# Florida Commission on Hurricane Loss Projection Methodology

## Professional Team Report

## 2021 Flood Standards


Hurricane Michael, Bay County


Hurricane Irma, Osceola County

## Karen Clark & Company

## On-Site Review: May 6-9, 2024

On May 6-9, 2024, the Professional Team conducted an on-site review of the Karen Clark & Company (KCC) US Flood Reference Model Version 2.0. The following individuals participated in the review.

**KCC**

Benjamin Aiken, Property Data Analyst
Adrian Corman, Ph.D., Principal Software Developer
Glen Daraskevich, Senior Vice President
Kelly Flanigan, Senior Technical Writer
Arjun Jayaprakash, Ph.D., Principal Engineer
Shaoning Li, Ph.D., Principal Engineer
Yingzhao Ma, Ph.D., Senior Hydrologist
Benjamin Miller, Risk Analyst
Marshall Pagano, Director, Client Services
Daniel Ward, Ph.D., Senior Director, Model Development
Nick Weed, Principal Software Engineer
Hongyu Wu, Ph.D., Statistician

**Professional Team**

Jimmy Booth, Ph.D., Meteorology
Jenni Evans, Ph.D., Meteorology, observer
Paul Fishwick, Ph.D., Computer/Information
Mark Johnson, Ph.D., Statistics, Team Leader
Chris Jones, P.E., Vulnerability, virtual
Stu Mathewson, FCAS, MAAA, Actuarial
Del Schwalls, P.E., CFM, Hydrology & Hydraulics
Donna Sirmons, Staff

The Professional Team began the review with an opening briefing and introductions were made. KCC provided a general overview of the flood model and detailed explanations of model updates.

The high-resolution storm surge model simulates coastal flooding from tropical cyclones. The model consists of over 80,000 potential hurricane events with over 30,000 impacting Florida. The same event catalog and hurricane tracks are in the current accepted KCC US Hurricane Reference Model version 4.0 and are used to generate coastal flood footprints. KCC discussed the structure of the storm surge model that calculates modeled storm surge on a 5-minute time step sufficient to model changes in peak surge over the life cycle of the storm. Storm surge intensity footprints are generated using parameters specific to storm surge from 5-minute hurricane track points. Storm surge intensity footprints from Hurricane Michael (2018) and Hurricane Ivan (2004) were reviewed.

KCC discussed the role of climate change in modeling storm surge. The model was updated to include the impact of climate change on hurricane intensity distributions at landfall. Mean sea-level height was updated in the coastal flood footprint generation to include post-1985 increases in sea level, and to be consistent with the current climate.

Treatment of storm surge heights for storm tracks exiting land was refined. This refinement improved the validation to historical observations. A validation example using Hurricane Wilma (2005) was reviewed.

The high-resolution inland flood model is physically based using hydrologic and hydraulic simulation. KCC discussed the water balance calculation for individual catchments in the six basins affecting Florida. An inland flood footprint demonstrating inundation depths for surface and riverine flooding from the Suwannee River during Tropical Storm Fay (2008) was reviewed. Example validation footprints of flooding at specific locations were reviewed.

KCC discussed updates to the inland flood model including the impacts of urban drainage systems on water balance for impervious surfaces, the change in treatment of input precipitation data from daily to hourly to better simulate the impacts of high precipitation-rate events, the application of high-resolution soil texture and land cover data used to determine surface and sub-surface characteristics, and the introduction of a dynamic (non-fixed) floodplain width allowing for channel flood waters to expand into the adjacent floodplain. The dynamic floodplain width results in a wider and shallower floodplain than is represented in the current accepted flood model.

KCC explained the impacts on model results for each of the hazard updates.

KCC discussed the component-based engineering methodology for building vulnerability function development. The calculation of modeled hydrostatic, hydrodynamic, and wave-action loads at different inundation depths for affected building components was explained. KCC reviewed the primary building characteristics, secondary characteristics, and mitigation measures included in the flood model.

KCC discussed updates to the vulnerability module including: 1) an update to the year-built inventory distribution for unknown year-built vulnerability functions based on newer datasets, 2) an update to unknown building height vulnerability functions for commercial residential, renter, and condo occupancy types based on an analysis of the weighted average of known building height combinations, 3) an update to the vulnerability regions based on more recent National Flood Insurance Program (NFIP) Community Rating System (CRS) data, and 4) an update to first floor height assignments when first floor height and foundation type are unknown.

KCC presented graphical comparisons to the current accepted model of the updated unknown building height vulnerability functions and updated vulnerability regions.

KCC explained the impacts on model results for each of the vulnerability updates.

KCC explained the development and underlying data used in creating their comprehensive exposure dataset used for projecting personal residential flood loss costs and flood probable maximum loss levels. Key factors in the exposure dataset development were discussed.

ZIP Codes and centroids were updated based on changes made by the U.S. Postal Service. Demand surge factors were updated to reflect the increased property values in the 2022 KCC Industry Exposure Database. KCC discussed the impacts of the ZIP Code and demand surge factor updates on model results.

The combined model updates resulted in a 10.8% increase in the average annual zero deductible statewide flood loss costs.

KCC discussed the challenges with creating the comprehensive exposure dataset and the impacts on the Report of Activities (ROA) process. Recommendations for potential ROA process updates and a uniform comprehensive exposure dataset to be provided by the Commission were discussed. KCC will present these recommendations to the Commission during the 2025 Flood Standards committee meetings.

The audit continued with a review of each standards section.

The Professional Team recommends the following trade secret data and information be presented to the Commission during the trade secret session of the meeting to review the model for acceptability under the 2021 Flood Standards.

1. Standard AF-6, Audit 1 map of the top coastal flood event at the occurrence level.

## Report on Deficiencies

The Professional Team reviewed the following deficiencies cited by the Commission at the April 4, 2024, meeting. The deficiencies were eliminated by the established time frame, and the modifications have been verified.

1. Incomplete. Equations are not numbered in the submission document.

2. GF-1.2, page 17: Incomplete. Provide supporting references for the Joint Probability Method.

3. GF-1.6, page 34: Incomplete. Seneveratne et al. 2001 (page 78) reference not included in list of references.

4. GF-2.3.B, page 69: Incomplete. Provide a copy of Melinda Vasecka's peer review in 2024.

5. Form GF-3, page 204: Non-responsive. The signatory certifying the Hydrological and Hydraulic Flood Standards does not meet the prerequisite experience identified in Standard GF-2.B.

6. GF-3.E, page 71: Incomplete. No reference is given to horizontal projections and datum.

7. HHF-1.4, page 99: Incomplete. Only sensitivity to soil moisture is documented. Provide sensitivity for additional initial and boundary conditions.

8. HHF-1.4, page 100: Incomplete. Provide a legend for Figure 17.

9. HHF-1.5, page 100: Incomplete. The vertical datum of the topographic data is omitted.

## Professional Team Pre-Visit Letter

The Professional Team's pre-visit letter questions are provided in the report under the corresponding standards. Following is the pre-visit letter preamble.

The purpose of this pre-visit letter is to outline specific issues unique to KCC's model submission under the 2021 flood standards, and to identify lines of inquiry that will be followed during the on-site review in order to allow time for adequate preparation. Aside from due diligence with respect to the full submission, various questions that the Professional Team will ask during the on-site review are provided herein. This letter does not preclude the Professional Team from asking for additional information during the on-site review that is not given below or discussed during an upcoming conference call to be held if requested by KCC. The goal of a potential conference call is to address your questions related to this letter or other matters pertaining to the on-site review. The overall intent is to help expedite the on-site review and to avoid last minute preparations that could have been undertaken earlier.

It is important that all material prepared for presentation during the on-site review be provided to the Professional Team and presented using a medium that is readable by all members of the Professional Team simultaneously.

The Professional Team will begin the review with an opening briefing. KCC should then proceed with a detailed explanation of new or extensively updated material related to the model. Afterwards, a review of the flood standards in the *Flood Standards Report of Activities as of November 1, 2021,* will commence. Each flood standard should be addressed beginning with responses to the pre-visit letter questions for that specific standard followed by responses to all of the audit items for that standard.

If changes have been made in any part of the model or the modeling process from the descriptions provided in the initial January 30, 2024, submission, provide the Professional Team with a complete and detailed description of those changes, the reasons for the changes (e.g., an error was discovered), and any revised forms. For each revised form, provide an additional form with cell-by-cell differences between the revised and the original submitted values.

Refer to the On-Site Review chapter of the *Flood Standards Report of Activities as of November 1, 2021*, for more details on materials to be presented and provided to the Professional Team. Particular attention should be paid to the requirements under Presentation of Materials.

In addition to the 6 items listed under Presentation of Materials, provide copies of:

1. Flowchart standard documents if internally developed, or references to published standards, and

2. Software engineering practice and coding guidelines if internally developed, or references to published standards.

In an effort to reduce the time and cost involved in producing hard copy materials, only 6 printed copies of the presentations (printed two slides per page and duplexed), and the Form AF-6 graphical summaries, color-coded contour or high-resolution map of the flood loss costs for slab foundation owners frame buildings, and the scatter plot of the flood loss costs against distance to closest coast for slab foundation owners frame buildings need to be provided.

All documentation should be easily accessible from a central location in order to be reviewed electronically.

The following pre-visit questions are arranged by flood standard groups.

## GENERAL FLOOD STANDARDS – Mark Johnson, Leader

### GF-1 Scope of the Flood Model and Its Implementation*

*(*Significant Revision)*

***A. The flood model shall project loss costs and probable maximum loss levels for primary damage to insured personal residential property from flood events.***

***B. A documented process shall be maintained to assure continual agreement and correct correspondence of databases, data files, and computer source code to presentation materials, scientific and technical literature, and modeling organization documents.***

***C. All software, data, and flowcharts (1) located within the flood model, (2) used to validate the flood model, (3) used to project modeled flood loss costs and flood probable maximum loss levels, and (4) used to create forms required by the Commission in the Flood Standards Report of Activities shall fall within the scope of the Computer/Information Flood Standards and shall be located in centralized, model-level file areas.***

***D. Differences between historical and modeled flood losses shall be reasonable, given available flood loss data.***

***E. Vintage of data, code, and scientific and technical literature used shall be justifiable.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

1. GF-1.2, page 17: Explain what is meant by residuals and how they are calculated. Provide the formula.

   Reviewed the equation for residuals.

2. GF-1.2, pages 17 and 21: Discuss how the model accounts for missing peaks occurring between the 60-minute time step in surface water and riverine flooding. Explain how this 60-minute time step relates to the 5-minute interval in the storm surge model.

   Discussed the 60-minute time step for surface flooding and riverine flooding, and relation to the 5-minute time step used for storm surge footprint generation.

3. GF-1.2, page 17: Provide a map showing the sub-basins used to model surface water flooding, and the supporting topographic data.

   Reviewed a map of the sub-basins in Florida for modeling surface flooding. Reviewed a corresponding map of the Digital Elevation Model (DEM) data in Florida. Reviewed the same maps for a specific sub-basin in Florida.

4. GF-1.2, page 19: Plot observed Rmax versus calculated Rmax. Demonstrate the goodness of fit of the distribution for Rmax.

   Reviewed comparison of modeled and historical Rmax. Reviewed a goodness-of-fit test for the cumulative distribution function for Rmax.

5. GF-1.2, page 21: Provide equations and figures explaining the calculated peak surge adjustment factors that account for storm forward speed, track direction with respect to the coast, and local bathymetry.

   Reviewed the calculation for a translation factor to account for changes in peak surge due to the speed and angle of approach that a hurricane takes relative to the coastline.

   Discussed the near shore adjustment factors used to capture the impacts of water depth in the ocean near the coastline on peak storm surge heights.

   Reviewed plot illustrating the impact of translation factors on peak storm surge.

   Reviewed an example file for the calculation of storm surge height that was updated during the review to include the near-shore factor.

   Reviewed the near-shore factor input file.

6. GF-1.2, page 21: Justify the use of 2,400 storm surge and storm tide measurements drawn from 23 hurricanes. Indicate the number of measurements per hurricane.

   Discussed the analysis of storm surge data and storm dates for 23 U.S. tropical cyclones. Discussed the criteria for selecting the 23 events from historical events. Reviewed the list of tropical cyclones and the number of observations for each.

7. GF-1.8, page 53: Discuss how urban drainage impacts are incorporated into the water balance model.

   Reviewed an illustration of the water balance model.

   Reviewed the equation for the impervious fraction of each catchment and the urban drainage term in each watershed in Florida.

Reviewed a map of the National Land Cover Database (NLCD) 2019 impervious area in Florida. Reviewed a specific area in southeast Florida in detail.

8. GF-1.8.B, page 53, Table 1: Regarding the 6.3% change due to Hazard, attribute the contribution to this change among changes to the coastal flood hazard, inland flood hazard, and flood extent or depth.

   Reviewed the changes in modeled average annual loss (AAL) due to changes in the coastal and inland flood hazards. Discussed the correlation between changes in flood extent and depth to changes in AAL.

9. GF-1.8.C, pages 54-56: Explain Figures 5-8, including maximum and minimum points. Explain the change in Lake County. Provide Figures 5-8 with numerical values superimposed on each county.

