Coastal Engineering

Appendix

Woodtick Peninsula CAP Section 204 Coastal Review

Date: August 31, 2021

Rev. Date: March 15, 2022

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1. Introduction

This appendix focuses on a coastal review of the proposed project with consideration for the alternatives. It presents feasibility-level design wave computations and stone sizing calculations for the preservation of Woodtick Peninsula and the protection of wetlands on the leeside of the peninsula under the Continuing Authorities Program (CAP) Section 204 authority. CAP Section 204 of the Water Resources Development Act of 1992 authorized the U.S. Army Corps of Engineers (USACE) to implement projects for the protection, restoration and creation of aquatic and ecologically related habitats in connection with the beneficial reuse of dredge sediment from an existing authorized Federal Navigation Project. Dredge material is expected to be obtained from the Maumee River shipping channel. Figure 1 below shows the location and approximate extents of the project site.

Figure 1. Woodtick Peninsula located in Erie, MI

2. Background and Existing Conditions

Woodtick Peninsula forms a natural barrier beach and peninsula wetlands that protects one of the few large, remaining protected wetlands and habitats for a variety of fish, birds and other wildlife on Lake Erie. The area hosts various activities including sport fishing, bird watching, recreational boating and duck hunting. Extensive shoreline armoring to the north of the project site has severely reduced the sediment supply and corresponding littoral drift that once fed the peninsula. Sediment supply to the peninsula primarily came from the erosion of remaining bluffs, beaches and the nearshore to the north of the project site. While the area lacks the significant wave energy of other Great Lakes coasts, reduced sediment supply coupled with record high water levels expose more of the peninsula to increased wave energy. Therefore, the peninsula is eroding faster than sediment can be supplied, and several breaches have occurred. This threatens not only the peninsula, but the large wetland habitats that are directly adjacent to Woodtick Peninsula.

3. Design Wave Computations

3.1 Coastal Hazards System Data

The Coastal Hazards System (CHS) is a database that contains modeled hydrodynamics and waves for the United States coastlines (Coastal and Hydraulics Laboratory 2012) - https://chs.erdc.dren.mil/. For this feasibility review, coupled ADCIRC and SWAN save points 1026, 1036, 1039 and 1043 were analyzed on the lakeside of the peninsula, moving from north to south along the peninsula. On the leeside of the peninsula, coupled ADCIRC and SWAN save points 1042, 1049 and 1046 were analyzed, from north to south. For save points 1026 and 1036, 140 storms were modeled, and a total of 139 storms were used for each of the remaining save points. The storms modeled occurred between 1960-2008. Peaks over threshold ADCIRC and SWAN datasets were used for hydrodynamics and waves, respectively. See Figure 2 for save point locations.

Figure 2. ADCIRC and SWAN save points from CHS and WIS save points

3.2 Design Wave Analysis

The StormSim joint probability analysis (JPA) and StormSim Stochastic Simulation Technique (StormSim-SST) MATLAB codes (Nadal-Caraballo et al. 2021) provided by ERDC-CHL were used to perform computations for design water level and wave parameters. This code is under continuous development. It was distributed to the Detroit District for operational purposes and is being implemented for this project's feasibility design efforts.

A JPA was used to produce correlated values for significant wave height (H_{m0}), peak wave period (T_p), mean wave direction (MWD) and still water levels (SWL). MWD is always referenced as toward the direction indicated with 0 degrees being true north. SWL is the elevation above or below low water datum (LWD). The 50-year annual recurrence interval (ARI) is acceptable for a feasibility design wave based on the nature of this project and results of the JPA. However, additional ARIs are provided for comparison purposes and could be considered for the project. Respectively, Tables 1 and 2 show the four lakeside and three leeside CHS JPA results with corresponding ARI in years for each of the save points. Table 1 wave results will be used to design and evaluate the proposed stone armoring, geosynthetic containers and open dredge placement for wetlands in alternatives on the exposed lakeside. Table 2 provides wave characteristics that the dredge material placed for wetland creation on the peninsula leeside may be exposed to.

