



National Institute of
BUILDING SCIENCES™

Panel Decision and Report

SRP MEYCCC093019

York & Cumberland, ME

October 18, 2020

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1. Summary

Based on the submitted scientific and technical information, and within the limitations of the Scientific Resolution Panel (SRP), the Panel has made determinations for the Town of Old Orchard Beach, York County, ME and the City of South Portland, Cumberland County, ME appeals. Due to geographical differences, the Panel has elected to issue separate determinations for the two locations:

For the **Town of Old Orchard Beach**, the Panel determined that portions of the Appellants data satisfy NFIP standards and correct or negate FEMA's data. These portions are as follows:

- The 1%-annual-chance total stillwater levels (TSWL¹) developed using the two-dimensional (2-D), coupled hydrodynamic and wave modeling approach; and
- The marsh/estuarine flood hazard mapping at Transects YK-142, YK-143, and YK-144.

The Appellant's approach considered 2-D effects on wave setup across a barrier island, satisfying NFIP standards and correcting or negating FEMA's approach of continuing the oceanfront wave setup across the negligibly inundated barrier island into the marsh/estuarine areas. This approach is more technically correct and results in a considerable (3-4 ft) reduction in the Base Flood Elevations (BFEs) in these areas when compared to those in the preliminary FEMA maps.

The portions that do not correct or negate FEMA's data include:

- Transect YK-137; and
- The oceanfront flood hazard mapping at Transects YK-142, YK-143, and YK-144.

These portions of the data were affected by a conversion error in the input data for the overland wave propagation analysis (Section 8.1.1).

The other two issues cited by FEMA in the August 30, 2019 appeal resolution letter upon which the appeal was rejected were omission of the Limit of Moderate Wave Action (LiMWA) and disjointed mapping tie-ins (Section 8.1). The LiMWA omission only affects mapping at transect YK-137. The disjointed mapping tie-in affects mapping at Mill Brook, upstream of the marsh mapped from transect YK-144. Thus, none of the three issues cited by FEMA are applicable to the 1%-annual-chance TSWL or the flood hazard mapping for the marsh/estuarine portions of Transects YK-142, YK-143, and YK-144.

¹The TSWL is defined to be the sum of the stillwater level (SWL) plus static wave setup. Terminology and abbreviation usage vary among practitioners for this concept. The Appellant uses both TSWL and TWL as abbreviations for total stillwater level. Stillwater elevation (SWEL) and total stillwater elevation (TSWEL) and are also used interchangeably by practitioners for the same concepts. This report will use SWL and TSWL except when quoting outside sources.

PANEL DECISION AND REPORT

For the **City of South Portland**, the Panel determined that FEMA's data does not satisfy NFIP mapping standards defined by FEMA's Guidelines and Standards for Flood Risk Analysis and Mapping and must be revisited. The preliminary FIRM shows the appeal site within a Zone VE with a BFE of 35 ft. The Panel was unable to locate explicit technical justification for this flood hazard mapping at the appeal site. Based on the information that was provided by FEMA, the Panel concluded that this mapping appears to be an error—a wave runup transition zone that was not revised when the surrounding modeled-based mapping was updated during the 2010 community coordination. (See Section 7.2 for a more complete discussion). This error appears to violate FEMA mapping standards 61 and 62 as the transition zones are not reproducible from the current Flood Insurance Study (FIS) modeling and mapping and are no longer based on engineering judgment.

The Appellant's analysis and mapping of CM-35-1 is acceptable and could be used to correct FEMA's data. The Appellant's submitted data does not however wholly negate or correct FEMA's data due to lack of consideration of longer-period waves impacting the study site at two of their transects (CM-35-2 and CM-35-3).

FEMA cited two issues in the August 30, 2019 appeal resolution letter upon which the appeal was rejected: a unit conversion error for one component of the flood hazard analysis and omission of the LiMWA in the appeal submission. Neither of these issues are applicable to the South Portland site due to the geography and dominant flood hazards (Section 8.1) and thus dismissal of the appeal on their basis does not have merit.

2. Introduction

This report serves as the recommendation to the Federal Emergency Management Agency (FEMA) Administrator from the National Institute of Building Sciences (NIBS) York and Cumberland Counties, Maine (ME) Scientific Resolution Panel (SRP). SRPs are independent panels of experts organized, administered, and managed by NIBS for the purpose of reviewing and resolving conflicting scientific and technical data submitted by a community challenging FEMA's proposed flood elevation. SRPs are charged with helping to efficiently resolve appeal and protest issues between FEMA and communities by acting as an independent third party, in an effort to obtain the best data possible for the community's Flood Insurance Rate Maps (FIRMs).

3. Panel

Panel ID: MEYCCC093019

Panel Name: York_& Cumberland, ME

FEMA Region: I

Panel Members:

- **Ms. Krista Conner**, Coastal Flood Hazard Specialist, Michael Baker International, Philadelphia, PA.

Ms. Conner has a technical background focusing on coastal flood risk analysis, floodplain mapping and risk communication. She has served as a technical lead and project manager for coastal flood risk projects throughout the U.S. She is a nationally recognized expert in National Flood Insurance Program policies and their application, with a specific focus on coastal flood hazard analyses and mapping. Ms. Conner has supported FEMA in the development of more than fifteen coastal flood study guidance documents and has led trainings on the FEMA study process. She also served as the coastal technical expert for national and regional coastal communication initiatives. On behalf of FEMA, Ms. Conner has led independent QC reviews of coastal flood risk projects and flood study appeals in every Region of the country.

- **Dr. Weixia Jin, Ph.D., P.E., D.CE.**, Principal Engineer and Southern California Coastal Technical Director, Moffatt & Nichol, Costa Mesa, CA.

Dr. Jin has been with Moffatt & Nichol since 1997. Prior to that, she was assistant professor and lecturer at the Hohai University for 5 years. Her educational background includes a master's degree in Coastal and Ocean Engineering from Hohai University and Ph.D. in hydraulic and water resources from University of Pittsburg. She holds a P.E. in the State of California and is a diplomate in coastal engineering. Her FEMA related experience includes wave and tsunami propagation modeling; FEMA coastal flood mapping and review; FEMA No-Rise, LOMR and CLOMR preparations; and engineering studies of wave runup, overtopping and damage. As a consultant to US Army Corps of Engineers (USACE)/FEMA, Dr. Jin was the technical lead and assistant Program Manager (PM) on the FEMA Region VI Map Modernization Program which updated the coastal flood maps for nine coastal parishes in Southeast Louisiana and Quality Assurance/Quality Control manager on the coastal flood mapping study for Harris, Brazoria, and Jefferson Counties, Texas. As a consultant to communities, Dr. Jin was PM for the technical review of FEMA California Coastal Analysis & Mapping Project (CCAMP) for the County of Ventura and City of Malibu in Southern California, and also led multiple technical reviews of FEMA preliminary FIRMS for

communities in Northern California. Recently, Dr. Jin helped City of Malibu and Faria Beach file coastal LOMRs.

- **Dr. Elizabeth Sciaudone, Ph.D., P.E.**, Research Assistant Professor, North Carolina State University, Raleigh, NC.

Dr. Sciaudone has worked at North Carolina State University, in Raleigh, North Carolina, since 2007. Prior to that, she worked in private consulting with Moffatt & Nichol Engineers. She has over 20 years of experience in coastal engineering research and design. Projects include work on beach stabilization, post-hurricane dune construction, Letters of Map Revision (LOMR), sediment budgets, and coastal highway vulnerability analyses. She has published peer reviewed articles on vulnerability of coastal dunes, identification and analysis of coastal erosion hazard areas, remote sensing of barrier island morphology, and topographic analysis of dune volume and position. She has presented at national and international sediment transport and coastal engineering conferences. Dr. Sciaudone served on the North Carolina Science Panel, advising state regulators on coastal issues, 2010-2018. Recent research work includes development of highway vulnerability indicators and dune construction guidelines for overtopping considering a constructed beach berm. She has taught introductory coastal engineering and fluid mechanics courses as well as preparatory courses for the F.E. and P.E. exams. Her educational background includes a B.S.E. from Duke University and M.C.E. and Ph.D. from North Carolina State University. She holds a P.E. in the state of Florida.

- **Dr. Malcolm Spaulding, PhD. P.E., F. ASCE**, Professor Emeritus, Ocean Engineering at the University of Rhode Island (URI) and Principal, Spaulding Environmental Associates (SEA), LLC., Wakefield, RI.

Dr. Spaulding served for 40 years on the faculty and over a decade as department chair. He was founding President of the Northeast Regional Association for Coastal Ocean Observing Systems (NERACOO) (2008 to 2014), and founder of Applied Science Associates (ASA) Inc in 1979, serving in various leadership and technical roles through 2014. He was a senior advisor and a lead investigator on the RI Ocean Special Area Management Plan (SAMP) that resulted in the first offshore wind farm in the US. He served as a senior advisor to RI Shoreline Change (Beach) SAMP and is leading an effort called **STORMTOOLS** to make state of art modeling systems available to support coastal and riverine flooding analysis in the presence of sea level rise. Dr. Spaulding served on the National Research Council's (NRC) Marine Board and was liaison to the Ocean Studies Board from 1996 to 2001 and has been a member of numerous NRC committees. He served on Scientific Resolution Panels (SRP) for New York City (2016), San Mateo County, CA (2017), and Santa Clara, CA County (2020). Dr. Spaulding is a registered Professional Engineer in Rhode Island. He was appointed a Fellow by the American Society of Civil Engineers (ASCE) in 2018.

- **Mr. Francis Way, P.E.**, Senior Coastal Engineer, ATM, Charleston, SC

Mr. Way is a Senior Coastal Engineer in ATM's Charleston, SC office with more than 21 years professional experience in coastal, environmental, and water resources engineering. He specializes in coastal and water resources analyses and permitting, modeling, beach nourishment, dredging and navigation studies, and shoreline stabilization projects. He performs hydrodynamic, water quality, flushing, watershed, sediment, and wave modeling. Mr. Way has performed dozens of FEMA remapping efforts including LOMRs, CLOMRs, seawalls, VE zone fill studies, and appeals. Mr. Way has also provided expert witness testimony related to FEMA flood zone mapping and has performed flood zone mapping for Caribbean islands using FEMA methodology. Mr. Way earned a MS in Ocean Engineering from Texas A&M University in 2000 and a BS from Boston College in 1993. He is licensed as a professional engineer in South Carolina and North Carolina.

4. Basis for Appeal

The City of South Portland, Cumberland County and Town of Old Orchard Beach, York County, ME submitted appeal reports to FEMA dated October 26, 2018 and October 22, 2018, respectively. These reports, prepared by Ransom Consulting, Inc., appealed the proposed BFEs and Special Flood Hazard Area (SFHA) boundaries for the coastal areas, as presented on the preliminary (FIRM for these communities dated April 14, 2017). The scientific and technical bases of these appeals were essentially identical for both communities. However, the applications involved two separate areas of the coast with distinct geographies and associated flood hazards. By letters dated October 30, 2019, FEMA rejected both appeals, for essentially the same reasons.

The appeals consisted of two parts: 1. a revised analysis of storm surge levels and wave setup (TSWL) that was performed by Ransom for all of York and Cumberland Counties (*Extreme Storm Coastal Hydrology & Numerical Modeling, York and Cumberland Counties, Maine*, October 17, 2018) and 2. the individual town appeal reports (referenced above) that included analysis of overland wave propagation and wave runup elevations at shoreline transects in the two Appellant communities.

The Appellants assert that the appeal analyses are more scientifically and technically correct than FEMA's because:

1. FEMA's estimate of the TSWL does not account for the coupled physics of storm surge and wave processes. In contrast, the appeal proposed TSWL is derived from scientifically more correct methods that incorporate storm and surge and wave physics.
2. FEMA's estimate of the TSWL (including wave setup, computed with parameterized Direct Integration Method (DIM)) was not validated. In contrast, the appeal proposed TSWL derived from 2-D modeling of coupled storm surge and wave physics was validated by comparison to tide gage observations and high-water marks from historic storm events.
3. FEMA's estimate of the SWL contained an unquantified component of wave setup that is double-counted in their estimate of the TSWL, when wave setup from the DIM calculations is added to the SWL. In contrast, the appeal proposed TSWL does not double-count wave setup and correctly included wave setup at the toe of slope for wave run-up calculations in locations where wave run-up dominates the flood hazard and correctly included wave setup in areas where overland wave action is the dominant flood hazard.
4. FEMA's methodology is based on the assumption that wave conditions which determine the Based Flood Elevation (BFE) results from meteorological forcing and wave transformation from a single steady-state 1% annual chance storm event. In contrast, the appeal methodology more correctly determines the BFE based on analysis of many possible dynamic

storm surge and meteorological events that contribute to the 1%-annual-chance flood hazard.

