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To: Shane Corbin and Steve Swann, PE, City of Atlantic Beach

From: Steven Peene, PhD, and Nicolas Pisarello, GISP

Date : February 23, 2021

Re : Additional Transect Modeling to Update 100-Year Flood Risks and Associated Coastal Flood Risk Maps Within and Outside of Atlantic Beach City Limits

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On May 24, 2019, ATM submitted to the City of Atlantic Beach a coastal flooding assessment that explained future 100-year flood hazards within city limits due to anticipated sea level rise (SLR) for the years 2044, 2069, and 2119. The analysis estimated future coastal flood risks from increased storm surge elevations and wave heights at Atlantic Beach due to rising seas based upon modeling at two transects (44 and 25) within city limits.

Since completion of the 2019 coastal flooding assessment, the City determined that it has critical infrastructure (lift stations and several water treatment plants) outside of city limits that could be vulnerable to flooding. Therefore, upon the City's request in December 2020, ATM extended its analysis to include the area north of the city up to Wonderwood Drive.

This memo summarizes the additional modeling at two new transects (21 and 42) in the extended northern area which results in updated 100-year flood risks and associated coastal flood risk maps for this area as well as within city limits (maps now reflect four total transects). ATM conducted the analysis of potential future coastal hazards using the effective 2018 Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Duval County, National Oceanic and Atmospheric Administration (NOAA) 2017 SLR projections, and site-specific modeling using FEMA's Coastal Hazard Analysis and Mapping Program (CHAMP) Version 2.0 model suite, including the FEMA Wave Height Analysis for Flood Insurance Studies (WHAFIS) overland wave propagation model, described in the subsequent sections. The Atlantic Beach digital elevation model (DEM), provided by Jones Edmunds, was derived from light detection and ranging (LiDAR) data originally obtained by the Florida Division of Emergency Management (FDEM) in 2007 and processed to a resolution of 5 feet horizontally and an elevation accuracy of 0.6 foot at the 95 percent confidence level. This DEM served as the basis of topographic data for the assessment. All elevations referenced in this document are in feet and referenced to the North American Vertical Datum of 1988 (NAVD88).

The resulting products of this updated assessment are four flood maps (Figures 22 to 25) depicting flood hazard areas of inundation with assigned base flood elevations (BFEs) for the current year and each SLR time horizon: 2044, 2069, and 2119. The digital map data were provided to Jones Edmunds under separate cover.

Recap of Methodology used in 2019 and Current Coastal Risk Assessment

FEMA Flood Mapping

In the United States, present-day flood hazards associated with extreme event coastal storm surge and waves are typically based on FEMA's FIS and Flood Insurance Rate Maps (FIRMs). These documents analyze rain event flooding, storm surge and wave impacts to provide map exhibits showing the geographical limits and severity of coastal risk. In general, the more severe the risk at any given location, the higher FEMA's recommended flood zone and BFE. In general, FEMA coastal mapping includes two major parts: water level/surge modeling and wave transect modeling.

Water Level/Surge Modeling

Water level/surge modeling results in extreme event stillwater elevations (SWELs) based on what is commonly referred to as a 100-year storm event. SWEL flood elevations can vary by location and comprise the following:

- Existing mean sea level (MSL) at the time of the study
- Tidal fluctuations
- Extreme event storm surge (including local wave setup)

These SWEL flood elevations do not include storm waves. Storm waves travel on top of the SWEL and will increase flood risks and elevations.

Wave Transect Modeling

Once the 100-year SWEL is determined, extreme event storm waves are analyzed at select locations along the shorelines (coastal analysis transects). Coastal analysis transects are typically spaced several hundred feet or farther apart and represent detailed cross-sections of the shoreline and upland from the ocean or from inland estuarine areas (flooding source) to higher ground. Figure 1 illustrates a coastal wave transect. Wave transect modeling results in FEMA's BFEs, which include SWEL flood elevations from surge modeling and the elevation of waves on top of the SWEL. The wave transect modeling results (BFE and flood zone type) are interpolated between transects to draw the FEMA flood zones and elevations that comprise FEMA maps.

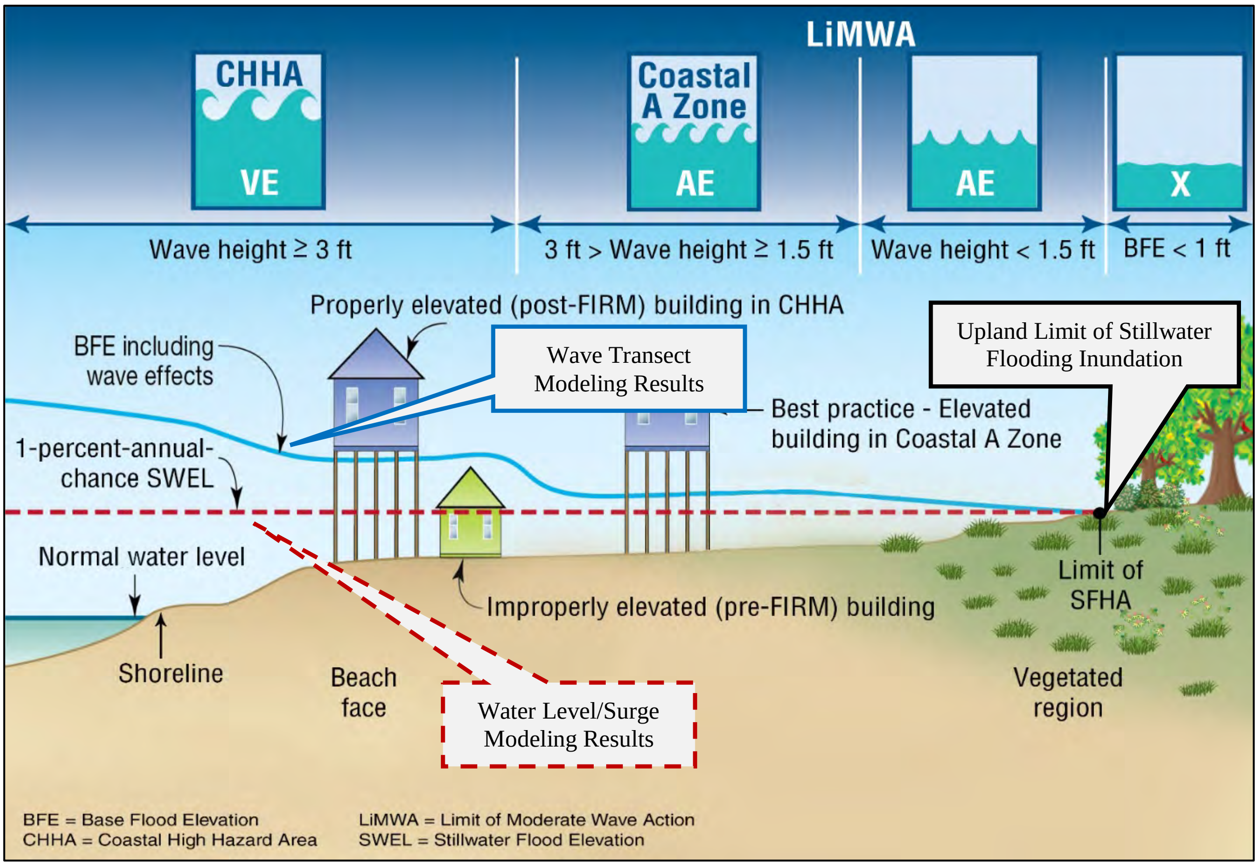

Figure 1. Illustration of a Coastal Wave Transect

Accounting for Sea Level Rise

FEMA flood maps are updated on a regular basis (typically every 10 years). FEMA considers only the existing MSL at the time of the update and does not account for future sea levels (i.e., SLR). For the current assessment, ATM conducted an analysis based on the FEMA flood mapping protocol and evaluated coastal flooding and wave risks under a range of SLR scenarios (25, 50, and 100 years into the future). *In essence, FEMA-type flood maps were created for future, higher sea level scenarios.* This process included:

- Using established SLR predictions from NOAA, the U.S. Army Corps of Engineers (USACE), and others to determine the predicted mean level at Atlantic Beach and surrounding area at 25, 50, and 100 years into the future.
- Using existing FEMA SWEL results but increasing the elevations to account for SLR and evaluate future sea level conditions. These elevations were used to create inundation maps that show the limits of extreme event flooding under future sea level conditions.
- Updating wave transect modeling on top of the increased SWEL elevations to predict BFEs under future higher sea levels.

- Wave modeling is very sensitive to water depth, and increased future sea levels will allow larger waves to travel further inland during storms because there is more area inundated with higher SWEL.
- These evaluations were used to create FEMA-type flood maps for future higher sea level scenarios.

The process is generally illustrated in Figure 2. The following sections provide detailed information on ATM's technical analysis.

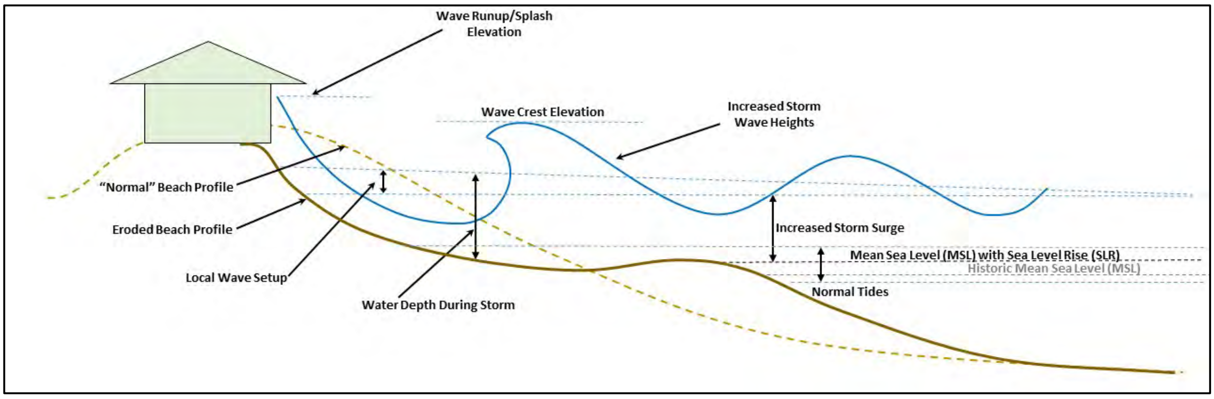

Figure 2. Illustration of Modeling Effects of SLR

FEMA Flood Maps and Supporting Data (Existing 100-Year Flood Risks)

The effective Duval County 2018 FEMA FIRMs and supporting FEMA data served as the basis of the existing/present-day 100-year flood risks for Atlantic Beach and surrounding area.

The 100-year SWEL raster included in the Technical Supporting Data Notebook (TSDN) for the Duval County FIS downloaded from FEMA's Flood Risk Study Engineering Library (FRiSEL) website (https://hazards.fema.gov/wps/portal/frisel) and imported into ArcGIS, version 10.6. Figure 3 depicts the 100-year (or 1 percent annual chance) SWEL surface over Atlantic Beach and the surrounding area. The SWEL shown in Figure 3 is referred to throughout this memo as the "existing" 100-year SWEL, because this represents the 1 percent annual chance SWEL under present-day conditions (without any additions to the water level to account for SLR).

