COAST & HARBOR ENGINEERING

Technical Memorandum
Coastal Engineering Analysis and Assistance with Design Boulevard Park Gravel Beach, Bellingham, Washington

1. Introduction

This technical memorandum summarizes the results of coastal modeling and analysis to determine the horizontal forces from the design wind-wave storm events on vertical piles of the overwater walkway at Boulevard Park Gravel Beach in Bellingham, Washington. Two design wind-wave storm events were considered with 25- and 50-year return periods of occurrence. Wind statistical and extreme analyses were performed, return periods of wind events from all possible wave generation directions were developed, and are shown in Table 1.

Table 1. Bellingham Bay, Return Periods of Wind Events from Wave-Forming Fetches

BELLINGHAM BAY, WA[1]
BOULEVARD-CORNWALL OVERWATER WALKWAY
RETURN PERIOD WIND SPEEDS (mph)
(1-min duration)

Return Period	Wind Direction (°T)															
(yr)	230	240	250	260	270	280	290	300	310	320	330	340	350	360	10	20
2	40.7	42.0	36.8	30.8	34.1	38.9	35.5	31.7	31.2	30.8	25.4	24.6	16.3	21.0	23.9	33.0
5	46.5	47.2	42.5	36.6	39.0	42.8	39.8	35.2	34.8	35.3	29.4	29.1	20.4	27.1	31.3	39.9
10	49.8	50.2	45.8	39.9	41.8	45.1	42.3	37.2	36.8	37.9	31.7	31.7	23.5	31.0	36.1	43.8
25	53.4	53.6	49.4	43.6	44.9	47.6	45.0	39.3	39.1	40.8	34.3	34.6	27.6	35.7	41.9	48.2
50	55.9	55.8	51.8	46.1	46.9	49.3	46.8	40.8	40.6	42.7	36.0	36.5	30.7	39.0	45.9	51.2
100	58.1	57.8	54.0	48.3	48.8	50.8	48.5	42.1	42.0	44.5	37.5	38.3	33.8	42.2	49.7	53.8

Notes:
[1]Period of record: 1973-2007

Based on previous analysis and sensitivity modeling, it was determined that the wind-wave fetch of 240^0 produces the largest wave parameters at the project site. Therefore, this direction (240^0) was used to generate the design storm events with 2-Dimensional numerical modeling. A large numerical modeling grid for this modeling effort was constructed to include the entire Bellingham Bay. Figure 1 shows the large modeling grid in color format.

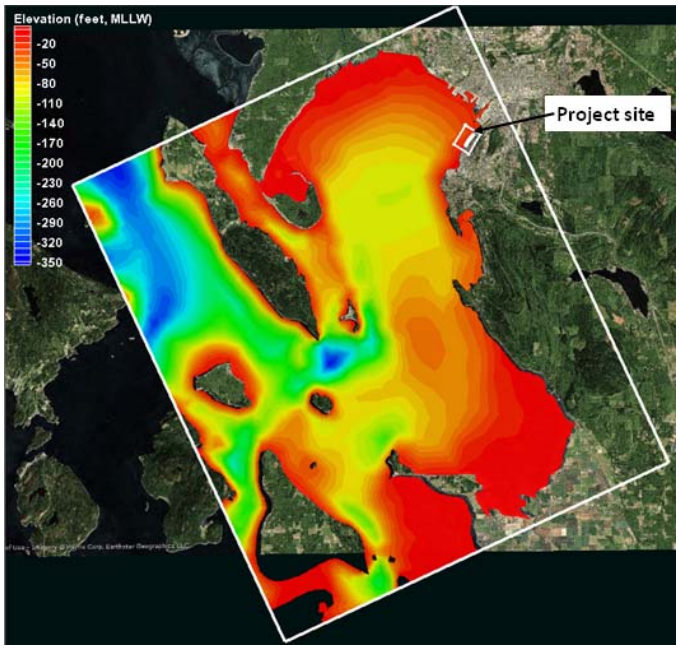


Figure 1. Large numerical modeling grid for Bellingham Bay

In order to optimize the modeling effort and provide detailed information on wave parameters at the project site and along the overwater walkway, a fine mesh (very detailed) nested numerical modeling grid was constructed. Figure 1 above shows the boundary of the nested modeling grid relative to the large modeling grid. Figure 2 below shows the zoomed-in nested modeling grid.

