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M E M O R A N D U M

To: Mr. Christian Krahforst, Director, Climate Adaptation and Conservation

Town of Hull, Massachusetts

From: Bin Wang, P.E., CFM, Russell Morgan, P.E., Matthew Page, P.E.

Date: January 18, 2024

File No.: 01.0177247.00

Re: 51 Harborview Road NOI Peer Review

GZA GeoEnvironmental, Inc. (GZA) is pleased to present this memorandum to the Town of Hull (Town) to support your review of the Notice of Intent (NOI) submitted to the Hull Conservation Commission (ConCom) for the subject property at 51 Harborview Road, Hull, MA (Site). The engineering peer review services were performed in accordance with our proposal dated May 24, 2023 and signed by the Town on June 26, 2023. GZA's review was performed on the design narrative package prepared by the Owner's Engineer CEC dated October 20, 2023. The design package summarizes and provides analysis and design information on a proposed soil nail wall to mitigate the currently unstable conditions at the Site.

Please note that providing engineering analysis or design services is not part of the current scope of work. This document is subject to GZA's Limitations (see **Attachment I**).

SITE LOCATION AND HYDROLOGIC SETTING

The project site is located at 51 Harborview Road in Hull, MA. A residential structure is located on the southern portion of a 0.4-acre parcel with a patio and deck located just north the residence. The northern portion of the parcel is a coastal bank (approximately 45-foot tall), facing the Massachusetts Bay to the north. At the toe of the coastal bank, there lies a cobble/boulder beach, named "Stony Beach". **Figure 1** presents a site locus map.

Per Massachusetts Wetland Protection Act (WPA), Coastal Bank is defined as "the seaward face or side of any elevated landform, other than a coastal dune, which lies at the landward edge of a coastal beach, land subject to tidal action, or other wetland." Two primary characteristics are associated with coastal banks: 1) sediment source banks and their ability to erode; or 2) vertical buffer and their stability. The coastal bank at the Site functions as both, albeit slightly more as a Type 2 bank, i.e., a vertical buffer to storm waves and flood water due to its significant height. Therefore, according to the WPA, the stability of the coastal bank, i.e., the natural resistance of the bank to erosion caused by wind and rain runoff, is critical to storm damage prevention and/or flood control.

The coastal bank and Stony Beach are subject to storm surge and wave actions from Massachusetts Bay. The Site is along an open coastline with no shelter from barrier islands for northerly and northeasterly fetches. Per Federal Emergency Management Agency (FEMA)

Flood Insurance Study (FIS) report (25023CV002D last dated July 2021), the 1-percent (%) annual chance stillwater elevation is 9.7 feet NAVD88[1], associated with a 1% annual chance wave height of over 15 feet, along Coastal Transect No. 18. As a result, the estimated Base Flood Elevation (BFE) is 20 feet NAVD88 with a zone designation of VE20 in the vicinity of the Site.

The Special Flood Hazard Area (SFHA) ends at the existing coastal bank, where the bank rises above Elevation 20 feet. This is the total water level (including wave actions) at the site, associated with the 100-year recurrence interval. **Figure 2** presents the FEMA Flood Insurance Rate Map (FIRM) panels on the National Flood Hazard Layer (NFHL) viewer. It is apparent that the coastal bank functions as a natural flood barrier in the project area.

SITE VISIT

GZA representatives (Bin Wang P.E. and Russ Morgan P.E.) visited the Site on June 7, 2023, accompanied by representatives from the Town, as well as the Owner and engineers from CEC[2]. GZA prepared a separate memorandum following the site visit dated June 27, 2023 (included as **Attachment II**). Details of the site visit are not repeated herein. GZA presented our observations, findings, and postulated failure mechanisms in the site visit memorandum.

LIST OF REFERENCES

The Town and CEC provided a collection of project-related documents for GZA to review as follows (numbered and grouped by type or author):

<u>WPA Forms</u>

1) Issued by Town of Hull:

   a. Massachusetts DEP Order of Conditions (OOC) WPA Form 5 (with attachments), dated 11/22/2019, prepared by the Town of Hull;

   b. Massachusetts DEP WPA Form 9 Enforcement Order (EO) dated September 16, 2014;

   c. Massachusetts DEP WPA Form 9 EO dated May 17, 2022 and amended October 2023;

2) Massachusetts Department of Environmental Protection (DEP) NOI WPA Form 3 (per Massachusetts Wetland Protection Act M.G.L. c. 131, §40) (with attachments), dated 12/1/2022, prepared by the Owner;

<u>Town of Hull</u>

3) "51 Harborview Road Relevant Events Timeline" (undated 1-page PDF);

4) "Pictures of Existing Conditions at 51 Harborview Rd and On-going work.pdf";

5) "51 Harborview Smll 03.14.23.jpg" – photograph taken in November 2022;

6) "Top of Coastal Bank Map" per CZM dated 3/30/2023 (1-page PDF);

[1] North American Vertical Datum of 1988 (NAVD88). All elevations in this document refer to NAVD88 unless otherwise noted.
[2] Owner's engineer Civil & Environmental Consultants (CEC) based in Raynham, MA.

7) Various ConCom meeting agenda/minutes;

CEC Engineering Design Plans and Documents

8) Drawing titled "Slope Stabilization Plan" Drawing # C100 dated 11/22/2022, prepared by CEC;

9) Memorandum regarding "Slope Stabilization DEP File # SE35-1735" dated 2/28/2023, prepared by CEC;

10) Grading and Drainage Plan, and Drainage Calculation (using HydroCAD) dated 9/14/2023[3], prepared by CEC;

11) "Soil Nail and Slope Stability Design Narrative - 51 Harborview Road Slope Stabilization" dated 10/20/2023, prepared by CEC;

Antonopoulos Company Design Plans and Documents

12) Drawing titled "Earth Retaining System", 51 Harborview Road, Hull, MA, Drawing # S-1, dated 11/6/2019, prepared by Antonopoulos Company;

13) Drawing titled "Soil Support Structure", 51 Harborview Road, Hull, MA, Drawing # S-1, dated 10/18/2019, prepared by Antonopoulos Company;

Documents/Correspondences by Others

14) Drawing titled "Topographic Site Plan of Northerly Portion of #51 Harborview Road, Hull, MA", dated 9/30/2019, prepared by Woods Hole Group (WHG) [4];

15) Letter titled "51 Harborview Road Existing Slope Conditions", dated 10/25/2019, addressed to Green Environmental, Inc. and prepared by GeoEngineers[5];

16) Letter titled "51 Harborview Road, Hull MA - Site Restoration and Revegetation" addressed to Green Environmental, Inc., dated 11/18/2019, prepared by WHG;

17) Letter regarding "Comments on Slope Stabilization Memo DEP File # SE35-1735" dated 3/14/2023, prepared by Environmental Consulting & Restoration (ECR), LLC from Plymouth, MA;

18) Letter titled "Response to Commission Inquiries" dated 3/23/2023, prepared by Peter S. Rosens, Ph.D., Coastal Geologist;

19) Letter titled "Request for Further Action for Coastal Bank Repair Property at 51 Harborview Road, Hull, MA", dated 12/22/2022, addressed to ConCom from B.P. Fogel (Keegan Werlin LLP);

20) Letter titled "Comments on Peer Review Proposal for SE35-1735, 51 Harborview Road", dated 5/22/2023, addressed to ConCom from B.P. Fogel (Keegan Werlin LLP)[6].

[3] Interim stormwater runoff mitigation plan per request from the Town.
[4] The 3 drawings above are from one single PDF named "0351516_51_Harborview Plans.pdf".
[5] Letter attached to Document #1, including attachments of #s 10, 11, and 12.
[6] Representing property owner at 53 Harborview Road.

21) Report (draft) titled "Harborview Road Full Condition Survey and Study", dated 9/23/2019, prepared by GEI Consultants (GEI).

22) Drawing (Fig. A) titled "Harborview Slope Failure" for Project "Stone Beach Site Survey, Hull, MA 02024", dated 10/21/2021, prepared by GEI.

Federal and State Regulations

23) Wetland Protection Act 310 CMR 10.00, Massachusetts Department of Environmental Protection

24) Applying The Massachusetts Coastal Wetland Regulations: A Practical Manual for Conservation Commissions to Protect the Storm Damage Prevention and Flood Control Functions of Coastal Resource Areas, Massachusetts Coastal Zone Management.

25) Applicable FEMA flood hazard delineation maps and study report (Plymouth County)

EXISTING DOCUMENT REVIEW SUMMARY

The timeline assembled by the Town indicates that there were two slope failure incidents, one in July 2019 and the other in September 2021. The initial failure in July 2019 occurred, with visible slope erosion on the coastal bank as shown in **Figure 3**. The coastal bank experienced significant slope failure starting at the crest of the slope, immediately abutting the stone patio at 51 Harborview. Approximately 1/4 to 1/3 of the width of the slope within the subject property was affected. Based on the photographs and site plan prepared by others, the slope failure did not extend significantly beyond the existing stone block wall at toe of the slope. After this failure incident, several engineers and coastal geologists were involved and provided repair/restoration solutions. The Town ConCom issued in December 2019 an OOC (Ref. 1), which approved "coastal bank stabilization consisting of installation of coastal bank retention system and native coastal bank plantings" according to the plans/sketches prepared by Antonopoulos and WHG (Refs. 12, 13, 14, and 16). The OOC included "Special Conditions" such as "[p]atio is to be partially removed so that it resides no closer than 12 ft" from the Top of Bank (TOB). There was a segment of toe failure before July 2019, as shown by the aerial photography taken in April 2019 (**Figure 4**).

Per information provided by the Town, an Earth Retaining System (ERS) was installed by the Owner without a construction permit sometime during the winter of 2019/2020. The ERS was exposed by additional slope failure/erosion following heavy rainfalls in early September 2021. A detailed aerial survey was performed on September 13, 2021 (Ref. 21). Note that the drone/LiDAR survey, tasked by the Town, was to assess the existing conditions of the Stony Beach shoreline, not specifically for the Site. The second slope failure impacted a larger/wider area with deeply seated slip surfaces (see photographs in **Attachment II**). After the 2019 slope failure, more soil masses slid downslope in September 2021, with large clumps of soils moving beyond the original stone wall and now lying over the Stony Beach, as shown in **Figure 5**. From the aerial image, it is apparent that the failed slope section encompasses more than 2/3 of the width of the property and affected the abutter property to the east (i.e., 53 Harborview). The massive slope failure did not encroach onto the abutter property to the west (i.e., 49 Harborview).

Among the existing documents from the Town, GZA also reviewed two Enforcement Orders (EO) for the subject property:

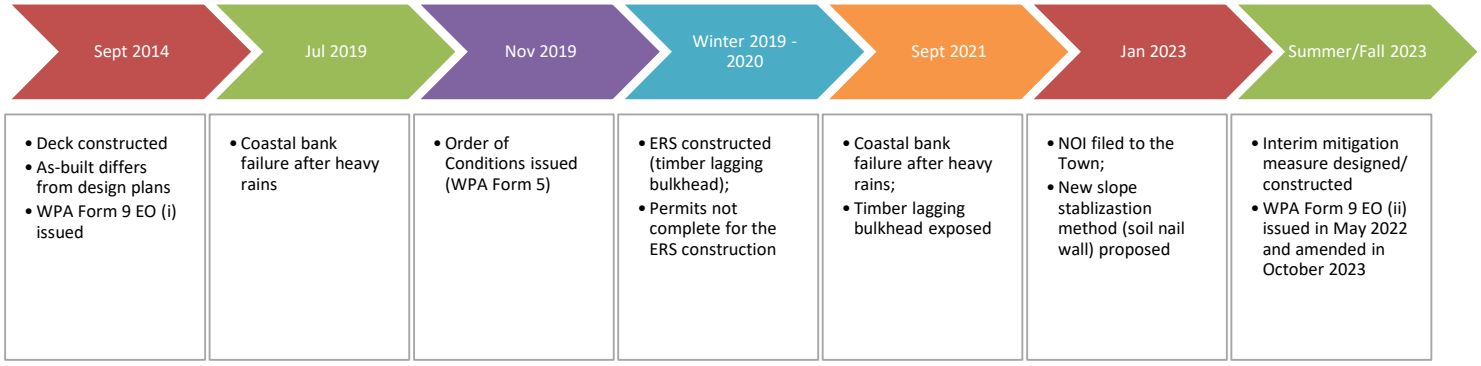
i) MassDEP WPA Form 9 dated September 16, 2014: the as-built deck encroaches onto the existing coastal bank and is in violation of the approved plans; existing coastal bank vegetation was removed due to construction; a (stormwater) drain was causing erosion of the coastal bank.