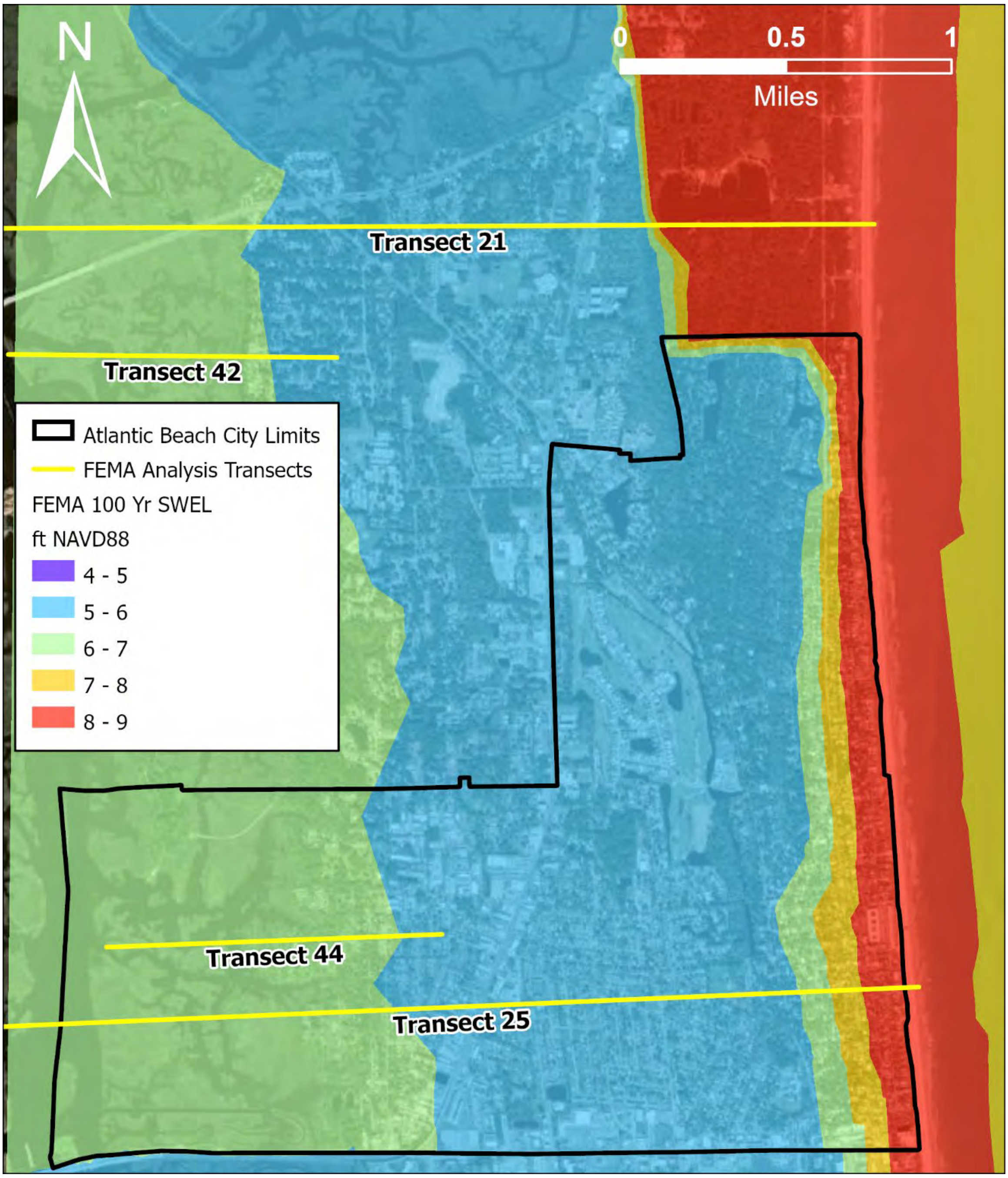

Figure 3. FEMA 100-Year SWEL and FIS Analysis Transects for Atlantic Beach City Limits and Extended Northern Area

Based on the most recent FEMA FIS, SWEL (storm surge) values are largest along the open Atlantic Coast. Larger SWEL values are also observed on the western estuarine shoreline due to elevated water levels from the St. Johns River Inlet and the Atlantic Intracoastal Waterway (AIWW) under extreme conditions. The SWEL is essentially the starting water level for coastal flood mapping purposes but does not include wave effects other than wave set-up. The other wave components that need to be considered are wave heights, wave run-up, and overtopping. For coastal communities such as Atlantic Beach, these unaccounted-for wave effects from the open coast as well as from back bays and sheltered waterways are added to the SWEL to determine the total BFE depicted on FEMA flood maps.

ATM utilized four existing FEMA wave analysis transects in and north of Atlantic Beach to evaluate wave conditions on top of the future higher sea level SWEL scenarios. Figure 4 presents the transects overlaid on Atlantic Beach topography (ground elevation). For consistency, ATM used the same transect numbering as the FIS. Transects 42 and 44 are representative of "sheltered water" and begin in the waterways adjacent to the AIWW and run east across the marsh and onto the upland of Atlantic Beach. Transects 21 and 25 are representative of "open coast" and begin in the Atlantic Ocean and run west across beach and onto the upland of Atlantic Beach. All transects are considered representative of the variation of topographic conditions occurring throughout Atlantic Beach. Transect 25 was conservatively selected as the open coast analysis transect due to the relatively lower dune topography and larger SWEL inundation extent observed along the more vulnerable southern shorelines of Atlantic Beach. Transects 21 and 42 were selected to account for facilities owned by Atlantic Beach that are outside of the city limits but are at risk of being impacted by future storm conditions.

FEMA wave analysis transects are modeled using inputs such as topography, vegetation, structural/building inputs, SWEL flood elevations, and storm wave height conditions. The updated CHAMP wave modeling for analysis Transects 21, 25, 42 and 44 under future SLR conditions is detailed in subsequent sections.

Based on effective FEMA flood maps, the majority of land within the jurisdictional limits of the City of Atlantic Beach is outside of the Special Flood Hazard Area (SFHA) (Figure 5). Areas outside the SFHA are not predicted to experience flooding or wave hazards during the 100-year storm condition. Areas within the SFHA are assigned BFEs depending on flood study results.

Updated Future 100-Year Coastal Flood Hazards

With anticipated rising sea levels, coastal flood hazards will increase both in terms of higher flood elevations as well as the inland extent to which inundation of extreme flood waters can reach. As greater areas of upland are inundated, larger waves are then able to propagate farther inland, further increasing the potential for storm damage. The following sections summarize the analyses used to assess the future coastal flood hazards from extreme (100-year return period/1 percent annual chance) surge and wave conditions for Atlantic Beach based on projected sea level increases.

SLR Projections

ATM's coastal hazard analysis of future sea level conditions utilized the NOAA 2017 Intermediate High Sea Level Rise projection curve for the NOAA tide gauge station at Mayport, FL (see Figure 6).

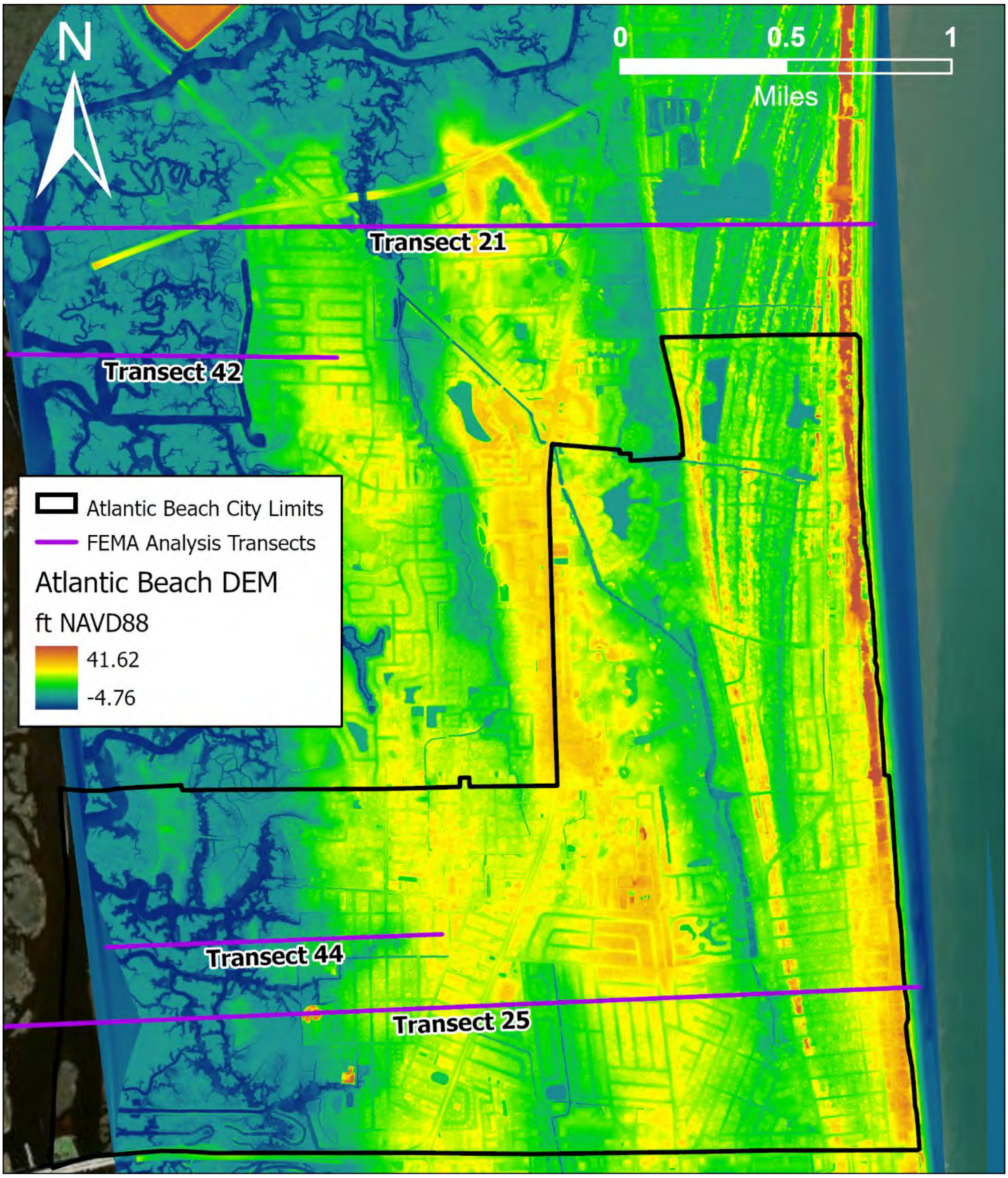

Figure 4. Topography and Transects within Atlantic Beach City Limits and Northern Extended Area