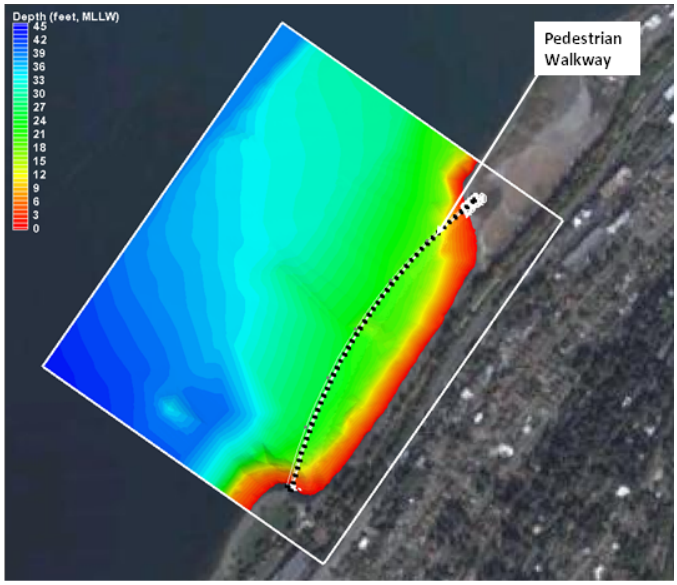
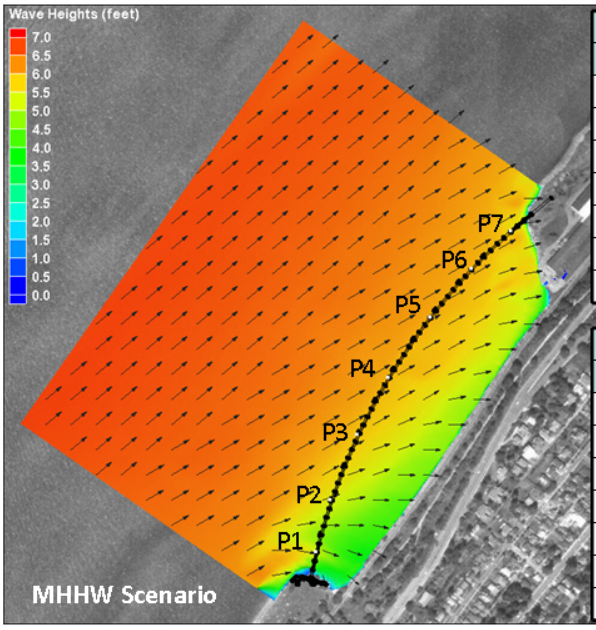


Figure 2. Zoomed-in nested numerical modeling grid for overwater walkway

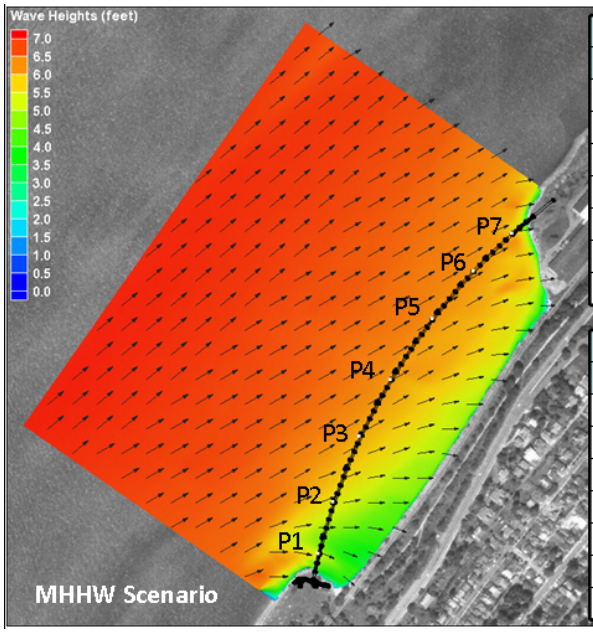
Wave refraction-diffraction modeling was conducted for two wind storm events with 25- and 50-year return periods. The modeling was conducted for MHHW tide elevations. Results of the modeling are shown in Figures 3 and 4 below.