5. FEMA's coastal hydrology does not consider the possibility of direct impacts from landfalling tropical storms or hurricanes in determination of the base flood SLW or incident wave conditions. In contrast the appeal methodology does consider the influence of possible landfalling tropical storms or hurricanes on the coastal hydrology statistics.
6. FEMA's estimate of the BFE, in many areas, is based on the assumption that wave setup on the open coast could propagate fully and unrestricted in coastal bays and estuarine areas, where such propagation is not possible. In contrast, the appeal proposed BFEs are based on more correctly considered 2-D effects as recommended in FEMA guidance on Coastal Wave Setup
7. FEMA's STWAVE models used to transform waves to nearshore conditions included incorrect bathymetry, which allowed waves to propagate across land and islands that would not be inundated during the base flood event in multiple locations. In contrast, the appeal proposed wave transformation modeling included more accurate bathymetry.
8. In many locations FEMA proposed BFEs and SFHA delineations are based on hydraulic analyses at wave transects that are not representative of local shoreline conditions. In contrast, the appeal proposed BFEs and SFHA delineation are based on evaluation of additional wave transects to provide more fine-grained and technically more correct information, where appropriate. [As no additional transects were included in the Town of Old Orchard Beach, York County appeal, this issue is considered applicable only to City of South Portland, Cumberland County.]

5. Data Submitted by the Appellants and FEMA

5.1. APPELLANTS

5.1.1. Town of Old Orchard Beach, York County, Maine

- Appeal resolution letter from FEMA Region I, dated August 30, 2019, addressed to Joseph Thornton, Chairperson, Town Council, Town of Old Orchard Beach.
- Memo Response to FEMA Region I's August 30, 2019 Letter, from Ransom Consulting Engineers and Scientists, dated September 26, 2019.
- Scientific Resolution Panel Request Form and Cover Letter, dated September 30, 2019.
- Report: Extreme Storm Coastal Hydrology & Numerical Modeling York and Cumberland Counties, Maine. Prepared by Ransom Consulting, Inc., dated October 17, 2018.
- Report: Appeal to Preliminary Flood Insurance Rate Maps Coastal Hydraulics Old Orchard Beach, Maine. Prepared by Ransom Consulting, Inc., dated October 22, 2018.
- Digital data files for SWAN and WHAFIS modeling.

5.1.2. City of South Portland, Cumberland County, Maine

- Appeal resolution letter from FEMA Region I, dated August 30, 2019, addressed to the Honorable Claude Morgan, Mayor, City of South Portland.
- Letter from Claude Morgan, Mayor, City of South Portland, addressed to Kerry Bogdan, FEMA Region I, dated September 24, 2019 in response to FEMA's appeal resolution letter. Enclosures: 1) Ransom Consulting Memorandum RE: Response to FEMA's August 30, 2019 Letter, and 2) Scientific Resolution Panel Request Form and Attachments.
- Report: Extreme Storm Coastal Hydrology & Numerical Modeling York and Cumberland Counties, Maine. Prepared by Ransom Consulting, Inc., dated October 17, 2018.
- Report: Appeal to Preliminary Flood Insurance Rate Maps Coastal Hydraulics 2 Bay Road, South Portland, Maine 04106. Prepared by Ransom Consulting, Inc., dated October 26, 2018.
- Digital data files for SWAN and WHAFIS modeling.

5.2. FEMA

The following are references that are pertinent to both appeal sites:

- Map Mod, 2008. Updating Tidal Profiles for the New England Coastline, Federal Emergency Management Agency, Map Mod Team, Washington, D.C. December 2008.

- Ransom, 2012 Hydrologic and Hydraulic Zone A Modeling for Falmouth, ME, Ransom Consulting Engineers and Scientists.
- STARR, 2012. Updated Tidal Profiles for the New England Coastline, for Federal Emergency Management Agency, STARR Washington, D.C. March 2012.
- U.S. Army Corps of Engineers, New England Division, 2004. Memorandum for the File: Development of the 1988 Tidal Flood Profiles, (CENAE-EP-EW), April 8, 2004.
- Coastal State University, 2007. Coastal State University Coastal Wave Model.

5.2.1. Town of Old Orchard Beach, York County, Maine

- FEMA, 2019. Flood Insurance Study (FIS), York County, Maine, Federal Emergency Management Agency, Flood Insurance Study Number: 23005CV002A, Version Number 2.3.2.1, Volumes 1 to 4 (preliminary March 28, 2018).
- CDM, 2007. Flood Mapping Activities for York County, Maine, Task Order 16, Tasks 1, 2, and 3 Field Surveys and Reconnaissance, Hydrology Review, and Hydraulics Summary Report.
- Ocean and Coastal Consultants (OCC), 2007. Technical Support Data Notebook for Coastal Engineering Analysis for Flood Insurance Study Revision" (TSDN) report for York County.
- Summary Report of Coastal Engineering Analyses DFIRM Update for Coastal Analysis for York County, ME Task Order 15 - Coastal Hazard Analysis Deliverable, prepared by STARR, dated March 2016.
- Digital files for WHAFIS and wave runup modeling and calculations.

5.2.2. City of South Portland, Cumberland County, Maine

- FEMA, 2019. Flood Insurance Study (FIS), Cumberland County, Maine, Federal Emergency Management Agency, Flood Insurance Study Number: 23005CV002A, Version Number 2.3.2.1, Volumes 1 to 4 (preliminary August 30, 2019).
- Ocean and Coastal Consultants (OCC), 2007. Technical Support Data Notebook for Coastal Engineering Analyses for Flood Insurance Study Revision. Cumberland County, Maine, Towns of Cape Elizabeth, Cumberland, Harpswell, Portland, South Portland, Scarborough. FEMA contract No. EME-2003-CO-0340 TO 17, OCC project No. 203075.5.
- Summary Report of Coastal Engineering Analyses DFIRM Update for Coastal Analysis for Cumberland County, ME Task Order 15 - Coastal Hazard Analysis Deliverable, prepared by STARR, dated April 2017.
- Digital files for WHAFIS and wave runup modeling and calculations for the 2019 preliminary flood study.

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- Email communication from FEMA Headquarters (HQ) regarding the basis of the flood hazard mapping at the South Portland appeal site, September 22, 2020 and transmitting documentation from 2010 community consultation.
- Documentation from 2010 community consultation:
 - Cover Letter from Robert Gerber, Sebago Technics, Inc. dated February 24, 2010. Re: Provisional Coastal Flood Zone Delineations So. Portland, Cumberland County, Maine
 - Report: Delineation of the VE-Zone in South Portland, ME, dated January 2010. Sebago Technics.
 - FEMA's response letter, dated June 4, 2010. RE: Revised Preliminary Digital Flood Insurance Rate Maps and Map Status Update for the City of South Portland, Cumberland County, Maine (All Jurisdictions).

6. Summary of Panel Procedures

The work of this SRP (the “Panel”) was performed during the period of July 21, 2020 through October 20, 2020. The Panel convened by web conference calls seven times during the review period, and once more for the purpose of listening to presentations by FEMA and the Appellant and participating in questions/answers with both parties. Below is a brief summary of the Panel’s work.

The Panel was officially formed and called to order during a web conference held on July 21, 2020. During that call, which was led by NIBS Institute Director, Ms. Dominique Fernandez, panelists were informed of the SRP policies and procedures; the scope and responsibilities of the Panel, limitations on material to be reviewed and final decisions, confidentiality, Panel schedule, and use of the SRP website for obtaining Appeal materials. A Panel Chair, Krista Conner, was appointed.

The Panel next met via a web conference call on August 4, 2020 for the purpose of discussing the reports and data submitted as part of the Appeal process and the issues identified in FEMA’s appeal resolution letter. The meeting was also used to identify questions to be asked of FEMA and the Appellants to be addressed in their oral presentations. These questions (Appendix A) were submitted by Ms. Fernandez to both parties in advance of their presentations to the Panel on August 19, 2020.

The Panel reconvened by web conference call on August 19, 2020 to listen to oral presentations by the Appellant and FEMA (and their designated appointees). The presentation slide decks for the Appellants and FEMA are provided in Appendix B and C, respectively. Following the presentations, the Panel was able to ask additional questions of FEMA and the Appellants.

The Panel reconvened by web conference call on August 25, 2020 and September 8, 2020 to further discuss the assertions and data submitted for the appeals and the explanations presented during the oral presentations. During these discussions the Panel agreed that the basis for the flood hazard mapping at the South Portland appeal site, specifically the Zone VE (EL 35), could not be located among the documentation provided. An email was sent to FEMA on September 9, 2020 requesting that FEMA help direct the panel to the modeling and/or documentation that supports the flood hazard data at the appeal site. FEMA provided additional material on September 22, 2020.

The Panel reconvened by web conference call on September 15, 2020. The focus of the call was for the panel to reach consensus on decisions for each appeal. The Decisions presented in Section 7 were unanimous. Additional team calls were held to coordinate report writing and review.

7. Decision

The Panel has made separate decisions for the two appeals.

7.1. TOWN OF OLD ORCHARD BEACH, YORK COUNTY

For the Town of Old Orchard Beach, the Panel determined that portions of the Appellant’s data satisfy NFIP standards and correct or negate FEMA’s data. The following section, as well as Section 8. Rationale for Findings, discuss which portions of the appeal data is more scientifically and or technically correct than the data presented in the preliminary FIS and FIRM.

The Panel considers that the overall 2-D, coupled hydrodynamic and wave modeling approach employed by the Appellant to determine the 1%-annual-chance TSWL to be superior to the FEMA approach of using tidal gauge data combined with limited wave modeling and transect-based DIM calculations for wave setup.

For the purposes of discussion, the Town of Old Orchard Beach appeal is divided into two areas:

- 1) Transects YK-142, YK-143, YK-144 and;
- 2) Transect YK-137

Figure 7-1 shows the locations of all four transects.

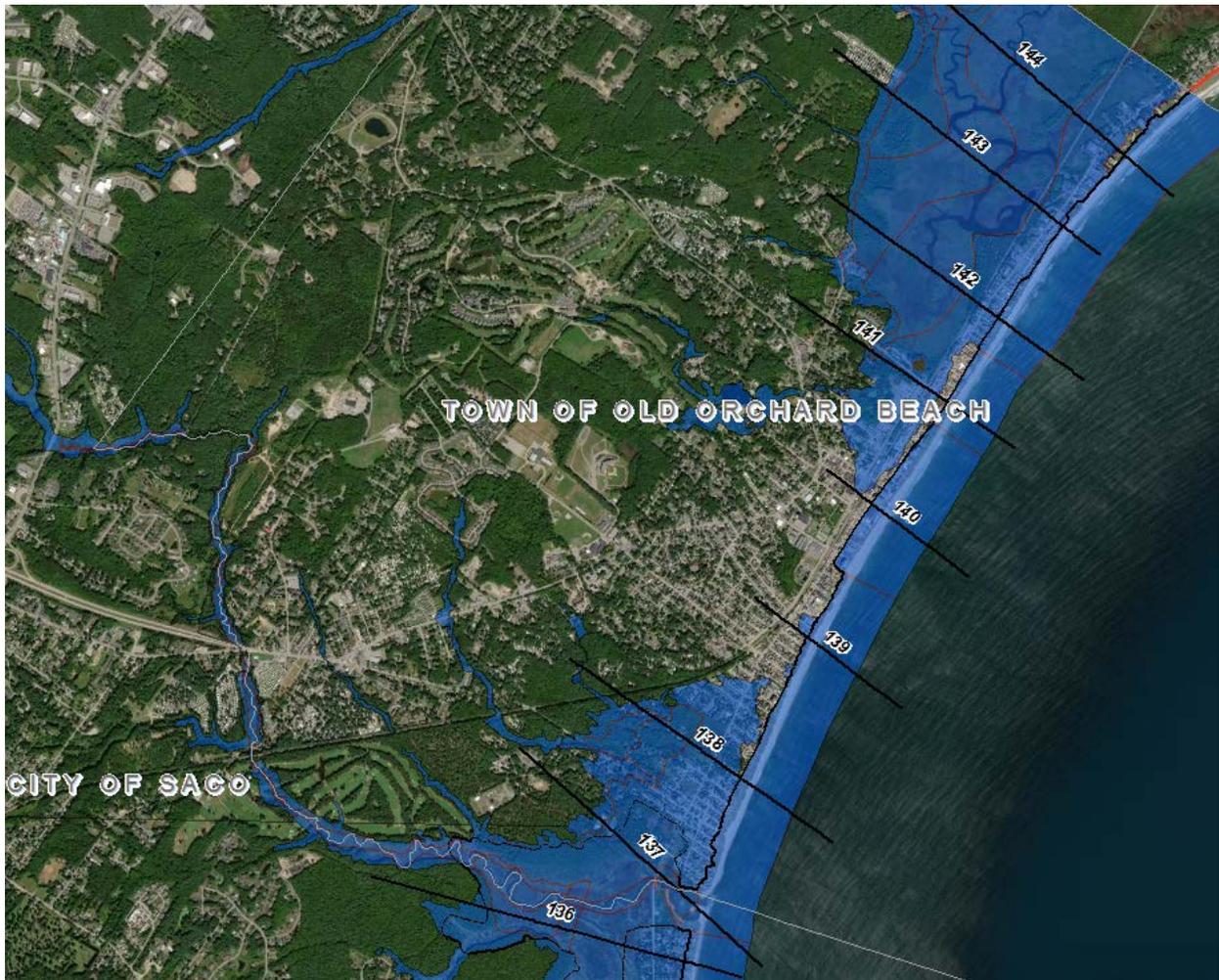


Figure 7-1. Map of Old Orchard Beach, York County, Maine Showing Transect Locations