   Reviewed Figures 5-8 with the percent difference in flood loss costs given for each county. Discussed the reasons for the loss cost increases, decreases, maximum values, and minimum values for each figure.

   Reviewed the increases in county-level loss costs relative to the current accepted model in Gilchrist and Columbia counties while adjacent counties show decreases.

   Reviewed details on the hazard change in Broward and Palm Beach counties.

10. GF-1.8.C, page 54: Explain why Gulf Coast counties in Figure 5 generally show an increase in Hazard, while Atlantic Coast counties generally show a decrease (exceptions: Miami-Dade, Martin, St. Lucie, Volusia).

    Discussed the reasons for the loss cost increases and decreases between the Gulf Coast and the Atlantic Coast depicted in Figure 5.

11. GF-1.8.C, page 54, Figure 5: Provide a map that demonstrates percent difference due to change in hazard by watersheds or drainage basins used in the model, rather than by county. Discuss the rationale for those areas with large differences, including the maximum and minimum.

    Reviewed a map of the percentage change in loss costs due to the model hazard updates for the 6 sub-basins affecting Florida. Discussed the reasons for the loss cost increases and decreases by sub-basin.

## Audit

1. Automated procedures used to create forms will be reviewed.

   Discussed the automated procedures to create the various submission forms. Reviewed the interface for selecting forms creation. Reviewed script that produces Form AF-1.

2. All primary scientific and technical literature that describes the underlying flood model theory and implementation (where applicable) should be available for review in hard copy or electronic form. Modeling-organization-specific publications cited must be available for review in hard copy or electronic form.

   All references were available electronically and were reviewed as necessary. Discussed the reasons for the addition and removal of several references.

3. Compliance with the process prescribed in Flood Standard GF-1.B in all stages of the flood modeling process will be reviewed.

   Reviewed the documented process for assuring continual agreement and correct correspondence of databases, data files, and computer source code to slides and technical papers. Reviewed several examples throughout the course of the audit.

4. Items specified in Flood Standard GF-1.C will be reviewed as part of the Computer/ Information Flood Standards.

   Reviewed a summary of all externally acquired flood-model-specific software and data assets.

   All data used in the generation of the submission documentation was available for review. Reviewed a sampling of the hazard, vulnerability, and exposure related datasets.

5. Maps, databases, and data files relevant to the modeling organization's submission will be reviewed.

   All maps, databases, and data files were available for review. Reviewed samples throughout the course of the audit.

6. Justification for the differences in modeled versus historical flood losses will be reviewed, recognizing that flood loss data may be limited to internal or proprietary datasets.

   Reviewed comparisons of modeled losses to insurer flood losses for coastal, inland, and combined events. Discussed the reasons for the differences between the historical and modeled flood losses. The differences appear reasonable and some differences are to be expected due to inconsistent reporting of flood losses as well as the reliability of the historical flood loss data.

7. Justification for the vintage of data, code, and scientific and technical literature used will be reviewed.

   Discussed the justification for the vintage of model component data, the RiskInsight® platform code base, and technical literature.

8. The modeling-organization-specified, predetermined, and comprehensive exposure dataset used for projecting personal residential flood loss costs and flood probable maximum loss levels will be reviewed.

   Reviewed the development and key elements of the KCC comprehensive exposure dataset.

9. The following information related to changes in the flood model, since the initial submission for each subsequent revision of the submission, will be reviewed.
   A. Flood model changes:
      1. A summary description of changes that affect, or are believed to affect, the personal residential flood loss costs or flood probable maximum loss levels,
      2. A list of all other changes, and
      3. The rationale for each change.
   B. Percentage difference in average annual zero deductible statewide flood loss costs based on a modeling-organization-specified, predetermined, and comprehensive exposure dataset for:
      1. All changes combined, and
      2. Each individual flood model component and subcomponent change.
   . For any modifications to Form AF-4, Flood Output Ranges, since the initial submission, a newly completed Form AF-5, Percentage Change in Flood Output Ranges, with:
      1. The initial submission as the baseline for computing the percentage changes, and
      2. Any intermediate revisions as the baseline for computing the percentage changes.
   D. Color-coded maps by rating area or zone reflecting the percentage difference in average annual zero deductible statewide flood loss costs based on the modeling-organization-specified, predetermined, and comprehensive exposure dataset for each flood model component change, between:
      1. The currently accepted flood model and the revised flood model,
      2. The initial submission and the revised submission, and
      3. Any intermediate revisions and the revised submission.

   Confirmed there have been no changes to the flood model since the initial submission.

## GF-2 Qualifications of Modeling Organization Personnel and Consultants Engaged in Development of the Flood Model*

*(*Significant Revision)*

***A. Flood model construction, testing, and evaluation shall be performed by modeling organization personnel or consultants who possess the necessary skills, formal education, and experience to develop the relevant components for flood loss projection methodologies.***

***B. The flood model and flood model submission documentation shall be reviewed by modeling organization personnel or consultants in the following professional disciplines with requisite experience: hydrology and hydraulics (advanced degree or currently licensed Professional Engineer, with experience in coastal and inland flooding), meteorology (advanced degree), statistics (advanced degree or equivalent experience), structural engineering (currently licensed Professional Engineer, with experience in the effects of coastal and inland flooding on buildings), actuarial science (Associate or Fellow of Casualty Actuarial Society or Society of Actuaries), and computer/information science (advanced degree or equivalent experience and certifications). These individuals shall certify Expert Certification Forms GF-1 through GF-7 as applicable.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

12. GF-2.2.A, pages 59-67: Provide, electronically only, resumes of new personnel since the previous flood model review.

Reviewed resumes of new personnel and consultants:

- Benjamin Aiken, M.S. in Urban Spatial Analytics, University of Pennsylvania, Philadelphia, PA; M.S. in Teaching, Texas Wesleyan University, Ft. Worth, TX; B. Design in Architecture, Washington University, St. Louis, MO
- Kelly Flanigan, M.S. in Climate and Society, University of Miami, Coral Gables, FL; B.S. in Atmospheric Sciences, University of Miami, Coral Gables, FL
- Shaoning Li, Ph.D. in Civil (Wind) Engineering, Northeastern University, Boston, MA; M.S. in Civil (Structural) Engineering, Northeastern University, Boston, MA; B.S. in Civil Engineering, China Agricultural University, Beijing, China

- Yingzhao Ma, Ph.D. in Physical Geography, Chinese Academy of Sciences, Beijing, China; B.E. in Geographic Information Systems, Zhengzhou University, Zhengzhou, China

- Farzam Maleki, Ph.D. in Civil Engineering, Clemson University, Clemson, SC; M.S. in Offshore Engineering, Amirkabir University of Technology, Tehran, Iran; B.S. in Civil Engineering, Azad University, Semnan, Iran

- Melinda Vasecka, B.A. in Mathematics, University of Minnesota, Minneapolis, MN

- Nick Weed, B.A. in Computer Science and Chinese, Williams College, Williamstown, MA

- Hongyu Wu, Ph.D. in Statistics, Florida State University, Tallahassee, FL; M.S. in Actuarial Science, Boston University, Boston, MA; B.S. in Finance, Guangdong University of Finance, Guangdong, China

**Audit**

1. The professional vitae of personnel and consultants engaged in the development of the flood model and responsible for the current flood model and the submission will be reviewed. Background information on the professional credentials and the requisite experience of individuals providing testimonial letters in the submission will be reviewed.

   See above for resumes reviewed.

2. Forms GF-1, General Flood Standards Expert Certification, GF-2, Meteorological Flood Standards Expert Certification, GF-3, Hydrological and Hydraulic Flood Standards Expert Certification, GF-4, Statistical Flood Standards Expert Certification, GF-5, Vulnerability Flood Standards Expert Certification, GF-6, Actuarial Flood Standards Expert Certification, GF-7, Computer/Information Flood Standards Expert Certification, and all independent peer reviews of the flood model under consideration will be reviewed. Signatories on the individual forms will be required to provide a description of their review process.

   Discussed the background expertise of Dr. Ma, the H&H Flood Standards signatory to confirm his qualifications for signing Form GF-3. Discussed the process Dr. Wu, the Statistical Flood Standards signatory, used to feel comfortable in signing Form GF-4.

3. Incidents where modeling organization personnel or consultants have been found to have failed to abide by the standards of professional conduct adopted by their profession will be discussed.

   Discussed that there were no departures of personnel attributable to violations of professional standards.

4. For each individual listed under Disclosure 2.A, specific information as to any consulting activities and any relationship with an insurer, reinsurer, trade association, governmental entity, consumer group, or other advocacy group within the previous four years will be reviewed.

   Discussed that no KCC professional has conducted any consulting activities or maintained a relationship with the entities listed in Audit 4 within the previous four years.

## GF-3 Insured Exposure Location*

*(*Significant Revision)*

***A. ZIP Codes used in the flood model shall not differ from the United States Postal Service publication date by more than 48 months at the date of submission of the flood model. ZIP Code information shall originate from the United States Postal Service.***

***B. Horizontal location information used by the modeling organization shall be verified by the modeling organization for accuracy and timeliness and linked to the personal residential structure where available. The publication date of the horizontal location data shall be no more than 48 months prior to the date of submission of the flood model. The horizontal location information data source shall be documented and updated.***

***C. If any flood model components are dependent on databases pertaining to location, a logical process shall be maintained for ensuring these components are consistent with the horizontal location database updates.***

***D. Geocoding methodology shall be justified.***

***E. Use and conversion of horizontal and vertical projections and datum references shall be consistent and justified.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

13. GF-3.E, page 71: The vertical datum of the digital elevation model (DEM) is referenced as the International Great Lakes Datum of 1985 (IGLD85) in MF-1.3 on page 78. The submission states this is consistent with North American Vertical Datum of 1998 (NAVD88) on page 71, but in MF-2.11 on page 85 states that the DEM is processed to NAVD88. Discuss the differences in the vertical datum of the model's various elevation-based datasets, including DEM and United States Geological Survey (USGS) gauge data, and how the model addresses these various datum. Explain how 10cm (the usual difference between IGLD85 and NAVD88) does not affect the loss modeling results.

    Discussed that all parameters in the flood model use World Geodetic System of 1984 (WGS84) and NAVD88 as the horizontal and vertical datums references. The reference to the datum was updated in the April revised submission.

14. GF-3.9, page 74: Identify and discuss the third-party software used for horizontal projection and datum conversions.

    Discussed the third-party software used to convert different horizontal datum to WGS84. Reviewed an example conversion for different coordinate systems.

**Audit**

1. Geographic displays of the spatial distribution of insured exposures will be reviewed. The treatment of any variations for populated versus unpopulated areas will be reviewed.

    Reviewed maps and images of geo-cluster centroids.

    Discussed the maximum number of single-family homes in a cluster in the exposure dataset. Reviewed the formula for determining the number of clusters within a group. Reviewed the basis for setting the occupancy threshold. Discussed the algorithm for determining the size of the clusters. Reviewed an example showing the output of the clustering code. Reviewed exhibits showing how centroids within water bodies are avoided.

2. Third party vendor information, if applicable, and a complete description of the process used to create, validate, and justify geographic grids will be reviewed.

    Discussed the review and validation of third-party ZIP Code data. Discussed the reason for the change in third-party vendor to Claritas.

3. The treatment of exposures over water or other uninhabitable terrain will be reviewed.

    Discussed the methodology used to ensure no exposure points fall over water or other uninhabitable terrains.

    Reviewed several quality checks on the datasets.

4. The process for geocoding complete and incomplete street addresses will be reviewed.

    Discussed the process for geocoding user-provided invalid address data or geocodes and the process that further validates user-provided valid address data. Reviewed stress test examples showing how a variety of input data is resolved.

5. Flood model geocode location databases will be reviewed.

    Reviewed geocode location databases and how they are hosted in the model. Discussed other spatial and non-spatial databases created and used in the development of the model and the modeler exposure dataset.

Discussed the quality control review performed on the NFIP redacted policies dataset. Reviewed examples of the processed NFIP data.

## GF-4 Independence of Flood Model Components

***The meteorology, hydrology and hydraulics, vulnerability, and actuarial components of the flood model shall each be theoretically sound without compensation for potential bias from other components.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

15. GF-4, page 75: Elaborate on "other methods" in the final paragraph.

Agreed with their rationale for the deletion of "other methods" in the April revised submission.

**Audit**

1. The flood model components will be reviewed for adequately portraying flood phenomena and effects (damage, flood loss costs, and flood probable maximum loss levels). Attention will be paid to an assessment of (1) the theoretical soundness of each component, (2) the basis of the integration of each component into the flood model, and (3) consistency between the results of one component and another.

   Reviewed flowcharts of the major model components in the flood model and the workflow for flood model development.

   Reviewed the theoretical soundness, integration of components, and consistency across components throughout the course of the audit.

   There was no evidence to suggest that one component of the model was deliberately adjusted to compensate for another component.

## GF-5 Editorial Compliance

***The flood model submission and any revisions provided to the Commission throughout the review process shall be reviewed and edited by a person or persons with experience in reviewing technical documents who shall certify on Form GF-8, Editorial Review Expert Certification, that the flood model submission has been personally reviewed and is editorially correct.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. An assessment that the person who has reviewed the flood model submission has experience in reviewing technical documentation and that such person is familiar with the flood model submission requirements as set forth in the *Flood Standards Report of Activities as of November 1, 2021* will be made.

