# Region II Coastal Storm Surge Study

# Overview

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This document was prepared by

A JV of Dewberry, URS, and ESP
RAMPP
Risk Assessment, Mapping, and Planning Partners
RAMPP
8401 Arlington Blvd.
Fairfax, VA 22031

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|---|---|
| ADCIRC | ADvanced CIRCulation Model for Oceanic, Coastal and Estuarine Waters |
| BFE | Base Flood Elevation |
| DEM | Digital Elevation Model |
| FEMA | Federal Emergency Management Agency |
| FIS | Flood Insurance Study |
| GIS | Geographic Information System |
| IDS | Intermediate Data Submittal |
| JPM | Joint Probability Method |
| NASA | National Aeronautics and Space Administration |
| NAVD88 | North American Vertical Datum of 1988 |
| NGA | National Geospatial-Intelligence Agency |
| NOAA | National Oceanic and Atmospheric Administration |
| RAMPP | Risk Assessment, Mapping, and Planning Partners |
| SWAN | Simulating WAves Nearshore model |
| TSDN | Technical Support Data Notebook |
| UnSWAN | Unstructured version of SWAN model |
| USACE | United States Army Corps of Engineers |
| USEC | U.S. East Coast |
| USGS | United States Geological Survey |

# SECTION ONE INTRODUCTION

The Federal Emergency Management Agency (FEMA) contracted Risk Assessment, Mapping, and Planning Partners (RAMPP), a joint venture of Dewberry, URS, and ESP, under its Risk Mapping, Assessment and Planning program to provide comprehensive floodplain mapping, Geographic Information System (GIS), and hazard risk mitigation services. This report summarizes the storm surge modeling analyses carried out to support Flood Insurance Study (FIS) updates in FEMA Region II that were initiated in November 2009 and also summarizes the overall process. The storm surge analysis effort is documented in multiple topic-specific Region II Storm Surge Project technical documents that are published separately. These reports represent various elements of Intermediate Data Submittals (IDS) as described in the Atlantic Ocean and Gulf of Mexico Coastal Guidelines (FEMA 2007). A brief summary of those documents and their relationship to the IDS items is provided in Table 1; more details are provided in Section Five of this document.

**Table 1 : Summary of Region II Storm Surge Project Technical Documents**

| Document Name | Brief Synopsis |
|---|---|
| Coastal Terrain Processing Methodology (IDS #1) | Provides details on the data and processing efforts that contributed to development of a digital elevation model (DEM) for the study area. |
| Spatially Varying Nodal Attribute Parameters (IDS #1) | Provides details on the methods used to develop inputs for various ADCIRC model parameters that can be varied on a node-by-node basis. |
| Mesh Development (IDS #1) | Details the methodology used to develop an ADCIRC model mesh with a consistent design throughout the study area. |
| Model Calibration and Validation (IDS #2) | Summarizes the methodologies and results from the storm surge model calibration and validation process. The validation process included a tidal calibration and validation to historic storms. |
| Development of Wind and Pressure Forcing in Tropical and Extratropical Storms (IDS #2) | Details the methods used to assemble a comprehensive historical meteorological dataset for the New York/New Jersey coast to provide characteristic storm parameters needed for the development of probability distributions. |
| Joint Probability Analysis Of Hurricane and Extratropical Flood Hazards (IDS #2) | Provides details of the methodologies used to develop a probabilistic characterization of hurricanes that may impact the study area; to develop representative storms for numerical modeling; and to develop statistical techniques for the analysis of extratropical storms. |
| Production Runs (IDS #3) | Documents the work conducted to perform ADCIRC-UnSWAN model simulations for each of the hurricanes and extratropical storms that were developed as part of the Joint Probability Method analysis. |
| Recurrence Interval Analysis of Coastal Storm Surge Levels and Wave Characteristics (IDS #3) | Details how results of the production simulations for the New Jersey and New York project area have been processed to develop recurrence interval stillwater elevations and wave characteristics. |

## SECTION TWO PROJECT AREA

In order to provide spatial consistency, FEMA elected to include a large area in this study. The coastal surge study project area includes the Atlantic Ocean side of New Jersey, New York City, Westchester County, New York, and the Hudson River up to the Troy, NY “tidal dam”. A detailed coastal surge analysis of the New Jersey counties facing Delaware Bay as well as up the Delaware River is included under a separate FEMA Region III study. The Region II coastal storm surge study area is shown on Figure 1.