It is our understanding based on discussions with the Town that the issues listed in this EO were partially addressed by the property owner. No change was made to the constructed deck (i.e., inconsistent with the approved plans).

ii) MassDEP WPA Form 9 dated May 17, 2022 (amended October 2023): the November 2019 OOC was not followed; pre-construction meeting with the Town was not held; geotechnical analysis report(s) were not provided for review; removal of 10 feet of patio on top of the coastal bank was not performed.

The 2022 EO required the property owner to take corrective actions to restore the resource areas. During the Fall of 2023, the owner took interim mitigating measures over the existing patio/deck area to reduce stormwater infiltration and runoff onto the coastal bank. GZA also reviewed the interim mitigation plans and provided input to the design engineer (CEC). The proposed construction items included removal of paver stones, regrading and tarping over the patio, and re-directing stormwater to a stone-lined dissipation bowl at Elevation 25 feet. If properly implemented, precipitation induced infiltration to the ground should be minimized.

The following diagram presents an approximate timeline of relevant events at this property including key events between 2014 and 2023:



The interim/temporary mitigation measures include collecting surface runoff over the patio/deck area in a catch basin and discharging through an outlet on the slope, to prevent further erosion and slope failure of the coastal bank.

One of the key findings from the site visit is that the slope failure was judged to be closely correlated to intense rainfall events, per GZA's observations and understanding. GZA downloaded monthly precipitation data from National Oceanic and Atmospheric Administration (NOAA) at the Hingham COOP Station[7] and plotted monthly total rainfall (in inches) in **Figure 6.** Both major failure incidents, July 2019 and September 2021, occurred following and/or during a few above-average wet months. Following the June 2023 site visit, GZA provided a hypothesis of the failure mechanism: heavy rainfall resulted in an elevated (or perched) groundwater table, which increased lateral pressure behind the slope (**Attachment II**). The construction activities at the Site over the years likely contributed to both incidents in GZA's opinion:

- Plant root systems provide additional strength to soil slopes. Removal of surface vegetation negatively impacts slope stability, and reduces surface water retention and resistance to surface erosion.

[7] National Weather Service Online Climate Data - NOWData

- The wooden deck and stone pavers increased the surface runoff volume and infiltration rate into the ground behind the coastal bank;

- Regrading of the backyard caused more infiltration and surface erosion in some localized areas;

- The large trenches (for installing the tie rods and deadman) during the 2019 ERS construction replaced the natural soil of the coastal bank - Glacial Till. The in-situ Glacial Till, consisting of approximately 40% fines (Ref. 11, Attachment 8), has a low hydraulic conductivity to groundwater seepage, whereas these trenches were backfilled with clean crushed stones with a much higher hydraulic conductivity. Perceivably, they acted as water conduits during heavy rainfall events and were able to wash out materials behind the ERS and caused the already disturbed coastal bank to move further downhill, resulting in the massive slope failure.

Please refer to **Attachment II** for more details.

GZA's overall understanding of the Site includes:

- The failed coastal bank segment at 51 Harborview Road did not have additional large-scale mass movement since October 2021 when the shoreline-wide topographic survey was performed by the Town. However, the rills carved out by groundwater flow have deepened and widened over time, comparing photographs taken between November 2022 and June 2023). This indicates that materials are being constantly washed out from behind the timber ERS structure and down the slope, most likely due to heavy rainfall infiltration over the patio/deck area.
- The Town noted that there were additional displacements of the seawall granite blocks in the vicinity of the failed slope between June and December 2023, based on visual observations. Under the Hull Sewer Department's supervision, the Town conducted a post-landslide damage assessment of the Sewer Main adjacent to the toe of the coastal bank in 2022. Vertical and horizontal displacements were reportedly detected, probably due to the slope movement. No remedial measures were taken at that time based on the overall structural assessment.
- The slope immediately below the existing ERS is currently at an unreasonably steep angle (approximately 60° relative to the Horizontal plane) without significant vegetation, which is resulting in high rates of erosion and reduced stability of the coastal bank. The slope angle of the failed section is greater than adjacent natural coastal bank slopes and underlain by a relatively gentle toe slope where the slumped bank soils accumulated.
- Based on GZA's understanding, the increased hydraulic conductivity of the backfill materials (clean sand/gravel mixtures; or crushed stone) increased the surface water infiltration and seepage during intense rain events. The excess water saturated the soils behind the already disturbed coastal bank. Conceivably, the saturated soils and groundwater increased the lateral pressure and contributed to the driving force for the slope to slide downhill, under gravity. Slope failure occurs when the driving force exceeds the resistance to sliding on the failure plane.
- The original coastal bank was able to stand at a slope angle of approximately 35 to 37° (approximately 1.5H:1V) because the in-situ Glacial Till is a dense material with a large fine content (silt and clay particles), which results in a relatively low hydraulic conductivity and surface vegetation decreases the potential for surface erosion. During a rainfall event, most rainwater retained by leaves and roots and did not saturate the slope as quickly. The root system of the vegetation on the natural slope also helped to resist surface erosion/sloughing and contributes to the long-term stability.
- GZA agrees with the comments made by Dr. Rosens (Ref. 18):

"*At Harborview Road, there is a gravel/boulder beach. There is no (significant) sand, no longshore transport issues, and apparently no exchange of sediment with the nearshore. The backbeach is a vertical stone wall extending up the base of the coastal bank. With the exception of isolated areas where stones in the wall were raveled or shifted, the bank is largely protected from coastal processes. This is confirmed by the generally thick, mostly upland, vegetation along most of the shoreline. Therefore, the wave energy, runup, and storm frequency characteristics are not important in this project design. The project site consists mostly of semi-cohesive glacial till and underwent a classic slump, or landslide. Although there are few details of the event itself, the failure event was driven by processes at the top of the slope, and consisted of development of a plane-of-failure, or crack in the material. The material seaward of the plane slid by gravity downward forming the slump block at the base.*"

- Between 2019 and 2022, a number of engineering consultants and coastal geologists worked on this project and provided opinions on the restoration/repair of the failed coastal bank.
    - Ref. 12 (annotated plan S-1 in red and blue ink) indicated that a large portion of the patio area needed to be removed and top of bank "restored to native coastal bank". Per conversation with the Town, it was the Owner's representative Ferguson who added the handwritten notes on Drawing S-1 dated Nov 6, 2019 (**Figure 7**).
    - Refs. 14 and 16 proposed to restore with a vegetated slope, with grades matching the abutting slope sections.
    - Ref. 15 pointed out that the slope was unstable (prior to the ERS construction) and prone to continued movement.
    - Ref. 17 included comments on removal of the ERS, extended section of the deck, and section of the stone-paved patio.
    - Ref. 18 agreed that the soil nail wall technology would be effective and should be used for the steeper areas of the failed slope.
- Based on the information provided by the Owner and design plan (Refs. 12 and 13), trenches (approximately 6 to 8 feet deep) were excavated during the ERS construction project to allow installation of the tie rods and concrete grade beams[8]. The trenches were then backfilled with sand/gravel/crushed stone (i.e., materials brought from offsite). **Figure 8** presents a schematic cross section through the failed slope and timber-lagging wall, based on GZA's understanding and existing design plans. GZA's opinion is that even though the ERS construction was originally intended to mitigate the slope stability issue, it likely became a significant contributor/driver to the subsequent slope failure within two years after the retaining structure was in place.

REVIEW SUMMARY OF SOIL NAIL WALL AND SLOPE STABILITY DESIGN

In September 2023, GZA reviewed a draft version of the "Soil Nail Wall and Slope Stability Design" with attachments of slope stability analysis results and provided preliminary comments to CEC. GZA's key comment was to ask CEC to consider groundwater in the slope stability assessment and a discussion of slope stabilization at the eastern boundary of the impacted embankment. CEC provided a revised, final version of the design narrative on October 20, 2023 (Ref. 11). GZA's peer review was based on CEC's final design package (including "For Review" design drawings). The revised version text indicates that the design document presents a schematic level design.

[8] Tie rods perpendicular to the shoreline/coastal bank alignment; grade beam (4.5 feet in height) parallel to the shoreline/coastal bank alignment.

Below is a summary of GZA's review of CEC's design package[9]:

- The proposed soil nail wall design includes removing the existing timber ERS and cut slightly into the slope to allow installation of the soil nails. The finished soil nail wall will have a 15-degree batter angle. The top of the new wall will be 4 feet behind the existing top of slope/ERS. The steep batter of the soil nail wall is to maintain the majority of the backyard footage of the subject property.
- Two different slope repair options were presented (**Figure 9**):
    - #1: Soil nail wall with gabion baskets and riprap slope ending at the property line between 51 and 53 Harborview. Gabion baskets were proposed to provide slope stabilization at the property line, where the proposed grades do not smoothly tie into the grades on the abutter property at 53 Harborview.
    - #2: Soil nail wall with riprap only (no gabion baskets) extending beyond the property line such that the scarp on the property of 53 Harborview is filled in with riprap stones.
- Geometries used for the analysis/calculations were verified and checked using the existing topographic information. The soil nail wall is approximately 14 feet in height, between El. 54' and El. 40'. Four rows of soil nails were proposed, at a 4' x 4' (vertical and horizonal) spacing. **Figure 10** presents a typical cross section of the soil nail wall developed by CEC, including the stone patio at the top and revegetation area at the toe.
- Soil (geotechnical) material properties such as frictional angle and cohesion values used were judged reasonable. Surcharge loads from the existing deck structure were included. First row of deck column will be underpinned and the third row of columns next to the house are included in the surcharge that represents the loads from the existing building. The elimination of the deck loads from the first (northern most) row of deck columns may not be fully represented of the driving forces on the soil nail wall. The type of underpinning will influence impacts on the wall stability. The type of underpinning should be provided.
- Groundwater effects[10] were evaluated per CEC's sensitivity analysis results by assuming a groundwater table at Elevation 29.3 feet NAVD88 which exists at Elevation 20 feet NAVD88 at the toe. The assumed groundwater table intersected with the slope failure plane in the back analysis (Ref. 11, Attachment 3); the groundwater table did not intersect with the failure block in the soil nail wall design analysis (Ref. 11, Attachment 4).
- Back analysis of the adjacent slope to the west (49 Harborview) indicates that the natural slopes are marginally stable with a factor of safety of 1.17 (i.e., calculated factor of safety values greater than 1.0 but not significantly higher).
- The proposed wall is able to achieve a factor of safety of 1.67 for a rotational type of slope failure, along the selected representative section.
- The gabion basket section did not meet the minimum factor of safety requirements (1.5) in all directions. In our opinion, the results are conservative as they were based on 2-dimensional analysis, whereas the gabion basket section is essentially a 3-dimensional structure. However, we suggest that a wider wall system be considered to

[9] GZA's comments (such as recommendations) are presented in the "additional comments" section. This section presents the findings based on the design package.
[10] Groundwater table was not encountered in soil testing boring SB-1 performed on June 28, 2023. CEC's draft design analysis assumed no groundwater presence in the slope stability calculations. GZA recommended that groundwater effects be considered, based on the apparent temporal correlation between the past slope failure incidents and heavy rainfall events.

achieve the minimum factors of safety against stability failure. The design did not provide details relative to the gabion wall such as basket layout, sizes, subgrade mitigation, or backfill requirements.

- Proposed grading generally follows the existing (as of 2023) contours, i.e., the coastal bank will continue to have a concave/indented area at 51 Harborview after the soil nail wall project is completed. The proposed project does not restore the site to the pre-2019 conditions. No restoration to the seawall and removal/re-use of the soils was included as part of the construction, which needs to be addressed (see Additional Comments section below). The proposed grading may continue to be impacted due to erosion caused by surface water. We suggest that the design consider surface protection in the form of vegetation supplemented with temporary erosion control measures such as surface matting or coir logs.
- The drainage strips specified appeared to be standard practice for soil nail construction, for constructability reasons. A constant, high flow of groundwater through the strips is not expected, in view of the generally low groundwater table at the Site.
- The proposed design should incorporate a method to limit seepage migrating to the proposed wall within the previously installed anchor trenches below the patio. [11]
- The proposed design should incorporate a method to capture runoff from the patio area and divert away from the new wall.
- Design drawings (plan and section views) should include the existing granite block wall. At the failed section/design cross section, GZA recommends that the existing granite block wall (beyond the failed cross section) be shown in the background (e.g., in gray/dash), for visual references and additional information. The failed section needs to be restored as part of this project, to fully align with the sections on both sides. See additional comments section below.
- The proposed project requires removal of additional vegetation from the existing coastal bank, which can cause further erosion and instability issues in the vicinity of the Site. See additional comments section below.