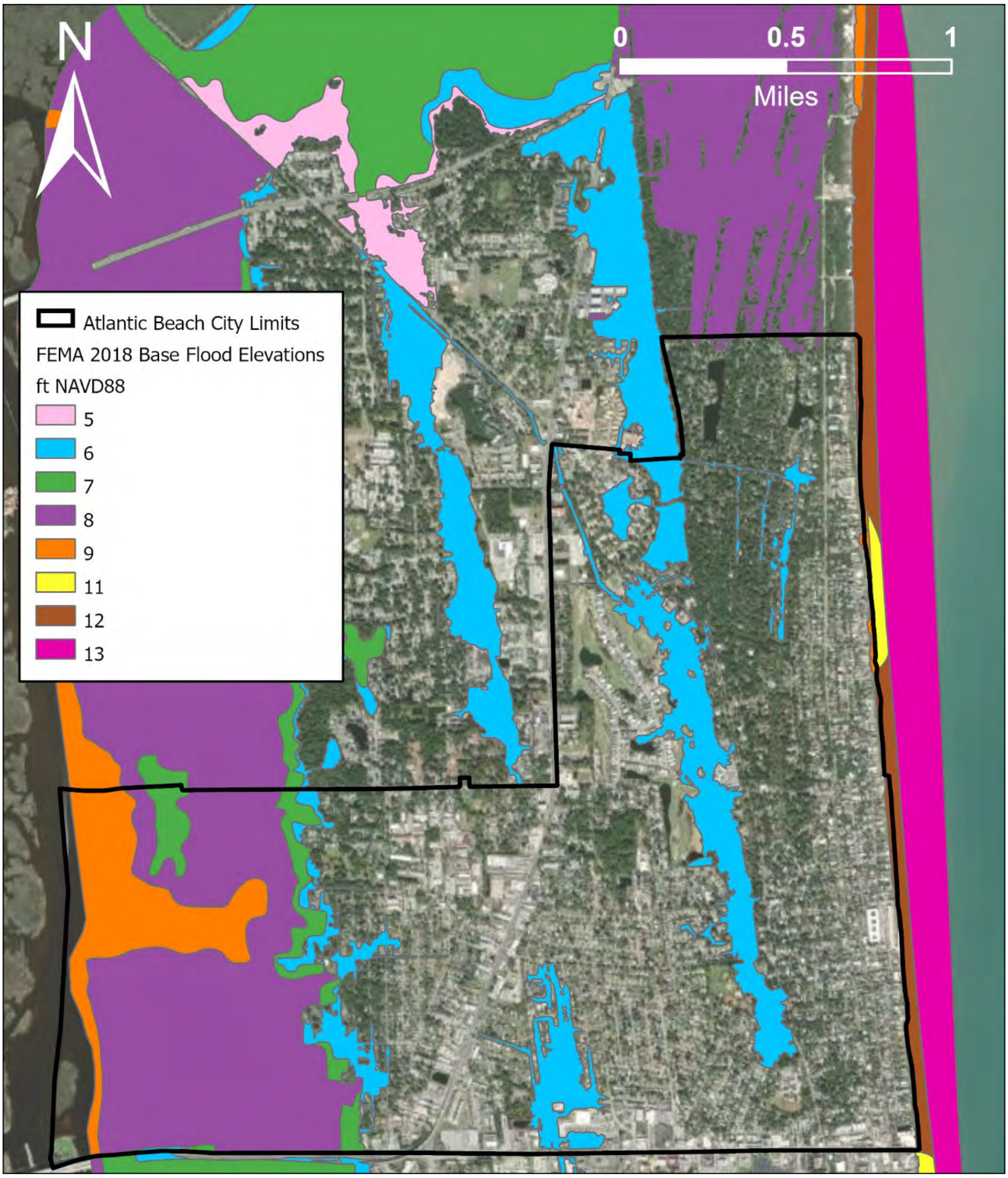

Figure 5. BFE Inundation Map Based on FEMA Effective 2018 Digital FIRM for Atlantic Beach City Limits and Northern Extended Area

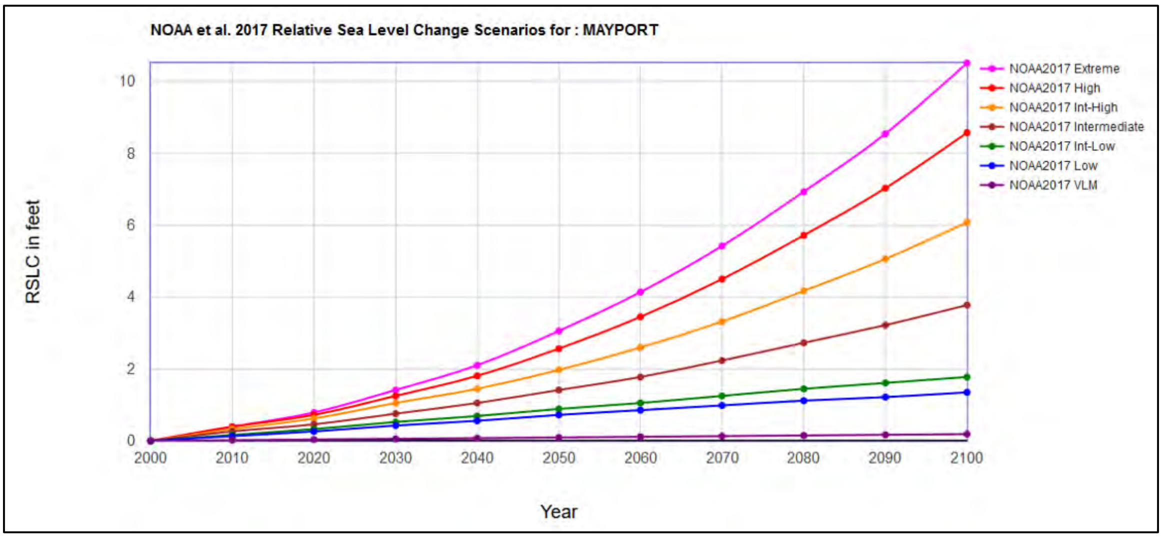

Figure 6. Mayport Gauge - USACE Sea-Level Change Curve Calculator

The NOAA 2017 SLR curves are based on a Year 2000 start date. Upon discussion with Jones Edmunds, it was determined that the SLR curve values should be adjusted for a baseline start date of 2013, since this was the date the effective FEMA FIS and mapping were completed for Duval County and represented existing sea level conditions at that time.

As a result, the curve values were adjusted for the three time-horizon scenarios by subtracting the projected SLR value of 0.39 foot for the year 2013 from the projected 2044, 2069, and 2119 values. The final values used for ATM's analysis are shown in bold in Table 1.

Table 1. SLR Values for Coastal Hazard Analysis

Year	Projected SLR (2000 Start Date)	Adjusted Projected SLR (2013 Start Date)
2044	1.65 feet	**1.26 feet**
2069	3.24 feet	**2.85 feet**
2119	7.34 feet	**6.95 feet**

Future SWEL and Inundation

Future 100-year SWEL elevations were developed for each time-horizon scenario by adding the values in Table 1 to the existing 100-year SWEL flood elevations from the effective FIS. Next, as a baseline assessment of inundation, a direct comparison of these surfaces to the existing Atlantic Beach topography was conducted.

Figures 7 through 9 present the resulting baseline data showing the areas of inundation/flooding in blue ("Below SWEL") under each SLR scenario. As would be expected, the extent of areas submerged during the 100-year event increase with elevated sea levels further into the future. As Figure 9 shows, almost all of Atlantic Beach will potentially be inundated during an extreme 100-year storm event in the year 2119.

These figures provide very useful information but are not truly representative of future coastal hazards possible for Atlantic Beach since wave effects (increases in BFEs) and increased flood extents in the areas of combined riverine and coastal flooding were not accounted for. Therefore, the inundation figures were used as a starting point for generating future flood hazards at Atlantic Beach and northern extended area. Based on the updated transect analysis modeling and FEMA flood mapping techniques and guidelines described in the subsequent sections, the inundation maps were assigned BFEs to represent future sea level scenario coastal risks.

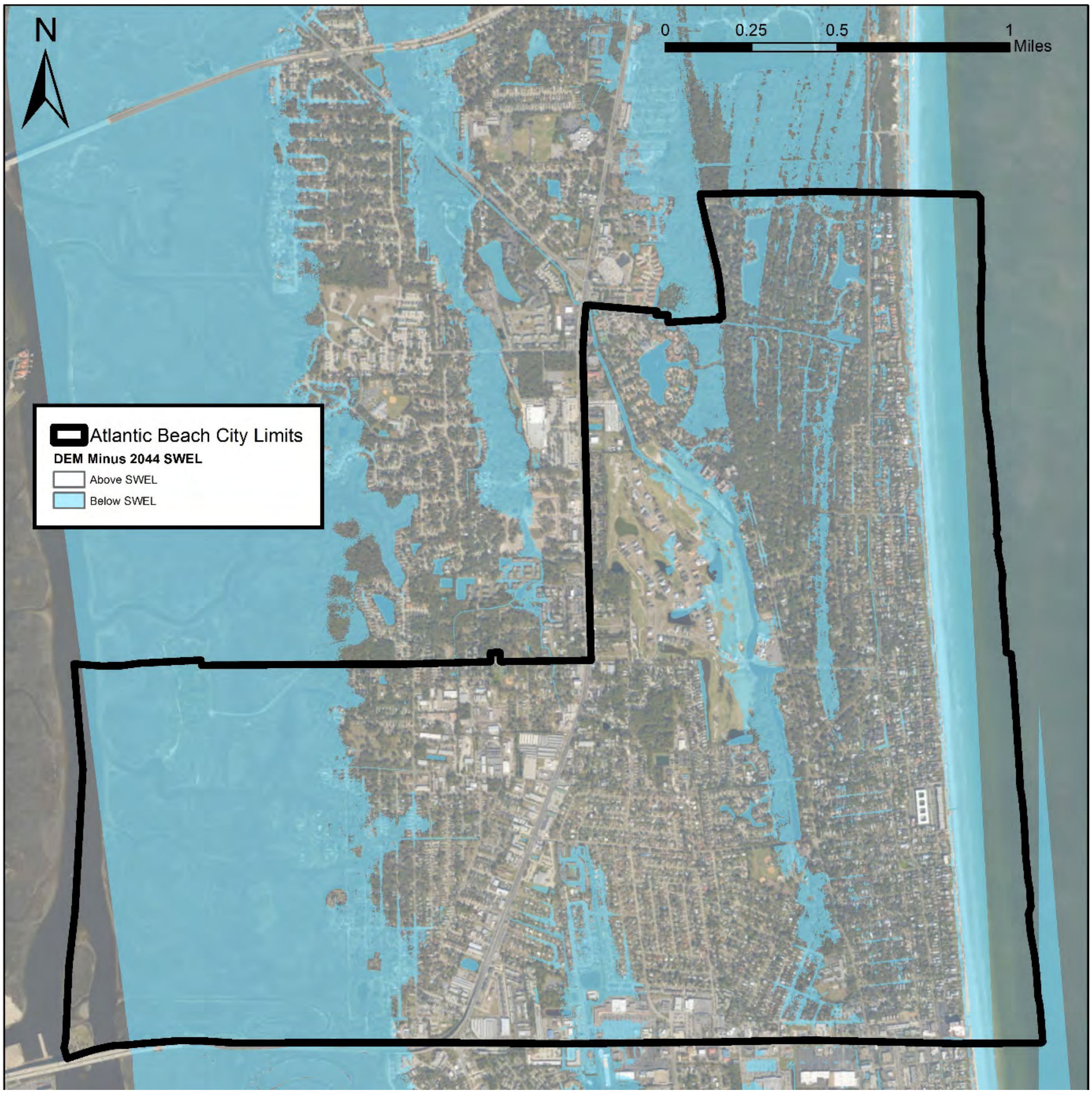

Figure 7. Year 2044 SWEL Inundation (topography below 2044 SWEL)

