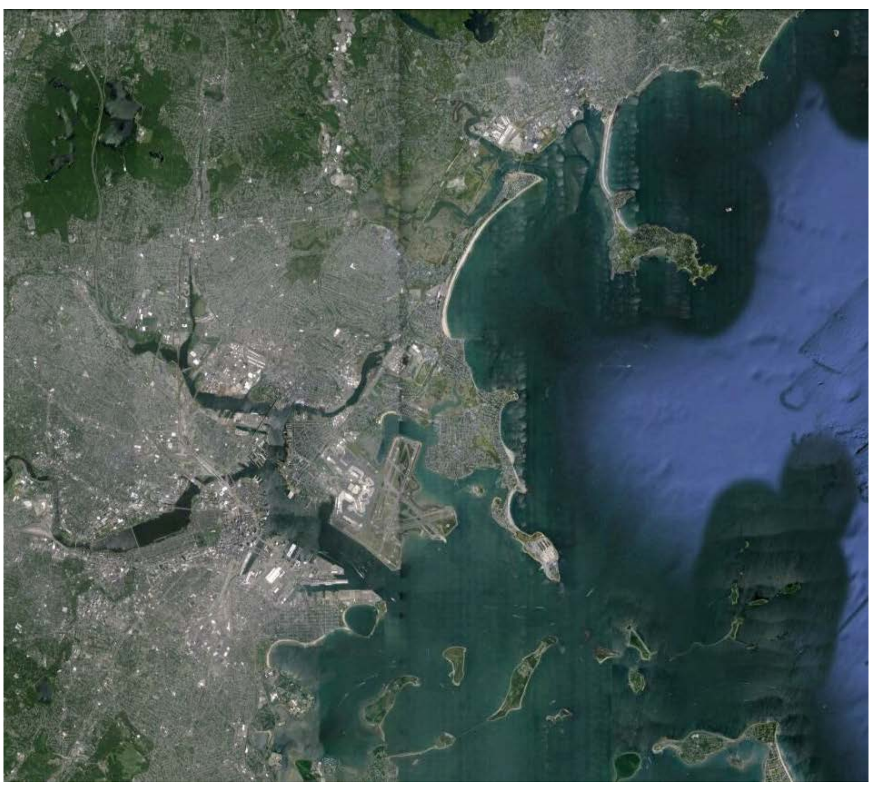
Evaluation of June 9, 2014 Federal Emergency Management Agency Flood Insurance Study for Town of Weymouth, Norfolk, Co, MA



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1.0 INTRODUCTION

Woods Hole Group has completed an evaluation of the June 9, 2014 Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) for the Weymouth Fore River area of the Town of Weymouth, MA. The evaluation included a coastal engineering analysis using methodologies described in the "Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update" (FEMA, 2007) to Appendix D and "Guidance for Coastal Flooding Analyses and Mapping" (FEMA, 2003). Specific components of the FEMA study evaluated by Woods Hole Group include the following:

- Stillwater elevations
- Wave climatology
- Erosion and structure failure
- Wave runup and overtopping
- Overland wave transformation
- Flood zone and Base Flood Elevation (BFE) mapping

FEMA's analyses for these components of the Flood Insurance Study (FIS) are described in this report, including data sources, assumptions, methods of analysis, and findings. Errors and inconsistencies in FEMA's approach were identified, and corrections were applied as part of an independent Woods Hole Group analysis. The evaluation was conducted specifically for the Idlewell Blvd. and northern shoreline areas of the Weymouth Fore River, which is covered by FEMA's Transect Nos. 31 and 32 (Figure 1; Map Panel 25021C0227F). Results from the Woods Hole Group analyses indicate the preparation and filing of a Letter of Map Revision (LOMR) application to correct errors in the Special Flood Hazard Area (SFHA) mapped around Transect Nos. 31 and 32 is warranted. The effective FIRM maps the subject area in VE (13, 14) zones. The Woods Hole Group analysis indicates a more accurate mapping in VE (15, 13) and AE (12) zones.

1.0 Stillwater Elevations

A fundamental component of FEMA's detailed FIS process is the determination of the 1-percent-annual-chance stillwater level (SWL). The SWL is the elevation of the water due to the effects of astronomic tides and storm surge on the water surface. The SWL is integral in establishing the base inundation levels, determining the average slope for wave setup calculations, and determining water depths along transects for overland wave transformation.