   Discussed the experience of the Technical Writer who reviewed the submission document.

2. Attestation that the flood model submission has been reviewed for grammatical correctness, typographical accuracy, completeness, and no inclusion of extraneous data or materials will be assessed.

   KCC confirmed that the flood model submission was reviewed throughout the development process for grammatical correctness, typographical accuracy, completeness, and no inclusion of extraneous data or materials.

3. Confirmation that the flood model submission has been reviewed by the signatories on the Expert Certification Forms GF-1 through GF-7 for accuracy and completeness will be assessed.

   KCC confirmed that subject matter experts reviewed all submitted materials for completeness and accuracy.

4. The modification history for flood model submission documentation will be reviewed.

   Discussed the process for preparing, reviewing, revising, and tracking revisions to the submission documentation. Reviewed the submission documentation modification history.

5. A flowchart defining the process for form creation will be reviewed.

   Reviewed a flowchart of the process for submission form creation.

6. Form GF-8, Editorial Review Expert Certification, will be reviewed.

Reviewed Form GF-8.

Editorial items noted in the pre-visit letter and during the on-site review by the Professional Team were satisfactorily addressed during the audit. The Professional Team has reviewed the submission per Audit item 3, but cannot guarantee that all editorial difficulties have been identified. The modeler is responsible for eliminating such errors.

## METEOROLOGICAL FLOOD STANDARDS – JIMMY BOOTH, LEADER

### MF-1 Flood Event Data Sources*

*(*Significant Revision)*

***A. The modeling of floods in Florida shall involve meteorological, hydrological, hydraulic, and other relevant data sources required to model coastal and inland flooding.***

***B. The flood model shall incorporate relevant data sources in order to account for meteorological, hydrological, and hydraulic events and circumstances occurring either inside or outside of Florida that result in, or contribute to, flooding in Florida.***

***C. Coastal and inland flood model calibration and validation shall be justified based upon historical data consistent with peer reviewed or publicly developed data sources.***

***D. Any trends, weighting, or partitioning shall be justified and consistent with current scientific and technical literature.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

16. MF-1.7, page 78: Discuss how the different rainfall data time steps and resolution (e.g., Climate Prediction Center (CPC) daily rainfall data at 0.25° resolution, National Center for Environmental Protection (NCEP) hourly rainfall data at 4km resolution) are reconciled and utilized in the model.

    Discussed how the CPC daily rainfall data and the NCEP hourly rainfall data are used in the model, with a code dive for the hourly data.

    Reviewed a plot of hourly precipitation rates for different event durations.

    Determined how hourly data is utilized in the inland flood component.

    Reviewed examples in North Florida and South Florida demonstrating how the flood model captures high-intensity, short duration events.

## Audit

1. The modeling organization's data sources will be reviewed.

   Reviewed and discussed several of the flood-event data sources used to develop and implement flood event frequencies and characteristics for coastal and inland flooding.

   Determined that hourly precipitation data is used in the model, but not for modeling flood frequencies.

2. Changes to the modeling organization's data sources from the currently accepted flood model will be reviewed.

   Discussed updates to the CPC and HURDAT2 datasets to include data through 2021 and the additional usage of NHC Tropical Cyclone Reports to extend storm surge data beyond what is currently available in SURGEDAT.

3. Justification for any modification, partitioning, or adjustment to historical data and the impact on flood model parameters and characteristics will be reviewed.

   Discussed that historical daily precipitation data are not modified, partitioned, or adjusted during the development of the model flood climatology.

   Discussed that the storm surge event catalog intensity distributions are developed using hurricane landfall event intensity data that have been adjusted for the effects of climate change.

   Clarified how sea level rise is incorporated into modeled storm tides.

   Clarified that surge model development involves two components that are developed with different (but overlapping) observation-based surge datasets: the peak surge and the coastal profile of surge.

4. The method and process used for calibration and validation of the flood model, including adjustments to input parameters, will be reviewed.

   Reviewed the methodology for calculating peak storm surge.

   Reviewed a plot of modeled peak surge compared to historical SURGEDAT and NHC Tropical Cyclone Report surge observations.

   Reviewed the factors used to account for changes in peak surge due to the speed and angle of approach that a tropical cyclone takes relative to the coastline.

Discussed the change in methodology for storm surge heights for exiting storms and bypassing storms. Reviewed comparisons to the current accepted model of storm surge heights for Hurricane Wilma (2005) and Hurricane Matthew (2016).

Reviewed a plot from the surge profile analysis of the storm surge coastal profile shape.

Discussed how historical storm tide data is used for validation. Reviewed validation illustrations.

Discussed inland flood model calibration and validation using USGS gauge data and flood inundation reports.

Reviewed comparison of modeled flow to USGS flow for a river discharge flood event.

Reviewed a map of USGS stream gauge locations affecting Florida.

Reviewed validation illustrations of inland flood footprints compared to NOAA storm data.

5. Any treatment of projected changes in sea level, precipitation, and storm characteristics will be reviewed.

Discussed that the flood model does not include treatment of projected changes in sea level, precipitation, or other storm characteristics.

## MF-2 Flood Parameters (Inputs)*

*(*Significant Revision)*

***A. The flood model shall be developed with consideration given to flood parameters that are scientifically appropriate for modeling coastal and inland flooding. The modeling organization shall justify the use of all flood parameters based on information documented in current scientific and technical literature.***

***B. Differences in the treatment of flood parameters between historical and stochastic events shall be justified.***

***C. Grid cell size(s) used in the flood model shall be justified.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

17. MF-2.1, page 80: Justify the relationship between translation speed and storm surge.

Discussed their choice of focusing on the relationship between translation speed and storm surge height demonstrated in Rego and Li (2009) and Irish et al. (2008).

Had a back-and-forth commentary on the possible considerations of translation speed and fetch.

18. MF-2.2, pages 81-82: Provide a plot for a location near Miami and a location near Jacksonville, of:
    a. Modeled maximum surge versus Vmax at time of maximum surge (one point in the plot per event),
    b. Modeled maximum surge versus central pressure minimum at time of maximum surge (one point in the plot per event),
    c. Modeled maximum surge versus modeled Rmax at time of maximum surge (one point in the plot per event), and
    d. Modeled maximum surge versus storm distance to coast at time of maximum surge (one point in the plot per event). In terms of the modeled storm center location relative to land, identify when modeling of storm surge begins.

Reviewed plots for a location near Miami and a location near Jacksonville of maximum storm surge versus Vmax, maximum storm surge versus central pressure, maximum storm surge versus Rmax, and maximum storm surge versus distance to coast. This made clear how their model captures some sensitivities relevant to flooding from storm surge. See further discussion under Standard SF-2.

Discussed the distance before landfall when modeling of storm surge begins.

Reviewed plots that illustrated the logical relationships in storm characteristics and modeled storm tide, and their similarities.

19. MF-2.2, page 82: Discuss how the minimum event duration of 1 day captures flooding and flood damage from short, high-intensity rainfall events.

    Discussed how the model rainfall captures the peak hourly rates of short, high-intensity rainfall events. Reviewed a graphical representation of hourly precipitation for a one-day duration event.

20. MF-2.6, page 84: Provide a map showing the rainfall locations used in the model and the basins affecting Florida.

    Reviewed a map of the spatial distribution of event center point locations within watersheds affecting Florida.

21. MF-2.6, page 84: Explain how rainfall rates are included in the total precipitation calculation.

    Discussed the relationship between total precipitation, rainfall rates, spatial extent, and duration.

22. MF-2.11, page 85: Explain how the bathymetry elevation data, referenced to “mean low water” datum, is integrated with the other elevation data used in the model which is referenced to different datum.

    Discussed that bathymetry data and other data sources are used to develop the near shore factors.

23. MF-2.11, page 85: Discuss how the mean relative vertical accuracy of the DEM of 2.6ft (0.81m) impacts modeled flood footprints and depth.

    Discussed that, in general, the overall vertical inaccuracies of the DEM are lower in low-slope, non-mountainous areas, such as the state of Florida. Discussed the methodology to minimize the impact of vertical inaccuracies in the DEM.

**Audit**

1. All flood parameters used in the flood model will be reviewed.

    Discussed the different parameters used in the flood model. Several analyses were reviewed.

2. For explicit representation of precipitation, data sources, calibration, and evaluation will be reviewed.

   Reviewed the precipitation and rainfall rate data sources, the methodology for defining precipitation events using the data sources, and the process for determining event characteristics.

   Reviewed the procedure to determine spatial extent of rainfall-event ellipses in the stochastic catalog and its relationship with rainfall amount in the historical data.

   Reviewed historical precipitation event data.

3. For implicit representation of precipitation, justification, data sources, method, and implementation will be reviewed.

   Discussed that precipitation is represented explicitly in the flood model.

4. Graphical depictions of flood parameters as used in the flood model will be reviewed. Descriptions and justification of the following will be reviewed:
   a. The dataset basis for any fitted distributions, the methods used, and any smoothing techniques employed,
   b. The modeled dependencies among correlated parameters in the flood model and how they are represented, and
   c. The dependencies between the coastal and inland flooding analyses.

   Reviewed distribution fit of historical and modeled Vmax.

   Reviewed the relationship between Vmax and central pressure.

   Reviewed the calculation of central pressure from windspeed, used for calculating storm surge heights.

   Reviewed the relationship between Rmax and Vmax.

   Reviewed comparison of modeled and historical forward speed.

   Reviewed comparisons of modeled and historical precipitation amount.

   Reviewed the relationship between precipitation amount and event duration.

   Reviewed comparisons of modeled and historical event duration.

   Reviewed the relationship between precipitation amount and spatial extent.

   Reviewed comparisons of historical and modeled functions for spatial extent.

Reviewed that their choice to divide precipitation modeling for north/south Florida is based on considerations for relative roles of extratropical versus tropical cyclones in precipitation events in the daily data.

Reviewed the selected distributions for precipitation event duration and precipitation event spatial extent as part of the linear regression model.

5. Scientific and technical literature cited in Flood Standard GF-1, Scope of the Flood Model and Its Implementation, may be reviewed to determine applicability.

Meteorological references were available electronically and were reviewed as necessary.

6. The initial and boundary conditions for coastal flood events will be reviewed.

Reviewed the initial and boundary conditions for coastal flood events. Reviewed maps of the bay adjustment factors and near-shore adjustment factors.

Clarified that tidal levels can be specified by the user.

Discussed that infrastructure failure can be specified by the user.

Reviewed a modeled 100-year flood map compared to the FEMA 100-year flood map for both coastal and inland flooding.

7. The basis or dependence of flood model parameters on NFIP FIRM or other FIS data will be reviewed.

Discussed that the flood model parameters do not depend on NFIP FIRM or other FIS data.

## MF-3 Wind and Pressure Fields for Storm Surge*

*(*Significant Revision)*

***A. Modeling of wind and pressure fields shall be employed to drive storm surge models due to tropical cyclones.***

***B. The wind and pressure fields shall be based on current scientific and technical literature or developed using scientifically defensible methods.***

***C. Physically-based simulation of atmosphere-ocean interactions resulting in storm surge shall be conducted over a sufficiently large domain that storm surge height has converged.***

***D. The features of modeled wind and pressure fields shall be consistent with those of historical storms affecting Florida.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. All external data sources that affect the modeled wind and pressure fields associated with storm surge will be identified and their appropriateness reviewed.

   Reviewed the historical data sources that affect the modeled wind and pressure fields associated with storm surge.

2. Calibration and evaluation of wind and pressure fields will be reviewed. Scientific comparisons of simulated wind and pressure fields to historical storms will be reviewed.

   Discussed that wind and pressure fields are not numerically modeled for storm surge event generation.

3. The sensitivity of flood extent and depth results to changes in the representation of wind and pressure fields will be reviewed.

   Reviewed examples of peak surge and the storm surge profile.

4. The over-land evolution of simulated wind and pressure fields and its impact on the simulated flooding will be reviewed.

   Reviewed time series of overland coastal surge estimates. Reviewed the process for recording the maximum event surge at each coastal location.

5. The derivation of surface water wind stress from surface windspeed will be reviewed. If a sea-surface drag coefficient is employed, how it is related to the surface windspeed will be reviewed. A comparison of the sea-surface drag coefficient to coefficients from current scientific and technical literature will be reviewed.

   Discussed that surface water wind stress is not explicitly modeled.

6. The uncertainties in the factors used to convert from a reference windfield to a geographic distribution of surface winds and the impact of the resulting winds upon the storm surge will be reviewed and compared with current scientific and technical literature.

   Discussed that storm surge is calculated using central pressure, not surface winds.

## MF-4 Flood Characteristics (Outputs)*

*(*Significant Revision)*

***A. Flood extent and elevation or depth generated by the flood model shall be consistent with observed historical floods affecting Florida.***

***B. Methods for deriving flood extent and elevation or depth shall be scientifically defensible and technically sound.***

***C. Methods for modeling or approximating wave conditions in coastal flooding shall be scientifically defensible and technically sound.***

***D. Modeled flood characteristics shall be sufficient for the calculation of flood damage.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

24. MF-4.1, pages 90-91: Explain the change in location of the storm tide dots in Figures 11-13 from the current accepted model.