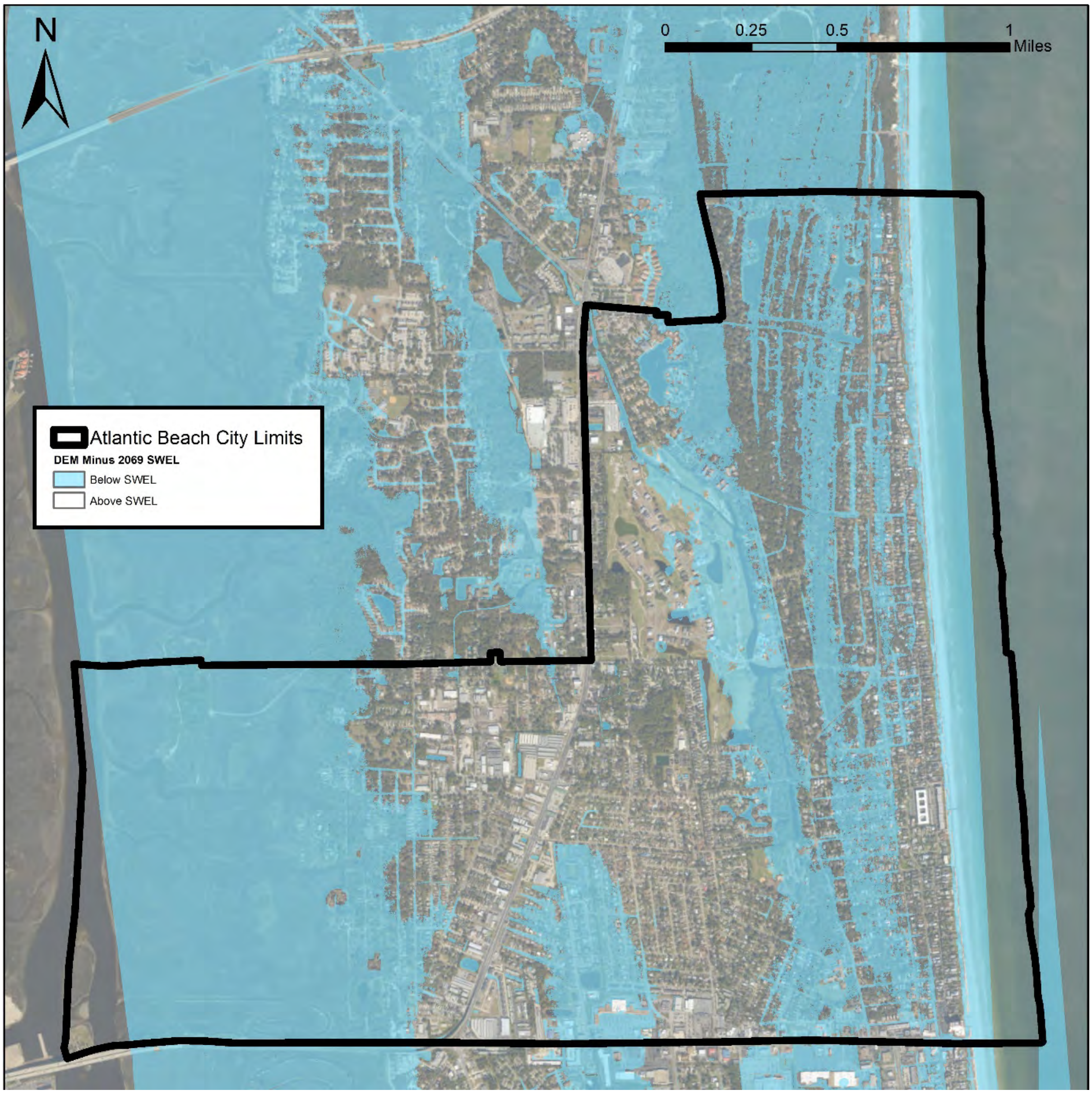

Figure 8. Year 2069 SWEL Inundation (topography below 2069 SWEL)

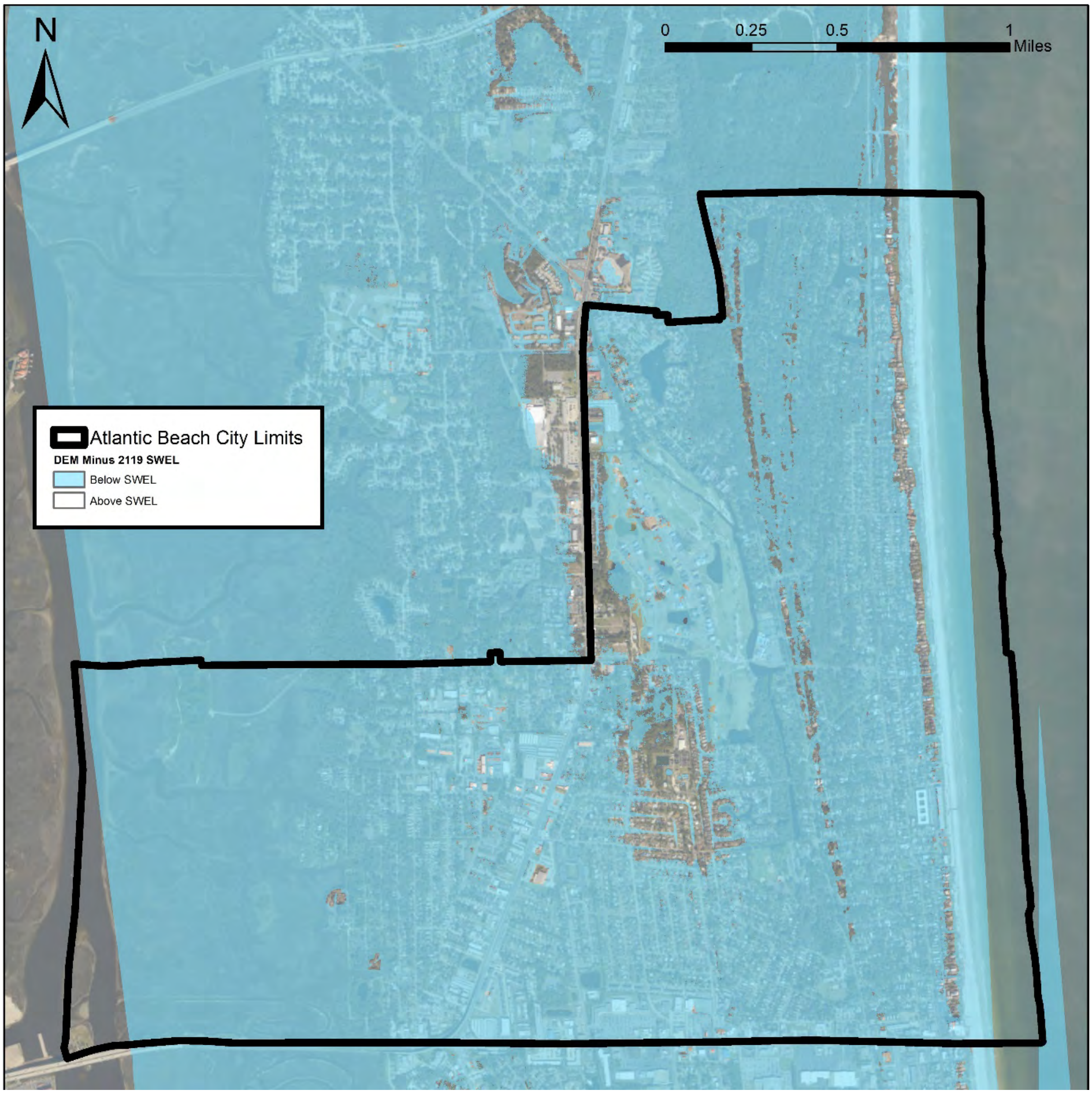

Figure 9. Year 2119 SWEL Inundation (topography below 2119 SWEL)

Sheltered Water (AIWW) Flood Hazards

Flood hazards along the estuarine shoreline due to waves incident from the AIWW were evaluated along Transects 42 and 44 using the FEMA Wave Height Analysis for Flood Insurance Studies (WHAFIS) overland wave propagation model. For conservatism, the entire transects were assumed as open space Inland Fetch (IF); no vegetation or obstruction cards were used. The future 100-year SWEL values were extracted along the transect for each scenario using the generated rasters mentioned previously. Input starting significant wave heights (Hs) of 3.0 and 2.9 feet, respectively, and peak wave periods (Tp) of 2.8 and 2.9 seconds were used based on the effective FEMA FIS. Results of the WHAFIS wave analysis for each SLR scenario are depicted in Figures 10 through 15.

As mentioned previously, larger waves are able to progress farther inland due to rising seas. As a result, BFEs can increase substantially since now there is both elevated water levels and increased wave heights, creating a higher wave crest elevation used for determining the total BFE.