The 100-year SWLs for FEMA's June 2014 FIRMs for Weymouth were taken from published values in the Tidal Flood Survey (USACE, 1988). The USACE Tidal Flood Survey utilized a combination of long-term tide gage data from NOAA stations, as well as high water marks from past storms to develop tidal flood profiles for the 1-, 10-, 50-, and 100-year frequency flood events. The closest NOAA station to Norfolk County was located in Boston Harbor. The USACE used a Pearson type III analysis to analyze adjusted peak tide levels from each year of the 19 year tidal epoch between 1960 and

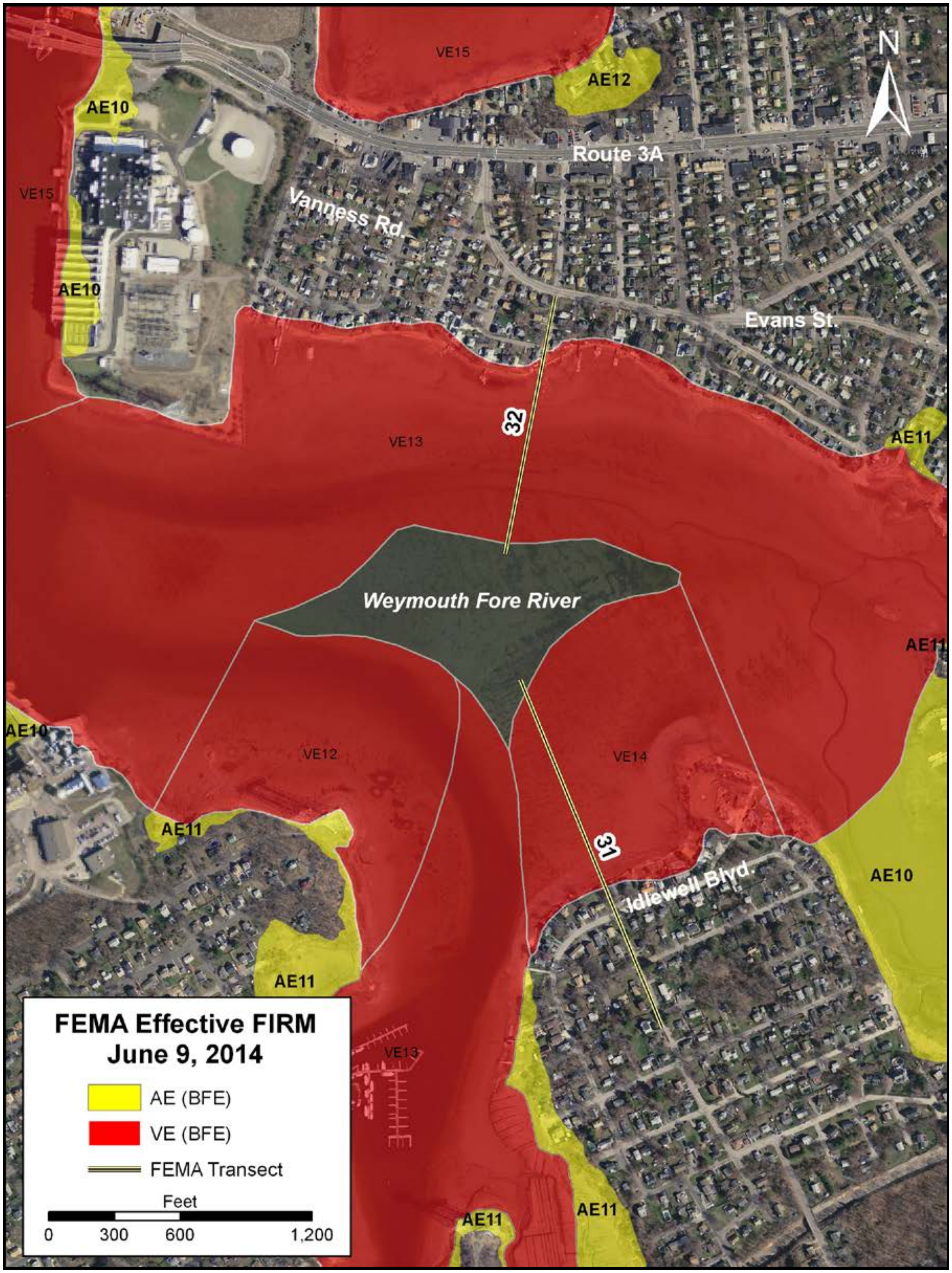

Figure 1. Locations of FEMA Transect Nos. 31 and 32 in Weymouth Fore River shown with effective flood zones and base flood elevations from the June 9, 2014 FEMA FIRM.