Reviewed revised Figures 11, 12, and 13 updated in the April revised submission to correct some of the observation values and locations from those plotted in the initial submission.

Reviewed additional revisions to Figures 11, 12, and 13 to update captions to note that footprint intensity is inundation depth above ground elevation from the USGS 3DEP DEM, and SURGEDAT storm tide observations are relative to NAVD88.

**Audit**

1. The method and supporting material for determining flood extent and elevation or depth for coastal flooding will be reviewed.

Discussed the methodology to calculate the flood extent and depth from storm surge. Clarified roles of peak surge and surge profile for events.

2. The inland propagation of coastal flood and the effect of coastal flood propagation on inland flood will be reviewed.

Discussed that the coastal and inland flood model components are treated independently, and there are no effects of coastal flood propagation on the inland flood.

3. Any modeling-organization-specific research performed to calculate the flood extent and elevation or depth and wave conditions will be reviewed, along with the associated databases.

   Discussed that no modeling-organization-specific research was performed to calculate the flood extent and depth from storm surge.

4. Historical data used as the basis for the flood model flood extent and elevation or depth will be reviewed. Historical data used as the basis for the flood model flood velocity, as available, will be reviewed.

   Discussed the historical data used as the basis for the flood extent and depth.

5. The comparison of the calculated characteristics with historical flood events will be reviewed. The selected locations and corresponding storm events will be reviewed to verify sufficient representation of the varied geographic areas. If a single storm is used for both coastal and inland flooding validation, then its appropriateness will be reviewed.

   Reviewed scatter plot of modeled peak surge compared to historical SURGEDAT observations.

   Reviewed maps comparing observed storm surge heights along the coastline with modeled storm surge heights for Hurricane Andrew (1992), Hurricane Ivan (2004), and Hurricane Matthew (2016).

   Reviewed map comparing NOAA storm data with the inland flood inundation footprint for Tropical Storm Fay (2008).

6. Consistency of the flood model stochastic flood extent and elevation or depth with reference to the historical flood databases will be reviewed. Consistency of the flood model stochastic flood velocity, as available, with reference to the historical flood databases will be reviewed.

   Reviewed comparison of the annual frequency of peak surge to historical peak surge data.

   Reviewed comparisons of the modeled 100-year flood footprint with the FEMA 100-year flood map for two counties. Discussed how the comparison validated the modeled results and demonstrated consistency.

7. Form HHF-2, Coastal Flood Characteristics by Annual Exceedance Probability, and Form HHF-3, Coastal Flood Characteristics by Annual Exceedance Probabilities (Trade Secret Item), will be reviewed.

   Reviewed return period maps for Bay, Lee, Miami-Dade, St. Lucie, and St. Johns Counties.

8. Modeled frequencies will be compared with the observed spatial distribution of flood frequencies across Florida using methods documented in current scientific and technical literature. The comparison of modeled to historical statewide and regional coastal flood frequencies as provided in Form HHF-2, Coastal Flood Characteristics by Annual Exceedance Probability, and Form HHF-3, Coastal Flood Characteristics by Annual Exceedance Probabilities (Trade Secret Item), will be reviewed.

   Reviewed maps of historical maximum, 0.01 and 0.002 annual exceedance probability flood frequencies for Bay, Lee, Miami-Dade, St. Lucie, and St. Johns Counties.

   Reviewed Form HHF-3 updated during the review to add FEMA 500-year return periods to the 0.002 probability flood zone maps.

9. Comparison of 0.01 and 0.002 annual exceedance probability flood extents produced by the flood model with those from the Federal Emergency Management Agency (FEMA) will be reviewed.

   Reviewed comparisons of 0.01 and 0.002 annual exceedance return period maps for Bay, Lee, Miami-Dade, St. Lucie, and St. Johns Counties to FEMA maps.

   Reviewed a combined coastal and inland flood return period map for Bay County.

   Reviewed flood return period maps for Bay County (inland flood) and Lee County (coastal flood) comparing to the FEMA 100 and 500-year return periods.

10. Temporal evolution of coastal flood characteristics will be reviewed. (Trade Secret Item to be provided during the closed meeting portion of the Commission meeting to review the flood model for acceptability.)

    Reviewed a temporal illustration of coastal inundation depth.

11. Comparisons of the flood flow calculated in the flood model with records from United States Geological Survey (USGS) or Florida Water Management District (FWMD) gauging stations will be reviewed.

    Reviewed comparisons of modeled river discharge to USGS gauge site data for a July 2013 flood event.

12. Calculation of relevant characteristics in the flood model, such as flood extent, elevation or depth, and waves, will be reviewed. The methods by which each flood model component utilizes the characteristics of other flood model components will be reviewed.

    Reviewed the calculation for peak surge and the storm surge profile at coastal points for each 5-minute point on the tropical cyclone track. Discussed inundation from the coastal points, the storm surge attenuation rate, and the flood-fill algorithm.

Reviewed storm surge intensity footprints with and without ponding. Discussed removal of ponding as an artifact not attributed to a water source.

Reviewed a map of storm surge model coastal locations for a select area in southeast Florida.

Discussed the calculation of flood extent from each channel location. Reviewed an illustration of flooding along the Peace River during Hurricane Irma (2017) illustrating the methodology.

Reviewed the methodology for calculating the flood extent and depth from surface water flow.

13. The modeled coincidence and interaction of inland and coastal flooding will be reviewed. If it is not modeled, justification will be reviewed.

Discussed that the coastal flood model and the inland flood model are independent models which generate separate footprints.

Impacts of flooding at locations affected by both coastal and inland flood are accounted for in the financial component of the model.

14. The basis or dependence of modeled flood characteristics on NFIP FIRM or other FIS data will be reviewed.

Discussed that modeled flood characteristics do not depend on NFIP FIRM or other FIS data.

## MF-5 Flood Probability Distributions

***A. Flood probability, its geographic variation, and the associated flood extent and elevation or depth shall be scientifically defensible and shall be consistent with flooding observed for Florida.***

***B. Flood probability distributions for storm tide affected areas shall include tropical, and if modeled, non-tropical events.***

***C. Probability distributions for coastal wave conditions, if modeled, shall arise from the same events as the storm tide modeling.***

***D. Any additional probability distributions of flood parameters and modeled characteristics shall be consistent with historical floods for Florida resulting from coastal and inland flooding.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

25. MF-5.3, page 97: Provide uncertainty bands for the curves in Figure 16, and the datum for the vertical axis.

    Reviewed return period plots for Cedar Key and Ft. Myers exceedance probabilities with the uncertainty bands plotted. The datum referenced by the vertical axis in Figure 16 is mean sea level.

Discussed the model's progression for storm surge from their first step to implementation of near-shore factors, with examination of equations.

Reviewed detailed flowcharts for inland and coastal flood events within the flood model.

Clarified how inclusion of urban drainage impacts model loss cost changes related to flood hazard.

## Audit

1. The consistency in accounting for similar flood parameters and characteristics across Florida and segments in adjacent states will be reviewed.

   Reviewed hurricane frequency and intensity distributions by landfall location and track direction at landfall. Discussed that this is the same hurricane event set as in the current accepted hurricane model.

   Reviewed the goodness-of-fit tests on Rmax and forward speed values for adjacent states.

   Reviewed comparisons of modeled and observed overland decay in adjacent states.

   Reviewed grid of the spatial distribution of event center locations for model precipitation events.

2. The method and supporting material for generating stochastic coastal and inland flood events will be reviewed.

   Reviewed the process for selecting model flood events using a joint probability method with a ternary tree structure. The hierarchy of the ternary tree is determined through the results of sensitivity tests. Reviewed the criteria defining events in the model event catalog.

   Reviewed the 60-day spin-up period used to generate initial water balance conditions for a flood event and the distribution fit for precipitation used for model initialization.

   Reviewed the process for creating model inland flood footprints. Reviewed maps of example precipitation events.

   Discussed that footprints are generated for all coastal flood events in the stochastic catalog using the same methodology as for historical storm surge events.

3. Any modeling-organization-specific research performed to develop the functions used for simulating flood model characteristics or to develop flood databases will be reviewed.

   Discussed that no modeling-organization-specific research was performed to develop the functions used for simulating flood model characteristics or to develop flood databases.

4. Form SF-1, Distributions of Stochastic Flood Parameters (Coastal, Inland), will be reviewed.

   The coastal and inland flooding distributions for stochastic flood parameters in Form SF-1 were reviewed under the statistical flood standards.

5. Comparisons of modeled flood probabilities and characteristics for coastal and inland flooding against the available historical record will be reviewed. Modeled probabilities from any subset, trend, or fitted function will be reviewed, compared, and justified against this historical record. In the case of partitioning, modeled probabilities from the partition and its complement will be reviewed and compared with the complete historical record.

   Reviewed comparison of modeled to observed annual frequency of peak surge.

   Reviewed comparison of modeled to historical coastal flood exceedance probabilities for Ft. Myers and Cedar Key.

   Reviewed 50-year return period flood map for a location in Seminole County.

## HYDROLOGICAL AND HYDRAULIC FLOOD STANDARDS – DEL SCHWALLS, LEADER

### HHF-1 Flood Parameters (Inputs)*

*(*Significant Revision)*

***A. Treatment of land use and land cover (LULC) effects shall be consistent with current scientific and technical literature. Any LULC database used shall be consistent with the National Land Cover Database (NLCD) 2016 or later. Use of alternate datasets shall be justified.***

***B. Treatment of soil effects on inland flooding shall be consistent with current scientific and technical literature.***

***C. Treatment of watersheds and hydrologic basins shall be consistent with current scientific and technical literature.***

***D. Treatment of hydraulic systems, including conveyance, storage, and hydraulic structures, shall be consistent with current scientific and technical literature.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

26. HHF-1.5, page 100: The submission states that all parameters in the model use the same horizontal and vertical datum references (page 74), World Geodetic System 1984 (WGS84) and NAVD88, respectively. The submission also states that other horizontal datum were converted to WGS84 using third-party software and other vertical datum were converted to NAVD88 using NOAA Orthometric Height Conversion. However, numerous sections of the submission reference data in other horizontal and vertical datum without conversion, or that the datum is similar (e.g., “and in conformance with North American Datum of 1983 (NAD83),” page 100; “which is consistent with the vertical datum of the DEM,” page 71). Discuss and address these inconsistencies in the submission and the datum of the data sets used by the model.

    The horizontal datum reference was updated to World Geodetic System 1984 (WGS84) in the April revised submission.

27. HHF-1.12, page 102: Provide a map of the watersheds and hydrologic basins generated by and used in the model, and the hydrologic connectivity.

    Reviewed maps of the watersheds and catchments used in the model. Reviewed an example of hydrologic connectivity for one of the basins.

28. HHF-1.13, page 102: Provide a map of the hydraulic network generated by and used by the model.

    Reviewed map of the model hydraulic network.

**Audit**

1. The initial and boundary conditions for flood events will be reviewed.

   Reviewed channel and catchment properties.

   Reviewed map of USGS gauges in each modeled basin. Discussed the initial and boundary conditions. Discussed initialization of water depth for surface and subsurface flow, soil moisture, and model spin-up for precipitation.

   Reviewed topographic maps of the NLCD (2019) database in Florida, the spatial distribution of soil texture, the NLCD (2019) impervious data, and the spatial distributions of runoff coefficient, surface roughness, and channel roughness.

2. The topographic representation will be reviewed.

   Reviewed topographic maps of the USGS DEM data for watersheds impacting Florida.

   Discussed the process to minimize the impact of vertical inaccuracies in the DEM on the flood footprints.

3. Any modeling-organization-specific methodology used to incorporate LULC information into the flood model will be reviewed.

   Reviewed the process for incorporating LULC information into the model.

   Reviewed channel roughness and runoff coefficient enumeration, and surface roughness enumeration.

4. Any modeling-organization-specific research performed to develop the soil infiltration and percolation rates or soil moisture conditions used in the flood model will be reviewed, if applicable.

   Discussed that no modeling-specific research was performed to develop the soil infiltration and percolation rates or soil moisture conditions.

5. The watershed and hydraulic basin boundaries in the flood model, and the methods for developing these boundaries, or any equivalent assumptions, will be reviewed.

   Reviewed maps of the model watersheds and catchment network. Discussed the process for determining and refining the boundaries.

6. The hydraulic network and treatment of hydraulic structures in the flood model will be reviewed.

   Reviewed maps of the model hydraulic network and the location of levees and major dams in Florida.

   Reviewed the water balance model.

   Discussed the use of a calibrated urban drainage term for each watershed.

   Discussed that bridges are not accounted for in the model.

7. The hydrologic and hydraulic mathematical models used will be reviewed.

   Reviewed an example water balance model file, including supporting reference files.

8. Any modeling-organization-specific research performed to develop hydrologic and hydraulic equations used in the flood model, and the variables and constants used in these equations, will be reviewed.

   Discussed that no unpublished research was applied to develop hydrologic and hydraulic equations.

9. The input files for the hydrologic and hydraulic components of the inland flood model will be reviewed.

   Reviewed the historical and stochastic catalogs for precipitation, as well as other input files.

10. The relationships between time steps used in the hydrologic and hydraulic components of the flood model will be reviewed, if applicable.