ADDITIONAL COMMENTS

Below is a list of recommended revisions/design considerations GZA proposes for improvement and/or sensitivity analysis[12] to better align/comply with the WPA performance standards and other applicable coastal restoration guidelines:

- The existing calculation package/design narrative of the proposed project does not include a section referencing the Wetland Protection Act (310 CMR 10.00). No discussion was provided on how the proposed soil nail wall system meets or affects the performance standards for "Coastal Banks", where the project site is located and classified per the current state regulations. The design engineer should include a detailed discussion regarding the coastal bank performance standards, including near- and long-term effects which may result from the proposed project. 310 CMR 10.30(6) is of particular interest that "[a]ny project on such a coastal bank or within 100 feet landward of the top of such coastal bank shall have no adverse effects on the stability of the coastal bank." Below is a list of <u>applicable</u> performance standards to be considered and incorporated in the design and construction of this project, based on GZA's review of the WPA:

[11] i.e., keeping the interim mitigation measures functional.
[12] For example, varying a particular design input parameter with a range of values/conditions to confirm that the selected final input produces conservative results or the results are not sensitive to the selection.

- coastal engineering structure or a modification thereto shall be designed and constructed so as to minimize, using best available measures, adverse effects on adjacent or nearby coastal beaches due to changes in wave action (310CMR 10.30(3));
- the applicant demonstrates that no method of protecting the building other than the proposed coastal engineering structure is feasible (310CMR 10.30(3));
- protective planting designed to reduce erosion may be permitted (310CMR 10.30(3));
- Any project on a coastal bank or within 100 feet landward of the top of a coastal bank, other than a structure permitted by 310 CMR 10.30(3), shall not have an adverse effect due to wave action on the movement of sediment from the coastal bank to coastal beaches or land subject to tidal action (310 CMR 10.30(4)).
- Any project on such a coastal bank or within 100 feet landward of the top of such coastal bank shall have no adverse effects on the stability of the coastal bank (310 CMR 10.30(6)).
- Bulkheads, revetments, seawalls, groins or other coastal engineering structures may be permitted on such a coastal bank except when such bank is significant to storm damage prevention or flood control because it supplies sediment to coastal beaches, coastal dunes, and barrier beaches (310 CMR 10.30(7)).

- Perched groundwater table (i.e., wetting front) due to heavy rain infiltration below the patio area (in addition to the main phreatic surface line) is highly recommended to be evaluated in the SLIDE model (see example in **Figure 11**) as a sensitivity check. Transient seepage modeling will be required.

- The final design plan should include the interim mitigation design components if left in place after the soil nail wall construction.

- Special attention should be paid to drainage strip spacing and construction details to allow proper performance in the long run. Installation should be in accordance with the manufacturer's specifications.

- Specify service life of the soil nail wall in the design package. Please note that the WPA provides no guidance on this particular parameter. However, it is available from general engineering guidance/standards.

- The schematic design did not include an alternative consisting of restoration of the coastal bank and existing granite block retaining wall. It is recommended that an additional alternative involving full restoration of the vegetated coastal bank and granite block wall be included as part of the final design package. By restoring the granite block wall, the differential height between the crest and the toe of the slope can be reduced to allow a more workable slope angle to establish new vegetations.

- The design engineer left underpinning design and construction phasing/sequencing to the Contractor. GZA did not review proposed construction sequence. It is recommended that these details be provided for review by the Town/Commission and GZA prior to construction. Below presents a common soil nail wall construction sequence, per GZA's experience:

  1. Walls shall be built from the top down in accordance with the staged excavation lifts and special provisions.
  2. The following wall construction sequence for each excavation lift shall be complete prior to initiating work on the next excavation lift unless otherwise approved by the Record Engineer.
     - 2.1 Install pre-production verification test nails. Establish verification test locations on the design drawings.
     - 2.2 Install inclinometer(s) according to the design drawings.

2.3 Excavate to stage 1 rough grade.
2.4 Trim to final wall face excavation line or to stabilizing berm (if used).
2.5 Install and grout nails. Trim stabilization berm {if used) to final wall face excavation line.
2.6 Install geocomposite drainage strip.
2.7 Place reinforcing and apply shotcrete. No exposed excavation shall be left unstabilized by shotcrete at the end of the work day unless engineer approves otherwise.
2.8 Perform nail pullout tests per specifications before shotcrete is applied and after nail grout has attained its specified strength.
2.9 Conduct verification and proof load tests per Specifications. Protect proof test locations from shotcrete. Grout proof test soil nails.
2.10 Conduct QC (quality control) of materials, including grout and shotcrete per Specifications.
2.11 Construct footing drain. Install pvc connector pipes during construction of the final shotcrete lift to provide drainage of the geocomposite drainage strips into the footing drain or wall base as shown on the design drawings.
2.12 Install final facing (if included).
2.13 Install concrete drainage gutter.

- The construction will require specialty drilling equipment, grout mixer, pumps to install and secure the nails. The construction activities are expected to be performed from the beach side. Therefore, access ramp via the Stony Beach / work platform will need to be constructed prior to the wall installation. Extra care should be paid to the phasing and sequencing plan that will limit and minimize any further erosion and slope loss. The construction plan (e.g., contract submittals) should provide details for access considerations, number and types of various construction equipment, durations for various activities, impacts, mitigative measures, and post-construction restoration measures. For example, extra matting will be required to spread vehicle and other surcharge loads (e.g., access ramp) over the beach area, to minimize stresses (both vertical and horizontal) on the underlying Force Main, during the construction. The Design Engineer/Contractor should evaluate construction phase impacts to the Force Main including stresses on Force Main to determine appropriate construction phasing, means and methods, and final slope configuration required to protect the Force Main, before finalizing the design / construction plans. Currently, the Force Main pipe sits approximately 7 feet below grade in the vicinity of the Site.

- Per the test boring information (B-1 performed on June 28, 2023), the underlying soil materials are typical Glacial Till consisting of dense sand and gravel. The test boring was terminated at split spoon refusal, indicating possible large boulders or sound bedrock. Installation of soil nails could be challenging due to very dense gravels, cobbles/boulders, and/or bedrock when encountered.

- Extra/extreme caution should be exercised to ensure no additional disturbance to the slopes supporting the abutting properties. Additional temporary support may be required to minimize impacts to the coastal bank on both sides of the proposed project footprint area.

- It is the Project Owner/Design Engineer's responsibility to make sure that the proposed project is permittable under the current Federal, State, and Local laws, besides the CZM performance standards listed above. Currently, the proposed design and information reviewed by GZA does not address the performance standards issues listed by the WPA. It's recommended that the project team address these issues upfront or explore a different

alternative that can meet those standards. A comprehensive regulatory review by the project team is required. GZA recommends that this project be considered for reviews by relevant regulatory state agencies for compliance on various issues related to the project and potential impacts:

- Massachusetts CZM for coastal resource area and waterfront impacts and compliance (including Chapter 91 Jurisdiction);
- MassDEP for environmental related compliance during and post construction (e.g., wetland, stormwater, endangered species);
- Massachusetts Department of Conservation and Recreation (DCR) Flood Hazard Management Program due to Coastal High Hazard Zone (VE 20) at the Site. Even though the proposal wall is above FEMA's BFE, construction access, equipment, storage, and material stock piling will potentially be within the floodplain. Floodplain management rules may apply.
- Massachusetts Emergency Management Agency (MEMA) for emergency preparedness and information during and after emergencies and disasters;
- Massachusetts Environmental Policy Act (MEPA) review under the Executive Office of Environmental and Energy Affairs (EEA);
- Massachusetts Department of Fish and Game for potential impacts to the nearshore marine fisheries (e.g., Blue Mussel spawning and settlement area per MassGIS).

- GZA reviewed CZM's preliminary comments, which also raised concerns about the proposed project from a regulator's perspective, particularly on its further negative impacts to the coastal bank such as instability and more erosion.
- GZA recommends that a minimum of 12 survey points be established throughout the Site (on the north side of 51 Harborview). These points should be able to cover horizonal and vertical movements in the entire slope in height and wide. For example, the points can be in a three by four formation (top of slope, mid slope and toe, along 4 selected cross sections with one on either side of the property boundary with 49 and 53 Harborview). The location monitoring points should be monitored for vertical and lateral movement on a regular interval (once every month at a minimum) and as needed (e.g., post severe storms). More points are recommended for the seawall granite blocks in the vicinity. Both temporal and spatial trendlines can be derived from the surveyed northing and eastings and elevations (i.e., 3 coordinates needed as x, y and z) once the data is collected. If drone survey is deployed, a larger area can be covered. Drove survey frequency should be a minimum of twice a year, for example, one in early Spring and the other in early Fall, to capture both cool and warm season events. The surveyed digital elevation models should be compared/analyzed carefully using appropriate desktop software (e.g., ArcGIS Spatial Analytics) to determine the slope/land/material movement between two adjacent "snapshots" (in time), to better inform future remedial measures.

CONCLUSIONS

GZA agrees that the soil nail wall approach is a reasonable, effective way to mitigate the currently unstable conditions at the Site, to maintain the existing configuration of the existing patio/deck/backyard. GZA also agrees with the analytical and numerical methods CEC used in the design process. The input design parameters and assumptions were judged reasonable. The results were judged reasonable by GZA. The wall, once completed, will be able to retain and stabilize the

soil mass under the existing deck and patio. However, the proposed design package does not provide sufficient information to satisfy the performance standards of the WPA. It is recommended that the applicant be required to resubmit the project as indicated above to address the many outstanding performance standards, per GZA's review. Note that long term impacts from the proposed manmade structure to the overall coastal bank remains uncertain and are difficult to predict at this moment, due to various factors including rising sea levels and increase in extreme precipitation due to climate change, which is of particular concern in the Northeast. The wall by itself may create new issues such as soil erosion and bank stability in the vicinity and the Force Main lying under the toe.

In conclusion, GZA does not think that the engineered wall is the best long-term solution, if the coastal bank ecology, other environmental factors, and aesthetics are taken into account. There are foreseeable permitting issues, due to the Site location within a protected coastal resource area (i.e., Coastal Bank). It is GZA's opinion that the fully vegetated bank restoration concept would provide a solution that blends well with the existing coastal bank along the shoreline in this area, as presented in Ref. 16 and shown on the annotated Drawing S-1 (included in the November 2019 OOC; **Figure 7**). Under this scenario, regrading is required to align with the adjacent slopes. We understand that regrading and revegetation of the slope will be a challenge due to the relatively steep slopes approximately at 1.6H:1V ratio to match the adjacent grades. However, regrading and revegetation is feasible with proper sequencing and post-construction maintenance. Restoring the slope to its natural state is an easier and more straightforward solution to the failed slope on the abutter property (53 Harborview) as well, in GZA's opinion.

Figure 12 presents the Top of Coastal Bank in the vicinity of the project area, over existing topographic 1-foot contours per MassMapper. The Coastal Bank at the Site protrudes towards the North primarily due to its lower grades. Top of Bank elevations at 53 and 49 Harborview are close to 60 feet NAVD88, whereas the Top of Bank elevation at 51 Harborview is around 50 feet NAVD88. The grade difference creates a depression in the ground such that surface runoff from the neighboring properties naturally discharges towards the backyard (patio) of 51 Harborview. The stormwater issue will persist after the installation of the soil nail wall/project and need to be addressed properly during the design phase to minimize further erosion of the bank and underlying materials, for the stability and long-term integrity of the entire coastal bank in the general area.

GZA understands that the soil nail wall / site restoration design may still undergo revisions with input from various stakeholders and permitting agencies. We highly recommend that GZA be retained for further review of new work being proposed at the Site and the final construction drawings and specifications.

