August 19, 2024

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Department of Public Works
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Re: Questions from the Conservation Commission Regarding Martins Lane Wave Analysis

This memorandum provides responses to questions asked by the Hingham Conservation Commission relative to the Martins Lane seawall wave analysis performed by Sustainable Coastal Solutions, Inc. (Coastal Solutions), dated July 8, 2024. The questions from the Conservation Commission are shown in blue, with answers provided below in black:

There is no indication of whether these calculations will manage the projected future changes that have been taken into account in the work being proposed by the Town Beach and Landing area. They have used the old data from 81 and 85 found in the 2011 USACE Coastal Engineering Manual, Part VI of the 2011 Version. This seems to be what most designers use at this point. So, the questions:

1. *Why are the 100-year storm winds relevant in contemporary recognition of the wind velocities?*

   We have attached the relevant portions of the wind analysis utilized to assess wave action for the harbor shoreline from Hingham Bathing Beach to Barnes Wharf, also performed by Coastal Solutions. The full coastal processes analysis is included in the recently submitted Expanded Environmental Notification Form for the harbor shoreline. While the calculation techniques utilize standard methodologies from the 1980s, these methods have not changed and remain accurate. The wind data incorporated into the analysis represents 40 years of data between 1980 and 2020. This represents the most contemporary information available for wind velocities.

2. *What have you calculated in for rising sea level values for Hingham Harbor?*

   Based on the latest projections from NOAA (Sweet, *et al*., 2022) the mean sea level in Boston Harbor is expected to be 1.0 feet NAVD88 in 2050 and 1.8 feet NAVD88 in 2070. Therefore, in 2070, the 100-year flood elevation in Boston Harbor is expected to be 11.4 feet NAVD88 or about 0.6 feet below the crest of the designed seawall.

3. *Is it desirable to have the wave break over top of the proposed as noted in your report? What are the implications of that?*

   Although it is never “desirable” to allow any wave overtopping, it is not practicable to prevent some overtopping during severe conditions, especially in low-lying areas such as Martins Lane. Similar design elevations were incorporated into the Town Wharf and Barnes Wharf designs, with the understanding that (a) adjustments in elevation may need to be considered in the future (as we approach 2070) and (b) the amount of wave overtopping is reduced to a level that will not damage pavement. In the case of the wharves along the harbor shoreline, storm wave conditions are significantly larger than conditions at Martins Lane; however, the design elevations for the seawalls are essentially the same.

4. *As it is now, we have waves cresting across the lower elevation of the road at the entrance now.*

   The design is intended to rectify this issue.

5. *What force calculations have you determined for the overtopping pressures?*

   The wave forces for overtopping waves at Martins Lane will be less than those computed for Town and Barnes Wharves improvements, as the wave heights impacting the seawall are significantly lower at Martins Lane. Therefore, any wave overtopping will not damage the roadway.

Reference

Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak, 2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf

Wave and Wind Data for Hingham Harbor Analysis

Wave Data. The USACE Wave Information Study (WIS) hindcast provides wave data time series at dozens of stations along the US coastline. Wave parameters (including Hs wave height, T_p Peak Period, and mean direction for sea and swell components of the sea state) are available at a regular hourly interval starting January 1, 1980 through to January 1, 2021. Though NOAA (through is National Data Buoy Center, NDBC) maintains a wave buoy in Massachusetts Bay (station 44013), this record does not have directional wave data until June 2012, and there are significant periods within the time span of the record (1984 to present) where no data are available. Because of this, WIS hindcast is better suited for the development of the extreme wave conditions.

The hindcast record from WIS station 63052 (mapped in Figure 11) was used for this study. This station is about 13 nautical miles northeast of the entrance to Boston Harbor, in Massachusetts Bay, in an area with ocean depths of about 180 feet. 63052 is the closest WIS station to Boston Light on Little Brewster Island, at the entrance to Boston Harbor. Rose plots showing the occurrence of wave height and periods by compass sector is shown in Figure 12. From this plot is it seen that the most commonly occurring wave direction is the east sector, from where wave come from 26.6% of the record. 72.6% of wave heights in the record have a Hs significant wave height that is less than 3 feet. In 43.7% of the span of the record, wave periods are between 6.5 and 9.5 seconds.

An extremal analysis of wave heights was performed to develop appropriate wave heights and periods to represent storm conditions of various return periods (for example, the 10-year or 100-year storm events). The largest Hs wave height in each compass sector for every year of the 41-year-long hindcast record were determined sorted from smallest to largest. Weibull and Fischer-Tippet (FT) probability density functions (PDF) where used to fit the sorted extreme wave height data. The FT PDF provides the best fit of the data with an R^2 correlation of the FT PDF is 0.99 and an RMS error of 0.2 feet for waves from the north. This analysis results in a 100-year offshore wave height from the SE of 14.8 feet. Extreme periods were determined using a linear fit of wave height vs. mean period for all wave records in the WIS hindcast. Using this linear fit, the mean period of the 100-year wave from the north sector is calculated to be 11.5 feet. A linear regression of extreme wave heights and associated periods from the WIS record was used to determine a mean period of 7.4 seconds for this particular wave height at station 63052.