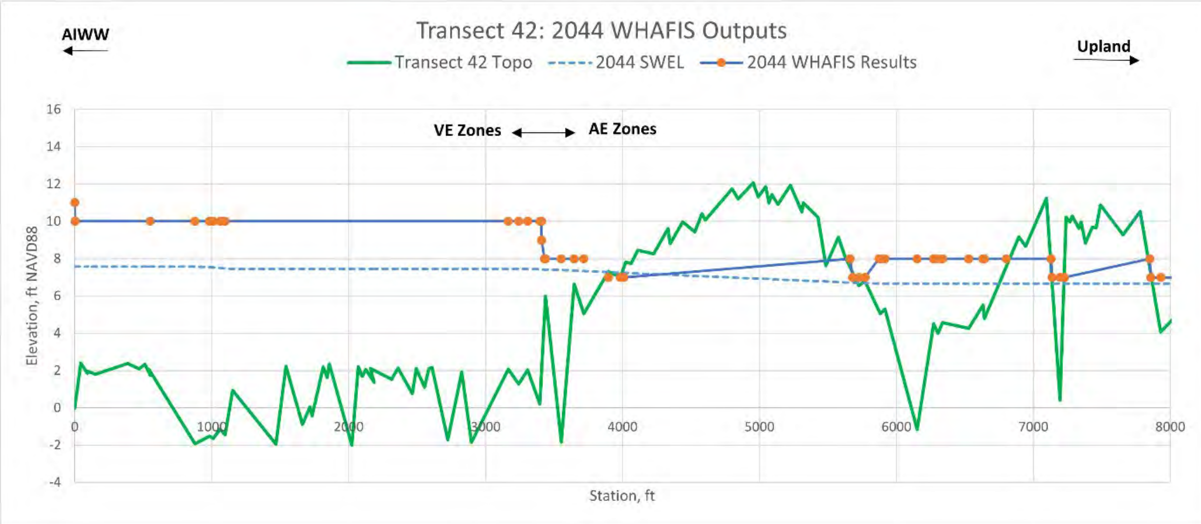

Figure 10. Estuarine Transect 42 WHAFIS Results for Year 2044

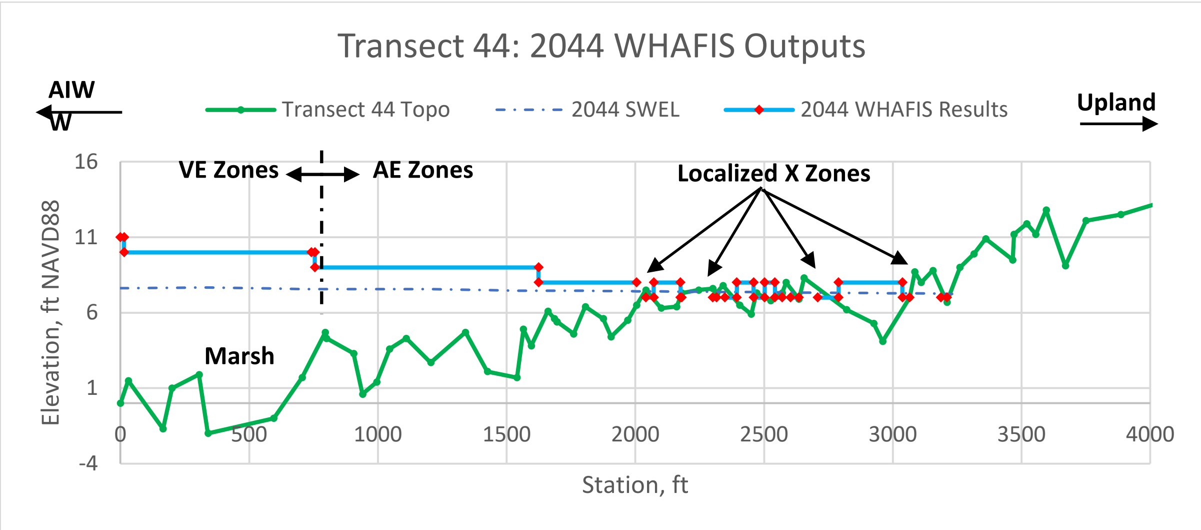

Figure 11. Estuarine Transect 44 WHAFIS Results for Year 2044

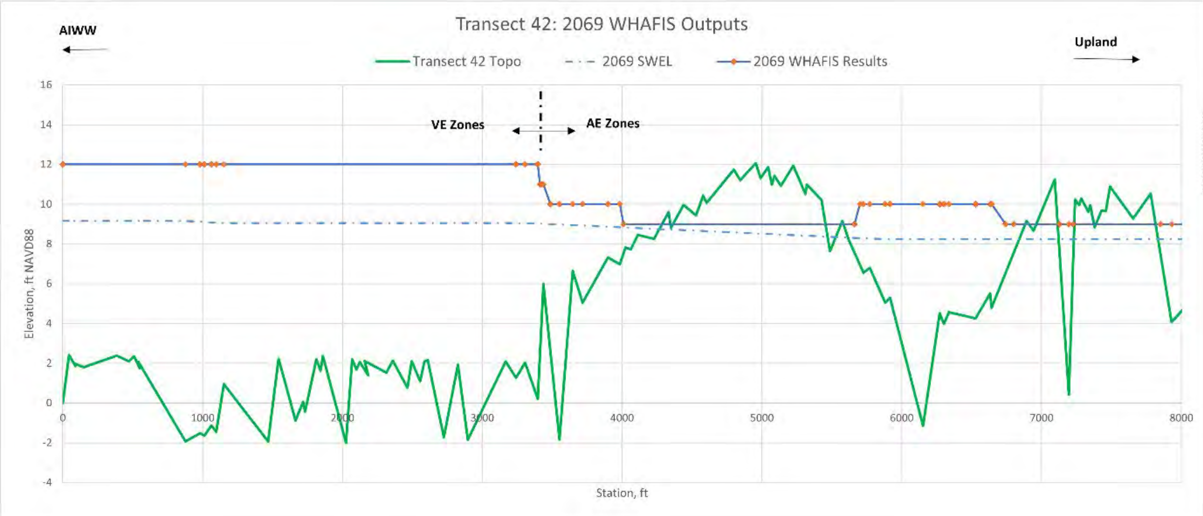

Figure 12. Estuarine Transect 42 WHAFIS Results for Year 2069

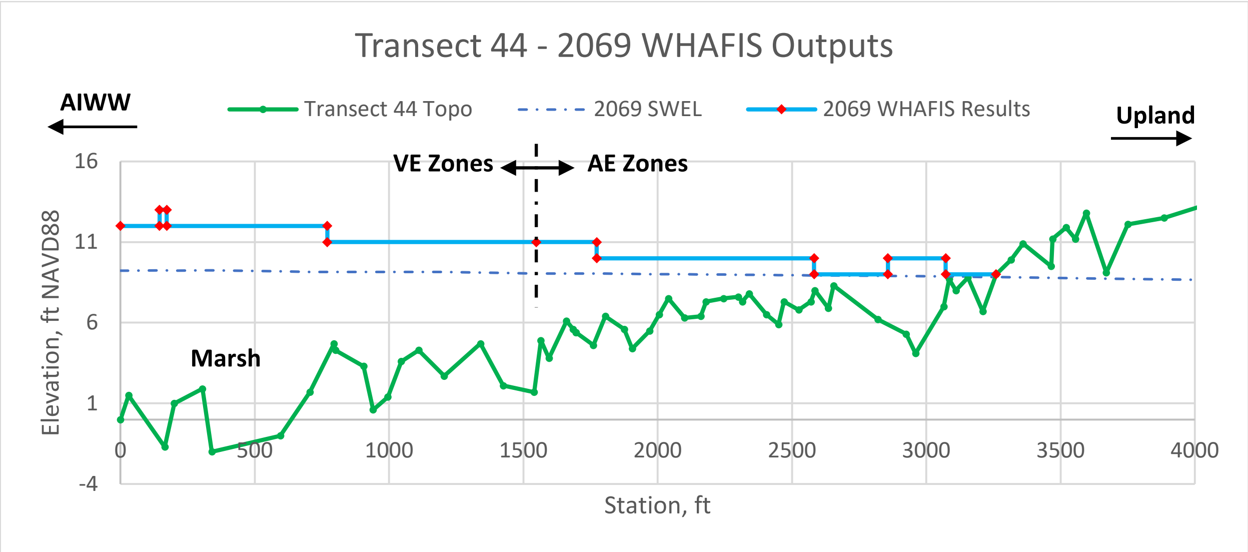

Figure 13. Estuarine Transect 44 WHAFIS Results for Year 2069

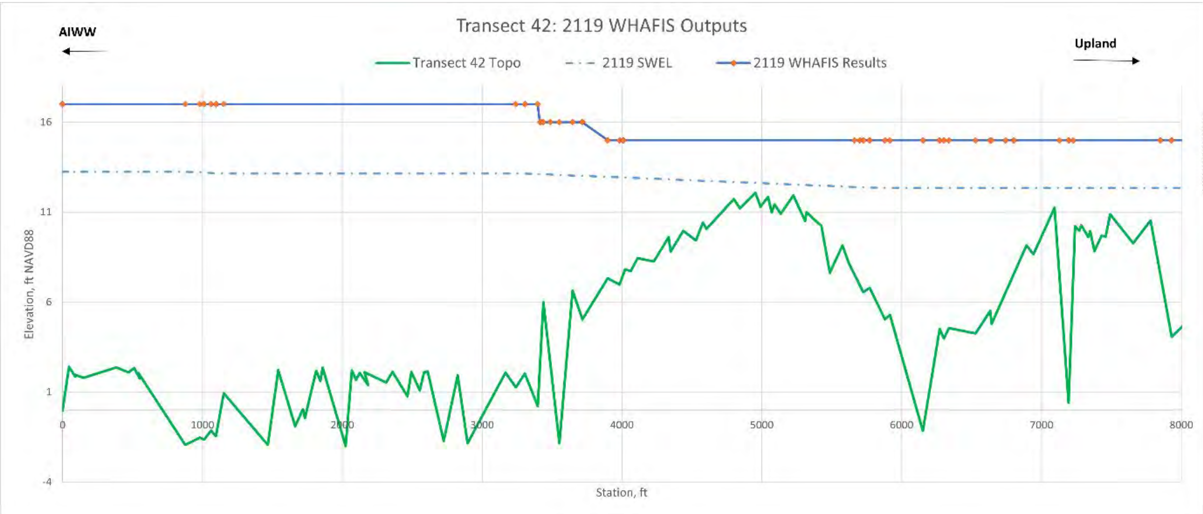

Figure 14. Estuarine Transect 42 WHAFIS Results for Year 2119

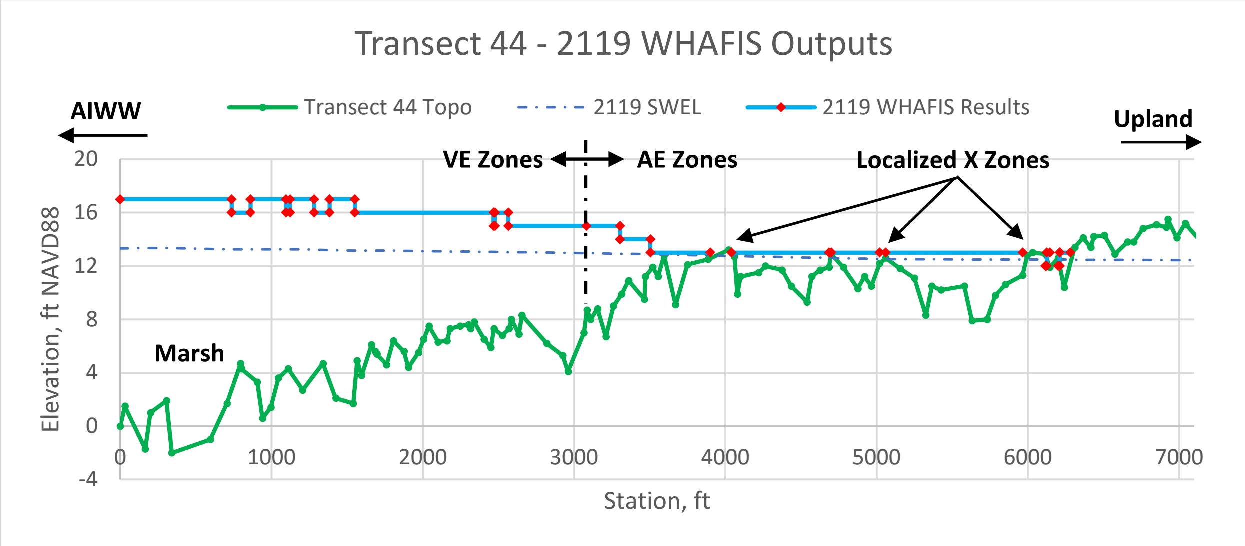

Figure 15. Estuarine Transect 44 WHAFIS Results for Year 2119

The output AE zones and VE zones (representative of a 3-foot wave height delineation in this area) are shown based on the WHAFIS results; however, the important focus is the extent and elevation since waves less than 3 feet can cause substantial damage and should be considered for resiliency planning purposes. Similarly, although locations above SWEL are output as X zones and not considered within the floodplain extent, these areas can still be at risk and subject to wave ramping/ splash effects.