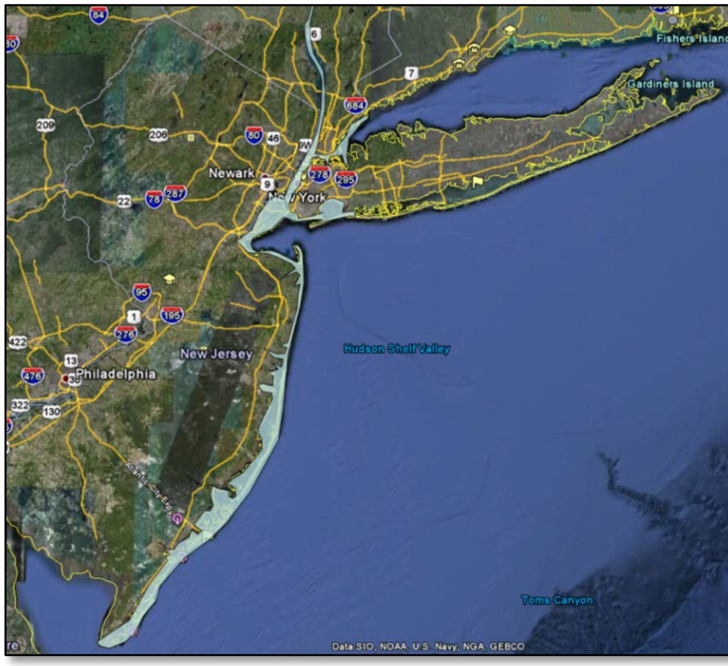


**Figure 1: Coastal Flood Study Project Area**

The modeled study area ranged from an inland limit defined by the 25-foot (NAVD 88) contour well out into the Atlantic Ocean. The shaded area in Figure 1 indicates the inland limit of the model. This inland elevation was deliberately selected to be above any expected coastal storm surge inundation level to ensure that no surge level resulting from the numerical model simulations could encounter an inland grid boundary.

## SECTION THREE METHODOLOGY OVERVIEW

This section presents a brief overview of the entire coastal flood hazard analysis process. The sections that follow provide brief descriptions of key parts of the process and reference reports where more detailed information can be found.

Coastal flood studies to determine federally-subsidized flood hazard insurance have been conducted in the United States since the late 1970s, predating the establishment of FEMA in 1979. These studies consist of a comprehensive examination of the region’s storm climate, combined with numerical modeling to convert storm climatology to statistical measures of storm surge elevations. Earlier studies of all U.S. coastlines were generally completed in the 1980s. Although the methods used in current FEMA studies largely parallel that earlier work, significant advances and improvements have occurred in the quality of storm data and the resolution of meteorological and hydrodynamic numerical models. The data associated with more recent storms are of higher quality and allow for a more complete climatological summary.

Storm surge numerical modeling is necessary to overcome the dearth of direct storm surge measurements. Few sites exist in the entire study area where long-term accurate measurements of past storm surge heights are available. Not only are these widely spaced (especially in comparison to the small dimensions of the region where the peak effects of a particular hurricane are felt); they are also located on the shoreline. Therefore, places between and inland of these scattered gages have no direct measurements. Accordingly, it is necessary to use the more common meteorological measurements of strong storms to characterize the exposure to coastal surge flooding within the study area. The meteorological parameters derived from these measurements are used to develop a numerical model that represents the wind and atmospheric pressure fields of storms. These meteorological parameters are also used to develop probabilistic models that describe the annual storm frequency, intensity and the statistical representation of each of the parameters. When a numerical meteorological model is used in conjunction with other models representing coastal surge hydrodynamics and waves, the time histories and maximum values of storm surge elevations and waves for any particular storm can be computed. This results in a detailed and complete spatial coverage of surge elevations and waves for each simulated event.

In the FEMA Region II Coastal Storm Surge Study, two different methods were used to characterize tropical and extratropical storms. For the overall class designated as tropical cyclonic events, which include tropical storms and hurricanes, the meteorological model developed by Dr. Vince Cardone of Oceanweather, Inc. (Cardone and Cox, 2009) was used. This is a parametric model wherein a time series of a limited number of parameters (usually central pressure, storm radius, radial wind and pressure distributions, forward speed, track orientation, and landfall location) are inputs into an algorithm that develops a series of outputs representing a moving field of wind and pressure.