1978. For locations between the long-term tide gage stations, including the Town of Weymouth, the flood levels were estimated using a combination of interpolation between NOAA stations and observed high water marks following major storms. For the east coast of New England high water marks from the Blizzard of 1978 were used to refine the tidal flood profiles at locations where long-term data were not available.

The USACE (1988) update of the Tidal Flood Survey was based on tide gage data referenced to the National Tidal Datum Epoch (NTDE) of 1960-1978. Since the current tidal datum is based on the more recent NTDE of 1983-2001, FEMA applied a correction factor of +0.11 ft to the SWLs published in the Tidal Flood Survey (USACE, 1988). The resulting 1-, 50-, 100-, and 500 year SWLs for the Weymouth Fore River used as the basis for FEMA's June 2014 FIRMs are shown in Table 1.

Table 1. Stillwater Elevations for Boston Harbor Long-Term Tide Gage Station and Weymouth Fore River used in FEMA's June 2014 Flood Insurance Study.

Location	1-year SWL (ft, NAVD)	50-year SWL (ft, NAVD)	100-year SWL (ft, NAVD)	500-year SWL (ft, NAVD)
Weymouth Fore River (Tran. Nos. 31-32)	8.3	9.2	9.5	10.4

Review of the SWLs presented in Table 1 for the Weymouth Fore River correspond with values reported in the USACE (1988) Tidal Flood Survey. The SWLs for the 1-percent-annual-chance water level also match closely with dynamic model results developed by Woods Hole Group for the Boston Harbor region (Woods Hole Group et. al., in press). Consequently, the SWLs utilized by FEMA for the June 2014 flood study were found to be accurate in the Weymouth Fore River area, and no changes were made for the subsequent analyses.

2.0 WAVE CLIMATOLOGY

Evaluation of 100-year wave conditions is another fundamental component of FEMA's detailed FIS process. FEMA utilizes offshore significant wave conditions (height and period) as the basis for coastal engineering analyses performed in support of mapping flood zones and associated water levels. In sheltered areas, FEMA uses wind generated wave models to develop more appropriate conditions. The wave conditions are transformed closer to the shoreline and inner harbor areas, and then used for calculations of wave setup, wave runup and overtopping, and for overland wave transformation modeling.

Woods Hole Group conducted an independent analysis of significant wave conditions in the Weymouth Fore River at Transects No. 31 and 32. The Automated Coastal Engineering System (ACES) software available through the Coastal Engineering and Design Analysis System (CEDAS, Version 4.0) was utilized to generate the wave conditions needed for subsequent modeling and flood zone mapping. In the Weymouth Fore River it is expected that the wave conditions will be solely wind generated waves from storm winds. The geometry of the shoreline and landforms that surround Transect No. 31 and 32 were defined by establishing a series of radial fetches at 10 degree intervals (Figures 2 and 3). The fetch bands were used in the Wave Prediction – Wind Adjustment and Wave Growth (restricted fetch) module of ACES to define the distance and depth over water that storm winds can generate local waves. A wind speed of 25.7 meters/sec (50 knots) taken from the FEMA FIS for Norfolk County was used to simulate the 100-year storm condition. Results of the ACES output for Transect Nos. 31 and 32 are provided in Figures 4 and 5. The simulation indicates that wave growth at the site is limited by the fetch distance and water depth along each radial band.