SWAN SP1043 and ADCIRC SP1043					
Prob	ARI	H_{m0} (ft)	T_p (s)	MWD (deg, az)	SWL (ft)
0.93	5	2.5	4.5	209	1.3
0.965	10	2.6	4.8	218	1.6
0.993	**50**	**2.8**	**5.3**	**233**	**1.9**
0.997	100	2.8	5.4	239	2.0
0.999	500	2.9	5.7	251	2.1

SWAN SP1039 and ADCIRC SP1039					
Prob	ARI	H_{m0} (ft)	T_p (s)	MWD (deg, az)	SWL (ft)
0.93	5	2.6	5.0	207	1.4
0.965	10	2.6	5.3	209	1.6
0.993	**50**	**2.7**	**5.7**	**214**	**1.9**
0.997	100	2.8	5.8	216	2.0
0.999	500	2.8	5.9	220	2.1

SWAN SP1036 and ADCIRC SP1036					
Prob	ARI	H_{m0} (ft)	T_p (s)	MWD (deg, az)	SWL (ft)
0.93	5	2.7	5.1	200	1.4
0.965	10	2.8	5.4	201	1.6
0.993	**50**	**2.9**	**5.7**	**203**	**1.9**
0.997	100	2.9	5.8	204	2.0
0.999	500	3.0	5.9	205	2.1

SWAN SP1026 and ADCIRC SP1026					
Prob	ARI	H_{m0} (ft)	T_p (s)	MWD (deg, az)	SWL (ft)
0.93	5	2.8	5.0	198	1.4
0.965	10	2.9	5.3	199	1.6
0.993	**50**	**3.0**	**5.7**	**201**	**1.9**
0.997	100	3.0	5.8	201	2.0
0.999	500	3.0	5.9	203	2.0

Table 1. Lakeside SWAN and ADCIRC JPA Results

SWAN SP1042 and ADCIRC SP1042					
Prob	ARI	H_{m0} (ft)	T_p (s)	MWD (deg, az)	SWL (m)
0.65	1	0.70	1.6	118.3	-0.1
0.93	5	0.98	1.9	119.2	0.3
0.965	10	1.04	1.9	119.5	0.4
0.986	25	1.08	2.0	119.8	0.5
0.993	50	1.10	2.0	120.0	0.5
0.997	100	1.11	2.0	120.2	0.6
0.999	500	1.12	2.0	120.6	0.6

SWAN SP1046 and ADCIRC SP1046					
Prob	ARI	H_{m0} (ft)	T_p (s)	MWD (deg, az)	SWL (m)
0.65	1	1.00	1.9	139.3	-0.1
0.93	5	1.42	2.5	154.4	0.3
0.965	10	1.49	2.7	159.1	0.4
0.986	25	1.54	3.0	164.5	0.4
0.993	50	1.56	3.1	168.1	0.5
0.997	100	1.58	3.3	171.4	0.5
0.999	500	1.59	3.7	178.3	0.6

Table 2. Leeside SWAN and ADCIRC JPA Results

Reviewing the results from Table 1 show good agreement between the 50-year results for each of the save points along the lakeside of the peninsula. As is shown, the wave climate along the peninsula is low energy with small wave heights and short periods regardless of the ARI chosen. Wave transformation was not necessary due to the SWAN and ADCIRC save points being in shallow water in the approximate locations of the alternatives' structures. SP1043 will be used for stone design in this feasibility study. A H_{m0} = 2.8 ft and a T_p = 5.3 s will be used to review the lakeside section of the project and initial stone sizing design. The MWD of 233 degrees is predominately to the southwest.

3.3 Design Water Levels

Three SWLs were evaluated. The first is Low Water Datum (LWD) which is 569.2 ft IGLD85 in Lake Erie. Since there was good correlation in the JPA between the wave characteristics and SWL, the second is the 50-year correlated SWL for SP1043 of 571.1 ft IGLD85 from Table 1. Ordinary High Water Mark (OHWM) was the final considered at 573.4 ft. The 20-year uncorrelated water level of

575.2 ft is often considered for worst-case scenarios, but after a review of the long-term water levels in Figure 3 below, it was determined OHWM would be an appropriate worst-case high scenario. Information in Figure 3 can be found at the following - https://www.lre.usace.army.mil/.