For extratropical storms, which are generally designated as Northeasters on the North Atlantic coast, there is no agreed upon set of controlling parameters, and each storm must be individually analyzed. This starts with the general representation of the regional North Atlantic atmospheric conditions from an analysis provided by the National Oceanic and Atmospheric Administration (NOAA). A number of data sources are used to create the database necessary to develop individual detailed representations of the wind and pressure fields at 3-hour intervals over the storm's duration. A moving center computer algorithm interpolates between these individual representations of 3-hour patterns to produce a set of output files representing the moving wind and pressure fields for each storm.

The data files representing the moving wind and pressure fields of either tropical or extratropical storms serve as input to another numerical model that computes the time varying coastal water levels and wave conditions. This model combines the hydrodynamics of the ADvanced CIRCulation Model for Oceanic, Coastal and Estuarine Waters (ADCIRC) model with the wave generation and propagation dynamics of the Simulating WAves Nearshore (SWAN) model. ADCIRC is a coastal hydrodynamics finite element model (Leutich et al., 1992) that represents the depth-averaged response of water levels and circulation to wind and atmospheric pressure fields. It operates on a triangular mesh grid (also referred to as an unstructured mesh) with triangular elements of topographic and bathymetric features. For this study a minimum mesh resolution of about 260 feet (80 meters) was used. The SWAN model used for this study uses the same wind and pressure field files and operates on the same unstructured mesh as the ADCIRC model to represent the time varying storm wave generation and propagation. Although developed separately, these models have recently been combined to operate in unison on the same unstructured grid. This combined model is called the ADCIRC-UnSWAN model. This combined model shares resulting calculations between the two separate models at each UnSWAN time-step as opposed to passing data between them after a completed simulation of one storm. This allows for a better integration of the calculation of the physics as well as a more efficient simulation.

All the numerical models used in the FEMA Region II Coastal Storm Surge Study have been independently developed, extensively tested, and repeatedly used in other studies. These models have undergone specific verifications for the type of storm conditions encountered in this project area.

The overall storm surge study approach consists of work tasks to:

- Acquire topographic, bathymetric, and land cover data and perform field reconnaissance;
- Characterize the local storm climate (tropical cyclones and extratropical storms);
- Develop methods to statistically describe the storm climate;
- Develop inputs for numerical models;
- Conduct model tidal calibration and storm validation
- Compute surge heights with the numerical models for multiple storms;
- Analyze recurrence interval statistics for surge height and wave setup conditions; and
- Develop 0.2-, 1-, 2- and 10-percent-annual-chance exceedance coastal surge elevations.

The data generated by the coastal storm surge study is used as input data for developing final Base Flood Elevations (BFEs) using the program Wave Height Analysis for Flood Insurance Studies (WHAFIS) as well as wave runup and overtopping analyses to analyze overland coastal flood hazard conditions.

## SECTION FOUR DATA ACQUISITION

Data acquisition began with the initiation of the project in November 2009. The size of the study area and diverse nature of the required data necessitated data acquisition from a variety of sources. The following describes key data collection efforts, which was completed in 2010.

Detailed topographic and bathymetric data were required to assign elevations and depths to the ADCIRC-UnSWAN model grid. Best available topographic and bathymetric data were collected from Federal and State entities. Supporting topographic data were acquired from the U.S. Geological Survey Earth Resources Observation and Science Center, National Geospatial-Intelligence Agency, FEMA; as well as the New York City Department of Information Technology and Telecommunications. Supporting bathymetric data were acquired from NOAA, National Geophysical Data Center, NOAA Office of Coast Survey, U.S. Army Corps of Engineers New York and Philadelphia Districts, New York State GIS Clearinghouse, and the New Jersey Department of Environmental Protection.

Land use data are the basis for defining various “roughness” or “friction” factors used as input to the ADCIRC model. Three sources of land use data were available for various parts of the project area. These datasets are the National Land Cover Dataset, Gap Analysis Program dataset, and the New Jersey Land Use dataset. These datasets vary in age going back to 1999 with the most recent dated 2007 and classify land uses in different ways. These data sets represent the most current land use classifications and were spot checked against recent aerial photography. Field reconnaissance efforts were conducted with visits to areas of interest to provide additional verification of conditions to aid in model development. These data were collected and analyzed in 2010.

Climatological data analysis required data assembly from previous relevant studies of U.S. East Coast (USEC) tropical events and analysis of previous storm track and intensity databases maintained by the U.S. government. For older storms, efforts to rescue and digitize data from fragile microfilm and paper data media were required and were completed in 2010.