    Discussed the methodology for the 60-minute time steps used in the hydrologic and hydraulic flood model components.

11. The basis or dependence of flood parameters on NFIP FIRM or other FIS data will be reviewed, if relevant.

    Discussed that the modeled flood parameters do not depend on NFIP FIRM or other FIS data.

## HHF-2 Flood Characteristics (Outputs)*

*(*Significant Revision)*

***A. Flood extent and elevation or depth generated by the flood model shall be consistent with observed historical floods affecting Florida.***

***B. Methods for deriving flood extent and depth shall be scientifically defensible and technically sound.***

***C. Modeled flood characteristics shall be sufficient for the calculation of flood damage.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

29. HHF-2.C, page 104: Discuss the use of "maximum depth per second" as an estimate for inland flood velocity, and how that value is calculated.

    Discussed the relationships between inundation depth and flood velocity specified in FEMA (2011) which provides the upper and lower bound estimates of coastal flood velocity as functions of the inundation depths.

    Discussed how the model uses FEMA (2011) to estimate flood velocity for inland flooding.

30. HHF-2.1, pages 105-106 and 108-109, Form HHF-1, page 218: Explain the inconsistency between the legends that state, "inundation depth," and the figure captions that state, "storm tide heights," for Figures 18-21 and Figures 25-27. Explain the inconsistency between the labels and the caption for Figure 67.

    Reviewed revised Figures 18, 19, 20, 21, 25, 26, 27, and 67 and the corresponding captions that were updated in the April revised submission.

    Discussed that inundation depth in the legend of each figure represents flood footprints generated by the model. The storm tide heights in the caption of each figure stands for the observed water depths by the gauge equipment.

31. HHF-2.1, pages 106 and 108: Provide a revised Figure 20 (Jacksonville area, page 106) and a revised Figure 25 (Northeast Florida area, page 108) showing a comparison of modeled versus observations.

    Reviewed validation from Figure 20 showing a comparison of modeled versus observations for Hurricane Jeanne (2004).

    Reviewed validation from Figure 25 showing a comparison of modeled versus observations for Hurricane Matthew (2016).

34. Form HHF-1, pages 212-219: Provide Figures 57-66 with the storm tracks plotted. Provide Figure 68 with the vertical datum.

    Reviewed maps of coastal flooding for Hurricane Andrew (1992), Hurricane Ivan (2004), Hurricane Jeanne (2004), Hurricane Wilma (2005), Hurricane Matthew (2016), and Hurricane Michael (2018) with the storm track plotted. Reviewed map of Hurricane Irma (2017) coastal and inland flooding with the storm track plotted.

    Reviewed scatter plot of storm surge for historical events.

35. Form HHF-1, pages 212-217: Provide mapped model results (e.g., interactive GIS (geographic information system)) capable of being reviewed at higher resolution.

    Reviewed interactive GIS maps of coastal flooding return periods at high resolution for a selection of storm events and locations.

36. Form HHF-4, pages 227-229: Provide mapped model results (e.g., interactive GIS) capable of being reviewed at higher resolution.

    Reviewed interactive GIS maps of inland flooding at high resolution for a selection of rain events and locations.

37. Form HHF-4.B, pages 227-228, Figures 74 and 76: The Inundation Depth range upper limit of “>4ft” in the maps is much lower than the Maximum Modeled Depths. Provide Figures 74 and 76 with additional inundation depth intervals above 4ft.

    Reviewed 100-year return period inundation maps for Bay and Orange Counties with a higher resolution of inundation depth.

38. Form HHF-4.B, page 229: Figures 77 and 78 seem to indicate that both Lee County and Miami-Dade County are completely submerged during the 0.01 annual exceedance probability (AEP) event. Justify these results.

    Discussed that inundation during flood events in both Lee and Miami-Dade Counties is more widespread for relatively low depth compared to some other areas of the state.

## Audit

1. The method and supporting material for determining flood extent and elevation or depth for inland flooding will be reviewed.

   Reviewed the methodology and equations for determining flood extent and depth for inland flooding.

   Reviewed map of the inland flood intensity footprint for Suwannee River flooding in Tropical Storm Fay (2008).

2. Any modeling-organization-specific research performed to calculate the inland flood extent and elevation or depth will be reviewed along with the associated databases.

   Discussed that no unpublished research was applied to calculate the inland flood extent and elevation or depth.

3. Any modeling-organization-specific research performed to derive the hydrological characteristics associated with the topography, LULC distributions, soil conditions, watersheds, and hydrologic basins for the flood extent and elevation or depth will be reviewed.

   Discussed that no unpublished research was applied to derive hydrological characteristics.

4. Historical data used as the basis for the flood model flood extent and elevation or depth will be reviewed. Historical data used as the basis for the flood model flood flow and velocity, if applicable, will be reviewed.

   Reviewed the USGS river discharge and gauge height database for riverine flooding.

   Reviewed the NOAA historical database and the USGS high-water mark database for surface flooding.

5. The comparison of the calculated characteristics with historical inland flood events will be reviewed. The selected locations and corresponding storm events will be reviewed to verify sufficient representation of the varied geographic areas.

   Reviewed comparisons of modeled and recorded river discharge for Tropical Storm Fay (2008) and the May 2009 flood event.

   Reviewed comparisons of modeled to recorded river discharge for the July 2013 flood event for two USGS gauge sites.

6. Consistency of the flood model stochastic flood extent and elevation or depth with reference to the historical flood databases will be reviewed. Consistency of the flood model stochastic flood flow and velocity, if applicable, with reference to the historical flood databases will be reviewed.

   Reviewed the model 50-year return period flood map for a location in Seminole County.

7. Form HHF-1, Historical Event Flood Extent and Elevation or Depth Validation Maps, will be reviewed.

   Reviewed validation maps with the peak surge identified for Hurricane Andrew (1992), Hurricane Ivan (2004), Hurricane Jeanne (2004), Hurricane Wilma (2005), Tropical Storm Fay (2008), Unnamed Storm of May 2009, Unnamed Storm of July 2013, Hurricane Matthew (2016), Hurricane Irma (2017), and Hurricane Michael (2018).

8. For the historical flood events given in Form HHF-1, Historical Event Flood Extent and Elevation or Depth Validation Maps, the flood characteristics, including temporal and spatial variations contributing to modeled flood damage, will be reviewed.

   This information was reviewed in the maps under Audit 5 and Audit 7.

9. Form HHF-4, Inland Flood Characteristics by Annual Exceedance Probability, and Form HHF-5, Inland Flood Characteristics by Annual Exceedance Probabilities (Trade Secret Item), will be reviewed.

   Reviewed Forms HHF-4 and HHF-5.

   Reviewed Form HHF-5 updated during the review to add FEMA 500-year return periods to the 0.002 probability flood zone maps.

10. Modeled frequencies will be compared with the observed spatial distribution of flood frequencies across Florida using methods documented in current scientific and technical literature. The comparison of modeled to historical statewide and regional inland flood frequencies as provided in Form HHF-4, Inland Flood Characteristics by Annual Exceedance Probability, and Form HHF-5, Inland Flood Characteristics by Annual Exceedance Probabilities (Trade Secret Item), will be reviewed.

    Reviewed comparisons of modeled 100-year flood map with the FEMA flood map for Nassau and Bay Counties.

    Reviewed comparisons of modeled return period maps to historical maximum inundation for Miami-Dade and Bay Counties.

11. Comparison of 0.01 and 0.002 annual exceedance probability flood extents produced by the flood model, including both inland and coastal flood, with the flood extents from FEMA will be reviewed.

    Reviewed coastal flooding 100-year and 500-year return period maps for Bay, Lee, St. Johns, Miami-Dade, and St. Lucie Counties.

    Reviewed inland flooding 100-year and 500-year return period maps for Bay, Lee, Nassau, Miami-Dade, and Orange Counties.

12. The basis or dependence of flood characteristics on NFIP FIRM or other FIS data will be reviewed, if relevant.

    Discussed that modeled flood characteristics do not depend on NFIP FIRM or other FIS data.

13. Temporal evolution of inland flood characteristics will be reviewed, if applicable. (Trade Secret Item to be provided during the closed meeting portion of the Commission meeting to review the flood model for acceptability.)

    Reviewed temporal evolution of inland flooding from the Suwannee River during Tropical Storm Fay (2008).

14. Calculation of relevant characteristics in the inland flood model, such as flood extent and elevation or depth, will be reviewed. The methods by which each flood model component utilizes the characteristics of other flood model components will be reviewed.

    Reviewed equations for riverine flood depth and stormwater flooding.

15. The selected time steps representing peak flood extents and elevations or depths referenced in Flood Standard HHF-1, Flood Parameters (Inputs), Disclosure 14, will be reviewed, if applicable. Any assumptions used to account for peak flood extents and elevations or depths for flood events with shorter durations than the selected time steps will be reviewed.

    Discussed that the water balance calculation and input precipitation run with a 60-minute time step.

    Discussed that storm surge is modeled on a 5-minute time step.

## HHF-3 Modeling of Major Flood Control Measures

***A. The flood model's treatment of major flood control measures and their performance shall be consistent with available information and current state-of-the-science.***

***B. The modeling organization shall have a documented procedure for reviewing and updating information about major flood control measures and if justified, shall update the flood model flood control databases.***

***C. Treatment of the potential failure of major flood control measures shall be based upon current scientific and technical literature, empirical studies, or engineering analyses.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

32. HHF-3.4, page 117: Discuss how a levee failure is triggered in the model, and whether it is automated or user designated.

Discussed how levees are represented in the storm surge footprint generation process, how levee failure occurs in the model, and how levee breach is simulated.

Discussed that levee failure is user-designated.

**Audit**

1. Treatment of major flood control measures incorporated in the flood model will be reviewed.

Discussed how the flood model accounts for the major flood controls within the DEM data.

Reviewed maps with locations of major high-risk dams and levees in Florida.

Reviewed examples of dams included in the DEM.

2. The documented procedure addressing the updating of major flood control measures as necessary will be reviewed.

Discussed the process to verify all levees in the National Levee Database were included in the DEM data.

3. The methodology and justification used to account for the potential failure or alteration of major flood control measures in the flood model will be reviewed.

   Discussed how the inland flood model accounts for the potential failure of major flood control measures. Failures are specified by the user.

4. Examples of flood extent and depth showing the potential impact of major flood control measure failures will be reviewed.

   Discussed the methodology to represent levees and levee failure in the flood model.

5. If the flood model incorporates major flood control measures that require human intervention, the methodology used in the flood model will be reviewed.

   Discussed that the model does not include human intervention on major flood control measures.

## HHF-4 Logical Relationships Among Flood Parameters and Characteristics*

*(*Significant Revision)*

***A. At a specific location, water surface elevation shall increase with increasing terrain roughness at that location, all other factors held constant.***

***B. Rate of discharge shall increase with increase in steepness in the topography, all other factors held constant.***

***C. Rate of discharge shall increase with increase in imperviousness of LULC, all other factors held constant.***

***D. Inland flood extent and depth associated with riverine and lacustrine flooding shall increase with increasing discharge, all other factors held constant.***

***E. The coincidence of storm tide and inland flooding shall not decrease the flood extent and depth, all other factors held constant.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

33. HHF-4.C, page 118: The logical relationship of increased imperviousness resulting in increased rate of discharge is related to increased runoff due to less infiltration. Discuss how the relationship identified verifies this logical relationship.

Discussed that catchments with larger impervious area, such as in developed areas, have higher runoff coefficients that lead to larger contributions of incoming water to surface flow and channel discharge.

Discussed that catchments with larger imperviousness, which also have lower roughness coefficients, results in higher channel discharge.

Reviewed calculation of flow discharge rate.

Reviewed an example of catchments and channel network, and an illustration of a channel cross-section and channel profile.

The response to HHF-4.C in the submission was revised to include this information.

## Audit

1. The analysis performed to demonstrate the logical relationships will be reviewed.

   Reviewed the analysis demonstrating logical relationships.

2. Methods (including any software) used in verifying the logical relationships will be reviewed.

   Reviewed charts demonstrating the logical relationship of the effects of increased roughness on water surface elevation in the Panhandle, North Florida, Southwest Florida, East Florida, and Southeast Florida.

## STATISTICAL FLOOD STANDARDS – MARK JOHNSON, LEADER

### SF-1 Modeled Results and Goodness-of-Fit*

*(*Significant Revision)*

***A. The use of historical data in developing the flood model shall be supported by rigorous methods published in current scientific and technical literature.***

***B. Modeled results and historical observations shall reflect statistical agreement using current scientific and statistical methods for the academic disciplines appropriate for the various flood model components or characteristics.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. Forms SF-1, Distributions of Stochastic Flood Parameters (Coastal, Inland), and SF-2, Examples of Flood Loss Exceedance Estimates (Coastal and Inland Combined), will be reviewed. Justification for the distributions selected, including for example, citations to published literature or analyses of specific historical data, will be reviewed. Justification for the goodness-of-fit tests used will also be reviewed.

   Reviewed each of the distributions given in Form SF-1 with respect to selection, estimation, goodness-of-fit, and basis in the scientific literature.

2. The modeling organization characterization of uncertainty for damage estimates, annual flood loss, flood probable maximum loss levels, and flood loss costs will be reviewed.