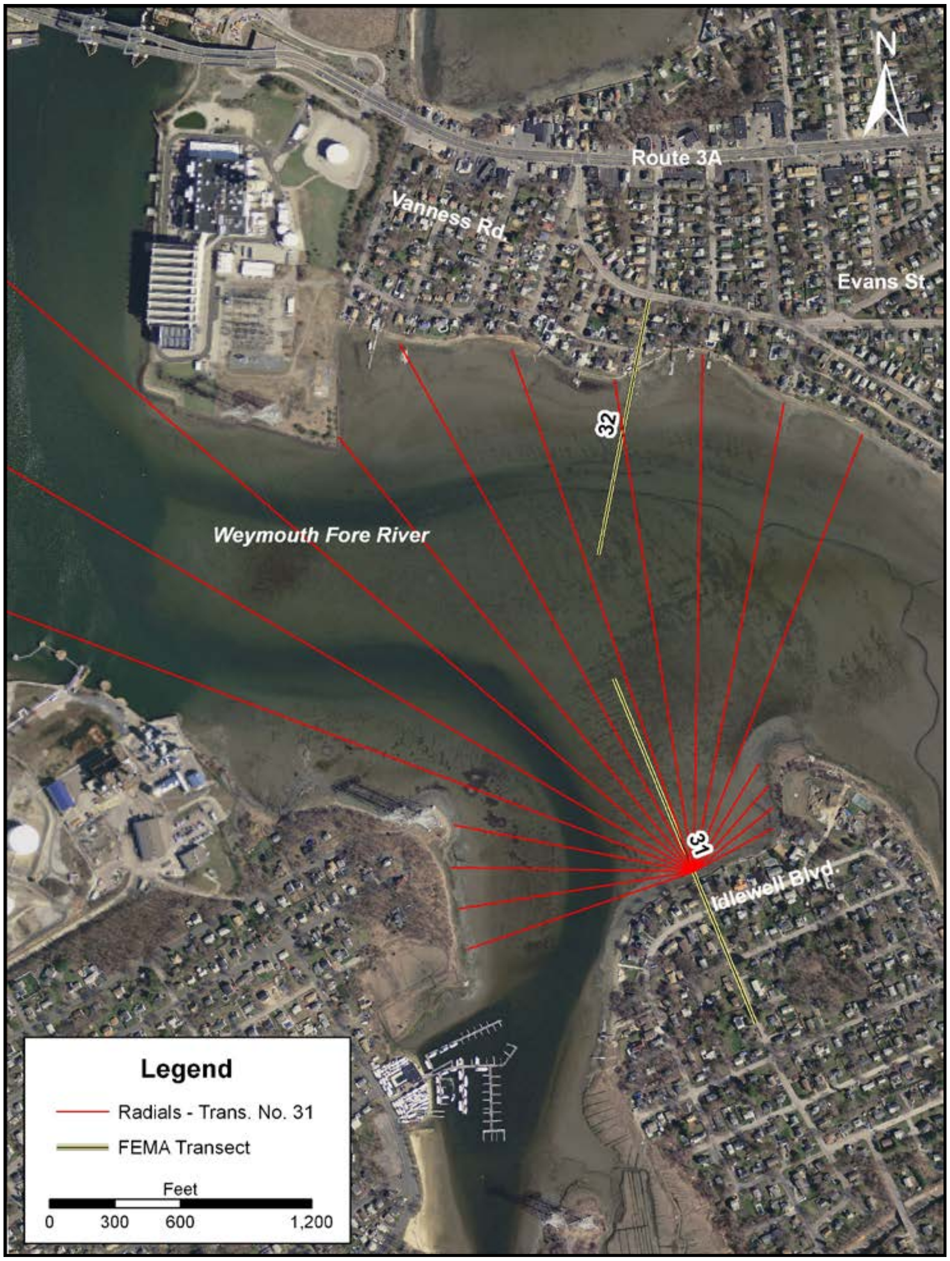

Figure 2. Radial fetch bands used in ACES to define wave conditions at Transect No. 31.

Figure 3. Radial fetch bands used in ACES to define wave conditions at Transect No. 32.