# SECTION FIVE SUPPORTING TECHNICAL DOCUMENTS

This section provides a summary of each of the 8 documents that were created to provide documentation of the methods used to update the flood hazard data along the Atlantic coast in New Jersey and New York City (also including the tidal influenced areas of the Hudson River).

## 5.1 COASTAL TERRAIN PROCESSING METHODLOGY (RAMPP 2014 a)

Storm surge modeling for coastal counties in FEMA Region II required the creation of seamless DEM products for the development of a consistent ADCIRC Mesh as described in Section 5.3. RAMPP used the most up-to-date topographic and bathymetric data available at the time of the study. Various topographic and bathymetric data sources were used to provide coverage throughout the region including NOAA, NASA, USGS, USACE, NGA, FEMA, and the State of New York. For storm surge modeling, a seamless DEM with a 10-meter horizontal resolution was created. This resolution is appropriate for storm surge modeling, as further described in Section 5.3.

Because the project area spans two state plane horizontal datums and the terrain and bathymetric data needed to be in a single datum for surge model input, all data had to be converted to a single datum. The final seamless DEM products used for the storm surge study were referenced to the

Project Datum: horizontal datum of NAD83 New Jersey State Plane FIPS 2900, in feet, vertical datum of NAVD88, in feet. (Note that final overland floodplain mapping is performed in the appropriate state plane for the jurisdiction being mapped). The final seamless DEMs are used as the elevation source for development of the ADCIRC-UnSWAN mesh. The Coastal Terrain Processing Methodology Documentation report (RAMPP 2014a) provides details on the source data and processing efforts that contributed to development of a seamless bathymetric and topographic DEM for the study area.

## 5.2 SPATIALLY VARYING NODAL ATTRIBUTE PARAMETERS (RAMPP 2014 b)

The ADCIRC-UnSWAN model allows the user to specify model parameters on a node-by-node basis for spatial variation in the parameter values. This allows detailed information about the study area to be incorporated into the model to provide an appropriate representation of conditions affecting the model hydrodynamic computations. This is an important input for developing the ADCIRC mesh as described in Section 5.3. These data inputs are used in the storm simulations for the model validation described in Section 5.4 and the production runs described in Section 5.7. The Region II Storm Surge Project - Spatially Varying Nodal Attribute Parameters report (RAMPP 2014b) provides details on the methods used to develop inputs for various ADCIRC-UnSWAN model parameters that can be varied on a node-by-node basis. For the Region II Coastal Storm Surge Study the following data parameters were developed and used:

- Manning's *n* at sea floor – Addresses friction effects on water movement. See Section Three of RAMPP 2014b for more details.
- Surface directional effective roughness length – Addresses friction effects of land cover on wind flow. See Section Four of RAMPP 2014b for more details.
- Surface canopy coefficient - Allows the user to turn off wind stress in heavily forested areas because the canopy shields the water from the effects of the wind. See Section Five of RAMPP 2014b for more details.
- Wave refraction in UnSWAN - Wave refraction can cause spurious spikes in wave heights that are detrimental to the model. To combat this, wave refraction is only calculated in a selected region around the study area. See Section Six of RAMPP 2014b for more details.
- Primitive weighting in continuity equation – Sets the parameter controlling the relative contribution of the primitive and wave portions of the Generalized Wave-Continuity Equation in ADCIRC. See Section Seven of RAMPP 2014b for more details.

## 5.3 MESH DEVELOPMENT (RAMPP 2014 c)

The ADCIRC-UnSWAN model uses an unstructured, triangulated mesh that allows for detailed representation of narrow flow features and major obstructions. The mesh triangles are called elements with each element consisting of three nodes. However, the model stability is sensitive to the mesh design (element size, connectivity, area changes, depths at nodes, etc.), and an ill-designed mesh can cause instability issues with the ADCIRC model. The UnSWAN model is not as sensitive as the ADCIRC model to the mesh design, but some additional constraints on element size along breaking wave zones are needed.

Although high-performance computers are used to run the ADCIRC-UnSWAN model, even with ample computing resources, this is still a computationally intensive model. Runtime is directly tied to the number of nodes in the mesh and minimum size of the elements. With more nodes comes more calculations and longer run times. For model stability, the minimum node spacing must be balanced by a small timestep, and thus smaller element sizes in the mesh lead to smaller timesteps and longer run times. Therefore, one goal while developing an ADCIRC mesh is to optimize the element size by using a minimum element size that is sufficient to identify major waterways and barriers to flow while at the same time maintaining reasonable run times. To decrease the number of elements, in upland areas far inland, far offshore, or far from the project area (such as the Caribbean Sea), the node-to-node spacing was increased. The largest elements in the deep ocean are approximately 5 miles wide (approximately 8 kilometers). In the project area, the maximum spacing inland was set at 1,650 feet (approximately 500 meters), and the minimum spacing was set at 260 feet (approximately 80 meters).

