MOTT MACDONALD

New York - New Jersey Coastal Reanalysis

FEMA 30-day Engineering Models Notification

Project:	Hastings-on-Hudson Shoreline Protection Analysis		
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Approved by:	DG	**Checked by:**	DG
Subject:	Assessment of 1-D coastal models proposed for the FEMA coastal reanalysis		

1 Introduction

The Village of Hastings-On-Hudson (HOH) in Westchester County reached out to Mott MacDonald to review the coastal engineering hydraulic models/methods proposed by FEMA to be used in the New York-New Jersey Coastal Reanalysis. This technical memo provides a brief introduction to each model and points out its benefits and drawbacks. The memo further recommends approaches to overcome these drawbacks and general guidance when applying a certain method or model to the HOH location. Finally, it recommends other FEMA-approved models that were not mentioned in the 2-D list of hydraulic models that may provide more accurate estimates of flood levels for the location of HOH.

2 Study Area

This note is a general guidance on the applicability of the FEMA 1-D coastal hydraulic models proposed for the HOH location. The bathymetry of the Hudson River channel by HOH is shown in Figure 2-1, and the contour lines and precent increase in elevation of the channel are shown in Figure 2-2. The contour lines are relatively parallel, except at some locations with sudden changes in the along channel depths above -16 m (52 ft).

HOH is approximately 33 Miles from the Lower Bay. Thus, extreme waves that enter the bay from the New York/New Jersey Bight will not be able to reach up to HOH. However, some fetch limited, locally-generated waves would exist due to local winds. HOH is within the estuary and therefore subject to both tides and river stage, both of which can contribute to flooding along with storm surge. Therefore, the main flooding drivers in this location are tide and surge driven water levels, and storm induced river flow. The existing Preliminary Flood Insurance Rate Map (PFIRM) of the study area is shown in Figure 2-3. The PFIRM map shows the ID of the panels and number of the transects used in the FEMA flood level calculation in any region of interest. The HOH region lies in panels 36119C0244G and 36119C0307G. Nine transects cover the HOH region (Transects 72 to 75) with an average spacing of 337 m (1,105ft).

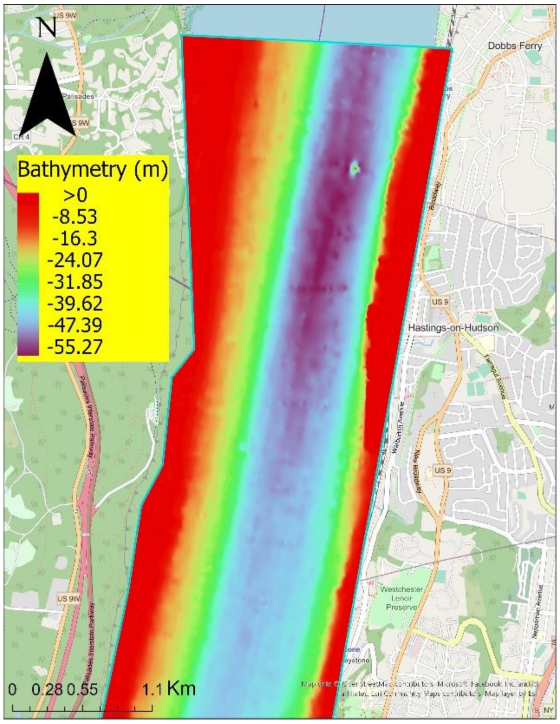

Figure 2-1: Study Area

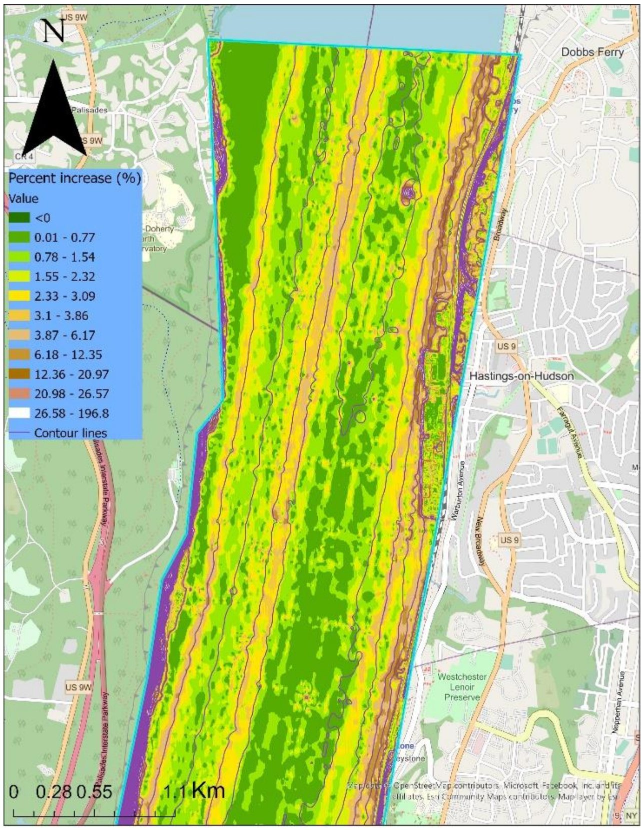

Figure 2-2: Percent increase in elevation

Figure 2-3: PFIRM map showing transect numbers and panel IDs.