FIGURES

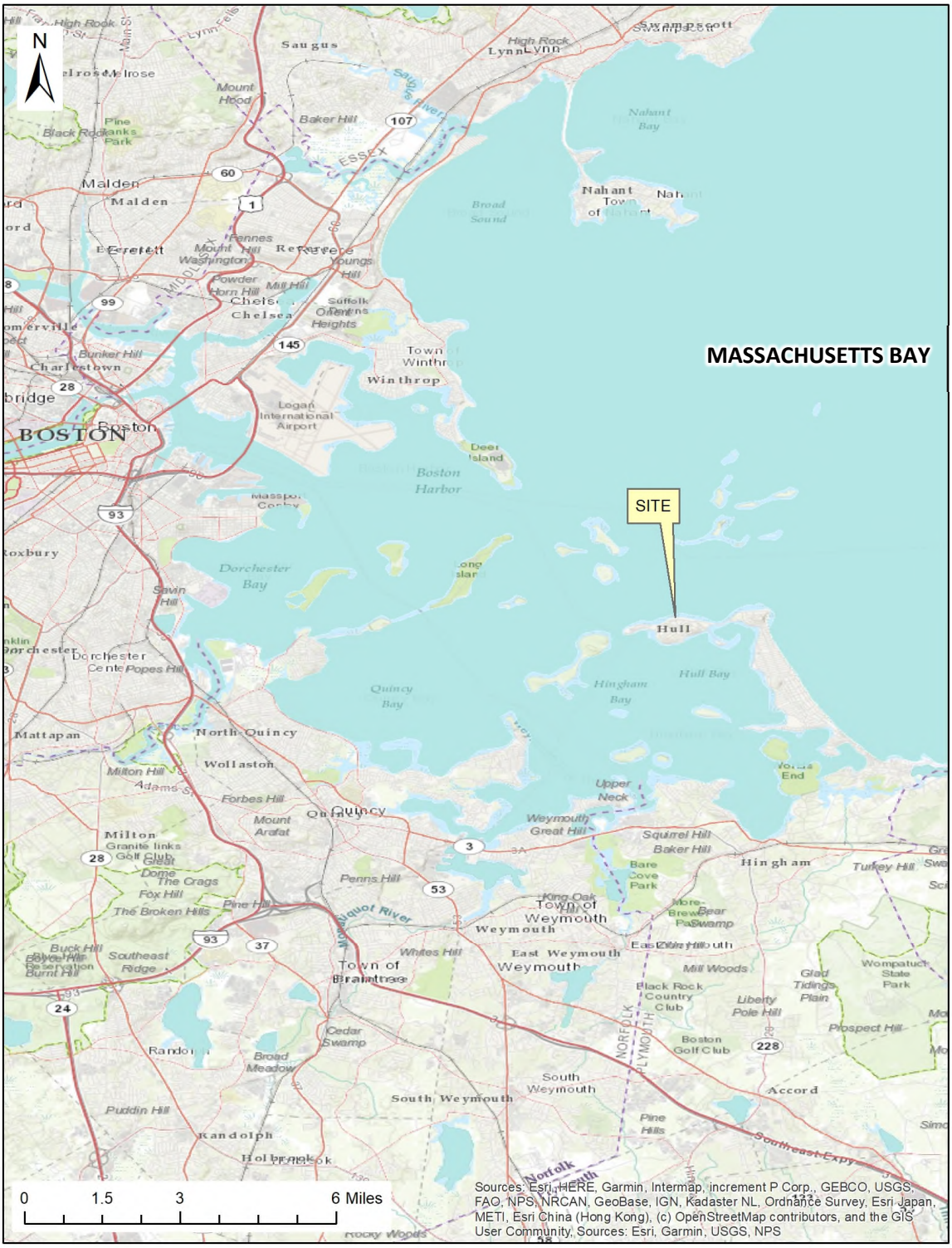


Figure 1: Site Locus Map

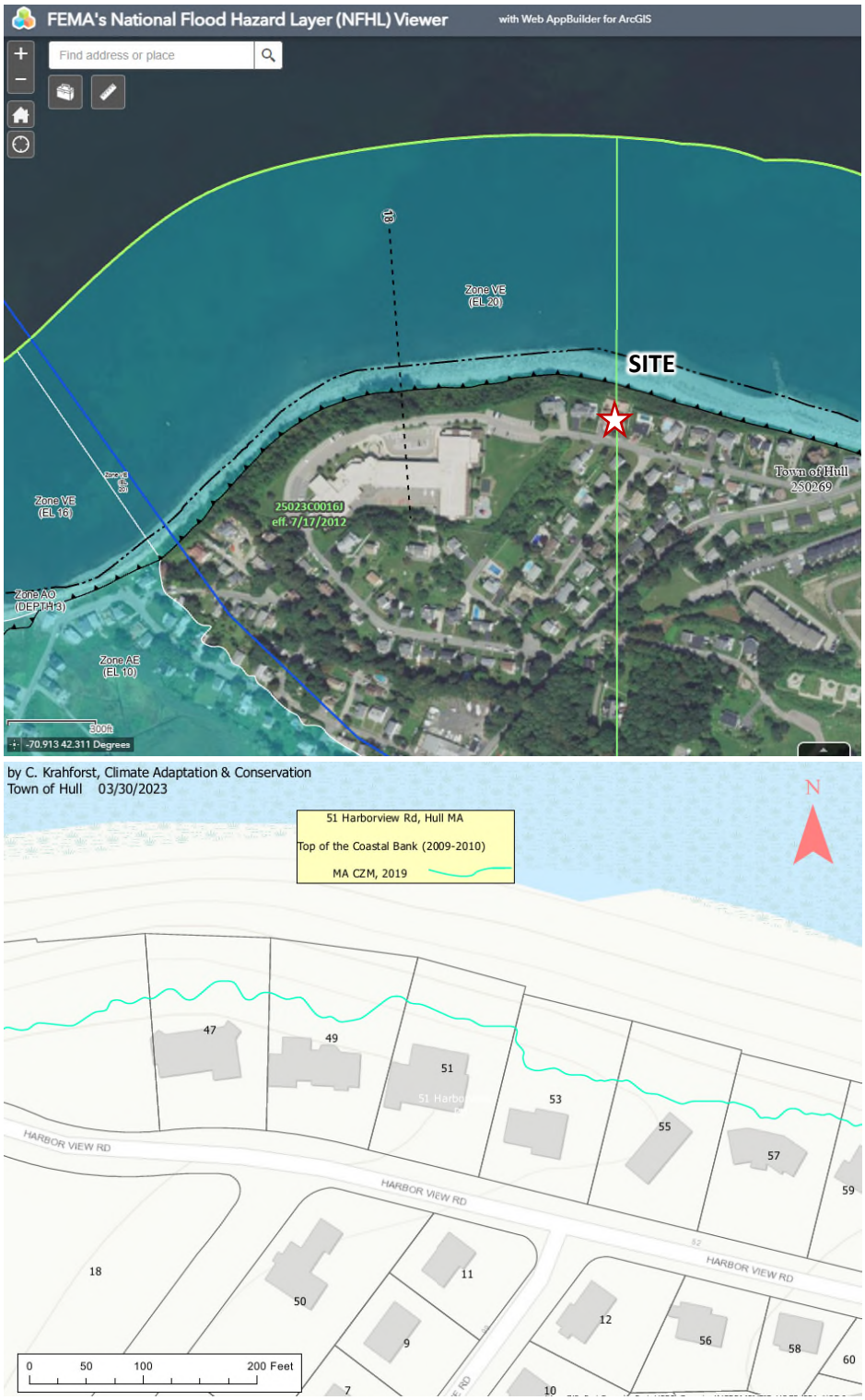
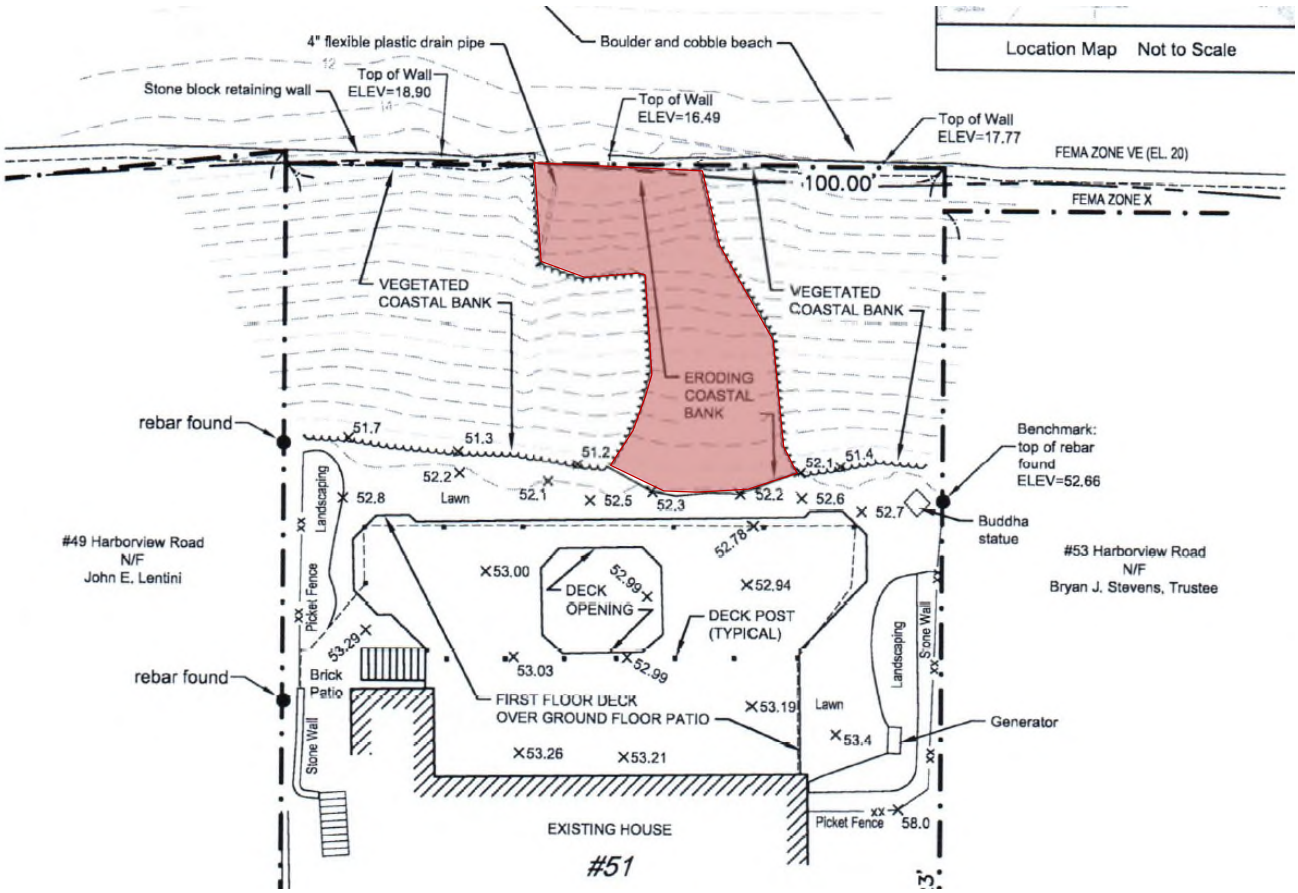