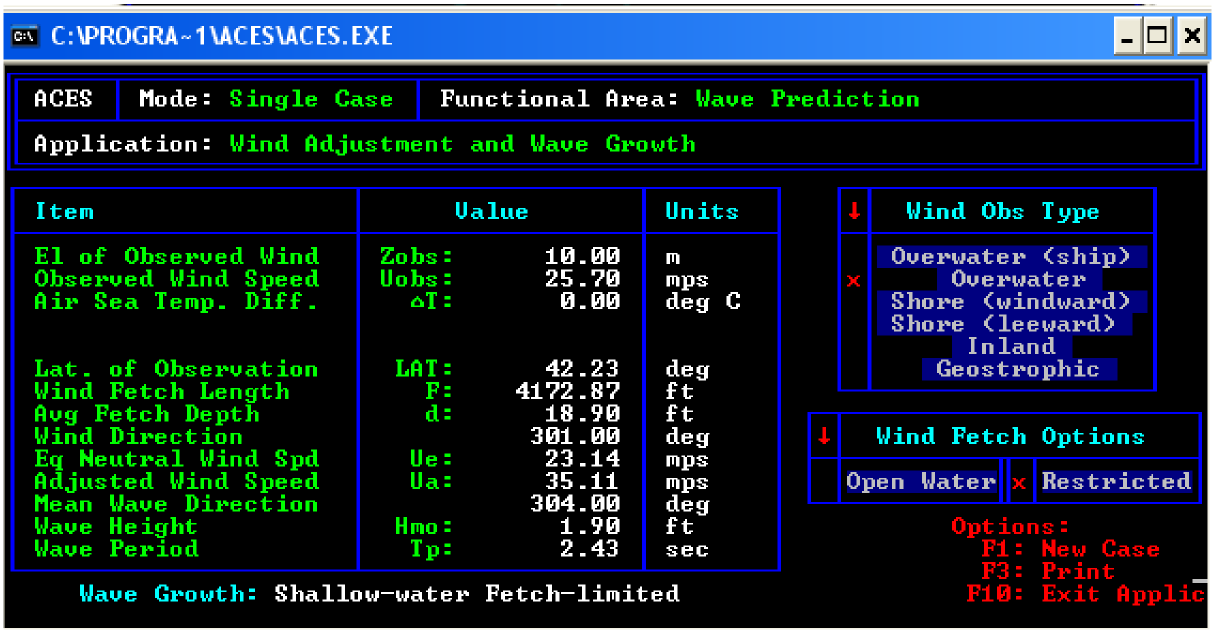

Figure 4. ACES model input and output wave conditions for Transect No. 31.

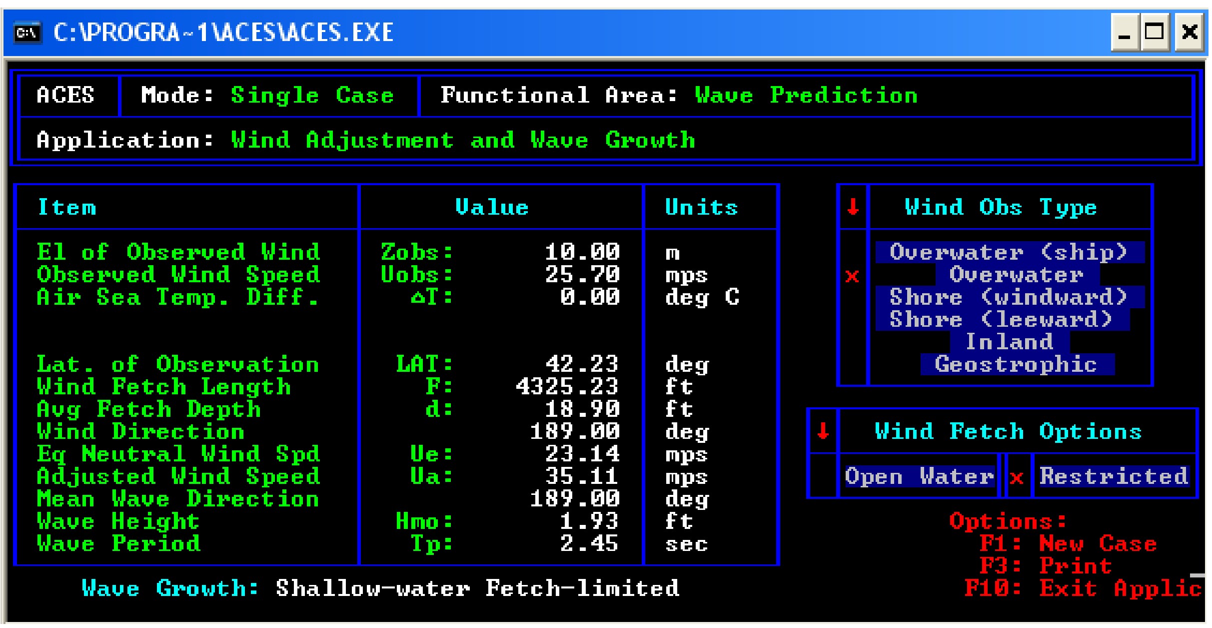

Figure 5. ACES model input and output wave conditions for Transect No. 32.

A summary of significant wave conditions for Transects No. 31 and 32 for the developed from the ACES modeling is provided in Table 2. For comparison purposes, FEMA's wave conditions developed for the June 2014 flood mapping are also provided. At both transects the revised Woods Hole Group modeling shows more accurate wave heights to be lower than FEMA's estimates.

Table 2. Comparison of Revised and FEMA June 2014 FIS Wave Conditions.