3 Assessment of the 1-D coastal hydraulic models

3.1 CSHORE:

3.1.1 Background and development:

CSHORE is a physics-based one-dimensional cross-shore coastal morphodynamic model that predicts wave heights, water level and wave-induced currents on the spatial scale of 100 m to 10 km and temporal scale of storms. The model includes a time-averaged and depth-averaged wave, current and sediment transport models. It uses a probabilistic model to simulate the location of the wet/dry zone and empirical formulas to predict the wave runup. The pre-storm (initial) bathymetry is specified at the beginning of the simulation. The model also takes the root-mean-square wave height, spectral peak period and setup/setdown as inputs at the offshore boundary of the computation domain. Since CSHORE is a cross-shore 1-D model, its results are more realistic when applied to cross section locations where bathymetric contours are approximately parallel, Kobayashi (2016).

3.1.2 Drawbacks and recommendations:

The model assumes longshore bathymetric uniformity. Longshore bathymetry influences the currents and wave breaking, consequently affecting runup and overtopping. As shown in Figure 2-2, although the bathymetry contours are relatively parallel there are some changes in the slope along the channel near shallow waters. This requires the CSHORE model to be applied at multiple cross sections where the slope changes in the along channel direction.

It’s not recommended to use CSHORE to predict the erosion at HOH as most of the shoreline is dominated by rock revetments or sheetpile walls with very little unconsolidated sand beach. Erosion would be dominated by open channel flow hydraulics and less so by waves or vessel wake. Furthermore, HOH lies on a convergent section in the Hudson River, where river velocity is expected to increase. The model is suitable to estimate wave overtopping due to locally wind generated waves.

3.2 Wave Height Analysis for Flood Insurance Studies (WHAFIS):

3.2.1 Background and development:

The WHAFIS model is used to assess overland wave propagation and flood hazard in coastal areas. It takes as inputs representative shoreline-perpendicular transects, still water elevations, ground elevations, and obstruction information. WHAFIS is mainly used to compute wave crest and water level elevations along each transect to find the base flood and still water elevations along the transects. Between transects, crest elevations are interpolated using topographic maps, land-use and land-cover data, aerial photography, and sound engineering judgment to determine the aerial extent of flooding, FEMA (2008).

Transect information such as topographic, vegetative, land use, and features along each transect landward of the shoreline are a crucial input to this model. Transect spacing can vary, from a few hundred feet apart in areas with high shoreline variability to a few thousand feet apart in areas with uniform characteristics.

3.2.2 Drawbacks and recommendations:

The WHAFIS model does not account for refraction, diffraction, or bottom dissipation effects. Therefore, additional calculations are required in regions where these factors significantly affect wave height. Furthermore, the surge and wave dynamics are decoupled in the model which would lead to over- or underestimates of flood levels. Interpolating the wave and surge conditions between transects is subjective and could lead to varying results depending on the mapping partner’s (i.e., Advancing Resilience in Communities) opinion.

Representing sudden changes in the topography due to levees, roadways, and railroads in the wave height analysis requires careful examination at each transects. As can be seen in Figure 2-3, only 9 transects are used in the PFIRM to establish flood levels in HOH. Due to the varying bathymetry and land use in the HOH region it's recommended to decrease the spacing between the transects to represent the variations in the bathymetry and capture different site characteristics. The appropriate number of transects and their location is decided by the mapping partner.

In the FEMA study WHAFIS is fed wave height and surge inputs at its seaward location from an ADCIRC and SWAN model. Since WHAFIS does not possess the capability to attenuate and transform waves, the location of the seaward end of the transect (i.e., location of ADCIRC and SWAN extracted output) should be chosen with care such that the waves are fully transformed.

3.3 Technical Advisory committee for Water retaining structures (TAW) runup method:

3.3.1 Background and development:

The TAW methodology is an empirical equation that predicts the runup elevation based on wave and water level conditions at the toe of the beach face slope (TOS). The equation was developed based on wave tank laboratory tests. In its essence the TAW method is a relationship between the runup and prevailing conditions at the face of the beach, which are represented by the Iribarren Number (i.e., surf similarity parameter). The relationship is governed by factors that control the influence of the berm, surface roughness, and angel of incident wave.

The TAW method takes as input the wave characteristics (i.e., significant wave height and peak wave period), structure or beach slope, reduction factors to account for the influence of a berm, shallow foreshore, slope roughness, and oblique wave attack. It's valid for conditions of Iribarren Numbers between 0.5 and 5 and a shoreline type of Rock-Armored Structures with Narrow Surf Zones.