Figure 2: FEMA FIRM Panels from NFHL Viewer and CZM Top of Coastal Bank

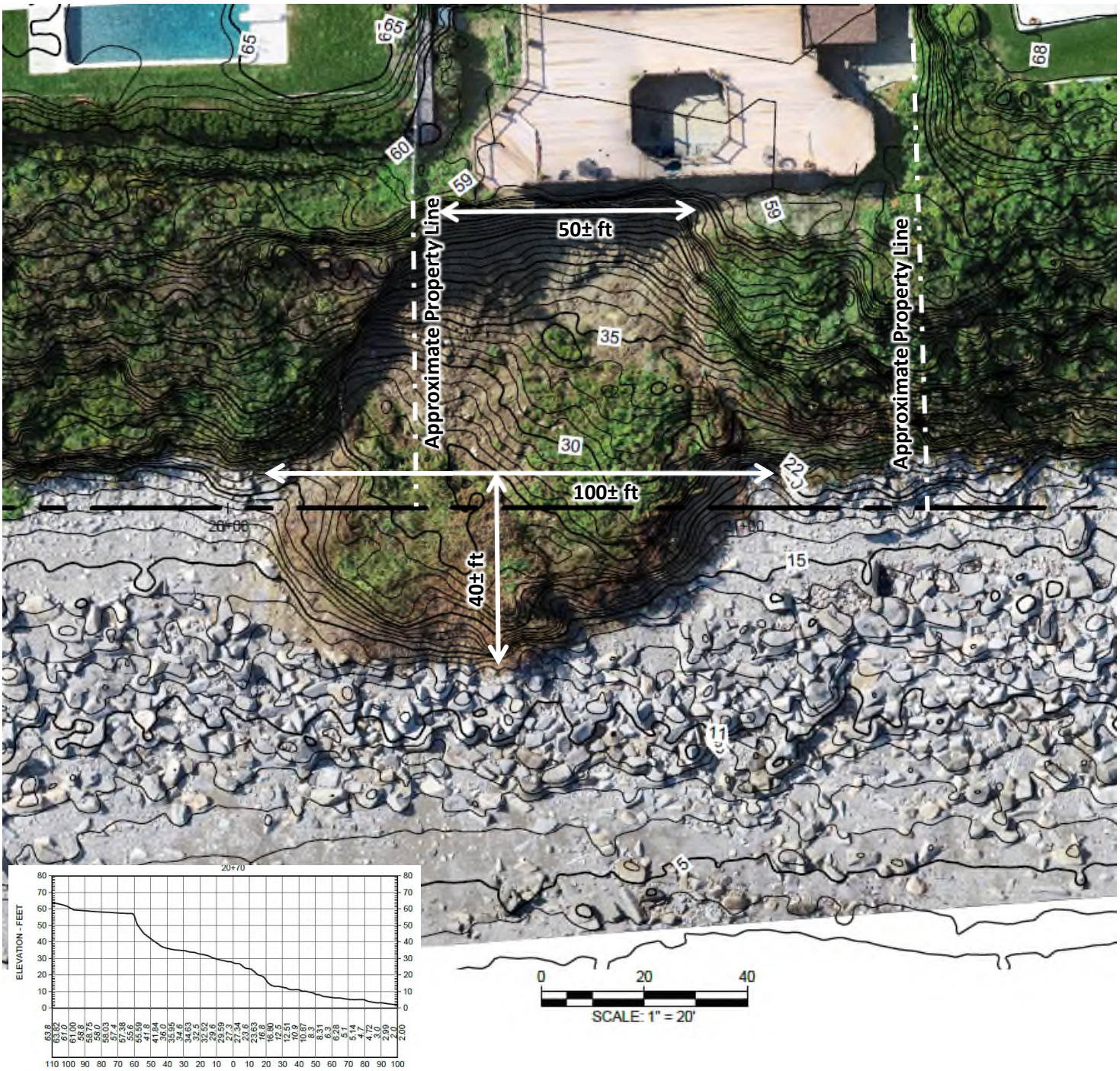


Note: Photographs from WHG's restoration letter (Ref. 16). Sketch from OOC (Ref. 1).

Figure 3: Photographs and Surveyed Site Conditions after July 2019 Slope Failure

Note: Photograph from Attachment B of GEI 2019 Report (Ref. 21).

Figure 4: Birds-Eye View in April 2019 before July 2019 Slope Failure



Note: Base aerial imagery from September 2021 (Ref. 22) and contour elevations in MLW datum.

Figure 5: Surveyed Site Conditions after September 2021 Slope Failure

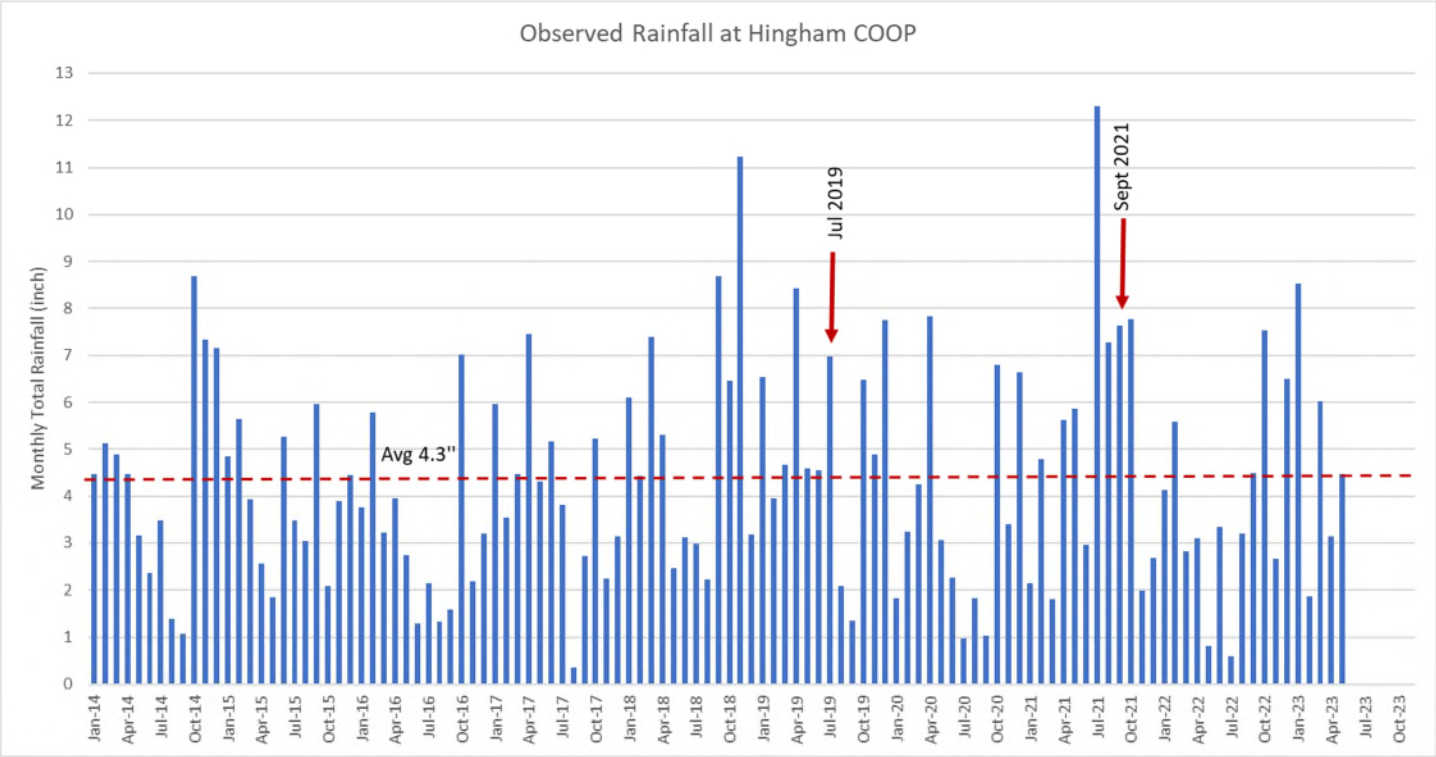


Figure 6: Monthly Rainfall Data 2014 through 2023

Note:

1. Dotted line represents average monthly rainfall between 2014 and 2023.
2. Two slope failure incidents occurred in July 2019 and September 2021 per information provided by the Town.

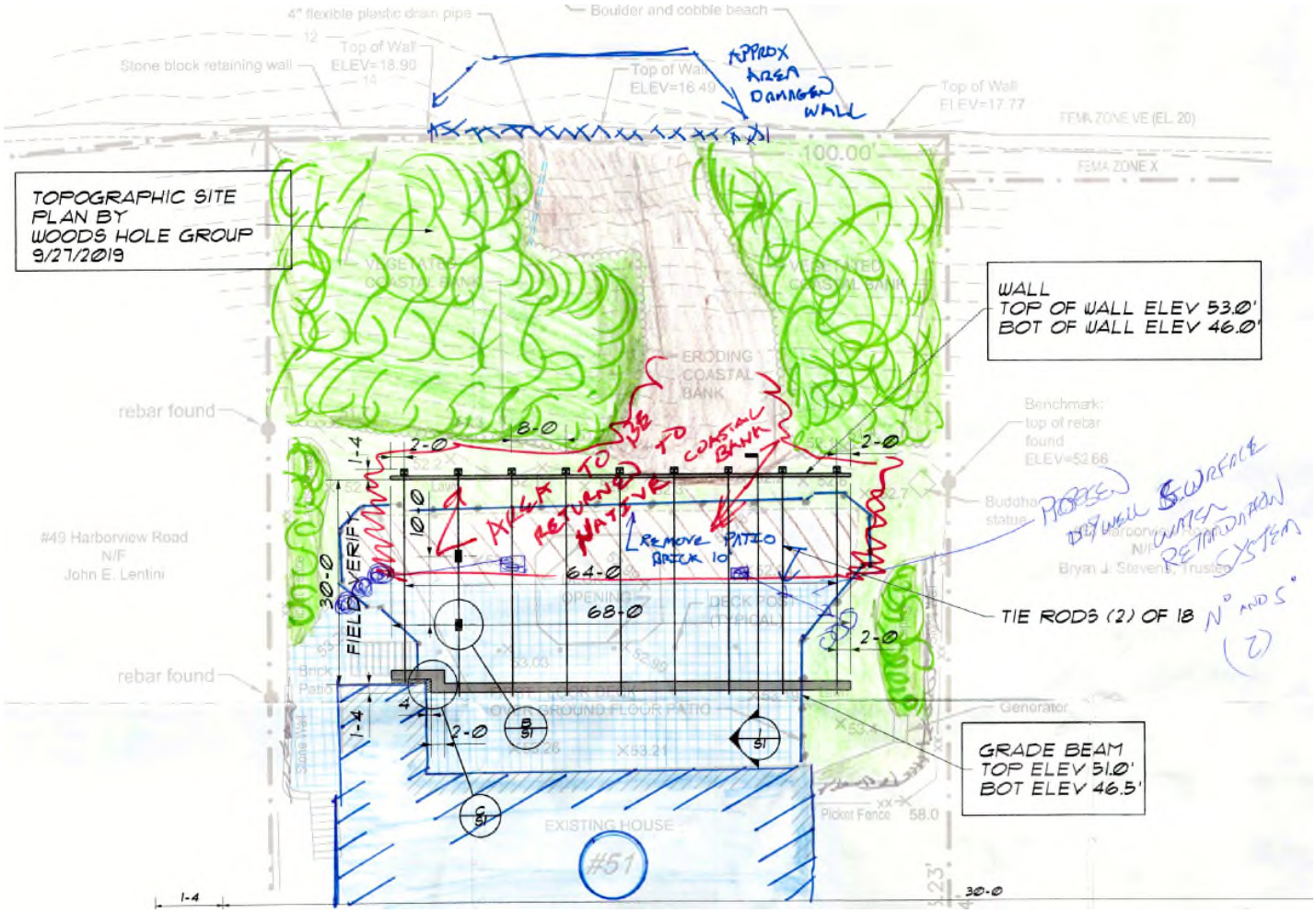


Figure 7: 2019 Coastal Bank Restoration Concept (Ref. 12)