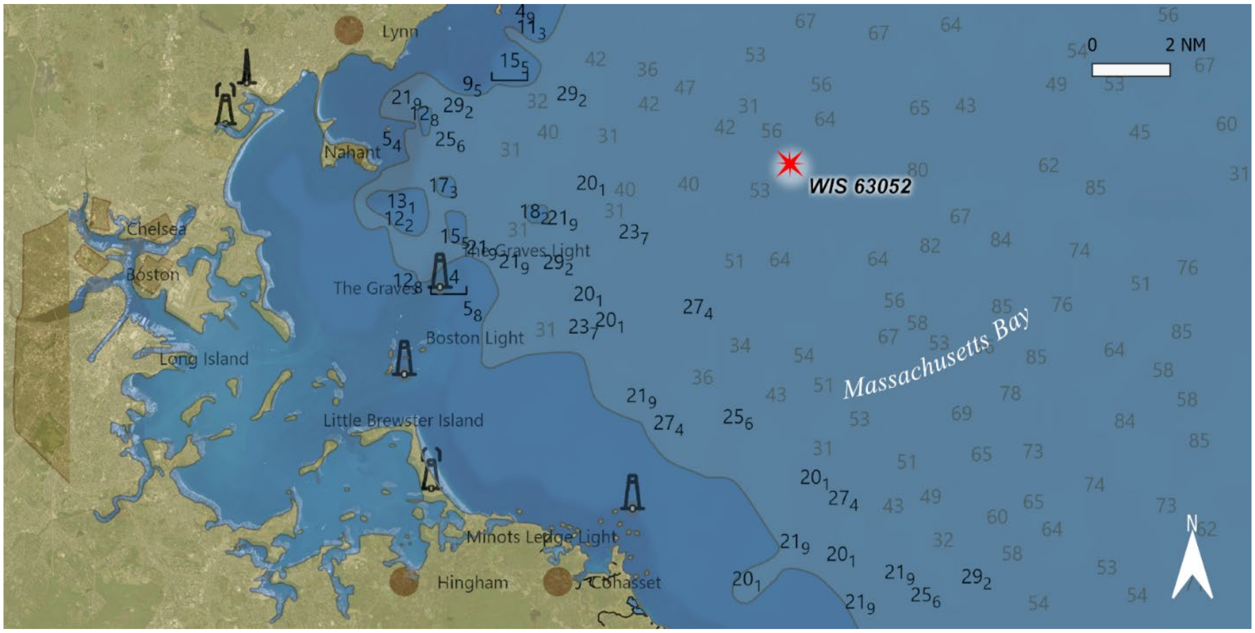

Figure 11. Location of WIS hindcast station 63052 in Massachusetts Bay, overlain on NOAA ENC chart of Massachusetts Bay (depths in meters and tenths).

Wind Data. Sources of wind data in the Boston Harbor region include the WIS hindcast, the Massachusetts Bay wave buoy (station 44013), and the record from Boston Logan International Airport (BOS). The record from BOS starts in 1943, and the record from buoy 44013 starts in 1984. Of these three sources, the WIS record is considered the best available option due to its offshore location, length of the record (because it is a reliably continuous record), and because it both wind speed and wave parameters together for each record. A rose plot of wind records from the WIS hindcast is presented in Figure 13. Most (50.2%) of the records are broadly distributed between the SSW and NW compass sectors, and the predominant direction is the SSW. The Fischer-Tippet II (FT) PDF is the best fit of annual extreme wind speeds taken from the WIS record. A plot of extreme return period winds from the north, based on the WIS record is presented in Figure 14. For the north sector, the 100-year sustained wind speed is 52.0 knots.