LAKE ERIE

2020	*573.49*	*573.82*	*573.98*	*574.31*	*574.41*	*574.48*	*574.31*	*573.92*	*573.59*	*573.23*	*573.00*	*573.00*	*573.79*
Mean	**570.93**	**570.90**	**571.19**	**571.65**	**571.95**	**572.05**	**571.98**	**571.78**	**571.49**	**571.16**	**570.93**	**570.90**	**571.42**
Max	573.69	573.82	573.98	574.31	574.41	574.61	574.57	574.21	573.72	573.95	573.65	573.79	
	1987	2020	2020	2020	2020	2019	2019	2019	2019	1986	1986	1986	
Min	568.27	568.18	568.24	568.83	569.03	569.06	569.06	569.00	568.83	568.57	568.24	568.21	
	1935	1936	1934	1934	1934	1934	1934	1934	1934	1934	1934	1934	

Figure 3. Lake Erie Long-Term Mean, Max and Min elevations in feet IGLD85

NOAA charts 14847 and 14830 were reviewed to look at approximate depths in the area of the proposed structure and peninsula, and depths were determined to be around 3 ft below LWD. This depth was compared to a hydrographic survey performed between 14-16 June 2021 and shows good agreement. It was also found that depths around Woodtick Peninsula remain extremely shallow for a long distance offshore with a slope of about 0.001 for several hundred yards lakeward. The depths at the proposed structures for LWD, 50-year correlated and OHWM were estimated to be 3.0 ft, 4.9 ft and 7.2 ft, respectively.

4. Design Wave Parameters

Due to the location of the SWAN save points being reasonably close to the structure location and the consistent shallow depths, no wave transformation was performed. However, each of the SWLs and waves were checked for breaking based on McCown's conservative criteria of 0.78 times the depth. A breaking wave was only produced at the LWD elevation. The resulting design range of waves can be found in Table 3 below.

Water Level	H_S (ft)	T_p (s)
LWD (569.2 ft)	2.3 (breaking)	5.3
50-year SWL (571.1 ft)	2.8	5.3
OHWM (573.4 ft)	2.8	5.3

Table 3. Design Wave Parameters

Due to the small size of the wave heights and short periods produced from the CHS data model runs, Wave Information Studies (WIS) data was reviewed from stations 92112 and 92113 to verify the validity of those values. See Figure 2 above for locations. Data studied from those offshore hindcast storm values produced similarly small waves and short-wave periods.

MWD was also considered from the CHS and WIS data to verify initial assumptions of primary direction of literal drift from north to south on the lakeside of the peninsula. The largest fetches for waves to develop come from northwest to west directions. The CHS JPA supports this showing primary wave directions for all lakeside save points approaching from the northwest. Additionally, evaluation of extremes data for the WIS save points and wave roses also support this conclusion. WIS data can be found here - http://wis.usace.army.mil/.

5. Stone Sizing

5.1 Stone Sizing Methodology

A stone sizing calculator developed in Microsoft Excel within LRE was used to determine stone sizing for any alternatives involving the use of stone for armoring and habitat. The four methods considered for stone sizing in this analysis are Hudson, van der Meer, van Gent, and Melby. The Hudson formula is based on regular waves, while van der Meer considers irregular waves in relatively deep water and moderate shallow water conditions (Guler 2014). Van Gent is based on irregular wave conditions mainly in shallow water conditions (Guler 2014) and is applied when wave breaking occurs before waves reach the structure (van Gent 2003). Melby equations are similar to Hudson and van der Meer but were developed to explicitly include the effects of nearshore wave height, wave period, water depth, storm duration, and characteristics of wave breaking on the structure (Melby 2005).

5.2 Stone Sizing Results

The following section provides input assumptions used in the Excel calculator and output results for stone intended to support and protect the proposed geosynthetic containers. The input wave values taken from the lakeside CHS JPA to be used in the calculations are H_{m0} = 2.8 ft (nonbreaking), T_p = 5.3 s and d_s = 7.2 ft based on the OHWM water elevation of 573.4 ft IGLD85. There are additional considerations that would require resolution outside the scope of this current study. These include addressing the shallow depths which while limiting wave energy impacting any structure, would pose potential scour issues. Additional structural design of the toe, geotechnical stability of the selected structure and other considerations may be required.