	Significant Wave Height (feet)			
Point	MLLW	MSL	MHHW	EHW
1	3.3	4.1	4.7	5.0
2	4.6	4.8	5.0	5.1
3	5.1	5.3	5.5	5.6
4	5.2	5.5	5.6	5.7
5	5.3	5.6	5.7	5.8
6	5.3	5.5	5.7	5.8
7	3.7	5.1	5.4	5.5

	Significant Wave Height (feet)			
Point	MLLW	MSL	MHHW	EHW
1	5.5	5.5	5.5	5.5
2	5.5	5.5	5.5	5.5
3	5.5	5.5	5.5	5.5
4	5.5	5.5	5.5	5.5
5	5.5	5.5	5.5	5.5
6	5.5	5.5	5.5	5.5
7	5.5	5.5	5.5	5.5

Figure 3. Wave modeling results for 25-year return period storm event, Dir 240^0 TN



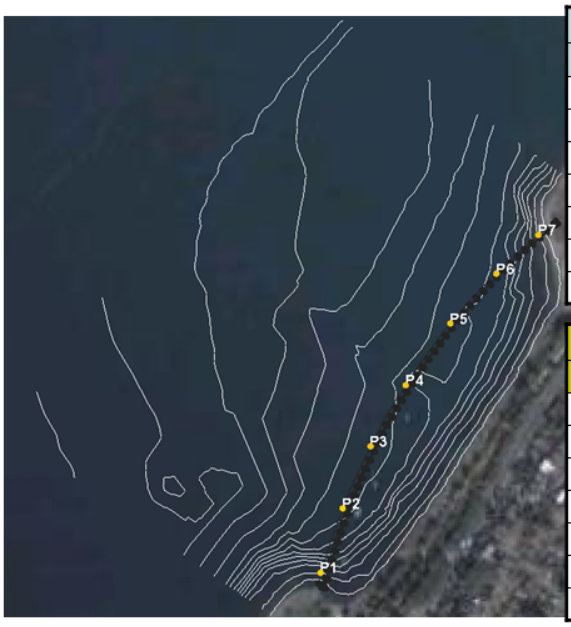
	Significant Wave Height (feet)			
Point	MLLW	MSL	MHHW	EHW
1	3.4	4.3	5.0	5.3
2	4.8	5.1	5.3	5.4
3	5.4	5.6	5.8	5.9
4	5.5	5.8	5.9	6.0
5	5.6	5.9	6.0	6.1
6	5.6	5.8	6.0	6.0
7	3.8	5.3	5.7	5.8

	Significant Wave Height (feet)			
Point	MLLW	MSL	MHHW	EHW
1	5.5	5.5	5.5	5.5
2	5.5	5.5	5.5	5.5
3	5.5	5.5	5.5	5.5
4	5.5	5.5	5.5	5.5
5	5.5	5.5	5.5	5.5
6	5.5	5.5	5.5	5.5
7	5.5	5.5	5.5	5.5

Figure 4. Wave modeling results for 50-year return period storm event, Dir 240^0 TN

The figures show wave height distributions over the nested modeling grid in color format. Red color corresponds to higher wave conditions. The figures also show the alignment of the overwater walkway. Seven controlling stations (points) were placed along the walkway alignment on the modeling grid. Wave parameters (wave heights and periods) were extracted from the modeling results at each of the controlling points on the grid. Results of the extraction (wave heights and periods) are shown in the tables depicted in Figures 3 and 4.

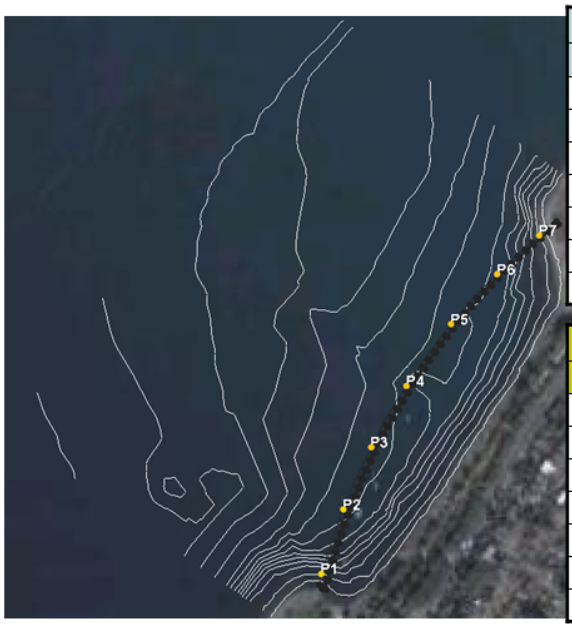
Wave horizontal forces on walkway piles were computed using recommendations from the U.S. Army Corps of Engineers (COE) Coastal Engineering Manual (COE, 2003 Part VI-5). Wave forces were computed for two wave storm events; 25- and 50- year return periods. Wave forces were determined at each pile located at the controlling points. Results of the calculations are presented in the tables depicted in Figures 5 and 6.