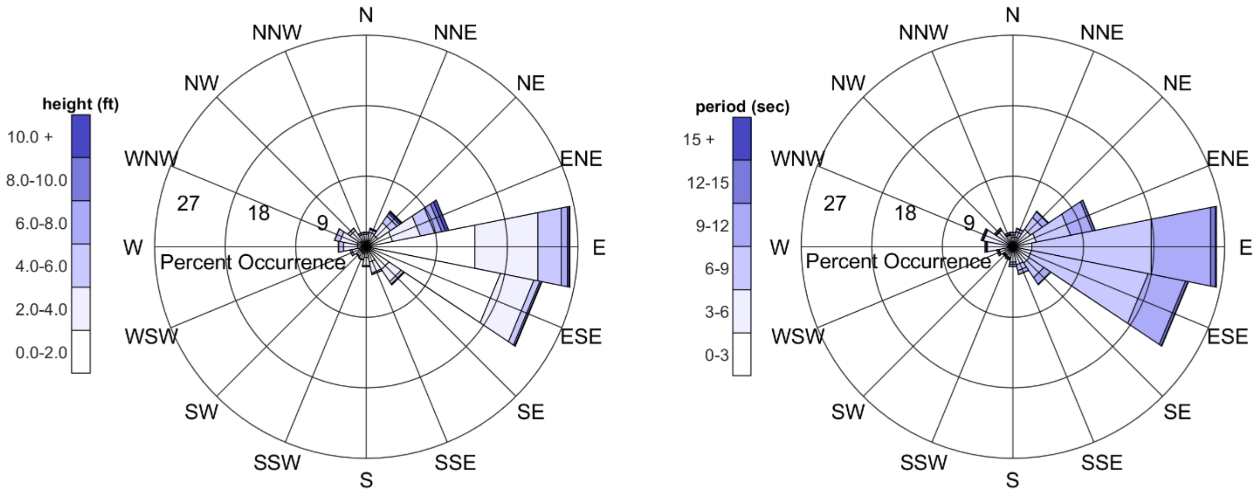

Figure 12. Rose plots of significant wave height (Hs, left) and peak wave period (Tp, right), for the WIS hindcast record at station 63052. Grey-tone segments indicate the percentage of time wave weights and periods in the record are within the indicated ranges for each compass sector.

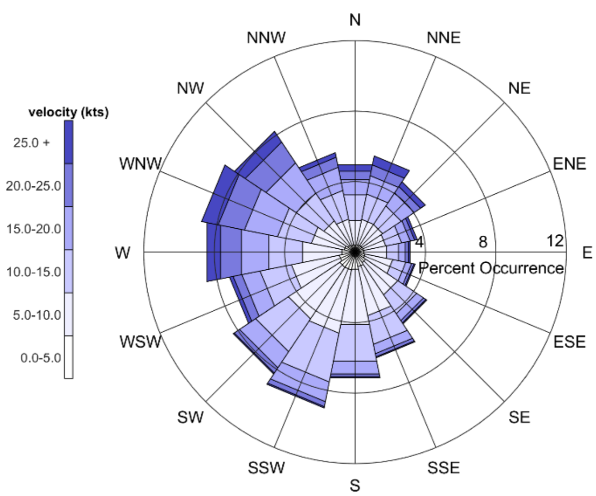

Figure 13. Rose plots of wind speed (knots) for the WIS hindcast record at station 63052. Grey-tone segments indicate the percentage of time winds in the record blow within the indicated speed range from the indicated compass sector.

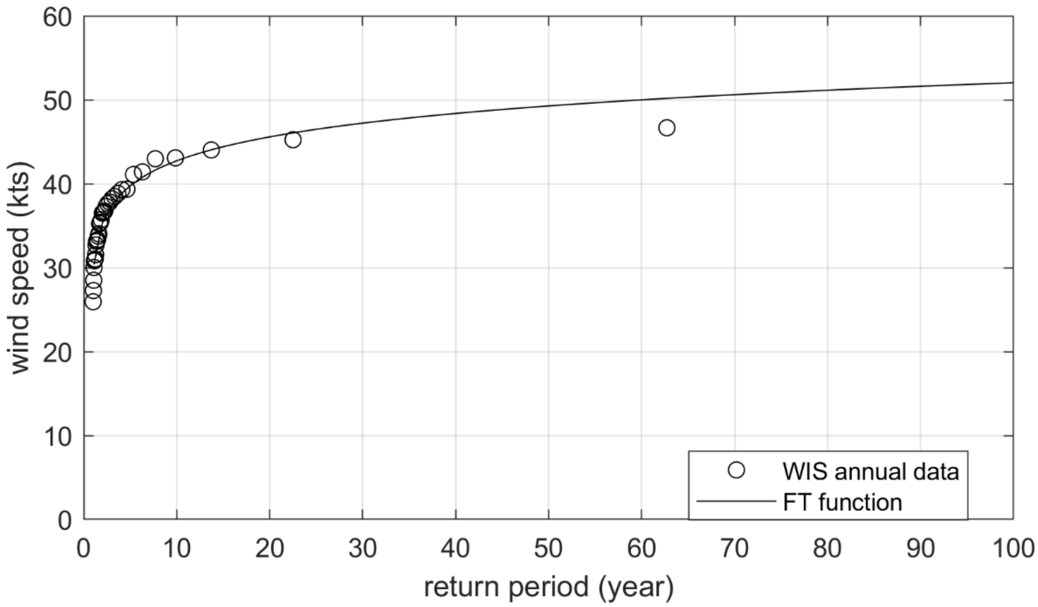

Figure 14. Plot of return period wind speeds for the north compass sector, using the WIS hindcast record (1980 through 2020) at station 63052. Sorted annual maximum windspeeds are indicated by the circle markers, and the Fischer-Tippet (FT) fit of the data is shown as the solid line. R^2 correlation of the FT PDF is 0.98, with an RMS error of 1.1 knots.