Transect No.	Revised Significant Wave Height (ft)	Revised Peak Period (sec)	June 2014 FIS Significant Wave Height (ft)	June 2014 FIS Significant Wave Period (sec)
31	1.90	2.43	2.80	2.9
32	1.93	2.45	2.86	3.0

3.0 EROSION AND STRUCTURE FAILURE

Topography for Transect Nos. 31 and 32 were taken directly from the 2014 FEMA CHAMP database. The transect data were checked against the 2011 LiDAR available from MassGIS and the Town of Weymouth 2 ft contours and found to compare well. Both transects contain coastal engineering structures which FEMA assumed would fail during the 100-yr storm event. FEMA's guidelines require such structures to be failed, unless supporting documentation can be provided showing the structures have been certified to withstand the 100-yr event. No such documentation was discovered for these structures, and as such, Woods Hole Group also assumed structure failure.

FEMA's methods for failing the structures were followed and new profiles were generated based on the revised wave heights shown in Table 2. Structure failure was performed in accordance with guidance in Section D.2.10 of the Atlantic Ocean and Gulf of Mexico Coastal Guidelines Updates (FEMA, 2007). Toe scour under the 100-year condition for the vertical seawalls was estimated based on the USACE Coastal Engineering Manual (2003). The structures were assumed to fail and fall on a rough, porous slope of 1:1.15 (V:H). The failure slope extended from the depth of scour at the toe of the structure, landward to where it intersected the existing grade. Figures 6 and 7 show a comparison of FEMA's intact and failed structure profiles in comparison with the revised failed structure profiles for Transect Nos. 31 and 32, respectively. In both cases the lower wave heights resulted in less scour at the toe of the structures and less overall impact from the failed structures.

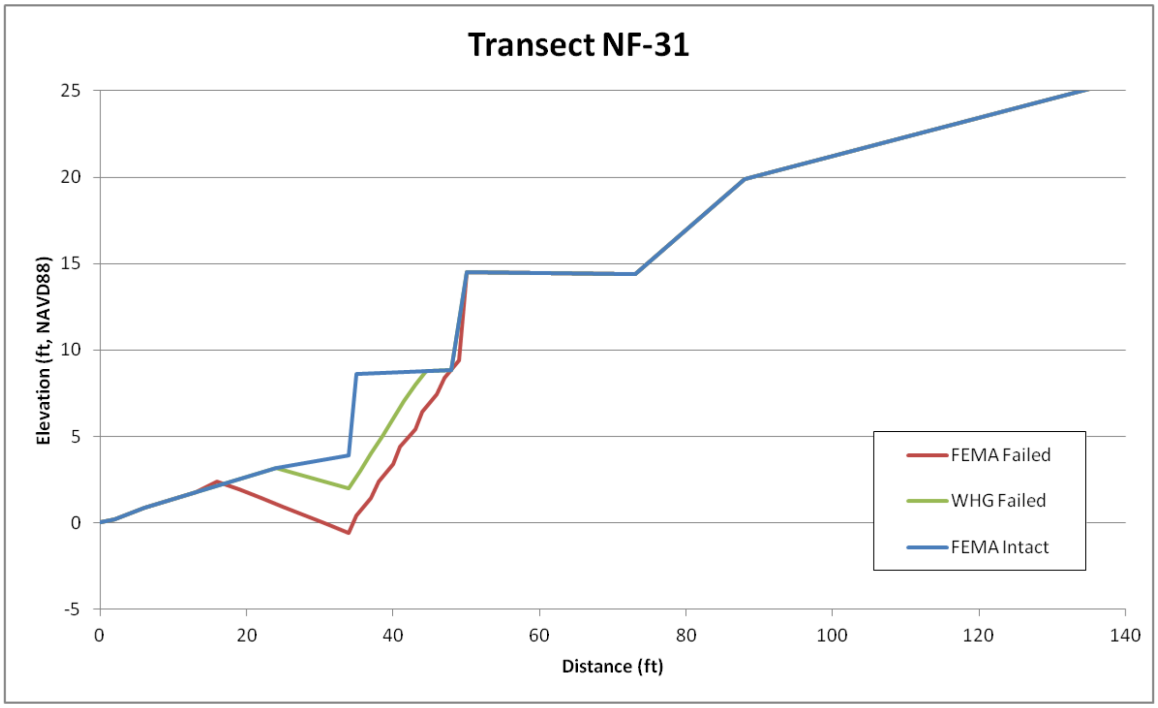

Figure 6. Comparison of FEMA's June 2014 and revised structure failure at Transect No. 31.