For Transects YK-142, YK-143, and YK-144, the appeal revisions to the oceanfront flood hazard mapping cannot be accepted due to the wave setup unit conversion error (Section 8.1.1) as this will have an effect on the ability to compare the overland wave propagation results to the wave runup results and determine which controls the flood hazard mapping. The appeal modeling and mapping for Transect YK-137 also cannot be accepted due to being affected by the wave setup unit conversion issue.

However, the SRP finds that the appeal mapping of the marsh/estuarine area is an improvement over the FEMA estuarine mapping. FEMA's WHAFIS methodology for Transects YK-142, YK-143, and YK-144 applied oceanfront wave setup across the entire marsh/estuarine area even though Transects YK-142 and YK-144 go "above surge" prior to reaching the marsh. ("Above surge" means that the ground is higher than the TSWL (storm surge + wave setup). While these above surge areas may still be subject to flood hazards from wave runup and overtopping, the presence of above surge areas in overland wave propagation means complete wave breaking and dissipation of wave setup. For Transect YK-143, FEMA's

WHAFIS modeling indicated that while not technically “above surge”, there is only a 0.01-foot difference between existing grade and 1%-annual-chance TSWL along the beachfront. WHAFIS results indicate a 0.01 ft controlling wave height across the barrier beach, indicating complete wave breaking occurs at this YK-143, also. Even if other stretches of the barrier beach that are not traversed by a modeled transect are somewhat lower in elevation and do allow some storm surge and associated wave setup to propagate into the marsh, modeling the marsh with ocean-based wave setup contributions does not account for local topographic conditions and the 2-D effects on wave setup due to the shallow inundations depths during flood conditions (see Section 8.2.6 for further discussion).

It is noted that since FEMA WHAFIS modeling at YK-143 is modeled with a 0.01 ft depth instead of above surge, it allows for the ocean-based wave period to remain along the transect within the marsh. As noted above, complete wave breaking can be expected at the beachfront and therefore, local wind-wave generation will occur in the marsh/estuarine area under 1%-annual-chance flood conditions. The appeal analysis shows the beachfront going “above surge” and local wind-waves are regenerated by WHAFIS.

FEMA’s appeal resolution letter points out that the submitted flood hazard mapping was not properly tied into the surrounding flood hazard zones along Mill Brook, near the inland end of YK-144. The disjointed flood zones should be corrected (Section 8.1.3).

7.2. CITY OF SOUTH PORTLAND, CUMBERLAND COUNTY

For the City of South Portland, the Panel determined that FEMA’s data does not satisfy NFIP mapping standards defined by FEMA’s Guidelines and Standards for Flood Risk Analysis and Mapping and must be revisited.

Specifically FEMA’s data does not satisfy NFIP mapping Standard IDs (SIDs) # 61 and 62 (FEMA, 2019):

- *SID 61: Engineering analyses must be documented and easily reproducible and must include study methods, reasoning for method selection, input data and parameters, sources of data, results, and justifications for major changes in computed flood hazard parameters.*
- *SID 62: New or updated flood hazard data used for the regulatory products must be supported by modeling and/or sound engineering judgment. All regulatory products must be in agreement.*

The Panel has reviewed the 2019 preliminary FIRM flood hazard mapping at the South Portland appeal site, 2 Bay Road, South Portland. The site is mapped as Zone VE with a BFE of 35 feet (ft). There is not a documented transect within the Zone VE (EL 35). The nearest transect in the preliminary FIS is transect 35 located to the south of the appeal site (Figure 7-2). The Panel has attempted to understand the basis of the Zone VE (EL 35) flood zone at the site and has concluded it to be as follows. Originally in 2007, FEMA’s wave runup elevation at transect 35, formerly identified as transect SP-6, was 43.9 ft (SWL 8.9 ft +

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35 ft of wave runup height) and the area surrounding the transect was mapped with a 41 ft BFE (Figure 7-3). Then in 2010 after some community coordination, revised flood hazard analyses were accepted and the mapping was revised, changing the BFE at transect 35 to 25 ft. The 2019 mapping shown in Figure 7-2 reflects the changes that were made as a result of the 2010 community consultation.

Comparison of the 2007 and 2019 mapping shows differences in flood zones represented by transects 35 and 36, but no changes to the three flood zones between the two transects, including the Zone VE (EL 35) at the appeal site. So where does the Zone VE (EL 35) at the appeal site come from? While the Panel was unable to locate explicit documentation that explains this mapping, it concluded that the origin of that mapping is likely from the implementation of FEMA guidance for mapping of transition zones between wave runup transects:

Transition zones may be necessary between areas with high runup elevations to avoid large differences in BFEs, and to smooth the change in flood zone boundaries. These zones should be fairly short and cover the shore segment with a slope not exactly typical of either area. The Mapping Partner should determine the transition elevation using judgment in examining runup transects with similar slopes. The Mapping Partner should not use transition zones if there is a very abrupt change in topography, such as at the end of a coastal structure. (FEMA, 2007. Section D.11.6.1)

The 2007 mapping (Figure 7-3) is interpreted to show that transect 35 was mapped with a 41-foot BFE and then three transition zones to the north were mapped with progressively decreasing BFEs. However, in 2010, when the mapping at the transects 35 and 36 was updated and the BFE at transect 35 was lowered from 41 to 25 ft, the three transitional zones to the north of it were left unchanged. The result was that two of the three transition zones now have higher BFEs than at the more exposed transect 35 where the wave runup hazard is explicitly evaluated. This seems to be an error; based on the original judgment that was applied in 2007 and the new modeled results from 2010, the transitional zones should decrease from 25 ft. This error appears to violate FEMA mapping standards 61 and 62 as the transition zones are not reproducible from the current FIS modeling and mapping and are no longer based on engineering judgment.

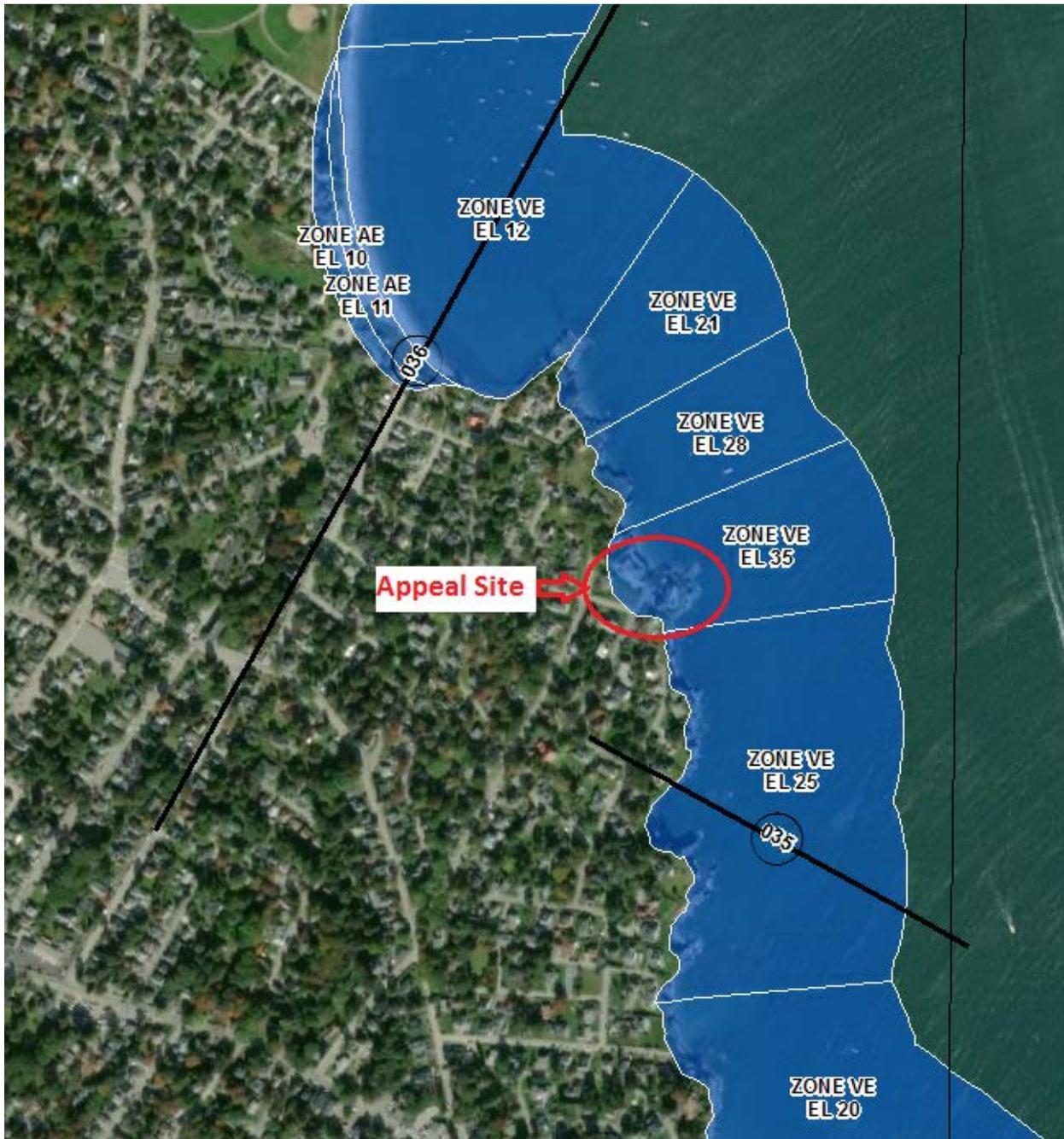


Figure 7-2. 2019 Preliminary Cumberland County FIS Flood Hazard Mapping of Appeal Site and Transects 35 and 36 (image received from FEMA HQ, September 22, 2020, with addition of Appeal Site label).



Figure 7-3. Original 2007 Cumberland County FIS Flood Hazard Mapping (image received from FEMA HQ, September 22, 2020).

The other possible explanation that the Panel considered for the Zone VE (EL 35) mapping was that it may have been based on the FEMA wave runup mapping guidance for representative transect reaches:

In some cases, fewer transects may be adequate to characterize flood hazards in geographically separate but physically similar shoreline reaches. Areas with significant flooding hazards from wave runup may have one transect representing multiple alongshore reaches because the areas have similar shore slopes. In this case, the Mapping Partner should identify the different areas and delineate the results of the typical transect in each area (FEMA, 2007. Section D.11.6.1).

However, use of results from a transect located elsewhere would not be appropriate due to the following reasons:

- the highly complex geometry of the Casco Bay, Cumberland County coast,
- the highly variable coastal orientations relative to offshore wave propagation, and
- the complex offshore characteristics of the appeal site which is situated on a portion of the coast that is semi-sheltered from offshore waves by Cushing and Peaks Islands.

Hence, it is unlikely that both the offshore wave conditions and the shoreline conditions elsewhere would be similar enough to the appeal site to be considered representative for flood hazard purposes.