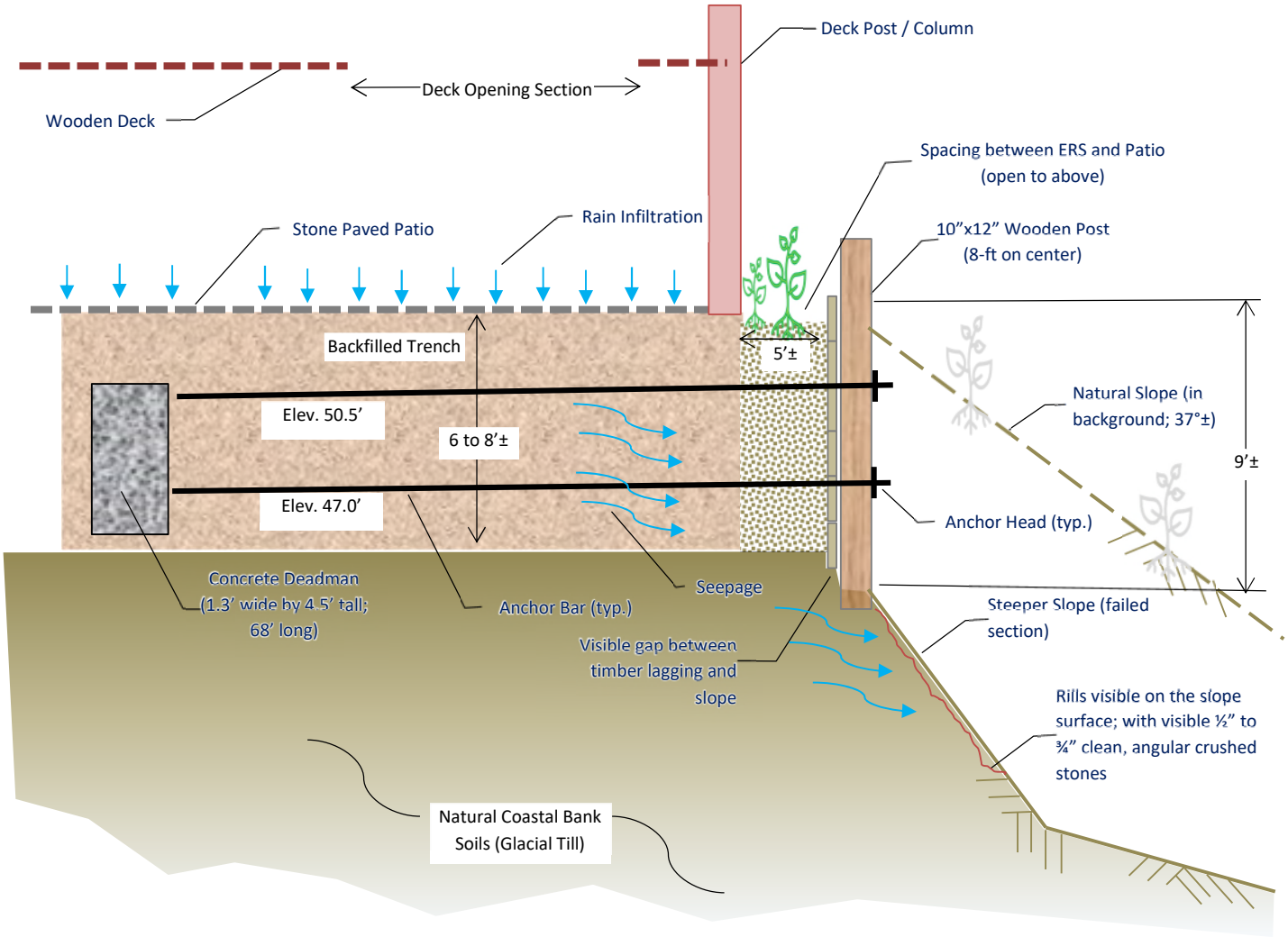


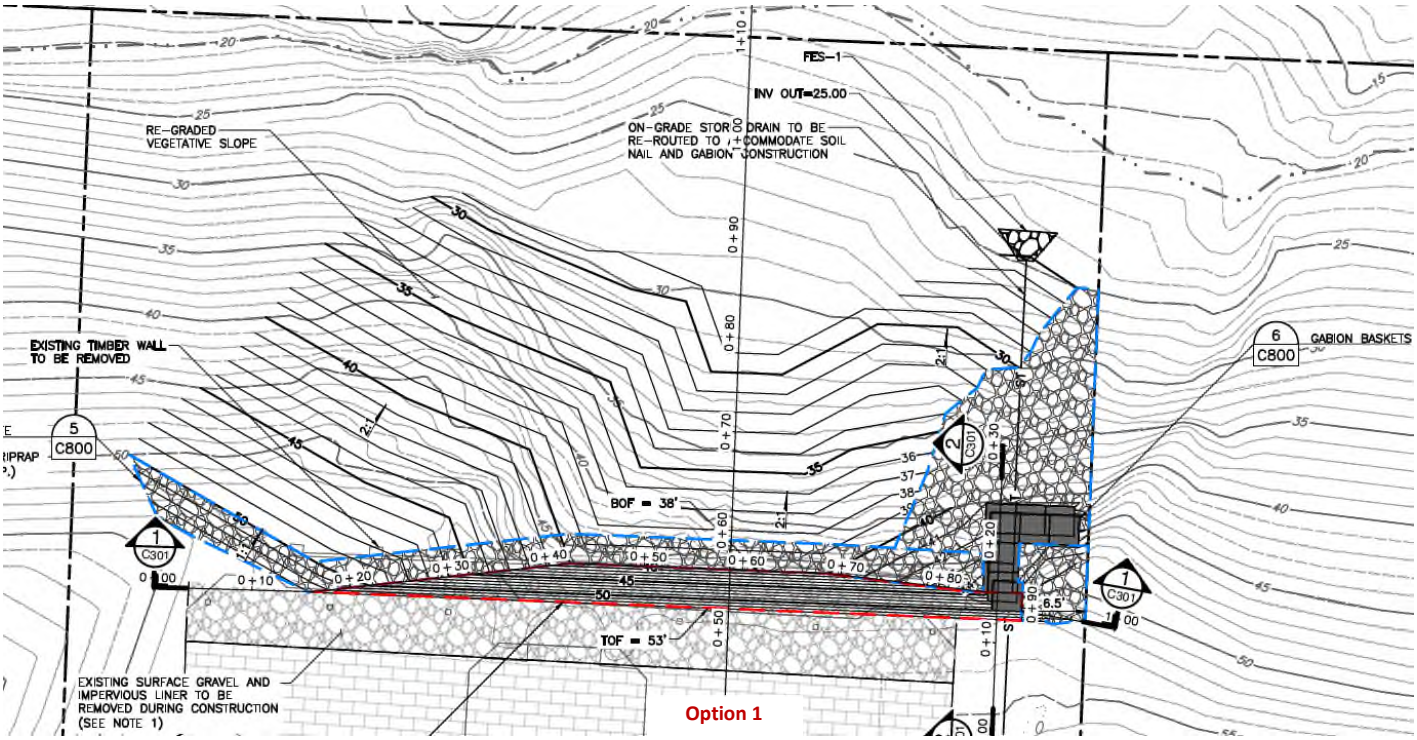
Figure 8: Schematic Profile of Existing Conditions (as of June 2023)

Note:

1. This cross section is through existing timber post, where two anchors were installed per post within an excavated trench back filled with sand and gravel. The 5-foot wide gap was also backfilled with non-native soils, based on the information provided by the Owner.

2. All dimensions are approximate and were based on field measurements, estimates and/or information provided by the Owner.

3. Sketch not to scale, for information/illustration only. Dimensions and elevations based on Drawing S-1 dated November 6, 2019 prepared by Antonopoulos Company (Ref. 12)