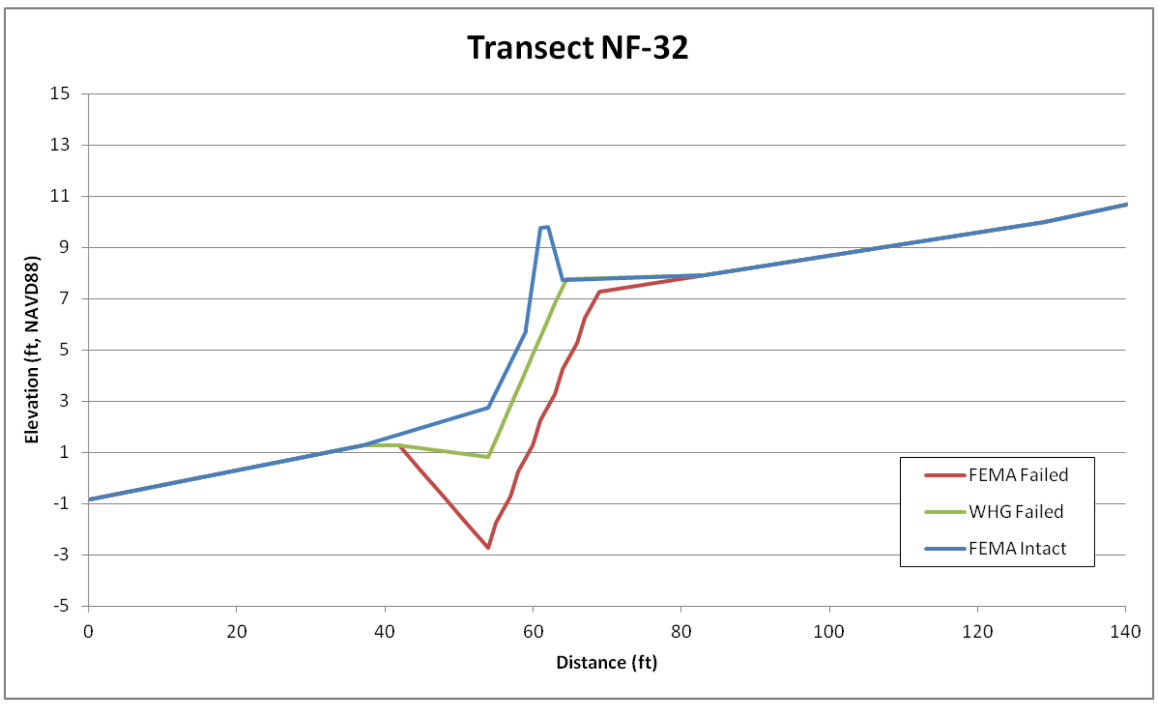

Figure 7. Comparison of FEMA's June 2014 and revised structure failure at Transect No. 32.

4.0 WAVE SETUP

Wave setup for this revised coastal analysis at transects NF-31 and NF-32 in the Town of Weymouth was computed using the numerical model Simulating Waves Nearshore (SWAN). SWAN is a third-generation wave model, approved by FEMA, for obtaining realistic estimates of wave parameters in coastal areas from given wind, bottom, and current conditions. SWAN includes wave generation, dissipation, non-linear interactions, and transformations. It also includes bottom friction, currents, shoaling, refraction, diffraction, depth induced breaking, and wave setup. SWAN represents a model based approach that accounts for the physics of the waves, and was therefore selected as an improved alternate to the empirically based Direct Integration Method (DIM) for computing wave setup. Use of a numerical method is especially valuable in more complicated coastal shorelines such as the Boston Harbor area where empirically based approaches may be less applicable.

SWAN can be operated in both 1-D and 2-D modes. The SWAN 1-D application was utilized to compute wave setup for the two (2) Weymouth transects. The 1-D model approach was considered to be more conservative for wave setup, since the 2-D model accounts for effects of the surrounding bathymetry and shoreline configuration on the wave form as it travels towards the coastline. The 1-D model is also consistent with FEMA's transect based analyses and readily allows representation of rapidly changing shoreline conditions at a high resolution.

Results from the ACES modeling for 100-year wave conditions (Table 2) were used as input to drive SWAN 1-D simulations at the two (2) Town of Weymouth transects evaluated as part of this study. The purpose of the SWAN 1-D simulations was to develop wave setup at each site specific transect location.

