalk Restoration\00_CAD\Figures\Fig.1 Helical Anchors.dwg - 2/18/2019



VERTICAL RAILING AT PILE CAP - SECTION



VERTICAL RAILING AT MIDSPAN - SECTION

NOTES:

1. NOT TO SCALE

Option D: Sandwich Boardwalk Sandwich, MA		GEI Consultants	Vertical Railing Detail
Town of Sandwich Sandwich, MA		Project 1802840	April 2019 Fig. 4

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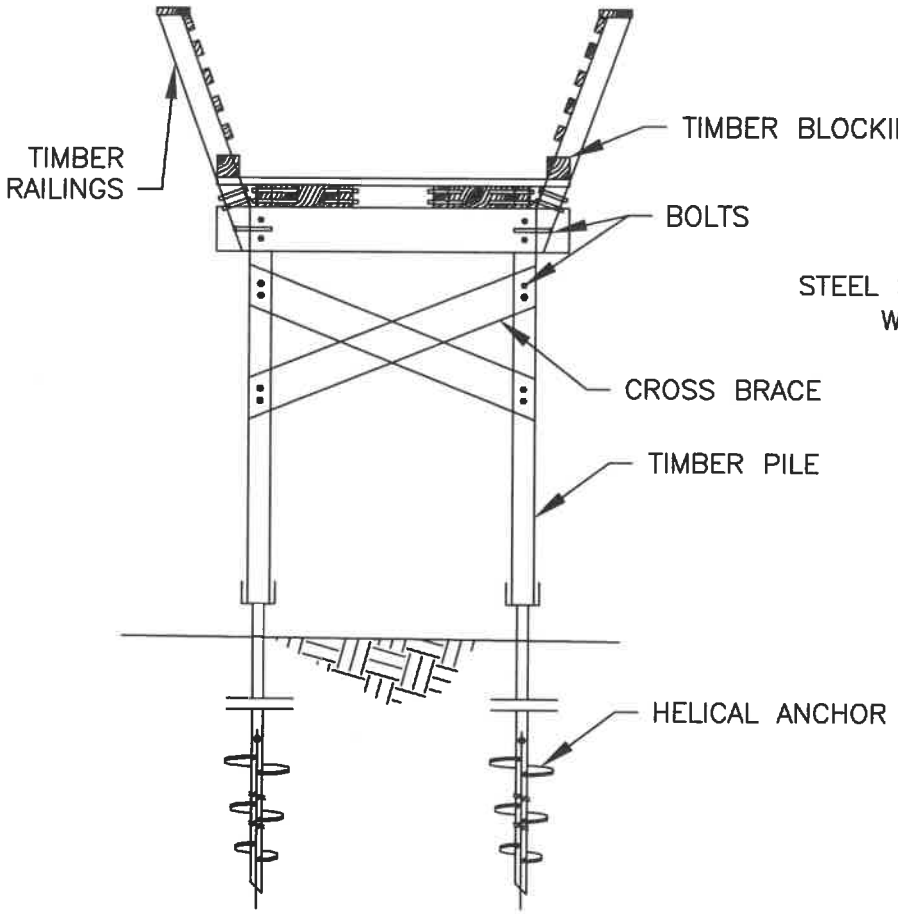
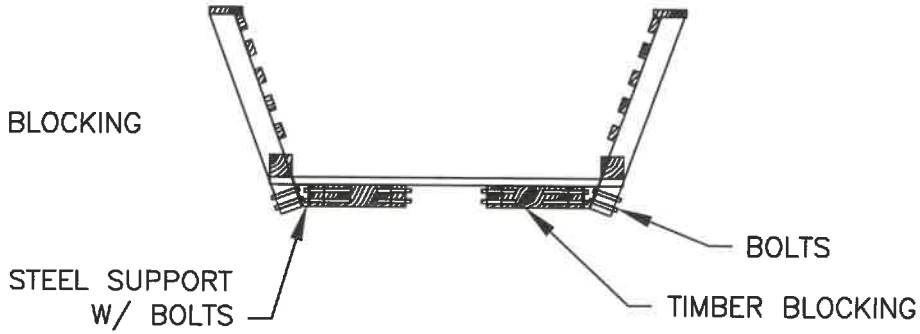


SLOPED RAILING AT PILE CAP - SECTION



SLOPED RAILING AT MIDSPAN - SECTION

NOTES:

1. NOT TO SCALE

Option D: Sandwich Boardwalk Sandwich, MA	GEI Consultants	Sloped Railing Detail	
Town of Sandwich Sandwich, MA	Project 1802840	April 2019	Fig. 5

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