While the Panel finds that FEMA's reasons for rejecting the appeal stated in their August 30, 2019 letter are not applicable to the South Portland appeal (see Section 8.1), the appeal analysis is not wholly correct and therefore cannot be used to fully correct the FEMA data. The Appellant added three new transects, namely CM-35-1, CM-35-2 and CM-35-3 in the vicinity of the appeal site (Figure 7-4).

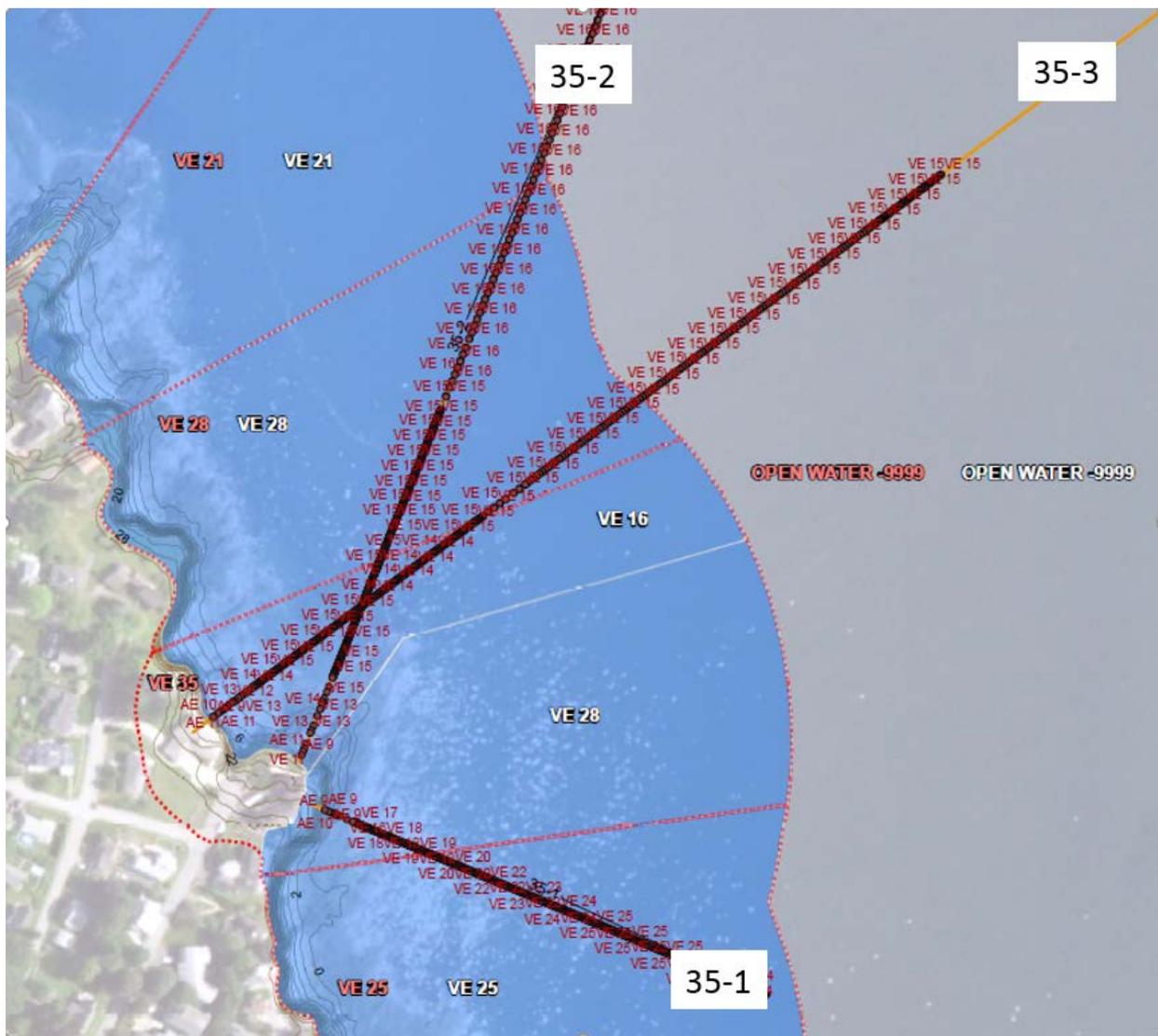


Figure 7-4. New Transects Modeled at the South Portland Appeal Site (from Ransom, 2018b with Transect Labels Added)

The flood hazard analysis and mapping of CM-35-2 and CM-35-3 are not correct and should not be used to correct the FEMA data. Based on Figure 50 in the report titled *Extreme Storm Coastal Hydrology & Numerical Modeling for York and Cumberland Counties, Maine* and dated October 17, 2018 (Figure 7-5 below), it shows that the site is exposed to northwest (NW) swells with a wave period around 12 seconds during the 100-yr storm. A wave period of 12.5 seconds was used in transect CM-35 analysis by FEMA and that of 11.75 seconds was used in transect CM-35-1 by the Appellant. Although the appeal’s 2-D wave modeling results indicated that the site is exposed to swells from the NW for transects CM-35-2 and CM-35-3, the Appellant only analyzed wind induced waves with a wave period around 5 seconds. Since longer period waves often produce significant wave runup, the impact of the NW swells should be considered in

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the wave runup analyses. Comparison of wave runup from the locally generated 5-second wave to runup from the NW swells would show which controls the 1%-annual-chance flood hazards at this site.

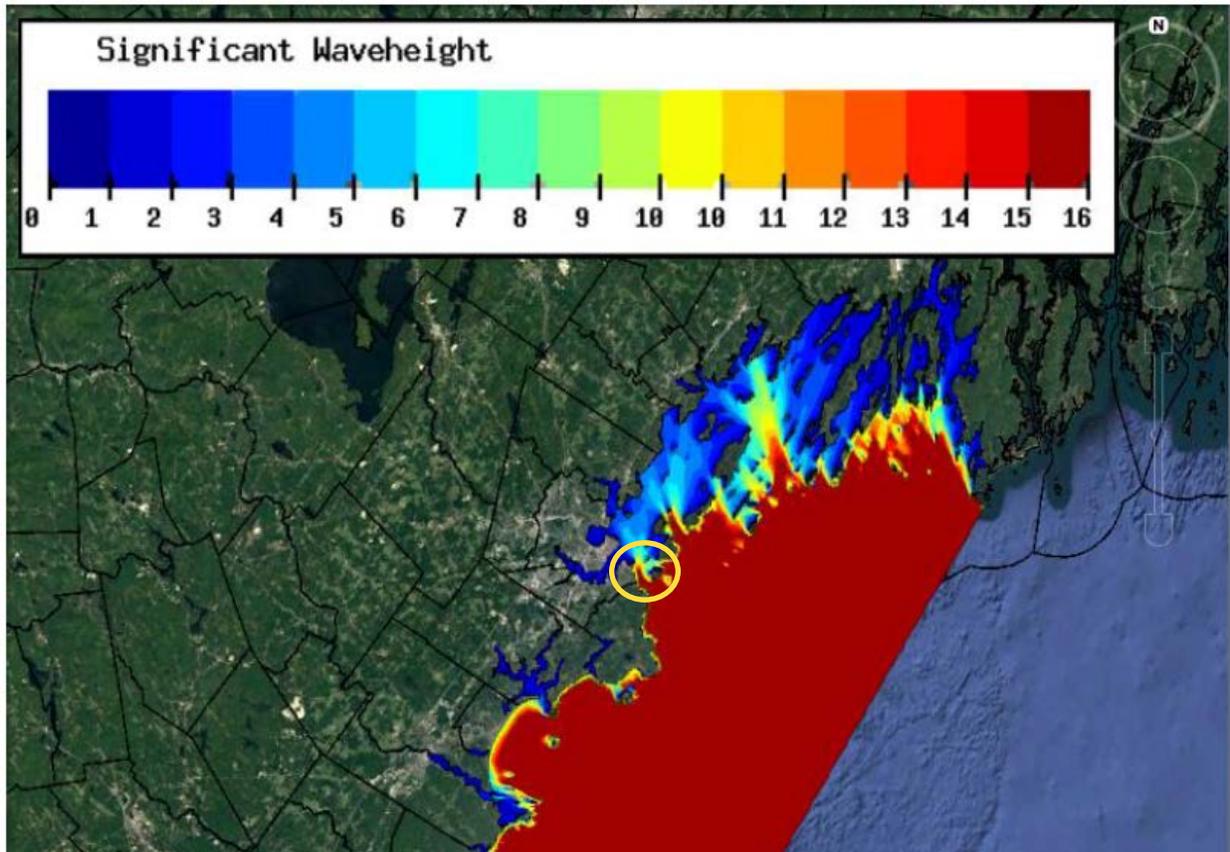


Figure 50: 100-year Significant Wave Height (feet) – Waves Traveling Northwest

Figure 7-5. 100-yr Wave Exposure at South Portland (yellow circle) (Ransom Consulting, 2018a).

The flood hazard analysis and mapping of CM-35-1 is acceptable and could be used to correct the FEMA data.

8. Rationale for Findings

The Panel's objective is to determine which of the two provided analyses is more scientifically and or technically correct. The following sections provide discussions of the Panel's rationale on each distinct element of dispute. Separate sections are provided for FEMA and Appellant issues.

8.1. FEMA'S APPEAL RESOLUTION ISSUES

FEMA issued appeal resolution letters for these two communities on August 30, 2019. The Old Orchard Beach appeal was rejected based on three technical issues:

1. a technical error that involved the failure to convert data from metric to English units when the wave setup component (from the SWAN one-dimensional (1-D) model) was incorporated into the overland wave propagation analysis (WHAFIS),
2. the omission of revised LIMWA mapping with the appeal submission, and
3. disjointed mapping tie-ins with surrounding areas.

The appeal resolution letter for the South Portland appeal was similar to but not identical to the Old Orchard Beach resolution letter. The South Portland appeal was rejected by FEMA based on items 1 and 2 above; however, item 3 was not an issue for the South Portland appeal submission.

Per 44 CFR 67.8:

If a community appeals the proposed flood elevation determination, the Federal Insurance Administrator shall review and take fully into account any technical or scientific data submitted by the community that tend to negate or contradict the information upon which his/her proposed determination is based.

Other than identifying the above three errors and omissions, FEMA did not comment on the scientific or technical merits of these complex appeals. By rejecting the appeals based on these issues, it does not appear that FEMA took fully into account the Appellant submitted scientific data that contradicted the FEMA study.

The Panel finds that the FEMA identified errors and omissions ultimately have limited relevancy to the coastal flood hazard analyses and flood hazard mapping for the sites. In particular, for the South Portland site, neither of the cited issues are applicable to the analysis and mapping at the specific site in question. The Old Orchard Beach site is larger and more complex with the issues raised by FEMA having merit, though of limited impact. While the errors prevent the finding that the Old Orchard Beach appeal data "satisfies NFIP standards and is wholly correct..." the Panel reviewed the FEMA and Appellants' analyses to determine which is more scientifically and/or technically correct. The three issues and their relevancy to each appeal site are discussed at greater length below.

8.1.1. Unit Conversion Error

FEMA identified an error in the engineering analysis provided with the appeal submittals. When the wave setup component resulting from the SWAN 1-D analysis was incorporated into the overland wave propagation modeling, the wave setup was left in meters and not converted to feet. This error is indeed present in the Appellant's submittals for both Old Orchard Beach and South Portland. In the appeal resolution letters for both locations, dated August 30, 2019, FEMA characterizes this error as "critical" with the explanation that, "As wave setup is an early input to the coastal hydraulics process, errors in wave setup propagate throughout the analyses, resulting in erroneous BFEs." However, the effect of this error on the analysis and resultant regulatory flood hazard mapping are more nuanced than this characterization suggests.

The wave setup conversion error that occurred in the appeal analyses only affects the open coast portions of the overland wave propagation modeling with the WHAFIS model. This means that the error only results in erroneous BFEs in open coast locations where the BFE is based on overland wave propagation. Within sheltered areas, specifically the marshes behind the Old Orchard Beach beachfront, the TSWL, which includes the wave setup component, was taken directly from the ADCIRC+SWAN model results; therefore, the sheltered water TSWLs are unaffected by the unit error from the SWAN 1-D analysis. Open coast locations where the mapped BFEs are based on wave runup were not affected by the wave setup unit conversion error. Since the dominant flood hazard on almost all open coast locations is wave runup, this greatly minimizes the impact of the wave setup unit conversion error on the mapped flood hazard information. The impacts on each site are discussed in greater detail below. The nuances of how this error affects the analysis and resultant regulatory flood hazard mapping are important when considering whether this error was "critical." Given the limited influence of the error, the appeals can be reviewed for technical or scientific data that tend to negate or contradict the FEMA study.

