WOODS HOLE GROUP

81 Technology Park Dr., East Falmouth, MA 02536
Direct Extension: (508) 495-6221
Main Telephone: (508) 540-8080
FAX: (508) 540-1001
e-mail:lweishar@whgrp.com
www.woodsholegroup.com

MEMORANDUM

Date: June 10, 2016
To: Mr. Arthur Leventis
From: Lee Weishar, Ph.D.; PWS
Re: Technical Memorandum in Completion of Task 5, Evaluation of Sea level Rise and Coastal Processes at Coughlin Park, Winthrop, MA

This memorandum examines the waves incident at the shoreline and the expected increase in water levels based on calculated estimates of Sea Level Rise that are expected to occur from present to 2070.

Estimates of Sea Level Rise at Coughlin Park

Global mean sea level (MSL) has been rising since the end of the last ice age thousands of years ago. However, when a more recent time period is considered, sea-level rise (SLR) rates have accelerated, with unprecedented rates along the northeastern U.S. since the late 19th century (Kemp et al., 2011). Global sea-level rise is driven by a number of factors, including thermal expansion of ocean water and freshwater inputs from melting glaciers and ice caps. As discussed in more detail below, global increases by 2100 may range from 0.2 m (0.7 ft) to 2.0 m (6.6 ft). At a local level, relative sea-level rise is a function of both global and regional changes. Local variations in sea-level rise result from factors such as vertical land movement (uplift or subsidence), changing gravitational attraction in some sections of the oceans due to ice masses, and changes in regional ocean circulation (Nicholls et al., 2014).

A consortium of government agencies has completed a National Climate Assessment (Parris et al., 2012, Figure 1) that provides guidance on the appropriate selection of Sea-Level Rise (SLR) scenarios. Under this guidance, four (4) projected rates of sea-level rise (highest, intermediate-high, intermediate-low, and low) are presented. Given the range of uncertainty in future global SLR, using multiple scenarios encourages experts and decision makers to consider a range of future conditions and to develop multiple response options. The highest scenario in Parris et al. (2012) surpasses the maximum of 1.2 m (3.9 ft) recently presented in the IPCC Fifth Assessment Report (AR5) WG1 material (shown in Figure 2). The highest scenario from Parris et al. (2012), combines thermal expansion estimates from IPCC SLR projections with the maximum possible glacier and ice sheet loss by the end of the century, and is therefore useful to consider “in situations where there is little tolerance for risk”. A recent article by Bamber and Aspinall (2013) supports using a high sea-level rise projection based on the likely impact of glacier ice sheet melting. CZM also relies on the projections produced by Parris et al. (2012) in their sea-level rise guidance document (CZM 2013), as well as other state agencies, such as MassDOT and Massport. For these reasons, we recommend using the SLR scenarios presented by Parris et al. (2012) for the U.S. National Climate Assessment (Figure 1).

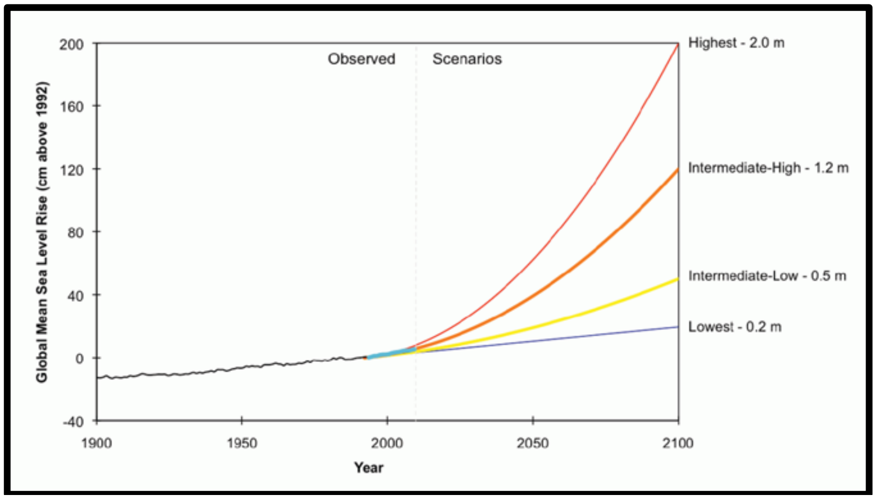

Figure 1. Projections of future sea-level rise recommended in Parris et al. (2012).