The mesh was developed using the terrain and spatially variable parameter data discussed in Sections 5.1 and 5.2 as well as the field reconnaissance data discussed in Section Four. Model testing was then conducted to make sure there were no stability issues resulting from poorly defined mesh elements. The final mesh was used for the model validation described in Section 5.4 and the production runs described in Section 5.7. The Region II Storm Surge Project - Mesh Development report (RAMPP 2014c) details the methodology used to develop a consistently designed ADCIRC-UnSWAN mesh that could be run without the need for extensive revisions during the validation process. The mesh development effort was completed in 2011.

## 5.4 MODEL CALIBRATION AND VALIDATION (RAMPP 2014 d)

After development of the ADCIRC-UnSWAN model mesh and other inputs, it was important to verify that the model generated appropriate results that compare well to known historic flooding events. The Region II Storm Surge Project - Model Calibration and Validation report (RAMPP 2014d) summarizes the methodologies and results from the storm surge model calibration and validation process. The validation process relies in large part on comparing results generated by the model for historical storms to historical records of surge elevations. The model input data for historical storms were developed as part of the Storm Climate Characterization efforts described in Section 5.5.

Seven historical storms (4 Hurricanes and 3 extratropical storms) were selected for validation. The storms selected were well-documented major storm events affecting the region with available observed water level and high water mark data.

The model validation effort included the following:

- NOAA Gage Water Level Hydrograph Comparisons.
- Peak Water Level Comparisons
- Wave Height and Period Comparisons

A detailed discussion of the validation results can be found in RAMPP 2014d. In summary, the validation results indicated that the model simulations of storm timing (Hydrograph comparison), peak water levels, and wave heights match well with the historical records. The validation of the model was completed before beginning any production runs as described in Section 5.7, to ensure high confidence that the model was generating appropriate results. The model validation efforts were completed in 2011.

## 5.5 DEVELOPMENT OF WIND AND PRESSURE FORCING (RAMPP 2014 e)

The Region II Storm Surge Project - Development of Wind and Pressure Forcing in Tropical and Extratropical Storms report (RAMPP 2014e) details the methods used to assemble a comprehensive historical meteorological dataset and analyze the track, intensity, and internal structure of the wind and pressure fields of historical, high ranking United States east coast storms. Data from these storms provide characteristic storm parameters needed for probability distribution development. The histories of storms that actually affect a study area are critical to the development of the statistics. The storm characteristics are used for the development of the storm statistics and Joint Probability Method described in Section 5.6. Only storms that have affected the study area are used in the statistical analysis so that the resultant recurrence intervals described in Section 5.8 are directly relevant to the area. However, the analysis is limited by the quality and quantity of accurate historic storm data. This report also summarizes the process of selecting historical wind and pressure fields with the best supporting data to validate the ADCIRC-UnSWAN hydrodynamic model. The historical wind and pressure fields are used as input to the model validation described in Section 5.4. Other aspects of the report include development of wind and pressure fields for historical extratropical cyclones; and wind and pressure field generation for tropical events defined as part of the Joint Probability Method (JPM) storm set.

## 5.6 JOINT PROBABILITY ANALYSIS (RAMPP 2014 f)

The Region II Storm Surge Project - Joint Probability Analysis of Hurricane and Extratropical Flood Hazards report (RAMPP, 2014f) provides the methodologies used to develop the following inputs to the storm surge analysis:

- A probabilistic characterization of the occurrence and characteristics of tropical events that can cause significant surge along the New York–New Jersey coast.
- A set of representative “synthetic storms” and their associated recurrence rates, to be used for the numerical wind, wave, and surge calculations, and in the final probability calculations.
- Development of statistical techniques to analyze extratropical storms.

The statistical method used for analysis of tropical storms is called the Joint Probability Method (JPM). The JPM defines the combination of storm parameters and the tracks that will be simulated during the production runs, described in Section 5.7, and that will be used to perform the recurrence interval analysis resulting in return period storm surge elevations as described in Section 5.8. For extratropical storms, a modified version of the Empirical Simulation Technique (EST) was used to develop storm statistics. The statistics of these two storm sets were combined to produce the final statistical results.