Old Orchard Beach

The impact of the unit conversion error to Old Orchard Beach is varied, but minimal. Along the beachfront at appeal modeled transects YK-142, YK-143, and YK-144, the error conversion issue does affect the WHAFIS results. Although wave runup is the predominant wave hazard that controls the FEMA and appeal study mapped BFEs, correction of the setup error does result in wave crest elevations along the first few feet of the beach being greater than the wave runup elevation, i.e. wave crest elevation of 14 ft up to ground elevation of 3ft, compared to a wave runup elevation of 13 ft. This impact is acknowledged in the Appellant's appeal response, though it should be noted that common FEMA mapping practice in situations such as this is to simplify the mapping, by mapping just the wave runup results since the wave crest elevation result at the shoreline does not impact developed land.

Within the sheltered areas, that is, the marshes inland of the Old Orchard Beach beachfront along appeal modeled transects YK-142, YK-143, and YK-144, the TSWL for the WHAFIS modeling was taken directly from the ADCIRC+SWAN model results. The unit conversion error did not affect the Appellant's modeling in this area and the resultant BFEs are also unaffected by the error. The exception to this is transect YK-137 at Goosefare Brook Inlet (Figure 8-1). The SWAN-1D wave setup results do affect the results and

associated mapping at the mouth of Goosefare Brook Inlet. As such, the WHAFIS modeling and flood hazard mapping along this transect are affected by the unit conversion error.



Figure 8-1. Transect YK-137 at Goosefare Brook Inlet

South Portland

The dominant flood hazard at the South Portland site is wave runoff. The high, steep topography of the shoreline makes this readily apparent without the need for comparative analysis between overland propagation and wave runoff—the ground is not submerged by the TSWL and therefore there is no overland wave propagation to be evaluated. In FEMA studies with steep coastlines such as this it is common practice to exclusively evaluate wave runoff (e.g. FEMA’s Pacific Coast studies). With wave runoff as the only wave hazard to need evaluation, and with the unit conversion error not being applicable to the wave runoff calculations, the South Portland site is not affected by this error.

8.1.2. Omission of Limit of Moderate Wave Action (LiMWA) Line

The Appellant’s flood hazard mapping did not include a LiMWA line. Through the Appellants’ written response memos to FEMA’s appeal resolution letters, and during oral presentations, the Appellants

indicated that the LiMWA was not provided because it was not clear to them that the LiMWA, which is considered an informational layer, not a regulatory layer, is a requirement of an appeal submission. FEMA's appeal resolution letter cites Standard ID 412: *For coastal Flood Risk Projects, the Limit of Moderate Wave Action (LiMWA) must be calculated, where appropriate.* While this standard doesn't specifically reference an appeal submission and therefore may be confusing to Appellants, FEMA has indicated that it does extend to appeals. Therefore, inclusion of a revised LiMWA line to go with associated revised flood hazard mapping, where appropriate, is a requirement for an appeal.

FEMA states in the appeal resolution letters for both appeals, dated August 30, 2019:

The LiMWA is identified where overland wave propagation is the dominant coastal hazard. In areas where the VE zone is defined by wave runup, overtopping or a risk not associated with breaking wave heights such as the primary frontal dune, the LiMWA is not necessary to depict on the FIRM per FEMA's "Coastal Floodplain Mapping Guidance".

At the **Old Orchard Beach** site, based on the Panel's review of the Appellant's study, the only location where it is necessary to map the LiMWA is at transect YK-137. This is consistent with the extent of where LiMWA is mapped for the preliminary FIS.

At the **South Portland** site, the VE zone is defined by wave runup and overtopping, therefore LiMWA mapping is not necessary.

8.1.3. Disjointed Mapping Tie-ins*

*[This issue was only cited for Old Orchard Beach.]

FEMA's appeal resolution letter points out that the submitted flood hazard mapping was not properly tied into the surrounding flood hazard zones. Specifically, in the northeast portion of the town Mill Brook has disjointed flood zones and mismatching BFEs on either side of the river. Indeed, the appeal mapping is disjointed in this area. This is a minor error in the mapping files, unrelated to the technical and scientific basis of the appeal itself.

8.2. APPELLANT'S ASSERTIONS

The assertions made by the Appellants are presented in *italics* at the beginning of each of the following subsections.

8.2.1. Coupled Physics of Surge and Wave Processes

FEMA's estimate of the TSWL does not account for the coupled physics of storm surge and wave processes. In contrast, the appeal proposed TSWL is derived from scientifically more correct methods that incorporate storm and surge and wave physics.

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FEMA Approach: FEMA’s approach employs two steps to determine the TSWL for the 1%-annual-chance flood. The first step is to estimate the inundation level (SWL) using the U.S. Army Corps of Engineers (USACE) Tidal Flood Profiles for New England (1988), with subsequent revisions, and then in the second step employ a transect dependent method to estimate the wave induced setup. The TSWL is then the sum of the two. The original USACE profiles assumed that the 1%-annual-chance (100- yr) event could be presented by the water levels from the Feb 7, 1978, extratropical storm event, with linear interpolation between NOAA NOS gauging stations. In subsequent iterations, FEMA modified the water levels by performing a formal return period analysis using all of the existing water level data at the time of the re-analysis. The method for performing the statistical analyses was changed and the vertical datum changed from NGVD29 to NAVD88. Analyses were performed in 2007 by OCC (2007), under the Map Mod (2008) effort in 2008, and again in 2012 (STARR, 2012). Figure 8-2. shows the locations along the coast for profile 11 that covers the York and Cumberland Counties, ME study areas. Figure 8-3 shows the estimated 0.2%, 1%, 2%, and 10% water levels at each NOAA NOS water level station. The annual maximum water levels and the water level from the February 1978 storm at the NOAA NOS Seavey Island and Portland, ME stations are provided. It is noted that the high-water mark at Seavey Island is 9.6 ft and for Portland 9.9 ft. The NOAA NOS records for the two stations show peak water levels of 8.06 ft and 8.49 ft, respectively.

Finally, the figure shows the water levels from the February 7, 1978 storm event. Both figures are from the STARR (2012b) report. The FIS for both York and Cumberland counties used the values of SWL from the OCC (2007) study.

It is instructive to compare the SWL at the Portland, ME site which has the longest record in York and Cumberland Counties study areas from the various re-analyses. These are summarized in Table 8.1. The values used in the FIS (2018/2019) for York and Cumberland Counties are consistent with value recommended by OCC (2007) and lower than the most recent estimate by STARR (2012b).

Table 8.1. 1%-Annual-Chance (100-yr) Water Level at Portland, ME (NOAA Gauge Station# 8418150)

Source	Water Level (ft, NAVD88)	Reference
Storm Event, February 7, 1978	8.49	NOAA NOS Website, Aug 27, 2020
NOAA NOS (extremal analysis)	9.15	NOAA NOS Website, Aug 27, 2020
Effective from prior FIS	8.88	STARR, 2012b
OCC (2007)	8.9	OCC, 2007
York and Cumberland County FIS (2018)	8.9	FIS, 2018
STARR (2012b)	9.5	STARR, 2012b

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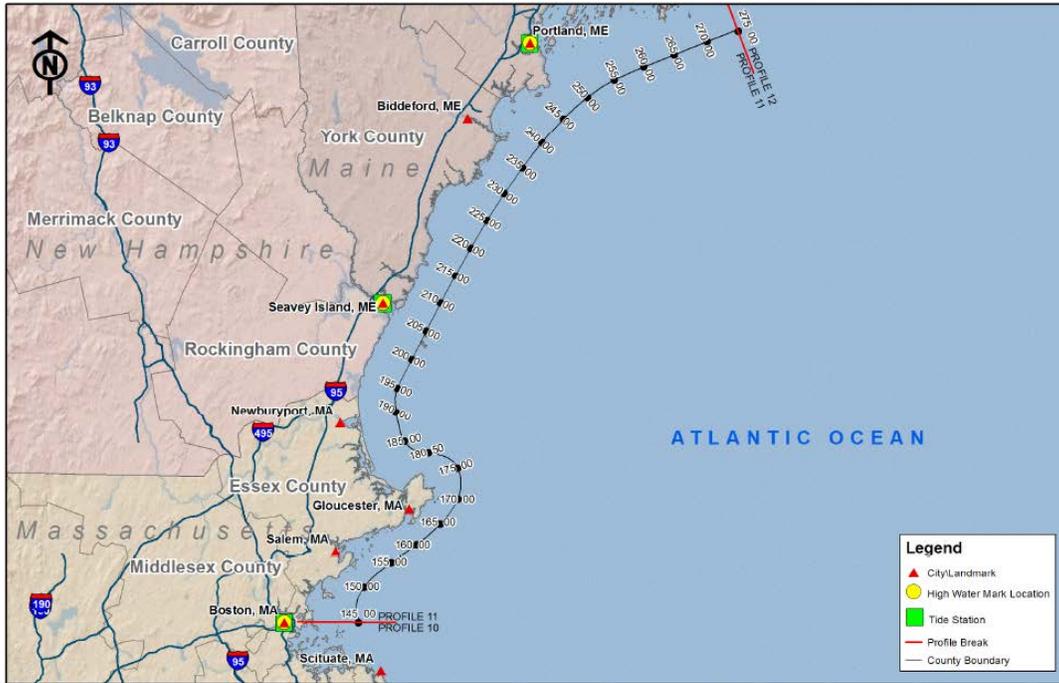


Figure B13. Base Map for Profile 11 from Boston, MA to mile 275

Figure 8-2. Base map for profile 11 from Boston, MA to mile 275 (Figure B13; STARR, 2012b).

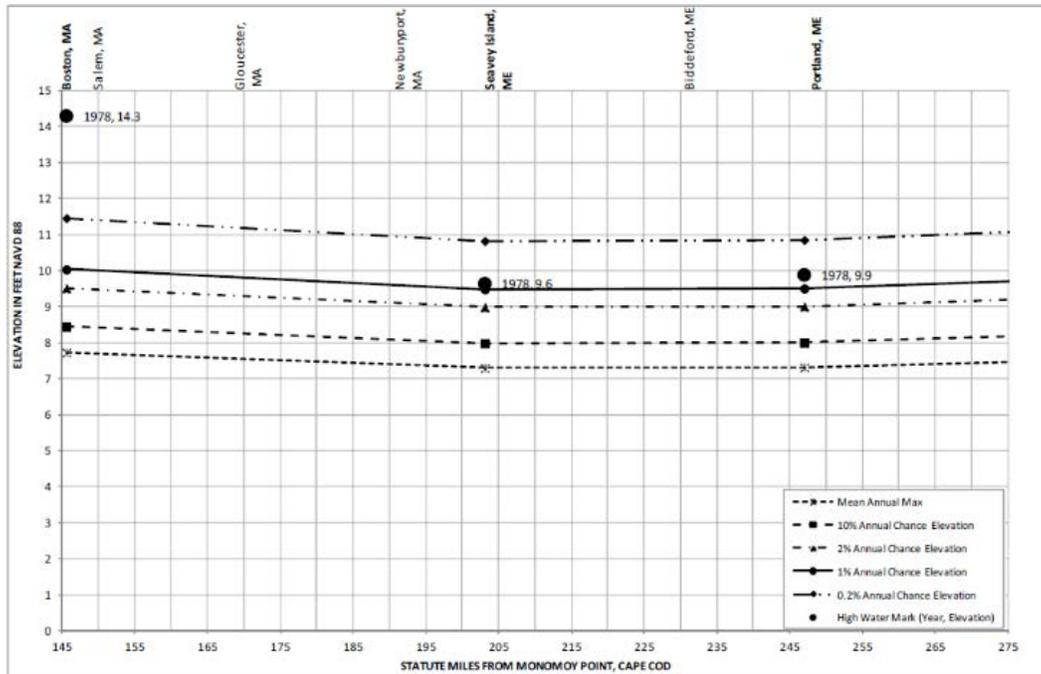


Figure C13. Tidal Flood Profile 11 from Boston, MA to mile 275

Figure 8-3. Tidal flood profile from Boston, MA to mile 275 (Figure C13; STARR, 2012b).