The low-SLR scenario presented in Parris et al. (2012) is based on observed historical SLR trends, which can vary from region to region. For example, the mean sea level trend for Boston is 2.80 millimeters/year with a 95% confidence interval of +/- 0.17 mm/yr based on monthly mean sea level data from 1921 to 2013 (Figure 3). Boston would therefore experience a relative SLR of 10.36 cm by 2050 from 2013 if current rates continued in a linear fashion (equivalent to low-SLR estimates).

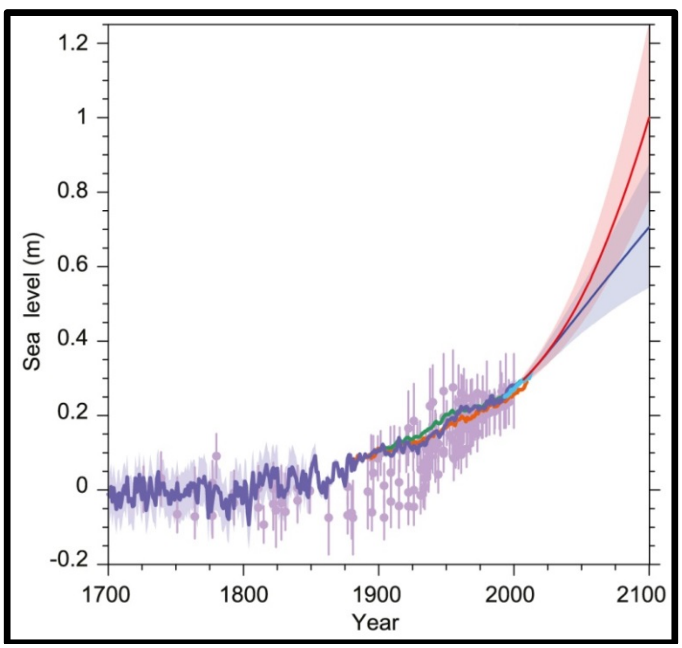

Figure 2. Sea-level rise projections in IPCC AR5 WG1. (Compilation of paleo sea level data, tide gauge data, and central estimates and likely ranges for projections of global-mean sea-level rise for PCP2.6 (blue) and RCP8.5 (red) scenarios, all relative to pre-industrial values.)

In this study, all four projected rates of sea-level rise are used as presented in the United States National Climate Assessment (Parris et al., 2012) to investigate the impacts of sea-level rise at Coughlin Park in Winthrop MA. This includes the low, intermediate-low, intermediate-high, and high sea-level rise projections. Model results are evaluated for specific out years for each sea-level rise scenario (2030 and 2070).