Table 4 below provides the D_{50} results from the stone sizing calculations. Based on the nonbreaking conditions for the worst-case SWL, the average W_{50} from Hudson, van der Meer, and Melby equations comes to an average W_{50} = 285.7 lbs. Due to the unusual small size of armor stone produced by the wave conditions, a minimum D_{50} = 3 ft with a design weight of W_{50} = 4,455 lbs is recommended as a minimum to counteract the effects of ice damage on the structure in this region. Prior design experience from LRB on Lake Erie has found that coastal projects with stone sizes less than D_{50} = 3 ft become susceptible to ice forces which cause dislocation of stones and damage to the structure.

	Hudson **(USACE 2006)**	**van der Meer** **(USACE 2006)**	**van Gent** **(van Gent 2003)**	**Melby** **(Melby 2005)**
H_{design} (ft)	3.56	2.8	N/A	2.80
D_{50} (ft)	N/A	1.14	N/A	1.12
W_{50} (lbs)	417.27	244.47	N/A	234.90
W_{50} (tons)	0.2	0.1	N/A	0.1

Table 4. Results of Stone Sizing Calculations

5.3 Summary of Stone Sizing

For the purpose of this feasibility study, initial evaluation and estimating purposes, the stone size below in Table 5 is selected for all alternatives requiring stone vulnerable to surface wave and ice forces. Gradation is also provided as a reference and is standard for stone structures in Part VI, Chapter 5 of the Coastal Engineering Manual. The final recommended stone sizing for armoring the proposed geosynthetic containers included in the alternates is D_{50} = 3 ft with a W_{50} = 4,500 lbs.

Layer	Rock Size, W_{50} (lb)	Gradation (lb)	
		Max	Min
Cover Layer, W ($1.25W_{50}$ to $0.75W_{50}$)	4,500	5,625	3,375

Table 5. Recommended Stone Sizing.

6. Tentatively Selected Plan (TSP) Summary

Alternative 4a is the TSP for Woodtick Peninsula Section 204 and details can be found in the main body of the report. See Figure 4 below for approximate locations of the dredge material placement on the leeside of the peninsula and the geosynthetic containers with armor stone reefs off the southern point of the peninsula. The primary save points used in evaluating this alternative are shown as well.

Figure 4. Alternative 4a with CHS save points

7. Conclusions

Due to a variety of considerations including cost, benefits, the shallow nearshore and fine dredge material, Alternative 4a was selected as the TSP. The current location of the proposed southern reef in Alternative 4a is in relatively shallow water and therefore, subject to the influence of ice as well as wave forces. Moving the structure into deeper water outside the influence of surface ice would allow stone sizes to be reduced to increase their habitat benefits, but the extended shallow depths make this alteration unattractive. As a result, it is recommended that the primary armor units for the geosynthetic containers in their current location remain sized at D_{50} = 3 ft with a W_{50} = 4,500 lbs which can be supplemented with 6-to-8-inch stone more suitable for habitat. The armor stone and geosynthetic container reef aside from encapsulating additional dredge material and potential habitat production will likely provide further benefits by protecting dredge material placed on the leeside of the peninsula and capturing littoral drift.

The sediment being utilized in the proposed project comes from the dredging of the lake approach to the Maumee River. From grain size analysis performed in 2021, silts and clays comprise over 85% of the sediment. This very fine material is easily transported in shallow water by minimal wave energy and small currents. The material is to be place in the protected lee of the peninsula in Alternative 4a away from the larger offshore waves. There is also no obvious origin of significant currents in the placement location from a river or other source. Additionally, the former shipping channel that was cut in the lee of the peninsula for the power plant has been shoaling in likely due to diffraction from lakeside waves and the absence of significant waves or currents to further transport material. See Table 2 above again for wave parameters. It is assumed some material will be transported during placement and consolidation, but a significant portion of the material should remain in place to facilitate additional wetland development even at shallow depths.

8. References

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