Open Coast (Atlantic Ocean) Flood Hazards

Flood hazards along the ocean shoreline of Atlantic Beach were assessed at Transects 21 and 25. The original and predicted storm-eroded profiles along the open coast are shown in Figures 16 through 19. FEMA flood mapping guidelines require that dunes be eroded under certain extreme event conditions. Calculated sand reservoirs in the existing dunes at the transects are less than 540 square feet; therefore, FEMA guidelines (FEMA, 2007) dictate that the dune be removed (erosion) for analysis. The eroded profile exhibits a 1-on-50 slope passing through the dune toe, per FEMA protocol, and the configuration is consistent with the erosion methods used for the transects in the effective FEMA FIS.

Following FEMA guidelines, the eroded profile was implemented for all modeling/analysis and resulting mapping, and the erosion configuration was kept consistent for each SLR scenario. No shoreline recession was assumed to take place between the time-horizon projections since it is expected that Atlantic Beach will continue its beach renourishment efforts in the future.

Wave propagation and wave runup were assessed at the transects using the WHAFIS and Runup 2.0 modules in FEMA's CHAMP model suite. The same input 100-year storm wave conditions (Hs and Tp) that FEMA predicted for the effective FIS were used in the updated modeling.

Based on WHAFIS and Runup 2.0 runs at the transects, wave runup elevations were significantly higher than wave crest elevations along the open coast under the 2044 and 2069 scenarios.

Therefore, along the open coastline, wave runup is the controlling hazard determining flood elevations, per FEMA protocol. The final BFE in these areas is the sum of the SWEL and the 2 percent runup value output from Runup 2.0, yielding a total water level that is conservatively rounded to a whole foot BFE. The resulting future BFEs determined from Runup 2.0 and the wave runup extents under the 2044 and 2069 scenarios are provided in Figures 16 through 19.

Under the 2119 scenario, the entire dune topography, as well as the majority of the transect continuing inland, is below the SWEL. Wave runup is not applicable in this situation because waves are able to propagate over the coastal topography in this more vulnerable reach of shoreline. Under the 2119 SLR projection, WHAFIS outputs are used to determine the coastal flood hazards along the transects (see Figures 20 and 21).