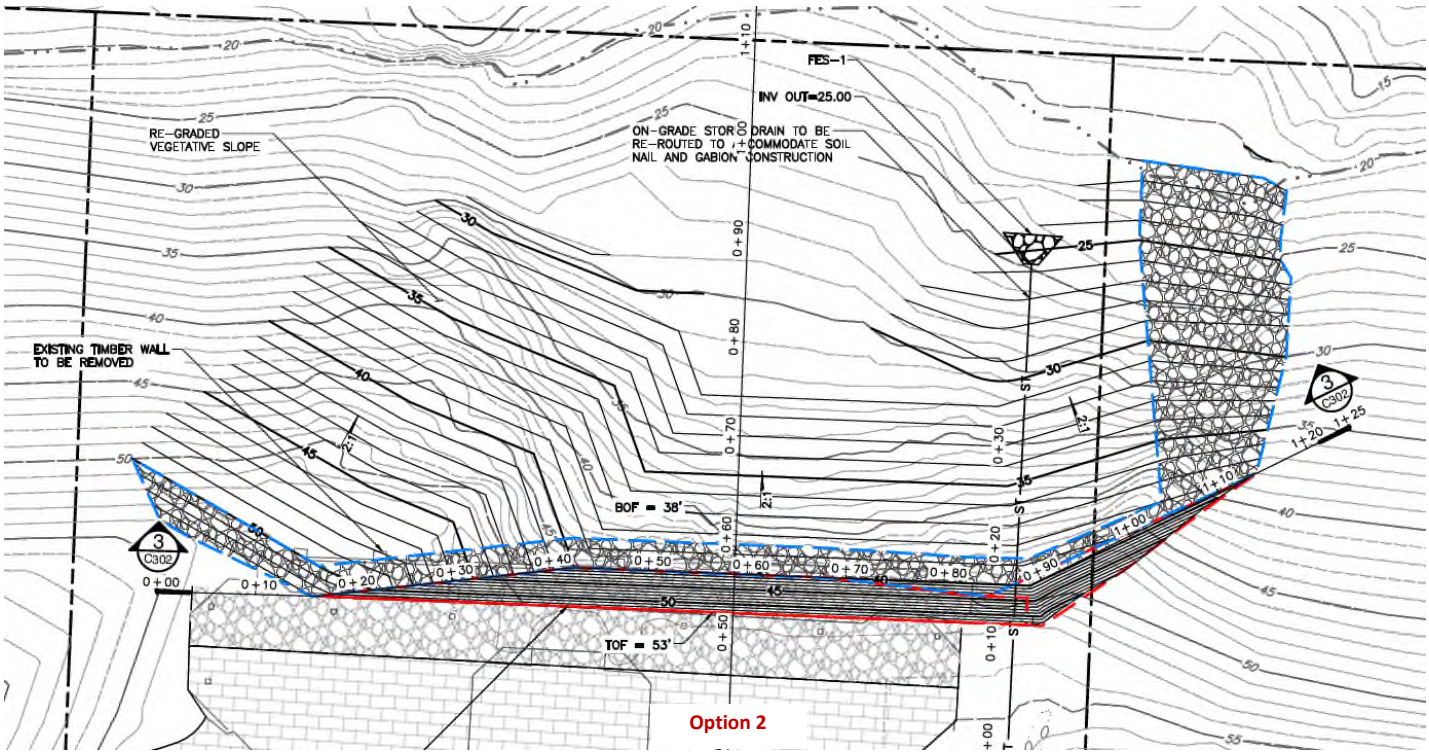


Figure 9: Plan View of Proposed Alternatives

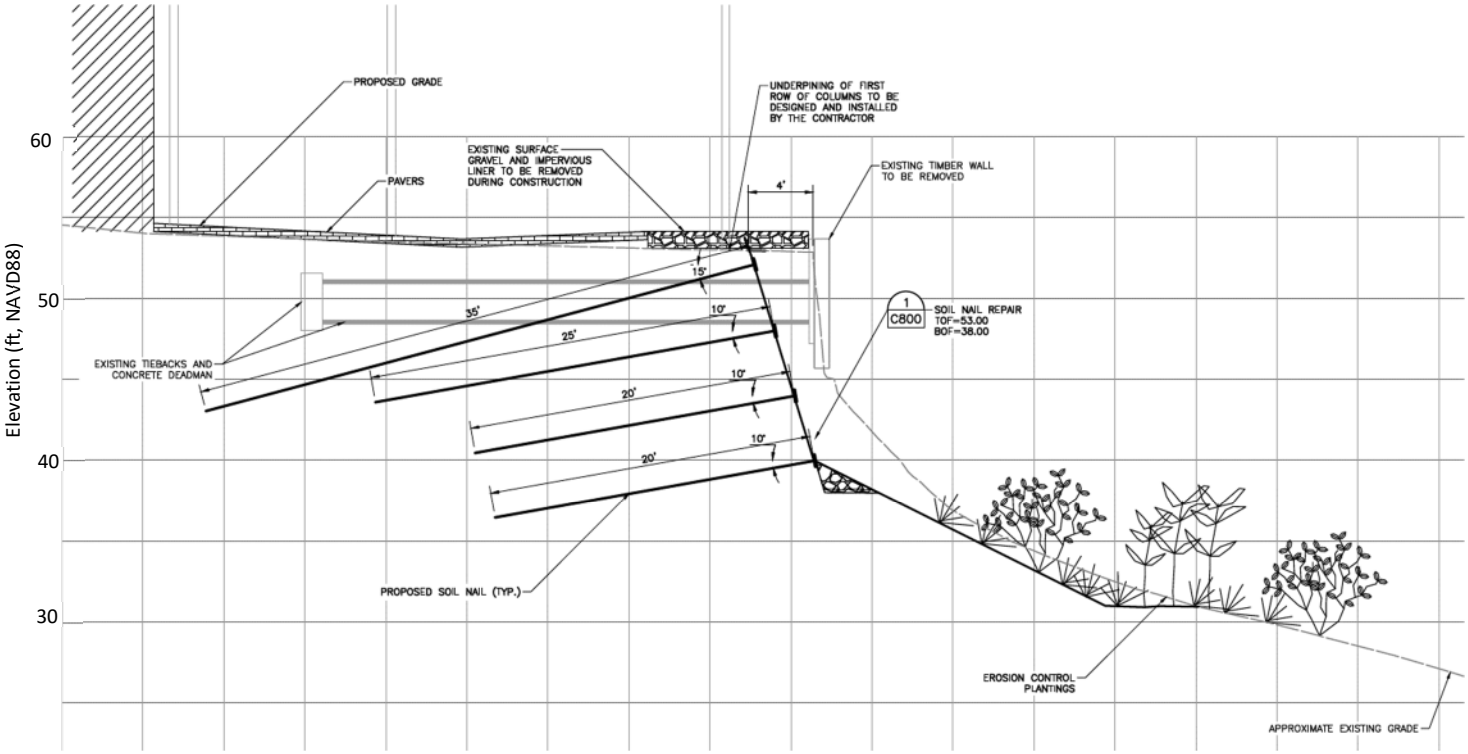


Figure 10: Typical Cross Section of Proposed Soil Nail Wall

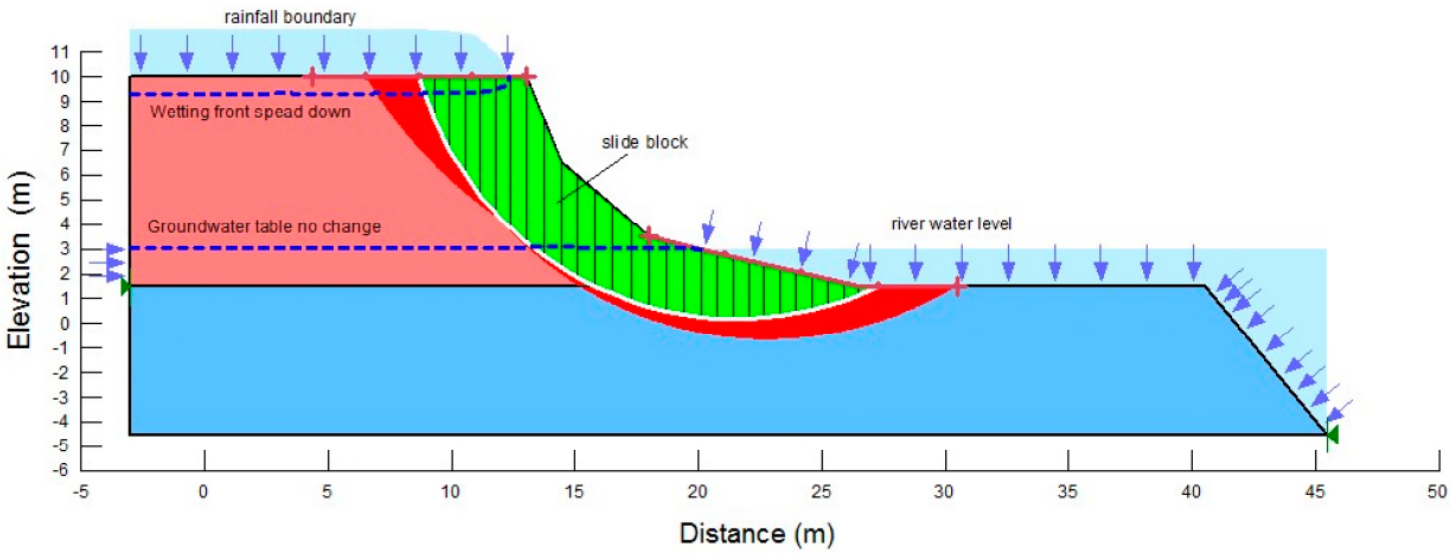


Figure 11: Example of Perched Groundwater Table/Wetting Front Line

Note: open source article titled "Assessing the Effects of Rainfall Intensity and Hydraulic Conductivity on Riverbank Stability" by Duong, et al. Water 2019, 11(4), 741; https://doi.org/10.3390/w11040741

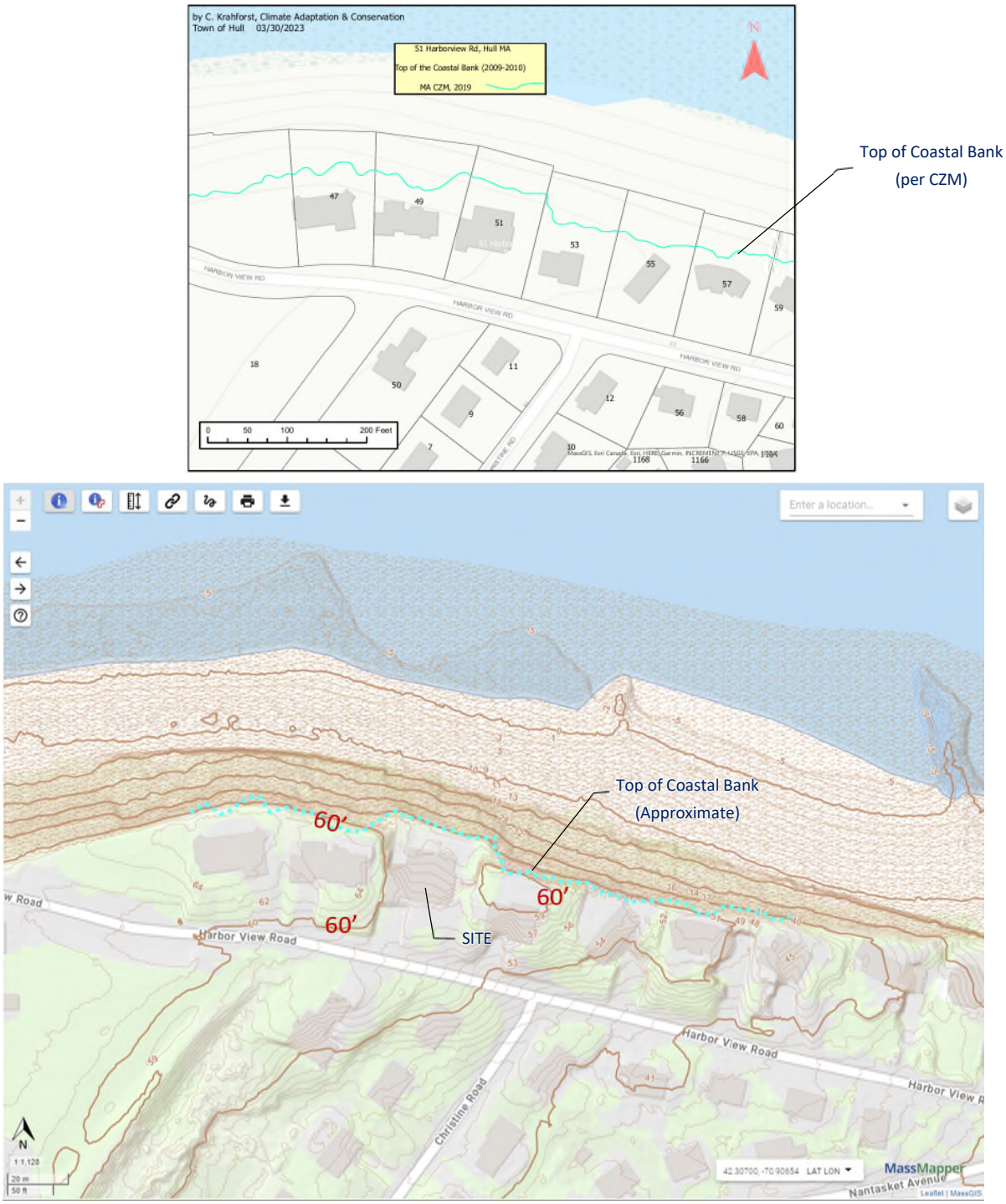


Figure 12: CZM Top of Coastal Bank Overlaid on MassGIS Topographic Contour Map

Note: Top of Coastal Bank sketched based on the Map prepared by C. Kranforst. Approximate and for reference only.

ATTACHMENT I: LIMITATIONS

Use of Report

1. GZA prepared this report on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in Proposal for Services and/or Report, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this report are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the report, as appropriate, to reflect the unanticipated changed conditions.

3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.

Subsurface Conditions

4. The generalized subsurface conditions provided in our Report are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs.

5. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

6. Limitations related to the technical aspects of the cost estimate analysis have been discussed in the main body of this document. Assumptions have been made based on available information/data and engineering judgment.

Compliance with Codes and Regulations

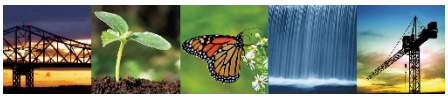
7. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

Additional Services

GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

ATTACHMENT II: MEMORANDUM - SITE VISIT

*** DRAFT FOR INFORMATION ONLY ***



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ECOLOGICAL
WATER
CONSTRUCTION MANAGEMENT

M E M O R A N D U M

To: Mr. Christian Krahforst, Director, Town of Hull, Massachusetts

From: Bin Wang, P.E., CFM, Russell Morgan, P.E., Matthew Page, P.E.

Date: June 13, 2023

File No.: 01.P000069.24

Re: 51 Harborview Road NOI Peer Review - Site Visit Follow-up

GZA GeoEnvironmental, Inc. (GZA) is pleased to present this memorandum to the Town of Hull (Town) to support your review of the Notice of Intent (NOI) submitted to the Hull Conservation Commission for the subject property at 51 Harborview Road, Hull, MA (Site). GZA representatives (Bin and Russ) walked the Site on June 7, 2023, accompanied by you, John Struzziery, and Ian MacDonald from the Town, as well as the Owner (Thomas Fitzgerald) and his representatives from Civil and Environmental Consultants, Inc. (CEC). This memorandum was prepared per your request in support of the Commission's upcoming meeting on June 13, 2023. This document is subject to GZA's Limitations (see **Attachment A**).

Figure 1 presents a site location and topographic plan.

SITE VISIT

The objective of the Site visit performed on June 7, 2023, was to observe and document existing site conditions and key site features, to support GZA's peer review of the proposed slope stabilization project using the soil-nail technique. During the site walk, GZA performed a cursory visual assessment of the stone patio area at the crest and toe of the coastal bank failure. The Owner was present to answer questions and provide additional information.

The Site has a long history of various construction activities and slope instability issues, not summarized in this memorandum. A description of the site history/background will be provided within our peer review report later.

FIELD OBSERVATIONS AND INFORMATION

GZA noted key observations below. Please refer to **Attachment B** for selected photographs from the site visit:

- The slope failure is immediately adjacent to the Earth Retaining System (ERS), which consists of timber soldier piles and lagging wall system constructed in 2019 (Photos 1 through 3). A section of the ERS, approximately 50 feet long, is exposed from top to toe (Photo 13) and approximately 9 to 10 feet in exposed height.

- There is significant existing and likely ongoing erosion/scour at the toe of the ERS, where large openings are visible. Orange colored (insulation) foam was used likely as an attempt to

plug the openings and stop soil from being washed out from behind the wall. However, there are now gaps between the foam and the soil slope, which can be observed at the toe (Photos 8, 9, and 10).

- Rills caused by water flow are visible at the surface (see Photos 8 and 10). Rills are up to 12 inches (") deep and 12" wide, based on visual estimates.

- Crushed stone (approximately ¾" typical size) was observed on the slope surface (e.g., Photo 10), which are apparently non-native, and was part of the backfill materials brought in for the construction of the patio and/or ERS and/or the drainage sumps on both sides (western and eastern ends) of the Patio area. The natural Glacial Till material was observed to be compact and consist predominantly of sand and gravel with up to 35% fines (Photo 11).

- A gap of ¾" in width between the patio pavers and edging stones is likely an indication of the lateral movement of the slope/coastal bank (see Photos 5 and 6) that has already occurred.

- The abutting slope (i.e., intact slope section) was estimated to be approximately at a 35 to 37° angle (Photo 12), where the slope immediately below the ERS is approximately at a 60° angle (1H:2V).