   Discussed that uncertainty analyses were performed for both coastal and inland flooding.

   Discussed that the uncertainty analysis for coastal flood showed that the track direction is the largest contributor to the uncertainty in the loss costs.

   Discussed that the uncertainty analysis for inland flood showed that the contributions of the different model parameters varied depending on the location of the event and the category of the precipitation amount.

   Reviewed the uncertainty in the annual flood loss characterized by confidence intervals around the mean annual flood loss as shown in Form AF-8.

3. Regression analyses performed will be reviewed, including for example parameter estimation, graphical summaries and numerical measures of the quality of fit, residual analysis and verification of regression assumptions, outlier treatment, and associated uncertainty assessment.

   Reviewed regression analyses with outlier detection for precipitation amount and duration in North Florida.

   Reviewed scatter plots of duration and spatial extent in North Florida.

## SF-2 Sensitivity Analysis for Flood Model Output

***The modeling organization shall have assessed the sensitivity of temporal and spatial outputs with respect to the simultaneous variation of input variables using current scientific and statistical methods in the appropriate disciplines and shall have taken appropriate action.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

### Audit

1. The modeling organization's sensitivity analysis for the flood model will be reviewed in detail. Statistical techniques used to perform sensitivity analysis will be reviewed. The results of the sensitivity analysis displayed in graphical format (e.g., contour or high-resolution plots with temporal animation) will be reviewed.

   Reviewed the sensitivity analyses performed based on the equivalent of Form S-6 used in the hurricane reviews adapted for the flood model. Standardized regression coefficients from the sensitivity analysis quantified the relative impact on model loss costs from each input parameter.

   Reviewed time series footprint development for coastal flooding.

   For coastal flood, the most sensitive aspect is the track direction. For inland flood, the most sensitive aspect varies significantly by both precipitation category and region. The event duration, spatial extent and precipitation amount are also large contributors to the sensitivity around the loss costs.

   Discussed that no actions were taken as the results of the sensitivity analyses were found to be reasonable.

## SF-3 Uncertainty Analysis for Flood Model Output

***The modeling organization shall have performed an uncertainty analysis on the temporal and spatial outputs of the flood model using current scientific and statistical methods in the appropriate disciplines and shall have taken appropriate action. The analysis shall identify and quantify the extent that input variables impact the uncertainty in flood model output as the input variables are simultaneously varied.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. The modeling organization uncertainty analysis for the flood model will be reviewed in detail. Statistical techniques used to perform uncertainty analysis will be reviewed. The results of the uncertainty analysis displayed in graphical format (e.g., contour or high-resolution plots with temporal animation) will be reviewed.

   Reviewed the uncertainty analyses performed based on the equivalent of Form S-6 used in the hurricane reviews adapted for the flood model. The major contributors to the uncertainty in flood model loss costs were the same as those from the sensitivity analyses for coastal and inland flooding.

   Expected percentage reduction from the uncertainty analysis quantified the contribution to the uncertainty in model loss costs from each input parameter.

   Reviewed time series footprint development for inland flooding.

   Discussed that no actions were taken as the results of the uncertainty analyses were found to be reasonable.

## SF-4 Flood Model Loss Cost Convergence by Geographic Zone

***At a modeling-organization-determined level of aggregation utilizing a minimum of 30 geographic zones encompassing the entire state, the contribution to the error in flood loss cost estimates attributable to the sampling process shall be negligible for the modeled coastal and inland flooding combined.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

### Audit

1. An exhibit of the standard error by each geographic zone will be reviewed.

   Reviewed map of the relative standard error percentage by county for inland and coastal flooding.

   Discussed the convergence test methodology.

## SF-5 Replication of Known Flood Losses

***The flood model shall estimate incurred flood losses in an unbiased manner on a sufficient body of past flood events, including the most current data available to the modeling organization. This standard applies to personal residential exposures. The replications shall be produced on an objective body of flood loss data by county or an appropriate level of geographic detail.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. The following information for each flood event in Form HHF-1, Historical Event Flood Extent and Elevation or Depth Validation Maps, will be reviewed:
   a. The validity of the flood model assessed by comparing projected flood losses produced by the flood model to available flood losses incurred by insurers at both the state and county level,
   b. The version of the flood model used to calculate modeled flood losses for each flood event provided,
   c. A general description of the data and its sources,
   d. A disclosure of any material mismatch of exposure and flood loss data problems, or other material consideration,
   e. The date of the exposures used for modeling and the date of the flood event,
   f. An explanation of differences in the actual and modeled flood parameters,
   g. A listing of the differences between the modeled and observed flood conditions used in validating a particular flood event,
   h. The type of coverage applied in each flood event to address:
      1. Personal residential structures
      2. Manufactured homes
      3. Condominiums
      4. Contents
      5. Time element,
   i. The treatment of demand surge or loss adjustment expenses in the actual flood losses or the modeled flood losses, and
   j. The treatment of wind losses in the actual flood losses or the modeled flood losses.

Reviewed state and county tables comparing modeled to actual losses.

Reviewed the number of policies and exposure amount by policy type of the claims data considered in Standard SF-5.

Discussed that there was no material mismatch of exposure and flood loss data.

Reviewed a table summarizing the dates of events in the insurance claims data used for validation of the flood model.

Discussed that hurricane parameters provided by NHC are used as input into the coastal flood model. For coastal flood, central pressure data from NHC are used when available for historical events. For model events, central pressure is calculated as a function of other hurricane parameters as developed by Courtney and Knaff (2009).

Discussed that historical flood footprints are validated against observed data and that there were no departures in any of the historical event footprints.

Discussed the coverages applied.

Discussed that there was no special treatment for demand surge or loss adjustment expenses in the actual or modeled flood losses.

Reviewed the KCC Insurance Claims Processing Guide used to determine which claims to include during model validation.

2. The following documentation will be reviewed:
   a. Publicly available documentation and data referenced in the flood model submission in hard copy or electronic form,
   b. Modeling-organization-specific documentation and data used in validation of flood losses,
   c. An analysis that identifies and explains anomalies observed in the validation data, and
   d. User input data for each insurer and flood event detailing specific assumptions made with regard to exposed personal residential property.

All publicly available and modeling-organization-specific documentation was available electronically and reviewed as necessary.

Discussed that no anomalies were observed in the course of the validation process. Discussed what qualifies as anomalies.

Reviewed samples of insurer exposure import documentation created for each insurer.

Discussed that input data provided by insurers were imported with standards and practices consistent with the KCC Exposure Data Processing Guide. Reviewed the KCC Exposure Data Process Guide.

3. The confidence intervals used to gauge the comparison between historical and modeled flood losses will be reviewed.

Discussed the calculation of confidence intervals for the comparison between historical and modeled flood losses.

Reviewed the 95% confidence interval for the mean flood loss cost, and the 95% confidence interval for the difference between historical and modeled loss.

Reviewed the standard deviation of the flood loss cost, and the model skill relative to said standard deviation.

4. The results for more than one flood event will be reviewed to the extent data are available.

Reviewed comparisons of modeled to actual results from four inland flood events, one combined inland and coastal flood event, and one coastal flood event.

Discussed the mismatch of events given in Standard SF-5 to those in Form AF-2. Storms included in Standard SF-5 that were previously omitted from Form AF-2 were added to a revised Form AF-2 during the review.

## VULNERABILITY FLOOD STANDARDS – CHRIS JONES, LEADER

### VF-1 Derivation of Building Flood Vulnerability Functions*

*(*Significant Revision)*

***A. Development of the building flood vulnerability functions shall be based on two or more of the following: (1) rational structural analysis, (2) post-event site investigations, (3) scientific and technical literature, (4) expert opinion, (5) laboratory or field testing, and (6) insurance claims data. Building flood vulnerability functions shall be supported by historical and other relevant data.***

***B. The derivation of building flood vulnerability functions and the treatment of associated uncertainties shall be theoretically sound and consistent with fundamental engineering principles.***

***C. Residential building stock classification shall be representative of Florida construction for personal residential buildings.***

***D. The following flood characteristics shall be used or accounted for in the derivation of building flood vulnerability functions: depth above ground, and in coastal areas, damaging wave action.***

***E. The following primary building characteristics shall be used or accounted for in the derivation of building flood vulnerability functions: lowest floor elevation relative to ground, foundation type, construction materials, number of stories, and year of construction.***

***F. Flood vulnerability functions shall be separately derived for personal residential buildings and manufactured homes.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

39. VF-1.7, page 145: Discuss how coastal flood vulnerability functions validate against claims data where claims locations are distant from the coast and subject to saltwater inundation only.

Discussed that claims do not indicate whether locations are subject to saltwater inundation only. All claims that are distant from the coast were included for the comparison regardless of if they were subject to saltwater inundation.

Reviewed comparison of modeled to actual loss using claims with different distances from the coast.

40. VF-1.8.e, page 146: Provide a comparison of vulnerability functions for freshwater and saltwater flooding, removing any contributions due to waves and velocity.

    Reviewed comparison of vulnerability functions for freshwater and saltwater.

    Discussed that differences in the flood model between freshwater and saltwater, except waves and velocity, are functional damage related to clean-up costs and water density.

41. VF-1.9.e, page 149: Explain the coastal construction control line changes mentioned in Table 12.

    Discussed that the requirements of the coastal construction control line were aligned with the V Zone requirement of the Florida Building Code (FBC). Discussed other FBC requirements and differences between FBC-B and FBC-R.

42. VF-1.9.e, page 150: Provide a comparison of flood vulnerability functions for the four manufactured homes year-built bands (pre-1976, 1976-1994, 1995-2008, post-2008).

    Reviewed comparison of coastal flood vulnerability functions for the four manufactured homes year-built bands.

    Reviewed comparison of inland flood vulnerability functions for the four manufactured homes year-built bands.

43. VF-1.11, page 151: Justify using the April 2023 Community Rating System (CRS) score for all construction dates.

    Discussed the methodology for applying CRS classification for construction dates in the same community. Construction dates are explicitly modeled as year-built band in the flood vulnerability functions. Therefore, buildings in the same community with different year-built bands are assigned to different flood vulnerability functions.

44. VF-1.11, page 151: Provide a comparison of flood vulnerability functions for similar buildings in communities with different CRS scores.

    Reviewed a comparison of coastal flood vulnerability functions for CRS classes.

    Reviewed a comparison of inland flood vulnerability functions for CRS classes.

46. Form VF-1, pages 237-238: Provide plots and tables comparing Mean Damage Ratio (MDR) versus Flood Depth for each of the 8 reference structures.

    Reviewed comparison of MDR versus Flood Depth for the Form VF-1 eight reference structures individually and combined, and the corresponding table of values.

47. Form VF-1, page 239, and Form VF-2, page 241: Explain how inland MDR is greater than coastal MDR at flood depths above ground = 2ft, 3ft.

    Discussed that damage to the building interior dominates the total loss when structural damage does not occur. Interior damage by water infiltration occurs at low inundation depth.

    Discussed that the water infiltration ratio is higher for inland flood events at low inundation depth due to the relatively longer duration of inland flood events compared to coastal flood events.

    Reviewed graphical comparison between Form VF-1, coastal flooding, and Form VF-2, inland flooding.

48. Form VF-2, pages 240-241: Provide plots and tables comparing MDR versus Flood Depth for each of the 8 reference structures.

    Reviewed comparison of MDR versus Flood Depth for the Form VF-2 eight reference structures individually and combined, and the corresponding table of values.

**Audit**

1. All building and manufactured home flood vulnerability functions will be reviewed. The magnitude of logical changes among these for given flood events and validation materials will be reviewed.

    Reviewed a comparison of coastal and inland flood vulnerability functions for a single family, wood frame, 1 story, 1-ft first floor height (FFH) structure.

    Reviewed the coastal and inland flood vulnerability functions.

2. Comparison of building flood vulnerability functions for Form VF-1, Coastal Flood with Damaging Wave Action, reference structures will be reviewed. Comparison of building flood vulnerability functions for Form VF-2, Inland Flood by Flood Depth, reference structures will be reviewed.

    Reviewed comparison of coastal flooding MDR versus Inundation Above Ground for the Form VF-1 eight reference structures individually and combined, and the corresponding table of values.

Reviewed comparison of inland flooding MDR versus Inundation Above Ground for the Form VF-2 eight reference structures individually and combined, and the corresponding table of values.

3. If the flood model uses component-based vulnerability functions, comparisons of the overall building flood vulnerability functions and the individual component-based vulnerability functions will be reviewed for each of the reference structures in Form VF-1, Coastal Flood with Damaging Wave Action, and Form VF-2, Inland Flood by Flood Depth (16 comparisons total, eight for each form).

   Reviewed comparisons of coastal flooding MDR versus Inundation Depth for 1) wood frame, one story, 4-ft FFH, 2) wood frame, two story, 1-ft FFH, 3) wood frame, two story, 9-ft FFH, 4) masonry, one story, 1-ft FFH, 5) masonry, two story, 1-ft FFH, 6) masonry, two story 9-ft FFH, 7) manufactured home, 4-ft FFH, and 8) manufactured home, 7-ft FFH.