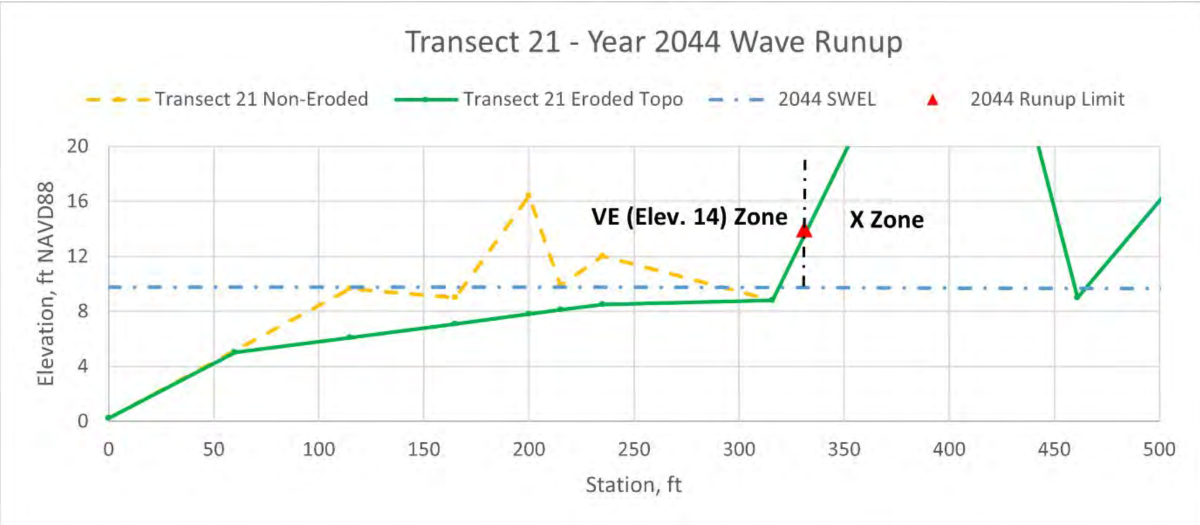

Figure 16.Transect 21 BFEs under the Year 2044 Scenario

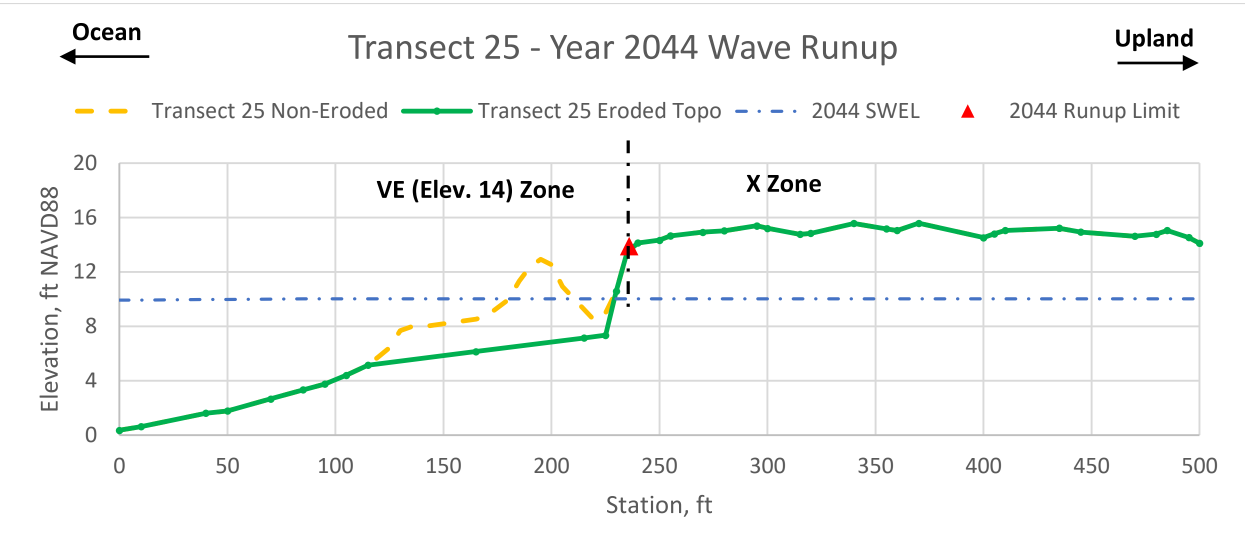

Figure 27. Transect 25 BFEs under the Year 2044 Scenario

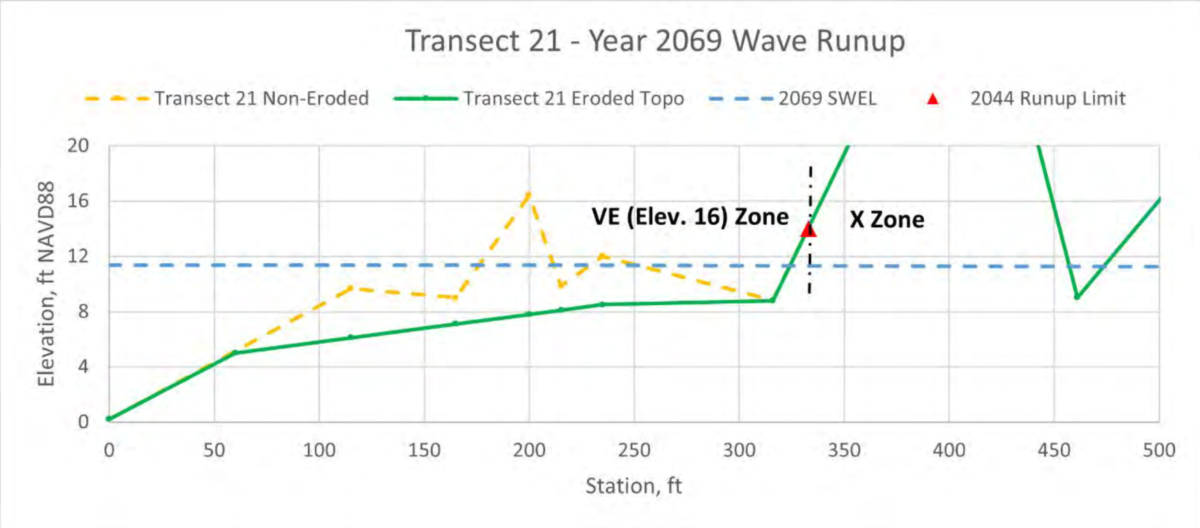

Figure 18. Transect 21 BFEs under Year 2069 Scenario

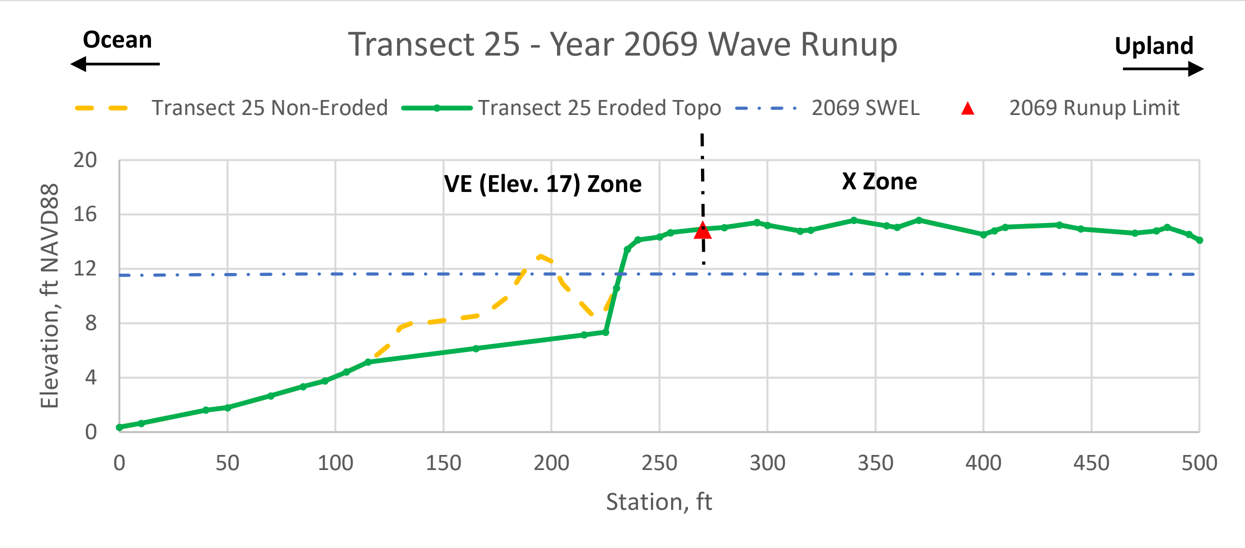

Figure 19. Transect 25 BFEs under Year 2069 Scenario

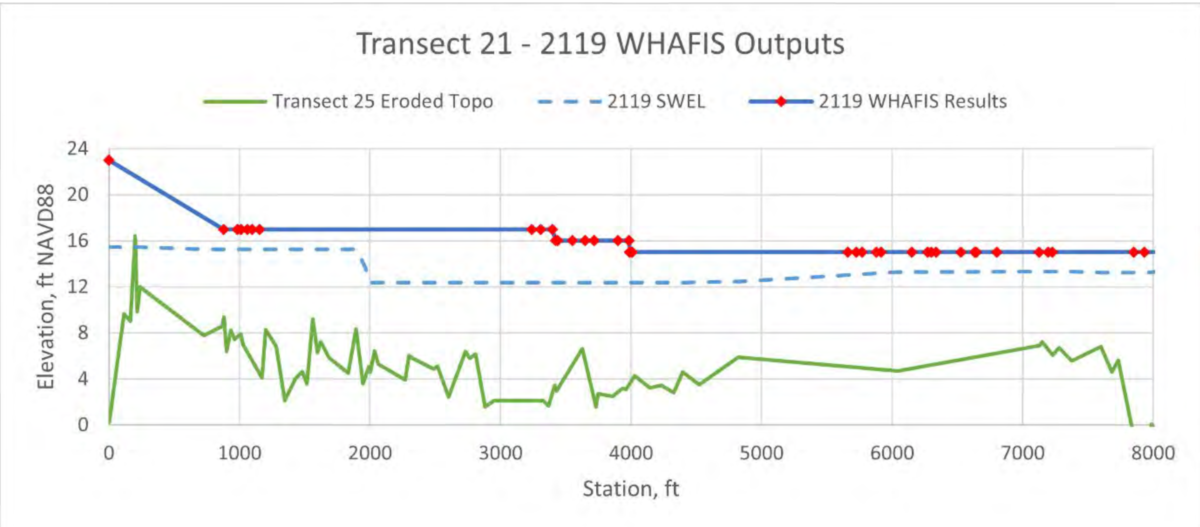

Figure 20. Transect 21 BFEs under the Year 2119 Scenario

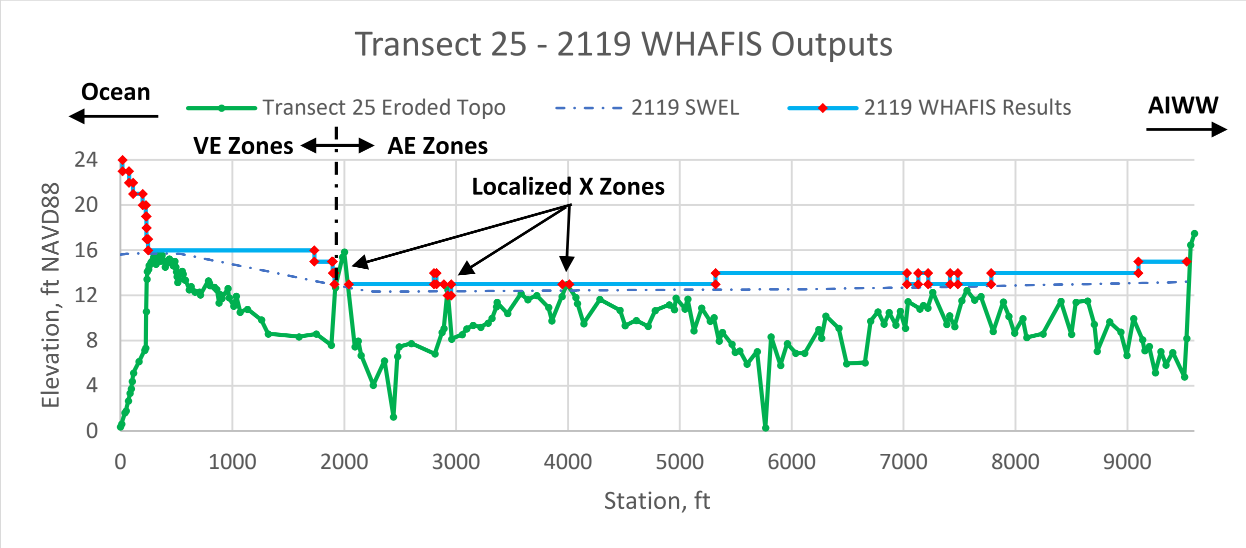

Figure 21. Transect 25 BFEs under the Year 2119 Scenario

Merging Results and Updated Flood Map Production

As previously mentioned, future inundation conditions were used as the starting flood hazard areas for updated BFE flood map production. The final flood maps for each future scenario are based on model results as well as engineering judgment using topography and ATM's knowledge of and experience with CHAMP modeling and the FEMA mapping process.

Additionally, existing/effective FEMA special flood hazard area zone designations were used to aid in determining future BFE flood elevations and extents/coverages. For example, areas that are currently designated as "Combined Riverine and Coastal Mapping" (as specified in the attribute table of FEMA's digital FIRM) were mapped under the future scenario through a conservative comparison of WHAFIS output BFEs and the value of the existing BFE for that particular location plus SLR. The greater of the two values was then assigned to that flooding area, which was extended to meet the contour matching that predicted future BFE.

Interpolation (based on topography and exposure) is used in transitioning to create relatively smooth, continuous flood boundary lines. Conservative mapping techniques considering map scale limitations (based on the existing FIRM scale of 1 inch = 500 feet) were also implemented so that higher BFEs are assigned when model output transitions would suggest lower elevations, but over a very short distance. Areas where the interpolation of model outputs overlap (e.g., the 2119 scenario) similarly used conservative engineering judgment and flood mapping experience in creating the final flood map polygons.

The final flood maps representing current coastal flood risk (Figure 22) and future coastal flood risk estimated for the years 2044, 2069, and 2119 are presented in Figures 23 through 25 and have been provided digitally to Jones Edmunds as GIS files.