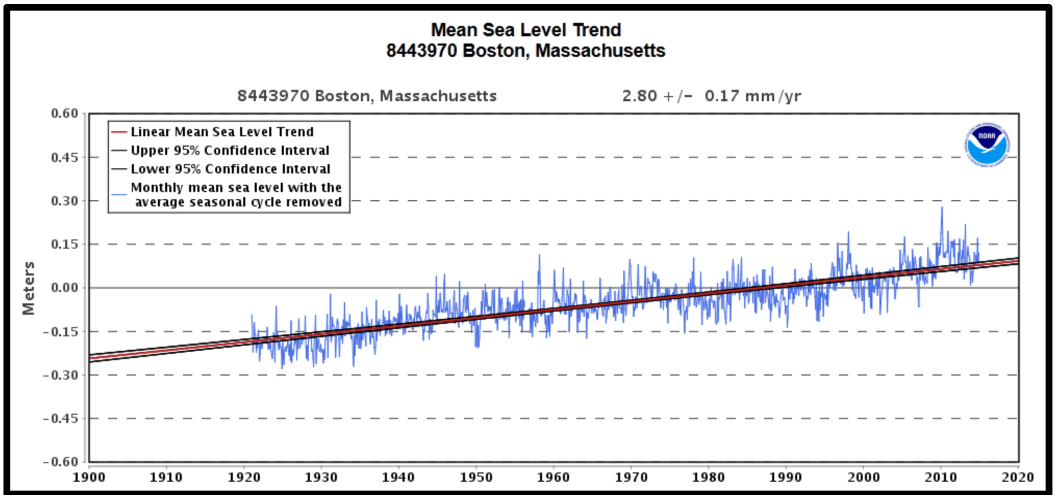

Figure 1-3. Comparison of mean sea-level rise trend at different locations in Massachusetts (NOAA, 2013). The upper panel shows Nantucket Island, while the lower panel shows Boston.

The sea-level rise projections below (Table 1) indicate the total expected change in sea level between 2015 and the final out year (2030 or 2070). Local subsidence at Boston (0.84 mm/yr) is accounted for in various sea-level rise scenarios. Linearly projecting the historic rates listed above out into the future corresponds to the low sea-level rise scenario presented below. Intermediate-Low, Intermediate-High, and High sea-level rise scenarios correspond to the projected rates of sea-level rise developed by Parris et al. (2012) for the U.S. National Climate Assessment, and discussed earlier in this report.

Table 1. Sea Level Rise projections for Coughlin Park, Winthrop, MA

Local Sea Level Rise (feet)		
	2030	**2070**
Low	0.14	0.51
Intermediate-Low	0.21	0.95
Intermediate-High	0.39	2.05
High	0.59	3.30

Examining community vulnerability cannot be limited to projecting estimated average sea level rise over a period of time. A complete vulnerability assessment also recognizes the dynamic physical processes and timing associated with storms, along with increasing risks of sea level rise and climate change. For example, typical flooding studies sometimes focus on the “bathtub” approach, which essentially forecasts future sea level rise, adds a static storm surge level, and then compares the forecast elevation to the surrounding land elevations and assumes every property lower than the forecast sea level will be flooded. This type of analysis, while useful at cursory planning levels, is not adequate for a vulnerability assessment. Storms do not produce uniform water levels, and are not the same everywhere due to the dynamic nature of storm events (e.g. winds, waves, etc.). As such, incorporating the dynamic influence of combined storm surge, waves, winds, and tides into community vulnerability assessments is critical in order for Winthrop to be climate ready. Woods Hole Group has already developed a comprehensive probabilistic flood risk model for Boston (the Boston Harbor Flood Risk Model [BH-FRM]) that can accurately assess flooding risk under present day and future climate change conditions with work completed for MassDOT (Bosma et al., 2015). The results of this investigation are readily available for Winthrop. The results from the BH-FRM model have already been utilized (or are currently being utilized) to complete community-wide and agency vulnerability assessments for MassDOT, Massport, Hingham, Harvard, East Boston, UMass Boston, Cambridge, Quincy, Chelsea, Partners Health Care, Gloucester, and other Massachusetts communities. Table 2 presents the results from the BH-FRM model directly at the Winthrop Coughlin Park site.

Table 2. Results from the BH-FRM Investigation

Return Period Water Levels (ft, NAVD88)			
	Present	**2030**	**2070**
5-yr	7.7	8.1	11.0
10-yr	8.1	9.0	11.6
20-yr	8.5	9.2	12.1
50-yr	9.0	9.7	12.5
100-yr	9.4	9.9	12.9

Wave Heights at Coughlin Park Shoreline

A potential green infrastructure shoreline erosion project on the Coughlin Park shoreline will be subjected to both increase in water levels due to seal level rise and local generated wind waves. It is important to know the height of the water level due to sea level rise that will occur because the increase in water level allows wind waves to reach farther up the shoreline and potentially increase the height of the incoming wave at the shoreline. The wave height at the shoreline may increase because the height of the breaking wave at the shoreline is dependent on the depth of water immediately offshore. If there are relatively large increases in water depth, then the height of the breaking wave at the shoreline may increase. Therefore, we calculated potential increases in wave height using the expected increases in water levels shown in Table 2.