3.3.2 Drawbacks and recommendations:

Since the method is an empirical equation that was developed under a controlled laboratory environment its application is limited to large scale natural conditions that are similar to the controlled laboratory test. This requires care when applying the equation and choosing the different factors that govern it. In the case of HOH, the variability of the shoreline characteristics requires careful examination of the land use the conditions and structural characteristics where this equation is used.

As the WHAFIS model, the TAW method does not include a mechanism to transform and attenuate waves. Therefore, care should be taken when extracting the wave characteristics and water surface elevations from the ADCIRC-SWAN model and, if necessary, to shoal and refract those waves till the appropriate depths near the toe location.

3.4 Automated Coastal Engineering System (ACES):

3.4.1 Background and development:

ACES is an aggregation of a variety of coastal engineering design and analysis methods. ACES provides a user-friendly environment to applying a broad spectrum of coastal engineering technologies. The methods range from theoretical and empirical equations to numerical algorithms for a better representation of coastal processes, Leenknecht et al. (1995). Simple methods range from classical theory describing wave motion, to expressions resulting from tests in wave flumes, and further includes numerical models describing the exchange of energy from the atmosphere to the sea surface. It contains equations and design methodologies from both the Shore Protection Manual (SPM) and Coastal Engineering Manual (CEM).

3.4.2 Drawbacks and recommendations:

None of the models/methods deployed included in the ACES are process-based evolutionary numerical physics-based models. Thus, all physical processes such as wave and current interactions are decoupled. Additionally, these methods and models were developed under certain assumptions and conditions. Therefore, care should be taken when applying the ACES to different locations and whether the assumptions behind the methods used are satisfied.

3.5 RUNUP 2.0

3.5.1 Background and development:

Like ACES, RUNUP 2.0 is a computer program that uses empirical equations to predict the wave runup on structures. The program is based on the empirical equations developed by Stoa (1978) for variations of structure slopes, approaching bathymetry and wave and water level conditions, under regular wave laboratory experiments. The model equations consider depth induced breaking of waves and wave setup effects into the calculations of runup.

3.5.2 Drawbacks and recommendations:

When tested against other data sets that have different wave conditions than the ones the model was developed under, RUNUP 2.0 generally over-predicted runup. It was also found that conditions such as irregular waves and complex profiles are out of the capabilities for RUNUP 2.0. Therefore, when applied at HOH, specific care should be taken for the wave and topographic conditions. It’s also recommended not to use these equations for runup predictions on complex profiles.

3.6 The Stockdon method (Stockdon et al. 2006):

3.6.1 Background and development:

The Stockdon method is a parameterization of the extreme wave runup defined as the runup with 2% exceedance probability. The parametrization was developed through 10 dynamic and varying field experiments. The parametrization was developed by separately parametrizing the wave setup and swash. The wave setup was parameterized using the Iribarren number while the total swash was parameterized separately for infragravity and incident waves using offshore wave characteristics and Iribarren number, respectively. The method can be applied to a variety of beach conditions and wave characteristics as it was developed with field measurements and full-scale experiments.

3.6.2 Drawbacks and recommendations:

As any another empirical method the physical process is decoupled in the Stockdon method. The method doesn’t account for alongshore variation in the bathymetry and was developed to predict runup on sandy beaches without a dune or obstruction. Therefore, care should be taken when applying the method to HOH, as the location is dominated by levees and protective structures with no beach.

3.7 Shore Protection Manual (SPM):

The SPM is a collection of state of practice methods, recommendations, case studies and empirical equations to solve a variety of coastal engineering questions. However, like the previous empirical equations applying the methods in SPM requires careful attention to the prevailing conditions at the cite. Additionally, the SPM has generally been superseded by the Coastal Engineering Manual (CEM).

4 Summary

In conclusion, due to variability in the topography and features along the HOH shoreline, the proposed 1-D hydraulic coastal models have to be applied with careful attention to the conditions of the site and assumptions under which they were developed. Since all the proposed models are one dimensional it's recommended that the models be applied to a variety of locations to capture the different features, structures, and conditions. All the proposed models will be fed data from ADCIRC-SWAN model, therefore, it's crucial to examine the input data to the proposed 1-D models and whether the 1-D models are applicable for the hydrodynamic conditions fed to them from ADCIRC-SWAN.

Additionally, due to the superseded information in the SPM, it is recommended to add the coastal engineering manual (CEM) to the proposed list of models and be relied on instead of the SPM. As HOH is also influenced by river flow hydrodynamics, it’s crucial to account for changes in the river stage elevation due to seasonal effects, storms and rainfall. An important seasonal effect that influences HOH is the snow melt from the Catskill watershed and upstream dam release. Such effects can be captured by also considering the results from a hydraulic routing model as HEC-RAS and feeding these results to the proposed methods and models to calculate flooding levels.

5 References:

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