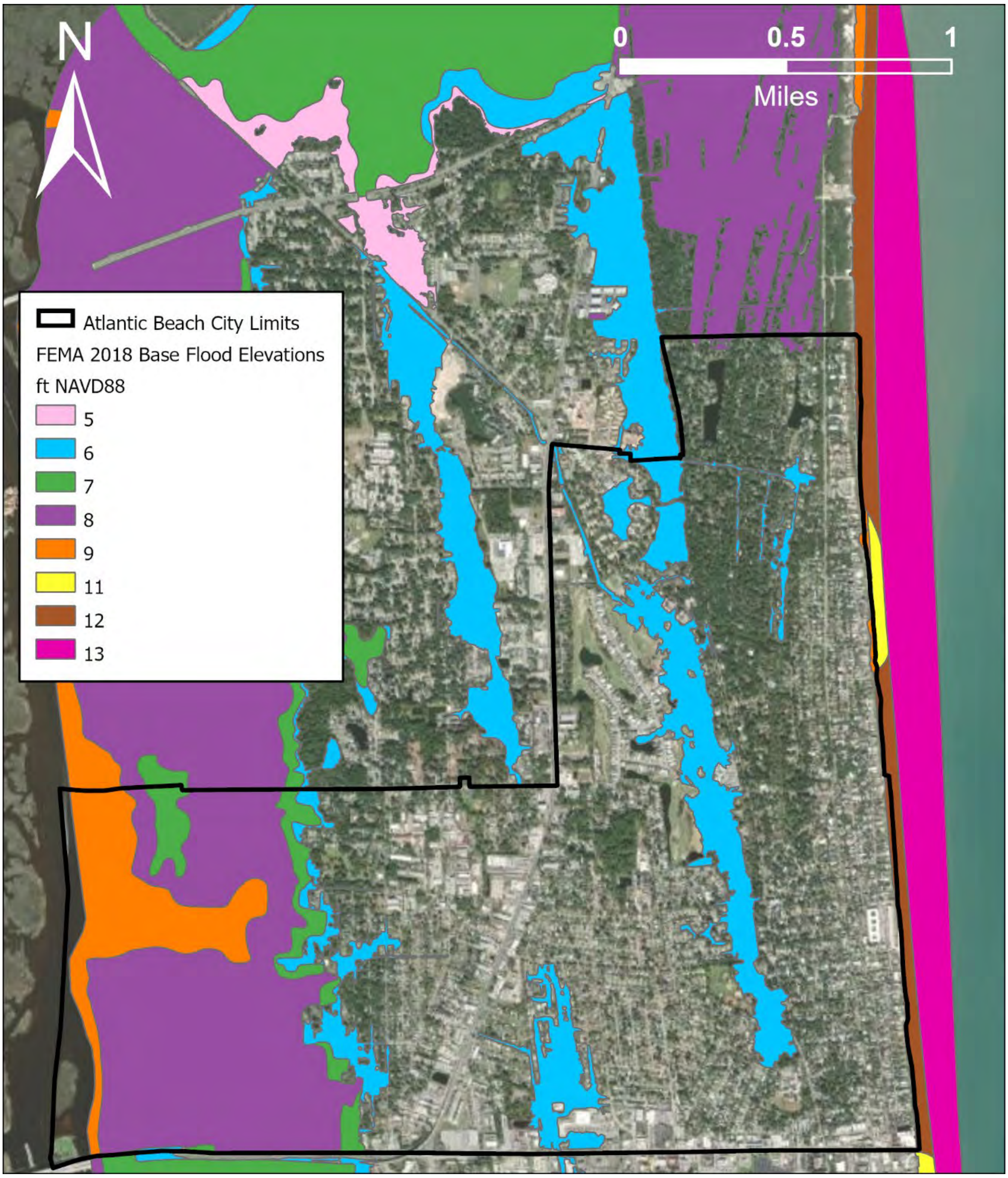

Figure 22. BFE Inundation Map Based on FEMA Effective 2018 Digital FIRM

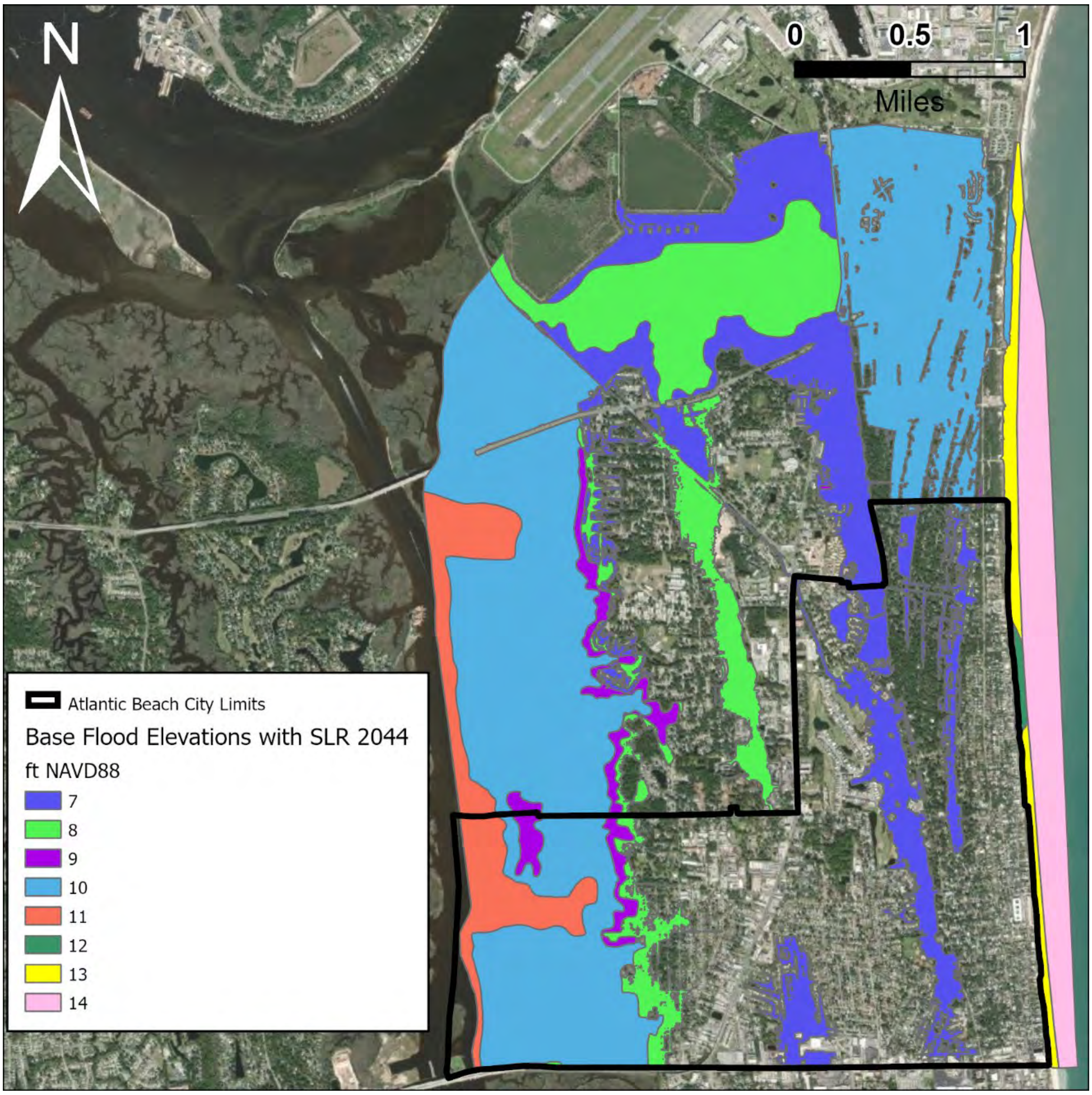

Figure 23. Base Flood Elevation, 2044

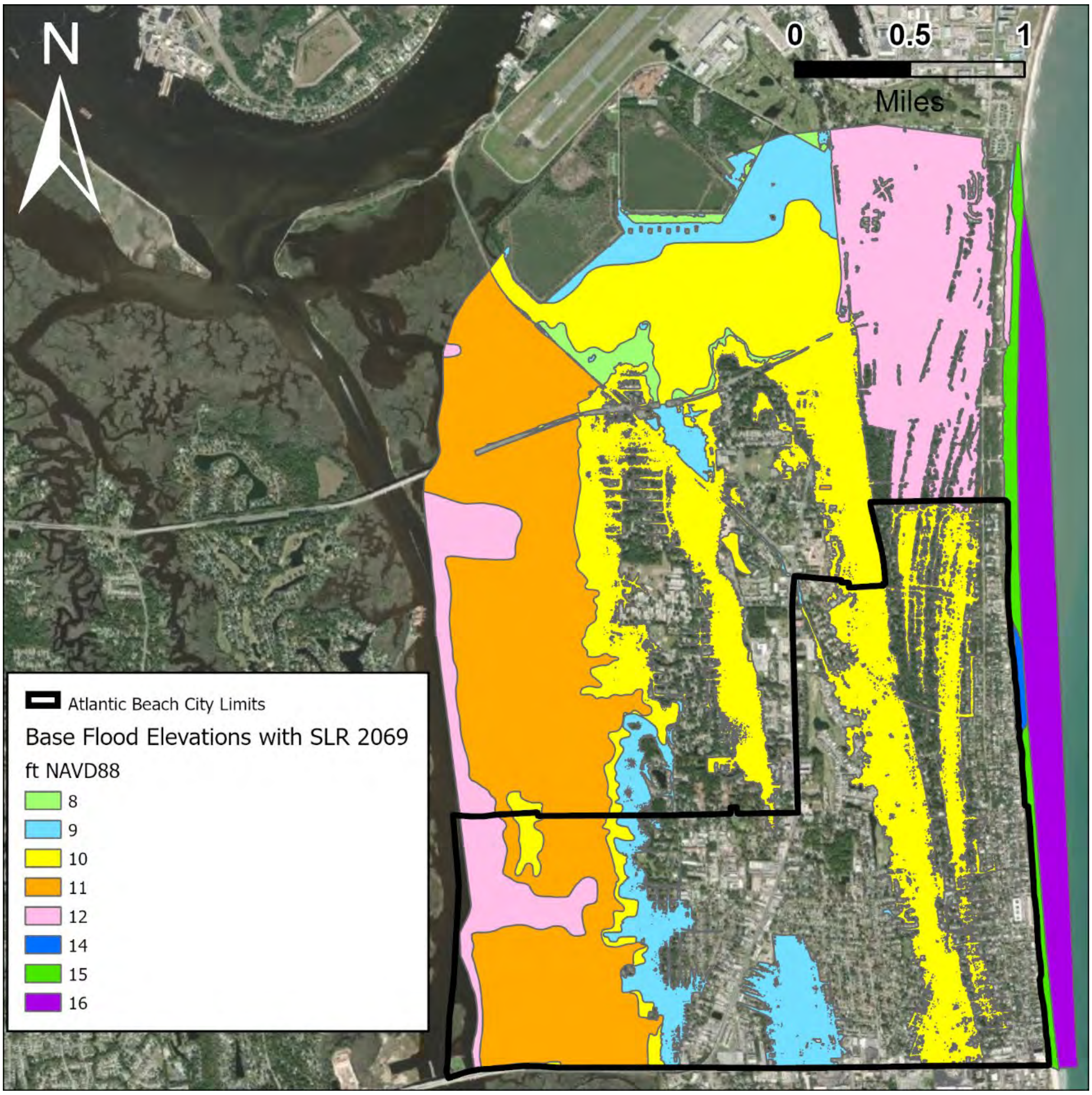

Figure 24. Base Flood Elevation, 2069

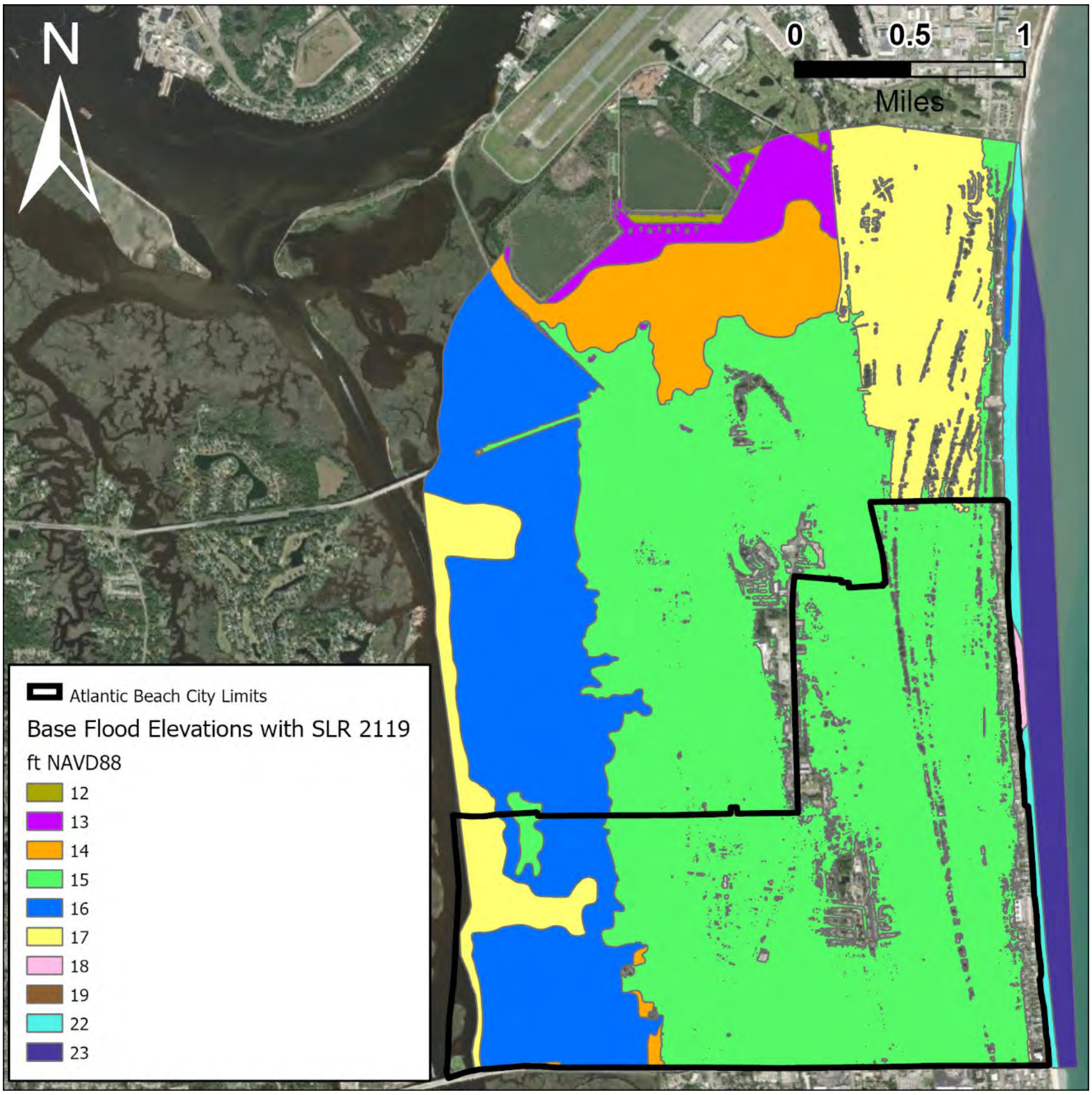

Figure 25. Base Flood Elevation, 2119

References

Federal Emergency Management Agency (FEMA). 2007. Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Final Draft. U.S. Federal Emergency Management Agency, Region VI. Denton, TX. February 2007.

Federal Emergency Management Agency (FEMA). 2007. Coastal Hydraulic Analysis Package (CHAMP), v. 2.0.

BakerAECOM. 2015. Coastal Hazard Analysis and Floodplain Mapping. Intermediate Data Submittals 4 & 5: Duval County, Florida. Task Order 75: Georgia-Northeast Florida Flood Insurance Study. Version 2.1. October 2015.

BakerAECOM. 2016. Coastal Hazard Analysis and Mapping TSDN. Duval County, Florida. March 2016.

Federal Emergency Management Agency (FEMA). 2018. Flood Insurance Rate Map (FIRM)12031, November 2018.

Federal Emergency Management Agency (FEMA). 2018. Flood Insurance Study (FIS), Duval County, Florida (All Jurisdictions). FEMA FIS # 12031CV001B. November 2018.

Jones Edmunds. 2019. Atlantic Beach Stormwater Master Plan Update. Sea Level Task Authorization #09 — Resiliency Support — Task 1. Jones Edmunds Project No. 95239-057-19. “AtlanticBeach_ResiliencyAnalysis_Task1_DRAFT_20190311.docx”. April 11, 2019.

National Oceanic and Atmospheric Administration (NOAA) Tides and Currents http://tidesandcurrents.noaa.gov/, Station: 8720218 Mayport, FL

US Army Corps of Engineers (USACE). 2017. Sea-Level Change Curve Calculator, Version 2017.55. Revised July 18, 2017. Available at: http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html.