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FEMA has recognized that their approach does not provide the details of surge amplification in inlets and embayment near the coast. They have applied Resource Management Associates (RMA) finite element hydrodynamic model to Knox, Lincoln, Sagadahoc, Waldo, and Hancock Counties but not York and Cumberland Counties shown in Figure 8-4 (STARR, 2012a). No explanation is provided on why York and Cumberland Counties have not been included in this high-resolution hydrodynamic modeling approach.

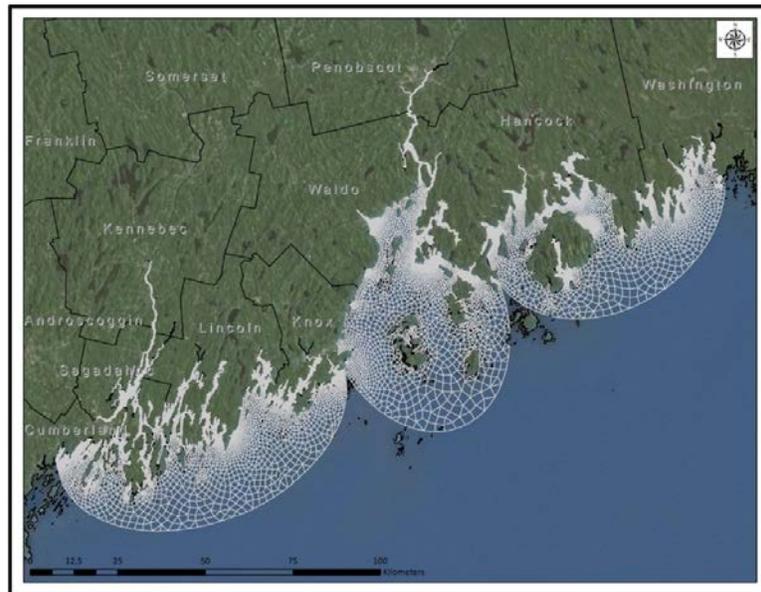


Figure 3-1 : RMA2 Model Domains

Figure 8-4. RMA2 model domains (Figure 3-1; STARR, 2012a)

The DIM was used to calculate wave setup. For Old Orchard Beach, where wave setup is an important component of the study and the appeal, wave setup was calculated to be 3.6-4.0 ft

Appellant Approach: Ransom (2018a) used the results of the USACE North Atlantic Coast Comprehensive Study (NACCS) where the Coastal Storm Modeling System (CSTORM-MS), which couples together a sequence of numerical models including the Planetary Boundary Layer model (PBL) to simulate wind and barometric pressure fields, the Wave Analysis Model (WAM) to simulate deep ocean wave generation and propagation, and the ADvanced CIRCulation hydrodynamic model tightly coupled with the STeady-state WAVE spectral model (ADCIRC+STWAVE), was used to simulate the combined physics of tides, storm surge, wave transformation, and wave setup. CSTORM-MS was used to simulate the coastal ocean's response to 1,050 synthetic tropical cyclones and 100 historic extra-tropical cyclones. For the present study the results were based on a subset of these tropical and extratropical storms that represented the study area. One unique feature of this approach is that since the hydrodynamic and wave model are tightly coupled the simulation predicts not only the surge water level and wave conditions but also the wave induced setup. Ransom downscaled results from the NACCS modeling and employed a coupled ADCIRC + SWAN circulation and wave model, termed the "Bigelow Bight model" in their 2018 report.

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Figure 8-5 shows the 1%-annual-chance TSWL (SWL plus static wave setup) resulting from both extratropical and tropical storms from the Ransom (2018a) study. Separate maps of the SWL and wave setup for the 1%-annual-chance event are not provided in the study report. The predictions show amplification of the storm water level from offshore to nearshore, one portion of which is due to amplification of the surge in nearshore embayment and the second from wave setup when the coast is exposed to open ocean conditions. The water levels at Portland, ME are approximately 8.9 ft, consistent with estimates provided in Table 8-1.

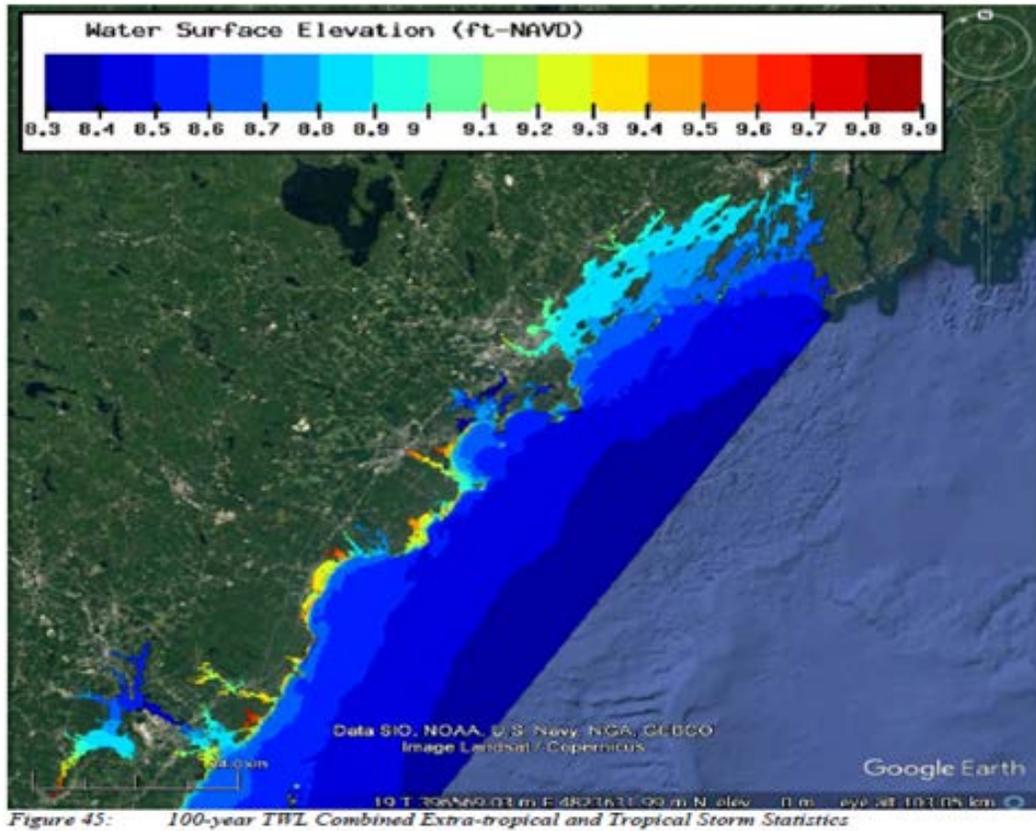


Figure 8-5. 1%-Annual-Chance (100-yr) TSWL (ft- NAVD88) combined extra tropical and tropical storm statistics (Figure 45; Ransom, 2018a).

To provide additional insight, Figure 8-6 shows the maximum water level, including wave setup, and Figure 8-7 the associated wave setup for the application of the fully coupled model for the February 1978 extratropical storm event. The model predictions were extensively validated against observations. Comparing the two figures shows that the wave setup is greatest at locations closest to the open ocean and decreases substantially in protected embayments (e.g. Casco Bay). Setup values range from 0 to 0.5 ft.

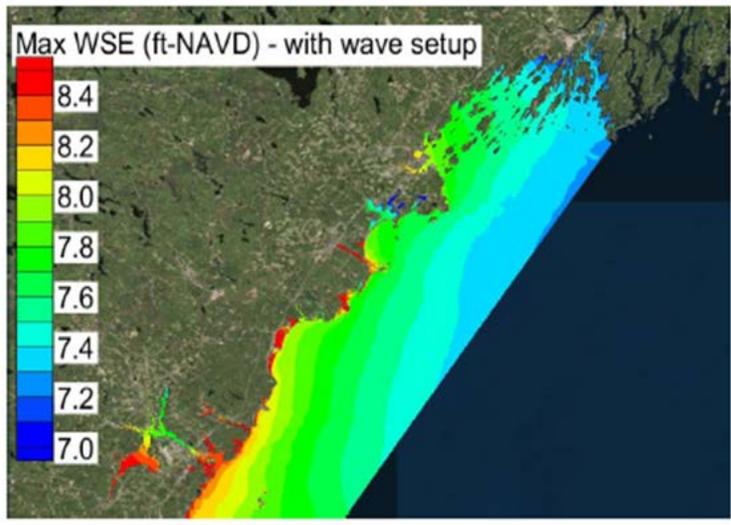


Figure 4: Maximum Water Surface Elevation from a tightly coupled ADCIRC-SWAN simulation of the February 1978 Blizzard.

Figure 8-6. Maximum water surface elevation from a tightly coupled ADCIRC+SWAN simulation of the February 1978 Blizzard (Figure 4; Ransom, 2018a).

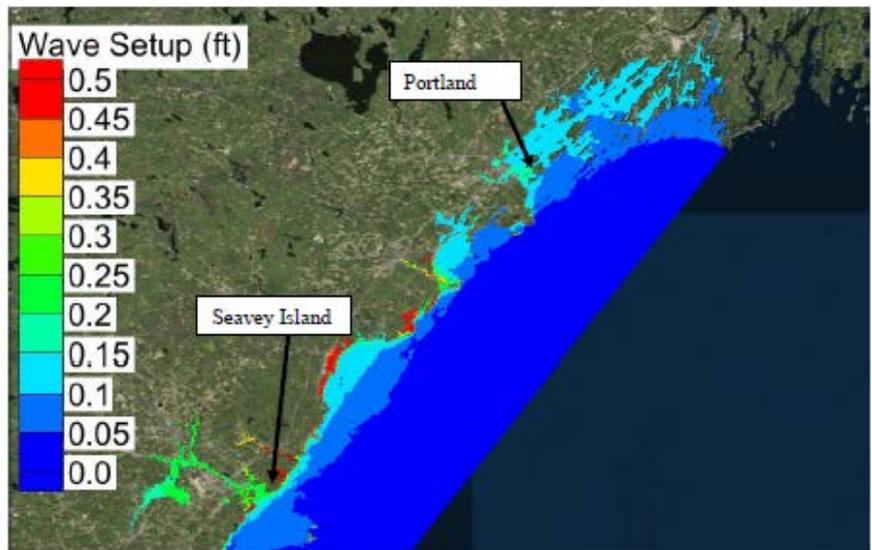


Figure 5: Maximum wave setup during the February 1978 Blizzard.

Figure 8-7. Maximum wave setup during the February 1978 Blizzard (Figure 5, Ransom, 2018a)

Panel Finding: The method that FEMA uses is based on an analysis of historical water level data and thus is constrained by the very limited water level measurement locations in the study area. It does not explicitly address the coupling between the surge and wave dynamics. The approach ignores the impact of nearshore embayments on amplification of the surge.

The method that the Appellant has employed to perform the analysis uses current state of the practice methods and extensively leverages work performed by the USACE NACCS in the study area. The hydrodynamic and wave models are fully coupled and include 2-D transformation processes.

It is noted that two approaches give comparable water levels at the NOAA NOS Portland, ME gauging station. The difference is much greater for the wave setup with FEMA values significantly larger than the Appellant (several feet compared to 0.5 ft or less). Neither FEMA nor the Appellant have offered any validation of the wave setup, but the Appellant approach is internally consistent with the underlying physics of the process.

Based on the comparison between the two approaches, the Appellant has demonstrated that their alternative method and its application yield more correct estimates of the flood elevation.

8.2.2. Validation

FEMA's estimate of the TSWL (including wave setup computed with parameterized DIM) was not validated. In contrast, the appeal proposed TSWL derived from 2-D modeling of coupled storm surge and wave physics was validated by comparison to tide gage observations and high-water marks from historic storm events.

FEMA Approach: FEMA used an approach to develop TSWL using the DIM to solve for wave setup, which was then linearly added to the SWL to obtain the TSWL. This method is described in FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners, Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update (2007), Section D.2.6.3, Guidelines for Estimating Static Wave Setup. The SWL was obtained from a frequency analysis of tide gauge data. The wave setup methodology is described in detail in an August 27, 2007 memorandum from Ocean and Coastal Consultants (OCC) and included in the TSDN notebook Section 2.4. Because the analysis was not performed for specific events, a comparison with measured data was not conducted as part of the wave setup methodology.