In order to calculate wave heights at the shoreline, it is necessary to obtain wind records and perform an extremal analysis on the wind record to extract wind speeds with the desired return periods. In order to perform wind extremal analysis a data set with a long-record is needed. Ideally, the wind data set would be obtained at or very near the site of interest. For this analysis we selected a wind record from the Weather Underground (www.wunderground.com) at the Boston Logan International Airport station for the years 1945-2015. The annual maximum wind speed value was extracted and then fit into the generalized extreme value (GEV) distribution. Wind speeds for the desired return periods were calculated from the cumulative distribution curve. The results are shown in Table 3.

Utilizing the results shown in Table 3, the wave heights generated at the Coughlin Park shoreline can be calculated. Based on the above return period water levels and wind speed, a combination of 15 scenarios were set up to compute the return period wind-generated waves. They are the years of present, 2030, and 2070 with return period of 5, 10, 20, 50, and 100 years (Table 4).

Table 3. Wind Speeds for 5, 10, 20, 50, and 100-year return periods

Return Period Wind Speed (mph)	
5-yr	50.9
10-yr	55.9
20-yr	60.9
50-yr	67.7
100-yr	73.1

The Automated Coastal Engineering System (ACES) from US Army Corps of Engineers was applied to calculate wind-generated waves. A set of radials with 10-degree interval were put at the shoreline of the project site to represent the fetch from all possible directions above the water. Different wind directions were compared to get the angle for the maximum wave height. The average depth is about 20 feet along the fetch. Along with other input parameters, such as water levels, wind speed, and fetch length, the wave information (wave height and period) were calculated for each scenario (Table 4).

Table 4. Wave heights and periods generated for the years 2030 and 2070

Return Period Wind-generated Waves						
	Present		**2030**		**2070**	
	Hmo (ft)	**Tp (sec)**	**Hmo (ft)**	**Tp (sec)**	**Hmo (ft)**	**Tp (sec)**
5-yr	2.38	2.79	2.38	2.79	2.39	2.80
10-yr	2.69	2.94	2.69	2.95	2.70	2.95
20-yr	3.00	3.09	3.01	3.09	3.02	3.10
50-yr	3.45	3.29	3.46	3.29	3.47	3.30
100-yr	3.82	3.44	3.82	3.44	3.85	3.45

Table 4 shows that there is little increase in the expected wave heights in the year 2030. This is because the expected increase in sea level rise is relatively small when compared to the existing tidal range that occurs in Boston Harbor and at Coughlin Park.

References

Bamber, J.L. and W.P. Aspinall. 2013. An expert judgement assessment of future sea level rise from the ice sheets. Nature Climate Change. DOI: 10.1038/ NCLIMATE1778.

Bosma, K., E. Douglas, P. Kirshen, K. McArthur, S. Miller, and C. Watson. 2015. MassDOT-FHWA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery.

CZM. 2013. Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning. Massachusetts Office of Coastal Zone Management. December 2013.

Kemp, A. C., B. P. Horton, J. P. Donnelly, M. E. Mann, M. Vermeer and S. Rahmstorf. 2011. Climate related sea-level variations over the past two millennia. PNAS. 108(27):11017–11022.

Nicholls, R., S. Hanson, J. Lowe, R. Warrick, X. Lu, and A. Long. 2014. Sea-Level Scenarios for Evaluating Coastal Impacts, WIREs Climate Change, 5, doi:10.1002/wcc.253.

NOAA. 2013. https://tidesandcurrents.noaa.gov/sltrends/sltrends_states.htm?gid=1245

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp. Available online December 2012: http://cpo.noaa.gov/sites/cpo/Reports/2012/NOAA_SLR_r3.pdf.