Bathymetric and topographic conditions were taken directly from the June 9, 2014 FEMA CHAMP database. SWAN 1-D simulations were run on the intact transects, as well as for failed structure cases. Transect elevations were revised in the cases of structure failure to account for the smaller wave heights utilized for the Town of Weymouth evaluation (see Section 3.0). The FEMA CHAMP transect data were interpolated to an evenly-spaced 1 meter resolution for input to SWAN 1-D. Water levels were set to reflect FEMA's 100-year SWLs shown in Table 1. Incident wave conditions (revised wave height and period) were obtained from the ACES modeling. Waves were assumed to conservatively approach normal to the shoreline (along the axis of the transects) and spectral spreading was turned off in the model (to ensure that the peak energy was not muted). This represents a conservation assumption where the model computed wave setup using peak wave conditions, rather than a spectral spread of the waves. The SWAN 1-D simulations allowed finer resolution along the shoreline necessary to capture site specific conditions at the transects (e.g., failed structures). Table 3 provides a summary of the revised and original FEMA wave setup values.

Table 3. Comparison of Revised and FEMA June 9, 2014 FIS Wave Setup Values.

Transect No.	Revised Wave Setup (ft)	FEMA June 9, 2014 Wave Setup (ft)
NF-31		
Intact	0.10	1.35
Failed	0.10	1.97
NF-32		
Intact	0.33	1.96
Failed	0.37	2.20

5.0 WAVE RUNUP AND OVERTOPPING

Wave runup and overtopping was calculated using the methodologies described in the FEMA Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update (FEMA, 2007). At transects where the slopes were milder than 1:8 (V:H) FEMA's Runup 2.0, within the CHAMP program, was used to calculate the mean wave runup. Values of mean runup were then multiplied by 2.2 to obtain the 2% runup height. At other transects where the slopes were steeper and shore protection structures were present, FEMA's Operating Guidance 10-13 was used to determine the preferred methodology for computing wave runup based on the slope of the structure.

A summary of 2% wave runup heights, runup calculation method, and overtopping at the two Town of Weymouth transects evaluated during this study is provided in Table 4.

Table 4. Summary of Wave Runup and Overtopping Calculations.

Transect	Revised 2% Wave Runup (ft)	Method	Overtopping
NF-31			
Intact	2.50	TAW	No
Failed	2.78	TAW	No
NF-32			
Intact	0.71	SPM	Yes
Failed	0.38	Runup 2.0	Yes

6.0 OVERLAND WAVE TRANSFORMATION

Overland wave heights were calculated using the Wave Height Analysis for Flood Insurance Studies (WHAFIS) software within the Coastal Hazard Analysis for Mapping Program (CHAMP), following the methodology described in the FEMA Guidelines and Specifications. Corrected wave heights from Table 2 were specified in CHAMP along with the SWL and wave setup values from Tables 1 and 3, respectively. Definitions for the major topographic, vegetative, and cultural features along Transect Nos. 31 and 32 were taken directly from the 2014 FIS CHAMP database.

7.0 FLOOD ZONE AND BASE FLOOD ELEVATION (BFE) MAPPING

The flood zone and BFE mapping was performed according to the procedures outlined in FEMA's Guidelines and Specifications. Revised flood zone locations and BFEs based on modeling and engineering analyses at Transect Nos. 31 and 32 are shown in Figure 8. For comparison purposes, the June 2014 Effective FEMA flood zones and BFEs for Transect Nos. 31 and 32 are also shown.

The revised mapping shows a 1 foot reduction in BFE for the VE Zone along the northern shoreline represented by Transect No. 32, and a 2 foot reduction in BFE for the VE Zone along the southern shoreline along Idlewell Blvd. The width of the VE Zone has also been reduced along both shorelines so it does not extend as far inland. This will likely result in the removal of a number of properties from the 100-yr floodplain.

If the Town is interested in pursuing these flood map changes, it will be necessary to file a LOMR with FEMA. This process can take up to 6 months to complete.

8.0 REFERENCES CITED

Federal Emergency Management Agency, Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update , Final Draft, Washington, D.C., February 2007.

Federal Emergency Management Agency, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping , Washington, D.C., April 2003.

Hydraulics and Water Quality Section; New England Division USACE. (1988). *Tidal Flood Profiles New England Coastline.* Waltham, MA: USACE.

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Figure 8. Comparison of flood zones and BFE between Effective June 2014 FIRM and LOMR revisions identified for this study.