- Based on the information provided by the Owner, trenches (6 to 8 feet deep) were excavated during the patio/deck construction project to allow installation of the tie rods at each timber post location. The trenches were then backfilled with sand/gravel/crushed stone. **Figure 2** presents a cross section through the failed slope and timber-lagging wall, based on GZA's understanding. We included most of our field observations on the sketch. Note that backfilled crushed stone-type of materials normally do not consist of fines. As a result, the hydraulic conductivity (permeability to groundwater seepage) associated with backfill soils is usually higher than the in-situ Glacial Till.

SUMMARY OF FINDINGS

Key findings from the site visit include:

- The failed coastal bank segment at 51 Harborview Road does not appear to have additional large-scale mass movement since October 2021 when the topographic survey was performed. However, the rills carved out by groundwater flow seem to have deepened and widened over time (compared to the photograph taken in November 2022). This indicates that materials are being constantly washed out from behind the wall and down the slope.

- The slope immediately below the ERS is currently at an unreasonably steep angle (approximately 60°), followed by a relatively gentle toe slope where the slumped bank soils accumulated.

- Based on GZA's preliminary understanding, the increased permeability of the backfill materials (clean sand/gravel mixtures; or crushed stone) increased the surface water infiltration and seepage during rain events. The excess water saturated the soils on the slope/coastal bank. The saturated soils and groundwater became the driving force for the slope to slide downhill, under gravity.

- The original coastal bank is able to stand at a slope angle of approximately 35 to 37° because the in-situ Glacial Till is a denser material and the fine content (silt and clay particles) results in a lower hydraulic conductivity. The original slope is also densely vegetated. During a rainfall event, most rainwater likely becomes surface runoff and

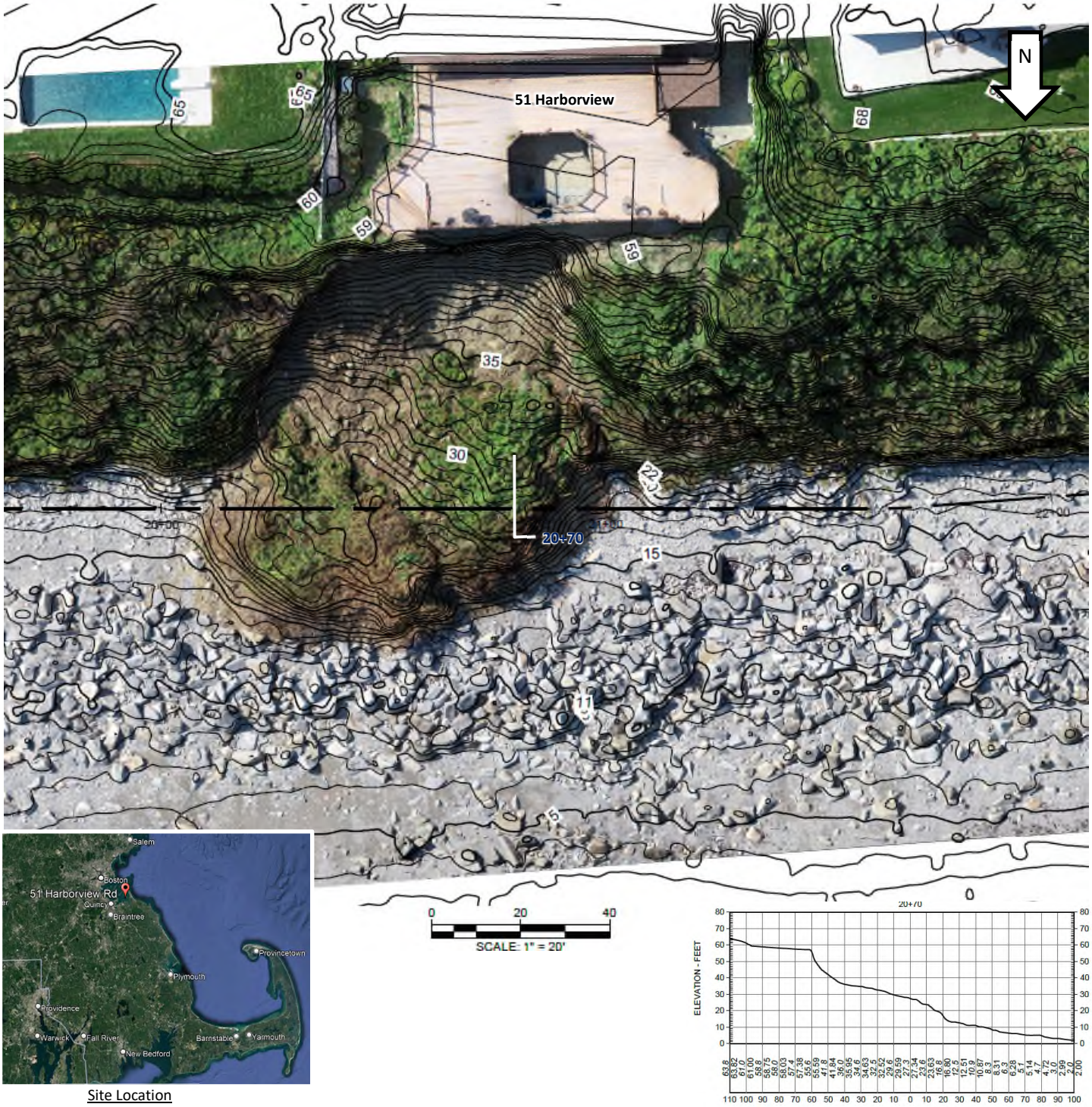
does not saturate the slope as quickly and the infiltration does not elevate the groundwater table significantly to cause a change in the Factor of Safety in the slope stability.

INTERIM MITIGATING MEASURES

Certain interim measures may be considered and implemented prior to the full slope stabilization project:

- One of the temporary solutions to prevent further slope failure is to intercept rainfall over the deck/patio area to reduce infiltration and surface runoff on the coastal bank. The intercepted rainwater needs to be collected at a designated location and rerouted to the street side (as normal stormwater runoff).
- Interception can be done by covering the deck/patio area with an impermeable material (e.g., tarp, plywood, etc.)
- Discharge by gravity flow will likely not work in this case. Harborview Road is several feet higher in elevation than the backyard. Pumping will be needed to get the water to the street side. It is anticipated that an emergency generator will be needed for the pump, in case of a power outage during a severe storm event.
- The drainpipes (see Photo 3), currently perpendicular to the slope, should be extended or turned parallel to the slope face and extended to an apron of 4” to 6” stone to minimize surface erosion.

FIGURES



Site Location

Figure 1: Topographic Plan with 1-foot Contours per Site Survey 2021

Note: Site survey plan and cross section at Station 20+70 prepared by GEI, dated October 2021.

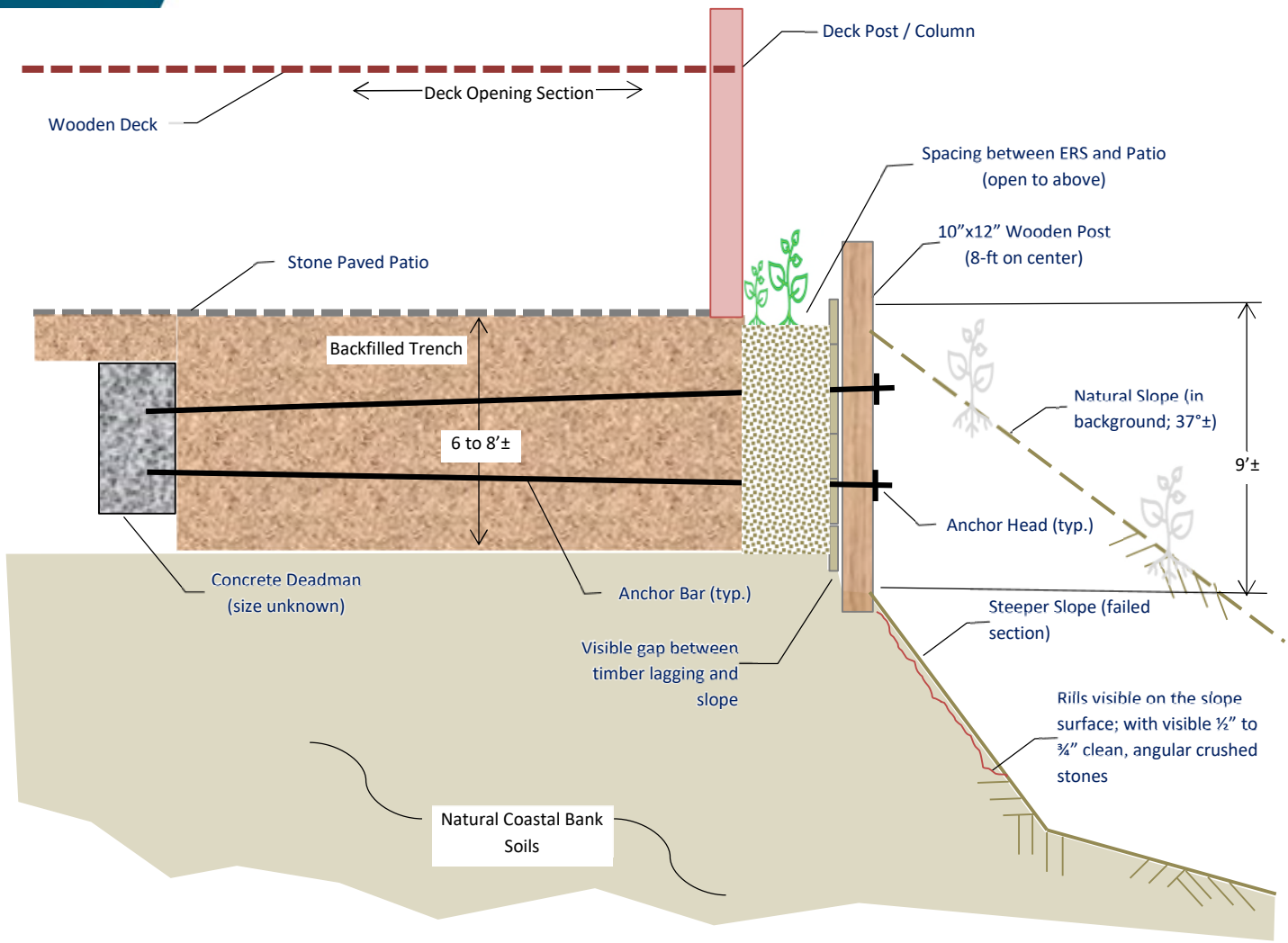


Figure 2: Schematic Profile of Existing Conditions

Note:

1. This cross section is through existing timber post, where two anchors were installed per post within an excavated trench back filled with sand and gravel. The 5-foot wide gap was also backfilled with non-native soils, based on the information provided by the Owner.

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ATTACHMENT A: LIMITATIONS

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ATTACHMENT B: PHOTOGRAPH LOG

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 1 Patio	Covered with stone pavers; looking north; wooden deck above	

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 2 Patio and Existing ERS	Five-foot spacing between ERS and Patio; looking east	

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 3 Failed Slope	Visible rills; clean crushed stone washed out behind the timber lagging wall/timber post; undermined toe of the ERS	

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 4 Insulation Foam Covered Section	Eastern end of the patio; large depression covered with foam, with a 4”± “floor” drain;	

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 5 Gap between pavers and edging stone	Looking west	

Photo 6 Gap between pavers and edging stone	Facing north; gap width approximately ¾” (indication of lateral movement of slope)

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24

Photo 7 Slope with rills | Viewed from top

Photo 8 Slope with rills | Viewed from toe

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24

Photo 9	Slope with rills	Large gaps between the bottom timber lagging and soil; patched with insulation foam; viewed from toe

Photo 10	Close-up view	Eastern end of toe: non-native crush stone probably washed out behind the wall;

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 11 Glacial Till on Coastal Bank	Close-up view of natural materials on the slope, poorly sorted sand and gravel, with some fines, feels dense/compacted.	

Photo 12 Abutting Slope (west)	Coastal bank covered with vegetation; less steep than the failed slope section; viewed from toe

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 13 Overall view	Viewed from toe	

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24

Photo 14 Toe Wall	Vertical stone wall (remnants; along previous railbed; looking east)

Photo 15 Toe Wall	Vertical stone wall (remnants; along previous railbed; looking west)

51 Harborview NOI Peer Review	Site Visit: 6/7/2023	Project Number 01.P000069.24
Photo 16 53 Harborview	Looking east; undermined slope section below chain-link fence