## 5.7 PRODUCTION RUNS (RAMPP 2014 g)

The Region II Storm Surge Project - Production Runs report (RAMPP 2014g) documents the work conducted to perform ADCIRC-UnSWAN model simulations for each of the 159 tropical events and 60 extratropical storms (30 unique storms simulated at two randomly-selected tidal phases) that were developed as part of the JPM and EST approaches described in Section 5.6. The production run simulations resulted in time series output files of wind speeds, water levels, water velocities, wave heights, and wave periods for each of the storms. The maximum water level elevations are extracted from the results of each storm simulation and used in the recurrence interval analysis to develop return period storm surge elevations as described in Section 5.8. The production run work was completed in 2011.

## 5.8 RECURRENCE INTERVAL ANALYSIS AND WAVE CHARACTERISTICS (RAMPP 2014 h)

The Region II Storm Surge Project Recurrence Interval Analysis of Coastal Storm Surge Levels and Wave Characteristics report (RAMPP 2014h) details how results of the production run simulations, described in Section 5.7, for the New Jersey and New York project area were processed to develop stillwater elevations and wave characteristics at desired recurrence intervals. The processing was applied to determine the coastal flood elevations for the 10-, 2-, 1-, and 0.2-percent-annual-chance exceedance levels and to determine the wave height and period associated with the 1-percent-annual-chance exceedance flood level for application in the overland wave analysis. The recurrence interval analysis is also where the uncertainty of all the collected and simulated data is accounted for by applying adjustment factors in the analysis. The computed stillwater elevations and wave conditions are a compilation of all the data inputs, analyses, and modeling as described above and referenced to in the individual reports. This work was completed in 2012.

## SECTION SIX SUMMARY

The analyses and reports developed as part of the storm surge phase of this work used units of measurement consistent with the data being analyzed and the requirements of the analysis or models being used. The data was brought to unified units and datum for model inputs. The data generated during the ADCIRC-UnSWAN simulations was output in units of meters and vertically referenced to mean sea level. During the post-processing steps, such as the generation of stillwater elevations and wave conditions, the data was converted to feet and vertically referenced to NAVD88 for application to the coastal overland modeling and mapping. Required data and results from the storm surge modeling were passed on to the overland modeling and mapping efforts for determining and mapping the BFEs. Specifically the resulting recurrence interval stillwater elevations and the associated 1-percent annual-chance wave height and wave period were passed on as data points throughout the study area. The overland modeling and mapping teams also generated GIS rasters to represent the results of the stillwater and wave data. The processing of the final data and the coastal overland modeling and hazard mapping is reported in the Technical Support Data Notebook (TSDN) for each individual coastal county in New York and New Jersey scheduled for updated coastal mapping. The TSDNs meets the requirements of IDS #4 & #5 (FEMA 2007).

# SECTION SEVEN REFERENCES

Advanced Circulation Model, The University of North Carolina at Chapel Hill, 2013, http://adcirc.org/.

Cardone, V.J., and A.T. Cox, 2009. "*Tropical cyclone wind field forcing for surge models: critical issues and sensitivities*". Natural Hazards: Volume 51, Issue 1 (2009), Page 29.

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

Luettich, R.A., Westerink, J.I. and N.W. Scheffner, 1992, ADCIRC an advanced three-dimensional circulation model for shelves, Coasts and Estuaries, I: Theory and Methodology, Tech. Rept. 1, U.S. Army Corps of Engineers, Waterways Experiment Station, MS.

RAMPP, 2014a, Region II Storm Surge Project - Coastal Terrain Processing Methodology, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014b, Region II Storm Surge Project - Spatially Varying Nodal Attribute Parameters, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014c, Region II Storm Surge Project - Mesh Development, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014d, Region II Storm Surge Project - Model Calibration and Validation, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014e (Oceanweather, Inc.), Region II Storm Surge Project - Development of Wind and Pressure Forcing in Tropical and Extratropical Storms, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014f (Lettis Consultants International, Inc.), Region II Storm Surge Project - Joint Probability Analysis Of Hurricane and Extratropical Flood Hazards, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014g, Region II Storm Surge Project - Production Runs, FEMA TO HSFE02-09-J-001, 2014

RAMPP, 2014h, Region II Storm Surge Project - Recurrence Interval Analysis of Coastal Storm Surge Levels and Wave Characteristics, FEMA TO HSFE02-09-J-001, 2014.