Appellant Approach: The Appellant details the approach to model the TSWL in the October 2018 report *Extreme Storm Coastal Hydrology & Numerical Modeling York and Cumberland Counties, Maine by Ransom* (2018a). The approach is summarized in Section 8.2.1. Validation of the Appellant's approach included a comparison of NACCS model results with tide gauge observations for a varying number of storms ranging from 7 storms at Fort Point, NH to 39 storms at Portland, ME (Section 3.2.2 of Ransom, 2018a). For this comparison, the root mean square error (RMSE) and bias between modeled and observed peak water levels were computed. The RMSE varied from a minimum of 0.43 ft at Portland, ME to a maximum of 1.25 ft at Seavey Island, ME. The bias ranged from a minimum of -0.16 ft at Portland, (negative values indicate underprediction) to a maximum of 1.05 ft (overprediction) at Seavey Island.

Ransom performed a validation of their coupled hydrodynamic-wave model of Bigelow Bight. Initially the model was validated using tidal-only forcing. Tidal validation showed RMSE and absolute errors less than 0.8 ft at all tide stations for all time periods (minimum 0.49 ft and maximum 0.79 ft); bias ranged from a

minimum of 0.02 ft (underprediction and overprediction at two different stations with the same magnitude) to a maximum of 0.46 ft (overprediction) (Section 3.3.7, Ransom, 2018a).

Validation was also performed for extratropical storms including the Blizzard of February 7, 1978 and the Halloween storm of 1991 (Section 3.3.9, Ransom, 2018a). Model output was compared with measured high-water mark data for those two storms, and showed a bias of approximately -0.8 ft (underprediction) and RMSE of 1.2 to 1.6 ft. Additional historic storm events were validated using tide gauge data at Seavey Island (16 storms), Fort Point (7 storms), Wells Harbor (5 storms), and Portland (39 storms). Combined error statistics for those four stations indicated an overall bias of 0.23 ft (overprediction) and RMSE of 0.48 ft. Ransom notes (p. 48, Ransom, 2018a) that *this validation demonstrated that the Bigelow Bight model is capable of reproducing observed TWLs with a high degree of accuracy, and then by extension, statistical analyses based on model results yield an estimation of the 1% annual chance TWL.*

Panel Finding: Ransom undertook a comprehensive approach to model validation at locations where well-documented observations existed (tide gauge stations) as well as in other portions of the study area (high water marks for two extratropical storms). The Ransom model has been shown to produce total water levels within approximately 1.5 ft of measured values (better accuracy was shown at the tide gauge stations). The FEMA wave setup analysis was not performed for specific events, therefore a comparison with measured values was not performed.

8.2.3. Double Counting of Wave Setup

FEMA's estimate of the SWL contained an unquantified component of wave setup that is double-counted in their estimate of the TSWL, when wave setup from DIM calculations is added to the SWL. In contrast, the appeal proposed TSWL does not double-count wave setup and correctly included wave setup at the toe of slope for wave run-up calculations in locations where wave run-up dominates the flood hazard and correctly included wave setup in areas where overland wave action is the dominant flood hazard.

FEMA Approach: As described previously, FEMA computed wave setup using the DIM methodology and linearly added the setup values to the SWL derived from tide gauge analysis.

Appellant Approach: The Appellant based the numerical modeling on work done as part of NACCS, downscaled for applicability to specific communities in York and Cumberland Counties, ME (Ransom, 2018a; Section 8.2.1 of this report). This model included hydrodynamic and wave effects and therefore included wave setup effects as part of the 2-D modeling of the TSWL.

Panel Finding: Because the SWL that FEMA used were derived from tide gauge analysis, they inherently include water level fluctuations that are captured by measurements at tide gauges. These fluctuations can be referred to as a non-tidal residual and include storm surge, sea level anomaly, and wave setup. The use of tide gauge data in extremal analysis is described by NOAA in the report *Extreme Water Levels of the United States, 1893-2010*, by Zervas (2013). This report includes a discussion of FEMA coastal flood

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mapping and notes *water levels measured by gauges correspond more closely to what FEMA defines as the SWEL. Although FEMA's definition does not include the wave setup effect, water levels recorded by gauges can include a limited amount of wave setup based on their degree of exposure to ocean waves.* This is also acknowledged in the FEMA 2007 Guidelines, Section D.2.4.5.2.

The tide gauge closest to the appeal areas (Town of Old Orchard Beach and City of South Portland) that was used in the USACE tidal profile analysis (1988) is the Portland, ME gauge. This gauge is located on the Maine State Pier in a sheltered area behind two islands (Cushing and Peaks) (Figure 8-8). While it is true that there could potentially be some unquantified component of wave setup in the gauge data, it is unlikely from the location of this gauge that it would be highly exposed to ocean waves, and any non-tidal residual due to wave setup would likely be relatively small. This is consistent with a wave setup sensitivity analysis done by Ransom in Section 2.4 of their 2018 report which showed 0.2 ft of wave setup at Portland and 0.3 ft at Seavey Island for a simulation of the February 1978 Blizzard.

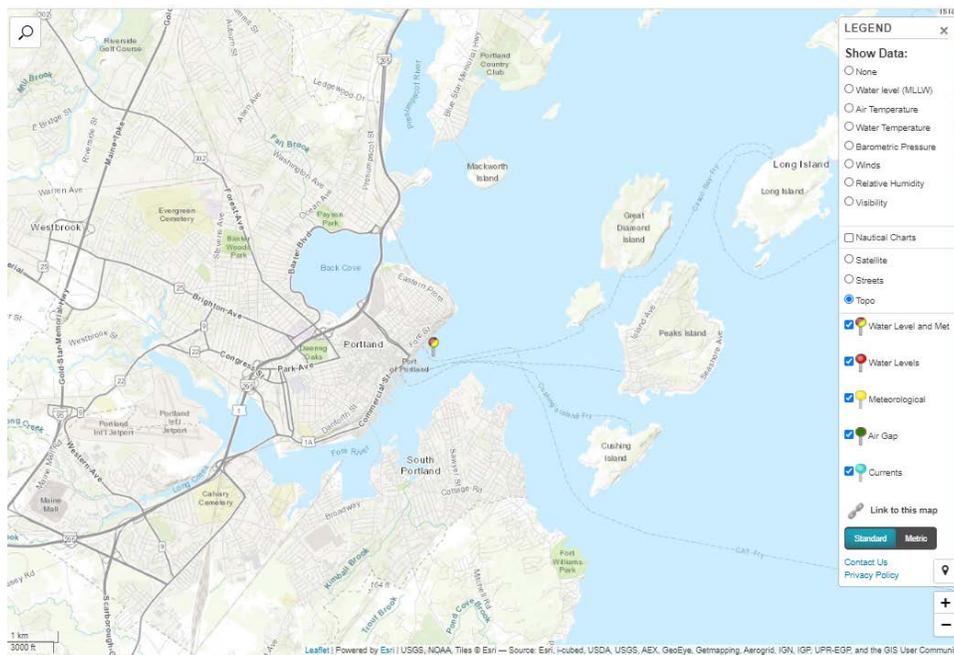


Figure 8-8. Location of Portland, ME NOAA NOS tide gauge (#8418150). Map from tidesandcurrents.noaa.gov.

8.2.4. Wave Determination

FEMA's methodology is based on the assumption that wave conditions which determine the BFE results from meteorological forcing and wave transformation from a single steady-state 1%-annual-chance storm event. In contrast, the appeal methodology more correctly determines the BFE based on analysis of many possible dynamic storm surge and meteorological events that contribute to the 1%-annual-chance flood hazard.

FEMA Approach: FEMA followed the guidelines and used the event-based approach, which assumes a single SWL and a single set of wave characteristics. The single storm event is representative of an extratropical nor'easter. The wave action component of coastal flood hazards for York and Cumberland Counties was determined from wave transformation models using STWAVE (Coastal Hydraulics and Hydrology, STARR 2012). The STWAVE model was not calibrated, due to lack of data, but validated with two simulations. 1-percent-annual-chance data were determined as follows for the STWAVE model offshore boundary input:

- Offshore 1%-annual-chance SWLs were taken from Update Tidal Profiles for New England Coastline (OCC, 2007), as discussed in Section 8.2.1.
- The 1%-annual-chance wave height was determined via the generalized extreme value analyses based on wave height recorded at NOAA Buoy 44005 between 1979 and 2011.
- Wave period: a qualitative examination of the observed relationship between wave period and wave height suggested that the wave period of the largest storm on record at NOAA Buoy 44005 (10.1 m wave height, 12.5 second period) is appropriate to use for the STWAVE simulation of the 1-percent-annual-chance storm.
- The wave direction perpendicular to the offshore boundary was selected to develop the energy spectrum.
- A Joint North Sea Wave Project (JONSWAP) parameterization was used to generate a wave energy spectrum for input to the STWAVE models, based on the <http://wis.usace.army.mil/hindcasts.html?dmn=atlantic> height, wave period, total water depth, and dominant energy direction.
- Wind speed of the 1-percent-annual-chance event was calculated using extremal analyses similar to the analyses performed for wave height, based on wind speed recorded at Buoy 44005 between 1979 and 2011.

Although the STWAVE model was developed and modeling was performed using three levels of nested grids varying from 10 m nearshore to 500 m offshore, initial wave conditions used for 1D transect based WHAFIS analyses were determined from deep water where the depth over the wave length is greater or equal to 0.5. Because input wave conditions were extracted from the deeper water, nearshore wave refraction, shoaling, and diffraction were not considered.

Appellant Approach: The modeling approach used by the Appellant is based on the NACCS and a 2-D coupled hydrodynamic and wave model. The approach is summarized in Section 8.2.1 of this report.

The southern Maine coast is susceptible to two different types of cyclonic storm systems that can cause significant storm surge and wave action. These include extra-tropical cyclones (e.g. nor'easters) and tropical cyclones (e.g. hurricanes). The Appellant modeled 72 tropical storms and 40 extra-tropical storms and determined the TWL and wave height statistically based on modeling results. This analysis provides

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10-yr, 50-yr, 100-yr, and 500-yr wave heights associated with waves coming from 8 different compass directions.

Wave periods associated with the directional extreme wave heights were determined based on an assumption that the equivalent deep-water wave steepness is constant for storm waves at a given location and for a given direction.

For the open coast transects, the Appellant applied SWAN 1-D model in the transect-based coastal hydraulic analyses as a supplemental calculation to better estimate wave conditions in the very nearshore area. Boundary input used for SWAN 1-D are the 1%-annual-chance TWL and directional 1% annual chance wave height and associated wave period seaward of breaking zone extracted from the 2-D model. SWAN 1-D is then run to determine wave setup, significant wave height, and peak wave period along the wave transect from the offshore boundary to the point where the wave transect first intersects the shoreline at the 1%-annual-chance TWL. The output from SWAN 1-D within this nearshore zone is then used to provide boundary conditions for the runup and overland wave height calculations.

Panel Finding: Since FEMA's input wave conditions were extracted from the deeper water, the nearshore wave processes of refraction, shoaling and diffraction were not considered, this in spite of the fact that STWAVE modeling was performed. The Appellant extracted wave parameters and water level from the hydrodynamic and wave coupled model just seaward of wave breaking zone, and then a supplemental calculation with 1-D SWAN transect-based coastal hydraulic analyses was performed. The Appellant approach is more accurate in determining wave parameters.

FEMA's analyses were based on 1%-annual-chance wave parameters, wave conditions, and wind conditions at STWAVE model offshore boundary. In contrast, the Appellant simulated 72 tropical storms and 40 extra-tropical storms and determined 1%-annual-chance wave parameters at the nearshore location (1-D SWAN input boundary) via extremal analyses. Hence, the Appellant approach is more accurate in determining wave parameters in specific nearshore conditions. However, due to the conversion error that FEMA noted, the WHAFIS modeling provided by the Appellant at the open coast was incorrect and BFE comparisons could not be made.

8.2.5. Tropical Storms

FEMA's coastal hydrology does not consider the possibility of direct impacts from landfalling tropical storms or hurricanes in determination of the base flood SWL or incident wave conditions. In contrast the appeal methodology does consider the influence of possible landfalling tropical storms or hurricanes on the coastal hydrology statistics.

FEMA Approach: FEMA's method to determine 1%-annual-chance wave conditions from storms is based on an analysis of historic observations at the NOAA NOS water gauging stations in the study area (Wells (#8419317) and Portland (#8418150), ME). A review of the extreme peak water levels at Portland, ME (as an

example) suggests that most of the events that constitute the peak water levels in the historical record are a result of extratropical storms (nor’easters) (e.g., Feb 7, 1978); and not tropical storms or hurricanes. FEMA’s method hence does not explicitly address the contributions from hurricanes.