	Force on piles LBS			
Point	MLLW	MSL	MHHW	EHW
1	586.5	1436.7	2103.4	2312.2
2	1661.5	1755.1	1872.7	1878.4
3	1949.8	2031.8	2138.9	2138.9
4	2220.9	2182.0	2235.0	2235.0
5	2241.9	2227.0	2273.0	2273.0
6	2313.3	2239.0	2289.4	2289.4
7	359.9	2300.2	2576.0	2576.0

	Elevation of Force Application (feet)			
Point	MLLW	MSL	MHHW	EHW
1	3.6	11.4	13.5	13.1
2	16.5	20.0	24.3	22.5
3	17.4	21.0	25.4	25.4
4	16.8	18.3	22.5	22.5
5	17.4	18.8	23.0	23.0
6	15.9	19.3	21.6	21.6
7	2.6	7.7	16.4	16.4

Figure 5. Forces on piles during 25-year return period storm



	Force on piles LBS			
Point	MLLW	MSL	MHHW	EHW
1	573.1	1436.7	2289.4	2500.0
2	1798.2	1893.2	1956.3	2006.3
3	2122.2	2201.8	2268.2	2304.4
4	2470.9	2376.9	2386.4	2420.5
5	2521.3	2431.3	2427.2	2462.9
6	2596.0	2530.1	2470.0	2454.1
7	387.8	2300.2	1997.4	2476.8

	Elevation of Force Application (feet)			
Point	MLLW	MSL	MHHW	EHW
1	3.6	11.4	15.2	13.3
2	16.6	20.2	22.8	24.5
3	17.6	21.2	23.9	25.6
4	17.0	20.6	20.9	22.7
5	17.7	21.2	21.5	23.2
6	16.2	19.8	22.4	21.6
7	2.5	7.7	13.9	16.3

Figure 6. Forces on piles during 50-year return period storm

The location (elevation) of the applied wave force was determined using COE recommendations. Figure 7 shows a conceptual diagram of the applied wave force on the piles. The computed elevations of design force application during 25- and 50-year return period storm events are shown in the tables depicted in Figure 5 and 6 above.

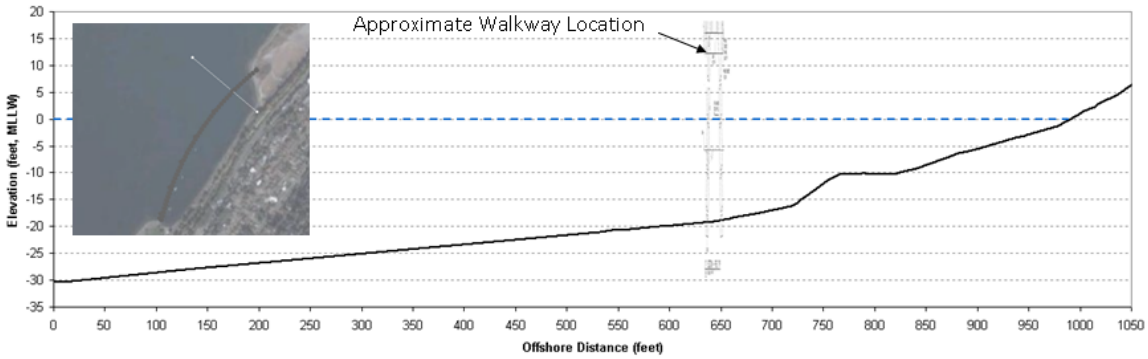


Figure 7. Conceptual diagram of location of design wave force on the piles

2. References

COE. 2003. Coastal Engineering Manual, Part VI-5.