   Reviewed comparisons of inland flooding MDR versus Inundation Depth for 1) wood frame, one story, 4-ft FFH, 2) wood frame, two story, 1-ft FFH, 3) wood frame, two story, 9-ft FFH, 4) masonry, one story, 1-ft FFH, 5) masonry, two story, 1-ft FFH, 6) masonry, two story, 9-ft FFH, 7) manufactured home, 4-ft FFH, and 8) manufactured home, 7-ft FFH.

4. Modifications to the building vulnerability component of the flood model since the currently accepted flood model will be reviewed in detail, including the rationale for the modifications, the scope of the modifications, the process, the resulting modifications, and their impacts on the building vulnerability functions.

   Discussed that the vulnerability module update is applied to buildings with unknown FFH, unknown foundation type, and pre-FIRM year-built in coastal regions. The assignment of FFH for buildings with unknown FFH, unknown foundation type and pre-FIRM year-built in the inland flood model has not changed from the current accepted model.

   Reviewed the coastal and riverine tables of the foundation type inventory data from the HAZUS Technical Manual used for FFH.

   Reviewed the year-built inventory distribution of single-family homes.

   Reviewed comparison to the current accepted model of the updated coastal flood vulnerability function for single-family wood frame structures with unknown year built.

   Reviewed the year-built inventory distribution of manufactured homes.

   Reviewed comparison to the current accepted model of the updated coastal flood vulnerability function for manufactured homes with unknown year built.

Discussed the process for vulnerability function development where building height is unknown or missing. Reviewed comparison to current accepted model of the updated coastal flood vulnerability function for multi-family wood frame structures with unknown building height.

Discussed the updated vulnerability regions based on newer CRS data. Reviewed comparison of the region changes from the current accepted model. Reviewed comparison to the current accepted model of the updated coastal flood vulnerability function for single-family, wood frame structures.

Discussed that the updated FFH assignments when FFH and foundation type are unknown only applies to cases when year-built is pre-FIRM. Reviewed comparison to the current accepted model of the vulnerability function change for FFH assignment.

Reviewed model implementation of the updated FFH assignments when FFH and foundation type are unknown for both coastal and inland flooding.

Discussed with Dr. Farzam Maleki, an external reviewer and one of the Vulnerability Standards signatories, his review of the vulnerability portion of the submission.

5. Comparisons of the building flood vulnerability functions with the currently accepted flood model will be reviewed.

Reviewed comparisons to the current accepted model of coastal and inland vulnerability functions for single family structures, manufactured homes, and multi-family structures.

6. Building vulnerability functions that incorporate waves or wave proxies will be reviewed. Thresholds for damaging wave action will be reviewed. The area over which building flood vulnerability functions for damaging waves or wave proxies are applied will be reviewed.

Discussed that wave action is considered for all exposures inundated by coastal flooding.

Reviewed examples of coastal flood vulnerability functions incorporating wave action.

7. Validation of the building flood vulnerability functions and the treatment of associated uncertainties will be reviewed.

Reviewed comparison of modeled losses to insurer flood losses for coastal, inland, and combined events.

Reviewed comparison of KCC vulnerability functions, USACE (2015) vulnerability functions, and NFIP flood claims analysis published in Wing et al. (2020).

Reviewed comparisons of USACE vulnerability curves to model vulnerability curves for a wood frame, one story, 1-ft FFH structure and a wood frame, two story, 3-ft FFH structure.

8. Historical data in the original form will be reviewed with explanations for any changes made and descriptions of how missing or incorrect data were handled. For historical data used to develop building flood vulnerability functions, the goodness-of-fit of the data will be reviewed. Complete reports detailing flooding conditions and damage suffered for any laboratory or field-testing data used will be reviewed. A variety of different personal residential building construction classes will be selected from the complete rational structural analyses and calculations to be reviewed. Laboratory or field tests and original post-event site investigation reports will be reviewed. Other scientific and technical literature and expert opinion summaries will be reviewed. Insurance claims data will be reviewed.

   Discussed that historical data were not used in development of the vulnerability functions. The KCC vulnerability functions were derived using a component method. Post-event surveys and external post-disaster investigations were used to inform the derivation of the vulnerability functions. Insurance claims data were used in validation.

   Reviewed vulnerability functions of building utilities damage and function damage based on USACE (2006).

9. All scientific and technical literature, reports, and studies used in the continual development of the building flood vulnerability functions must be available for review in hard copy or electronic form.

   All references were available electronically and were reviewed as necessary.

10. Justification for the personal residential building construction classes and characteristics used will be reviewed.

    Reviewed the primary building characteristics and construction types used in the development of the vulnerability functions.

    Reviewed breakdown of construction types applicable to personal residential and manufactured homes classifications.

    Reviewed breakdown of occupancy types for renters and condos.

    Reviewed the year-built classifications for site built and manufactured homes.

    Discussed assumptions made regarding the floor elevation requirement in the FBC for residential homes built before 2017.

11. Documentation and justification for the effects on the building flood vulnerability functions due to local and regional construction practices, and statewide and local building codes, floodplain management regulations, and their enforcement will be reviewed. If year of construction or geographical location of the building is used as a surrogate for building code, floodplain management regulation, and their enforcement, complete supporting information for the number of year of construction groups used as well as the year-bands and geographical regions of construction that separate particular groups will be reviewed.

    Discussed that the vulnerability functions vary by community within the state of Florida and vary by year built.

    Discussed the analysis of major changes in building code requirements for flood design and community-level FIRM adoption data used in classifying buildings.

12. Describe in detail the breakdown of new flood claims data into number of policies, number of insurers, dates of flood loss, amount of flood loss, and amount of dollar exposure; separated into personal residential and manufactured homes. Indicate whether or not the new flood claims datasets were incorporated into the flood model. Describe research performed and analyses on the new flood claims datasets and the impact on flood vulnerability functions.

    Reviewed the breakdown of new flood claims data by number of policies, amount of building loss, and amount of exposure for personal residential and manufactured homes.

13. How the claim practices of insurance companies are accounted for when flood claims data for those insurance companies are used to develop or to verify building flood vulnerability functions will be reviewed. Examples include the level of damage the insurer considers a loss to be a total loss, claim practices of insurers with respect to concurrent causation, the impact of public adjusting, or the impact of the legal environment.

    Discussed that exposure and claims data were reviewed to verify building vulnerability. The level of damage the insurer considers a loss to be a total loss, claim practices of insurers with respect to concurrent causation, and the impact of public adjusting were not considered when analyzing the claims.

14. The percentage of damage at or above which the flood model assumes a total building loss will be reviewed.

    Discussed that the model does not have a cut off damage percentage above which total loss is assumed. The vulnerability functions are computed as the ratio of repair cost to replacement cost; therefore, no assumption is required.

15. The treatment of law and ordinance in building flood vulnerability functions will be reviewed.

    Discussed that law and ordinance is implicitly included in the base vulnerability functions and accounted for in the model to the extent that law and ordinance coverage is present in the historical claims information.

16. Documentation and justification for the method of derivation and data on which the building flood vulnerability functions are based will be reviewed.

    Discussed that an engineering-based building component approach is used to develop the building vulnerability functions.

    Literature used in developing the vulnerability functions was available electronically for review.

17. If modeled, the treatment of water intrusion in building flood vulnerability functions will be reviewed.

    Discussed that water infiltration due to hydrostatic pressures on residential buildings is considered during the development of the vulnerability functions.

    Discussed that the rate of water rise inside a residence during a flood event is modeled based on Westrick (2009). The flow velocity and rate of water rise outside the building is also considered.

18. The basis or dependence of building flood vulnerability functions on NFIP FIRM or other FIS data will be reviewed.

    Discussed that the NFIP CRS classes effective April 2023 are used to determine different levels of flood vulnerability.

    Discussed that year-built bands are developed to capture the evolution in flood design provisions and requirements determined by the adoption of FIRM.

19. The process to account for FEMA's change in flood insurance premium rating to Risk Rating 2.0 will be reviewed, if applicable.

    Discussed that KCC experts reviewed FEMA's Risk Rating 2.0 methodology related to building vulnerability, and no changes to the current accepted model were required.

20. Form VF-1, Coastal Flood with Damaging Wave Action, will be reviewed.

    Reviewed Form VF-1. See comments under PVL #46.

21. Form VF-2, Inland Flood by Flood Depth, will be reviewed.

Reviewed Form VF-2. See comments under PVL #48.

## VF-2 Derivation of Contents Flood Vulnerability Functions*

*(*Significant Revision)*

***A. Development of the contents flood vulnerability functions shall be based on some combination of the following: (1) post-event site investigations, (2) scientific and technical literature, (3) expert opinion, (4) laboratory or field testing, and (5) insurance claims data. Contents flood vulnerability functions shall be supported by historical and other relevant data.***

***B. The relationship between building and contents flood vulnerability functions shall be reasonable.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. Modifications to the contents vulnerability component of the flood model since the currently accepted flood model will be reviewed in detail, including the rationale for the modifications, the scope of the modifications, the process, the resulting modifications and their impact on the contents vulnerability functions.

   Discussed that the contents vulnerability functions are derived from building vulnerability functions using building-to-contents damage relationships.

   Discussed that the only modifications to contents vulnerability functions are due to modifications of the building vulnerability functions.

2. Comparisons of the contents flood vulnerability functions with the currently accepted flood model will be reviewed.

   Reviewed comparisons of coastal and inland contents vulnerability functions to the current accepted model for single family, multi-family, and manufactured homes structures.

3. All contents flood vulnerability functions will be reviewed.

   Reviewed the coastal and inland contents vulnerability functions.

4. Contents flood vulnerability functions that incorporate waves or wave proxies will be reviewed. Thresholds for damaging wave action will be reviewed. The area over which contents flood vulnerability functions for damaging waves or wave proxies are applied will be reviewed.

   Discussed that wave action is considered for all exposures inundated by coastal flooding.

5. Validation of the contents flood vulnerability functions and the treatment of associated uncertainties will be reviewed.

   Discussed that contents vulnerability functions are derived from building vulnerability functions using a building-to-contents damage relationship.

   Discussed that claims data for several historical events in the state of Florida were used to validate the building-to-contents relationships used in development of the contents vulnerability functions.

   Reviewed validation of the building-to-contents damage relationship for residential buildings and condo units.

6. Documentation and justification of the method of derivation and underlying data or assumptions related to contents flood vulnerability functions will be reviewed.

   Discussed that the main assumption behind the derivation of contents vulnerability functions is that as building damage increases, contents damage increases.

   Reviewed the method and data for derivation of the contents vulnerability functions.

7. Historical data in the original form will be reviewed with explanations for any changes made and descriptions of how missing or incorrect data were handled. For historical data used to develop contents flood vulnerability functions, the goodness-of-fit of the data will be reviewed. Complete reports detailing flood conditions and damage suffered for any test data used will be reviewed. Original post-event site investigation reports will be reviewed. Other scientific and technical literature and expert opinion summaries will be reviewed. Insurance claims data will be reviewed.

   Discussed that no historical data were used in the development of contents vulnerability functions.

   Post-event surveys and observations were used to inform the contents vulnerability functions.

   Claims data were used to validate the building-to-contents damage relationship.

8. Justification for changes from the currently accepted flood model in the relativities between flood vulnerability functions for building and the corresponding flood vulnerability functions for contents will be reviewed.

   Discussed that the relativities between flood vulnerability functions for building and the corresponding contents vulnerability functions have not been modified since the current accepted model.

9. Documentation and justification of the method of derivation and underlying data or assumptions related to contents flood vulnerability functions will be reviewed.

   Refer to Audit item 6.

10. The basis or dependence of contents flood vulnerability functions on NFIP FIRM or other FIS data will be reviewed.

    Discussed that year-built band and vulnerability region are developed based on NFIP FIRM and CRS data in the building vulnerability functions. The variation by year-built band and vulnerability region seen in the building vulnerability functions will be observed in the contents vulnerability functions.

11. All scientific and technical literature, reports, and studies used in the continual development of the contents flood vulnerability functions must be available for review in hard copy or electronic form.

    All literature, reports, and studies were available electronically and were reviewed as necessary.

## VF-3 Derivation of Time Element Flood Vulnerability Functions*

*(*Significant Revision)*

***A. Development of the time element flood vulnerability functions shall be based on one or more of the following: (1) post-event site investigations, (2) scientific and technical literature, (3) expert opinion, (4) laboratory or field testing, and (5) insurance claims data.***

***B. The relationship among building, contents, and time element flood vulnerability functions shall be reasonable.***

***C. Time element flood vulnerability functions derivations shall consider the estimated time required to repair or replace the property.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. Modifications to the time element vulnerability component of the flood model since the currently accepted flood model will be reviewed in detail, including the rationale for the modifications, the scope of the modifications, the process, the resulting modifications and their impact on the time element vulnerability functions.

   Discussed that the time element vulnerability functions are derived from building vulnerability functions using building-to-time element damage relationships.

   Discussed that the only modifications to time element vulnerability functions are due to modifications of the building vulnerability functions.

2. Comparisons of the time element flood vulnerability functions with the currently accepted flood model will be reviewed.

   Reviewed comparisons of coastal and inland time element vulnerability functions to the current accepted model for single family, multi-family, and manufactured homes structures.