Appellant Approach: Ransom (2018a) used the USACE NACCS statistical methods to determine the magnitude and likelihood of the coastal flood hazard associated with coastal storms, including tropical cyclones (e.g. hurricanes) and extra-tropical cyclones (e.g. nor’easters). These statistical methods are known as the Joint Probability with Optimal Sampling (JPM-OS) method for tropical storms, and the Composite Storm Set (CSS) method for extra-tropical storms. They elected to use 40 historical extratropical storm events and 72 tropical storm events to represent the Gulf of Maine study area. Simulations were performed for each of these events using the fully coupled ADCIRC-SWAN model Figure 8-9 (Ransom, 2018a; Figure 42) shows the still water storm elevation vs return period for a location in the vicinity of the Portland, ME water level station. Results are provided for tropical (red) and extratropical (green) storms and all storms combined (blue). The analysis shows that extratropical storms dominate the return period analysis for annual exceedance probabilities of 1 % or higher, while tropical storms become dominate at longer return periods.

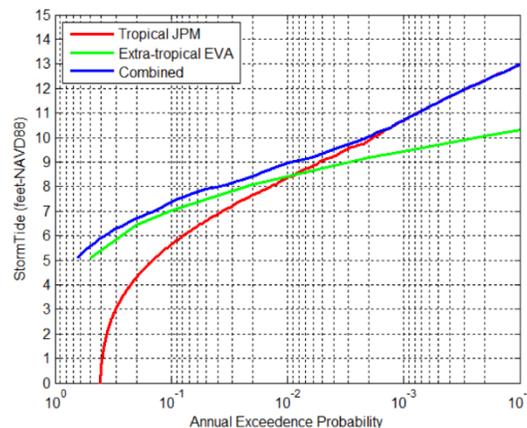


Figure 42: Combination of Tropical Storm and Extra-tropical storm TWL response exceedance probability for example location near Portland Tide Station.

Figure 8-9. Combination of tropical storm and extratropical storm TWL response exceedance for example location near the Portland tide station (Figure 42; Ransom, 2018a).

The Peak over Threshold (POT) based estimate of the 1%-annual-chance event is 8.9 ft (NAVD88) for Portland when combining tropical and extratropical storms. This compares to about 8.5 ft for extratropical or tropical storms individually. If only the Portland gauge data is employed using the same statistical method the water level is 8.6 ft. The results are very similar to those from FEMA (see Table 8.1).

Panel Finding: FEMA results are consistent with an analysis of the historical data (1912-2020 for Portland), which is dominated by extratropical events. No consideration is given in this approach to tropical events since they are rarely present in the record of extremes. Resio (2007) notes that a serious problem with the reliance only on historical storms for estimating coastal inundation is related to the small sample of storms

at any site. Resio cautions that *estimating coastal inundation based solely on historical analyses should not be used for coastal hazard assessment*. The Appellant's approach deals with this problem by generating statistical estimates of storms that are likely to be present in the area, thus eliminating the constraint of simply using the historical record.

The Appellant's estimate is based on consideration of both tropical and extratropical event and is not constrained by the observation record length. Based on the comparison between the two approaches the Appellant has demonstrated that their alternative method and its application yield more correct estimates of the flood elevation.

8.2.6. Wave Setup and Two-Dimensional Effects

FEMA's estimate of the BFE in many areas is based on the assumption that wave setup on the open coast could propagate fully and unrestricted in coastal bays and estuarine areas, where such propagation is not possible. In contrast, the appeal proposed BFEs are based on more correctly considered 2-D effects as recommended in FEMA guidance on Coastal Wave Setup (e.g. see Guidance Document 44, November 2015).

FEMA Approach: FEMA linearly added wave setup, computed using the DIM methodology, to SWL developed using tide gauge analysis to obtain TSWL. During the oral presentations, FEMA stated that they adhered to guidance in Section D.2.6.3.4.3 that *absent the types of 2-D effects described in the previous section, wave setup at the inland limit of flooding will be equal to or greater than the wave setup at the +/- MSL shoreline*. Wave setup was carried to the limit of floodplain, or decisions were made with FEMA regional staff to have a narrow portion of the floodplain act as a limiter of wave setup propagation.

Appellant Approach: Ransom (2018a) details their approach to model the TSWL in the October 2018 report *Extreme Storm Coastal Hydrology & Numerical Modeling York and Cumberland Counties, Maine*. Ransom evaluated hydrodynamic and wave effects with a coupled model (referred to as the "Bigelow Bight model" and employing the coupled ADCIRC+SWAN model). The numerical modeling was based on work done as part of the NACCS, downscaled for applicability to specific communities in York and Cumberland Counties, ME (Ransom, 2018a). This model included hydrodynamic and wave effects and therefore included wave setup effects as part of the 2-D modeling of the TSWL. The model accounted for wave propagation through coastal bays and estuarine areas and allowed for evaluation of 2-D effects on wave setup.

Panel Finding: FEMA guidance states that *there may be instances where wave setup calculations along a specific transect are complicated by the topography along the transect and possibly by 2-D effects*. Examples are given including storm surge and wave propagation over a barrier island and across a bay or sound. Scenarios are described that may result in either higher or lower wave setup depending on the bay size and amount of overtopping of the barrier.

The Old Orchard Beach site, in particular, seems to be within the parameters described in the “Wave Setup—Special Cases” section of the FEMA guidelines. FEMA guidance states:

If...only a small portion of the barrier is overtopped by surge and waves, wave setup calculations along a transect through the overtopped section may overstate the wave setup on the mainland. The wave setup that passes across the overtopped section may be drained laterally into regions of the bay where no wave setup crosses the island. Two-dimensional effects should be considered in this case. (FEMA, 2007. Section D.2.6.3.4)

At Old Orchard Beach only a small portion of the barrier is overtopped by surge and waves: a Zone X is mapped by FEMA along the beachfront at Transect YK-144 while FEMA WHAFIS results show “above surge” at YK-142 and an overland depth of just 0.01 ft at YK-143 indicating minimal overtopping.

The TSWLs developed by Ransom along the estuarine areas of this site more correctly incorporate 2-D effects of the topography on wave setup.

Because wave runup controlled determination of the Zone VE limit and SFHA Boundary for the South Portland site (Table 26, Preliminary FIS for Cumberland County, ME, Vol. 2), the wave setup calculation was less relevant to the mapping at this location.

8.2.7. Bathymetry Accuracy

FEMA’s STWAVE models used to transform waves to nearshore conditions included incorrect bathymetry, which allowed waves to propagate across land and islands that would not be inundated during the base flood event in multiple locations. In contrast, the appeal proposed wave transformation modeling included more accurate bathymetry.

FEMA Approach: The wave action component of coastal flood hazards for York and Cumberland Counties was determined from wave transformation models using STWAVE (Coastal Hydraulics and Hydrology, STARR 2012) as described in Section 8.2.4 of this report.

Although the STWAVE model was developed and modeling was performed using three levels of nested grids varying from 10 m nearshore to 500 m offshore, initial wave conditions used for 1D transect based wave hazard analyses were taken from deep water where the depth over the wave length is greater or equal to 0.5. Because input wave conditions were extracted from the deeper water, the nearshore wave refraction, shoaling, and diffraction were not considered.

Appellant Approach: As described previously, the Appellant used a coupled hydrodynamic and wave model (ADCIRC+SWAN) in their analysis. The topographic and bathymetric data sets used in model development are described in Ransom (2018a, details in Appendix D) and consisted of a combination of Light Detection and Ranging (LiDAR) data, NOAA hydrographic surveys, and USACE hydrographic surveys. Care was taken to resolve differences in vertical datums as described in that report.

Panel Finding: FEMA used wave parameters at the deep-water conditions from the STWAVE models for input to the transect based wave analyses. Because of the location where deep-water wave parameters were extracted, the nearshore bathymetry conditions have no effect on the wave input parameters. The 2-D effect nearshore is not considered in FEMA analyses, so even if the nearshore topographic and bathymetric data were outdated, they would not have any effect on the analysis results.

8.2.8. Additional Transects

In many locations FEMA proposed BFEs and SFHA delineations are based on hydraulic analyses at wave transects that are not representative of local shoreline conditions. In contrast, the appeal proposed BFEs and SFHA delineation are based on evaluation of additional wave transects to provide more fine-grained and technically more correct information, where appropriate. [As no additional transects were included in the Old Orchard Beach, York County appeal, this issue is considered applicable only to South Portland, Cumberland County.]

FEMA approach: The Cumberland County FIS is based on 162 transects. Transects are spaced approximately 1,500-5,000 ft apart. The transects are found to be generally well placed and representative of local shoreline conditions.

However, the floodplain mapping at the appeal site does not appear to be based on a FEMA study transect; the justification for the mapped BFE of 35 ft cannot be identified in the study documentation provided

Appellant approach: Three new, additional transects were used to evaluate local flood hazards for the Cumberland County appeal site.

Panel analysis and finding: The dominant flood hazard along the Cumberland County coast is wave runup, which is highly sensitive to local conditions. As such, additional transects can provide site-specific analysis to refine the flood hazard assessment for a specific location. However, as described in Section 7.2, the new analysis at the three additional transects was not wholly correct. The analysis and mapping at CM-35-1 is acceptable, but CM-35-2 and CM-35-3 are not correct and should not be used to correct FEMA's data.

9. References

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10. Abbreviations

1-D – One-dimensional
2-D – Two-dimensional
ADCIRC- Computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions.
AE, VE- FEMA flood zones
ASCE- America Society of Civil Engineers
BFE- Base Flood Elevation
CLOMR- Conditional Letter of Map Revision
CSS- Composite Storm Sets
CSTORMS_MS- Coastal Storms Modeling System
DFIRM-Digital Flood Insurance Rate Map
DIM- Direct Integration Method
EL- Elevation
FEMA- Federal Emergency Management Agency
Ft- Feet
FIRMS- Flood Insurance Rate Maps
FIS- Flood Insurance Study
HQ- Headquarters
JONSWAP- Joint North Sea Wave Project
LiDAR-Light Detection and Ranging
LiMWA- Limit of Moderate Wave Action Line
LOMR- Letter of Map Revision
m- meter
ME- Maine
NACCS- USACOE North Atlantic Coast Comprehensive Study
NAVD88- National Vertical Datum – 1988
NERACOOS_- Northeast Regional Association for Coastal Ocean Observing Systems
NFIP-SID National Flood Insurance Program, Mapping Standard ID
NGVD- National Geodetic Vertical Datum
NIBS- National Institute of Building Sciences
NOAA- National Oceanic and Atmospheric Administration
NOS- National Ocean Service
NRC- National Research Council
OCC- Ocean and Coastal Consulting
PE- Professional Engineering license
PLB- Planetary Boundary Layer
PM- Project Manager

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POT- Peak Over Threshold
QA/QC- Quality Assurance/ Quality Control
RMA- Resource Management Associates
RMSE- Root Mean Square Error
SFHA- Special Flood Hazard Area
SIDs- Standard IDs
SRP- Scientific Resolution Panel
STARR- Strategic Alliance for Risk Reduction
STWAVE- Steady-state, finite difference, spectral model based on the wave action balance equation
SWAN- third-generation wave model computes random, short-crested wind-generated waves in coastal regions and inland waters.
SWL– Stillwater Level
SWEL- Stillwater Elevation
TSDN- Technical Support Data Notebook
TSWL- Total Stillwater Level
TSWEL- Total Stillwater Elevation
TWL- Total Water Level
WAM- Wave Analysis Model
WHAFIS- Wave Height Analysis for Flood Insurance Studies
WSE- Water Surface Elevation
US ACOE/ACE- US Army Corps of Engineers
Yr - Year

Appendix A. Questions for FEMA and Appellants in York and Cumberland Counties

A stand-alone file can be found on the NIBS portal:

<https://portal.nibs.org/files/wl/?id=SdWtHseKJ2bU3od1k7tKI3EScHXC97Zg>

Appendix B. Appellant Oral Presentation, Town of Old Orchard Beach and City of South Portland

A stand-alone file can be found on the NIBS portal:

<https://portal.nibs.org/files/wl/?id=6hohr3Qvr82kx1OK0LZPZ2U99IOyn7Bd>

Appendix C. FEMA Oral Presentation

A stand-alone file can be found on the NIBS portal:

<https://portal.nibs.org/files/wl/?id=4jy50kygSK9gualqc6MnemJnBPGTxXC8>