3. All time element flood vulnerability functions will be reviewed.

   Reviewed the coastal and inland time element vulnerability functions.

4. Time element flood vulnerability functions that incorporate waves or wave proxies will be reviewed. Thresholds for damaging wave action will be reviewed. The area over which time element flood vulnerability functions for waves or wave proxies are applied will be reviewed.

   Discussed that wave action is considered for all exposures inundated by coastal flooding.

5. Validation of the time element flood vulnerability functions and the treatment of associated uncertainties will be reviewed.

   Discussed that time element vulnerability functions are derived from building vulnerability functions using a building-to-time element damage relationship.

   Discussed that NFIP does not cover time element losses.

   Discussed that the building-to-time element relationship was validated using a similar relationship from Baradarnshoraka (2017).

   Reviewed validation of building-to-time element damage relationship for residential buildings and condo units.

6. Documentation and justification of the method of derivation and underlying data or assumptions related to time element flood vulnerability functions will be reviewed.

   Discussed that the main assumption behind the derivation of time element vulnerability functions is that as building damage increases, time element losses increase.

   Reviewed the method and underlying data for derivation of the time element vulnerability functions.

   Reviewed a comparison of the building-related time, event-related time, and total time building damage ratios.

   Reviewed direct loss to time element loss.

7. Historical data in the original form will be reviewed with explanations for any changes made and descriptions of how missing or incorrect data were handled. To the extent historical data are used to develop time element flood vulnerability functions, the goodness-of-fit of the data will be reviewed. Complete reports detailing flooding conditions and damage suffered for any test data used will be reviewed. Original post-event site investigation reports will be reviewed. Other scientific and technical literature and expert opinion summaries will be reviewed. Insurance claims data will be reviewed.

   Discussed that no historical or test data were used in development of time element vulnerability functions. Post-event site observations were used to inform the time element vulnerability functions.

8. If included, the methodology and validation for determining the extent of infrastructure flood damage and governmental mandate and their effect on time element flood vulnerability will be reviewed.

   Discussed that infrastructure flood damage and government mandates are not explicitly modeled. They have been implicitly included in the event time expense during the derivation of time element vulnerability functions. Indirect time element losses were derived based on engineering judgement.

9. Justification for changes from the currently accepted flood model in relativities between flood vulnerability functions for building and the corresponding flood vulnerability functions for time element will be reviewed.

   Discussed that the relativities between flood vulnerability functions for building and the corresponding time element vulnerability functions have not been modified since the current accepted model.

10. Documentation and justification of the method of derivation and underlying data or assumptions related to time element flood vulnerability functions will be reviewed.

    See Audit 6.

## VF-4 Flood Mitigation Measures*

*(*Significant Revision)*

***A. Modeling of flood mitigation measures to improve flood resistance of buildings, and the corresponding effects on flood vulnerability and associated uncertainties shall be theoretically sound and consistent with fundamental engineering principles. These measures shall include design, construction, and retrofit techniques that affect the flood resistance or flood protection of personal residential buildings.***

***B. The modeling organization shall justify all flood mitigation measures considered by the flood model.***

***C. Application of flood mitigation measures that affect the performance of personal residential buildings and the damage to contents shall be justified as to the impact on reducing flood damage whether done individually or in combination.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

45. VF-4.4, page 164: For Building Enclosure in Table 17, justify the statement, "Enclosures below the BFE are required to be breakaway walls."

Discussed that the NFIP regulations within V zones on a community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls. The statement for Building Enclosure in Table 17 was clarified in the April revised submission to read, "Enclosures below the BEF are required to be breakaway walls in the V Zones."

49. Form VF-3, pages 242-243: Explain the results contained in the form.

Discussed the results given in Form VF-3.

Discussed the effectiveness of dry floodproofing and the role of human intervention in its deployment.

**Audit**

1. Flood mitigation measures used by the flood model, whether or not referenced in Form VF-3, Flood Mitigation Measures, will be reviewed for theoretical soundness and reasonability.

   Discussed that secondary characteristics and mitigation measures can increase or decrease a building's vulnerability, and their impact varies with flood depth.

   Reviewed the secondary characteristics and mitigation measures used in the model.

   Discussed the difference between mitigation by elevating the floor versus elevating utility equipment, versus wet- and dry-floodproofing. Discussed the impact to vulnerability of adding flood openings in foundation walls.

2. Modifications to flood mitigation measures in the flood model since the currently accepted flood model will be reviewed in detail, including the rationale for the modifications, the scope of the modifications, the process, the resulting modifications, and their impacts on the flood vulnerability component.

   Discussed that flood mitigation measures have not been modified since the current accepted model.

3. Comparisons of flood mitigation measures in the flood model with the currently accepted flood model will be reviewed.

   Discussed that flood mitigation measures have not been modified since the current accepted model.

4. Procedures, including software, used to calculate the impact of flood mitigation measures will be reviewed.

   Reviewed the method used to derive the impact of flood mitigation measures. Discussed the approach has not changed since the current accepted model.

5. Form VF-3, Flood Mitigation Measures, Range of Changes in Flood Damage, and Form VF-4, Differences in Flood Mitigation Measures, will be reviewed.

   Reviewed Forms VF-3 and VF-4. Discussed changes to model results from the current accepted model.

6. Implementation of flood mitigation measures will be reviewed as well as the effect of individual flood mitigation measures on flood damage. Any variation in the change in flood damage over the range of flood depths above ground for individual flood mitigation measures will be reviewed. Historical data, scientific and technical literature, expert opinion, or insurance company claims data used to support the assumptions and implementation of flood mitigation measures will be reviewed. How flood mitigation measures affect the uncertainty of the vulnerability will be reviewed.

   Reviewed the calculation for the effects of secondary characteristics, which vary with flood depth.

7. Implementation of multiple flood mitigation measures will be reviewed. The combined effects of these flood mitigation measures on flood damage will be reviewed. Any variation in the change in flood damage over the range of flood depths above ground for multiple flood mitigation measures will be reviewed.

   Reviewed the grouping of flood mitigation measures, and the process for grouping and combining multiple mitigation measures.

## ACTUARIAL FLOOD STANDARDS – STU MATHEWSON, LEADER

### AF-1 Flood Model Input Data and Output Reports*

*(*Significant Revision)*

***A. Adjustments, edits, inclusions, or deletions to insurance company or other input data used by the modeling organization shall be based upon generally accepted actuarial, underwriting, and statistical procedures.***

***B. All modifications, adjustments, assumptions, inputs and input file identification, and defaults necessary to use the flood model shall be actuarially sound and shall be included with the flood model output report. Treatment of missing values for user inputs required to run the flood model shall be actuarially sound and described with the flood model output report.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

50. AF-1.4, pages 167-168: Explain the revisions in Table 18 from the current accepted model.

Discussed that the revisions in Table 18 from the current accepted model are due to updates to the RiskInsight user interface.

51. AF-1.6, page 173: Discuss the new Table 19.

Discussed that Table 19 illustrates the loss analysis, model, and job options selected when the Florida Flood Rate Filing v2.0 template is selected.

**Audit**

1. Quality assurance procedures, including methods to assure accuracy of flood insurance or other input data, will be reviewed. Compliance with this standard will be readily demonstrated through documented rules and procedures.

Reviewed the Exposure Data Processing Guide that details the procedures and methods used to ensure accuracy of insurance and other input data.

Reviewed the Exposure Import User's Guide that details the process for using KCC's data import functionality which validates input data imported into the RiskInsight software.

2. All flood model inputs and assumptions will be reviewed to determine that the flood model output report appropriately discloses all modifications, adjustments, assumptions, and defaults used to produce the flood loss costs and flood probable maximum loss levels.

   Reviewed the analysis report and corresponding inputs in loss analysis.

3. Explanation of the differences in data input and flood model output for coastal and inland flood modeling will be reviewed.

   Discussed that data input is identical for coastal and inland flood modeling. For any given form, the same database and portfolio(s) are used for both the coastal and inland flood components with no differences in primary or secondary characteristics of exposure, total insured value (TIV), financial terms, or geopoints.

   Discussed that flood model output is structured identically for coastal and inland flood.

4. The human-computer interface relevant to input data and output reports and corresponding nomenclature used in Florida rate filings will be reviewed.

   Reviewed the Florida Flood Rate Filing v2.0 template and the read-only model options available to the user.

   The modeler demonstrated that once the Florida option is selected, all settings that affect loss costs are automatically set and cannot be changed.

## AF-2 Flood Events Resulting in Modeled Flood Losses*

*(*Significant Revision)*

***A. Modeled flood loss costs and flood probable maximum loss levels shall reflect insured flood related damages from both coastal and inland flood events impacting Florida.***

***B. The modeling organization shall have a documented procedure for distinguishing flood-related losses from other peril losses.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

52. AF-2.B, page 175: Provide an electronic copy of the documented procedure for distinguishing flood losses from other peril losses.

Reviewed the documented procedure for distinguishing flood losses from other peril losses.

**Audit**

1. The flood model will be reviewed to evaluate whether the determination of flood losses in the flood model is consistent with this standard.

Discussed that for inland flood, a flood event is defined as a period of extreme precipitation that leads to riverine and surface flooding.

Discussed that for coastal flood, landfalling hurricanes that result in storm surge in the model are defined as events with a 1-minute sustained windspeed at 10-meter height of at least 74mph at landfall.

Discussed that the model begins to estimate flood-related damage at a 1-inch inundation depth.

2. The flood model will be reviewed to determine that meteorological or hydrological and hydraulic events originating either inside or outside of Florida are modeled for flood losses occurring in Florida and that such effects are considered in a manner which is consistent with this standard.

Reviewed the model precipitation events centered at locations throughout the six watersheds affecting Florida.

Reviewed a graphical representation of hurricane events by landfall location and category. Discussed that hurricane intensity is consistent with the model distributions that are based on the historical record for Florida and adjacent states.

3. The flood model will be reviewed to determine whether and how the flood model takes into account any damage resulting directly and solely from wind and water infiltration.

   Discussed that the inland and coastal flood models calculate only flood-related insured losses. The inland and coastal flood models are independent which precludes the introduction of any damage resulting directly and solely from wind. Wind losses and wind-driven precipitation losses are excluded from all losses given in the flood model submission.

4. The flood model will be reviewed to determine how flood losses from water intrusion are identified and calculated.

   Reviewed the process for identifying and calculating water-intrusion flood losses.

   Discussed that losses from water intrusion are implicitly included in the loss costs as part of the flood vulnerability function development and damage estimation.

5. The documented procedure for distinguishing flood-only losses from other peril losses will be reviewed.

   Reviewed the documented procedure for distinguishing flood losses from other peril losses.

6. The effect on flood loss costs and flood probable maximum loss levels arising from flood events that are neither inland nor coastal flooding will be reviewed.

   Discussed that the model does not account for events that are neither inland nor coastal flooding events.

## AF-3 Flood Coverages*

*(*Significant Revision)*

***A. The methods used in the calculation of personal residential structure flood loss costs, including the effect of law and ordinance coverage, shall be actuarially sound.***

***B. The methods used in the calculation of personal residential appurtenant structure flood loss costs shall be actuarially sound.***

***C. The methods used in the calculation of personal residential contents flood loss costs shall be actuarially sound.***

***D. The methods used in the calculation of personal residential time element flood loss costs shall be actuarially sound.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

53. AF-3.B, page 176: Explain how the calculation of appurtenant structure flood loss costs are similar to the methods used for building flood loss costs.

Reviewed the calculation of AAL. Discussed that appurtenant structure loss costs and building flood loss costs use the same calculation methodology.

**Audit**

1. The methods used to produce personal residential structure, appurtenant structure, contents, and time element flood loss costs will be reviewed.

Discussed that loss cost calculations are the same for appurtenant structure, contents, and time element flood loss costs.

Discussed with Melinda Vasecka, an external reviewer and Actuarial Standards signatory, her review of the actuarial portion of the submission document. Discussed how she attested the model results to be actuarially sound.

2. The treatment of law and ordinance coverage will be reviewed, including the 25% and 50% coverage options for personal residential policies.

   Discussed that law and ordinance coverage is not explicitly considered in the model. To the extent that law and ordinance coverage is included in historical claims information, then it is implicitly included in the base vulnerability functions and accounted for in the model.

## AF-4 Modeled Flood Loss Cost and Flood Probable Maximum Loss Level Considerations*

*(*Significant Revision)*

***A. Flood loss cost projections and flood probable maximum loss levels shall not include expenses, risk load, investment income, premium reserves, taxes, assessments, or profit margin.***

***B. Flood loss cost projections and flood probable maximum loss levels shall not make a prospective provision for economic inflation.***

***C. Flood loss cost projections and flood probable maximum loss levels shall not include any explicit provision for wind losses.***

***D. Damage caused from inland and coastal flooding shall be included in the calculation of flood loss costs and flood probable maximum loss levels.***

***E. Flood loss cost projections and flood probable maximum loss levels shall be capable of being calculated from exposures at a geocode (latitude-longitude) level of resolution including the consideration of flood extent and depth.***

***F. Demand surge shall be included in the flood model's calculation of flood loss costs and flood probable maximum loss levels using relevant data and actuarially sound methods and assumptions.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

54. AF-4.1, pages 178-179: Provide, in Excel, tables of 1,000 years descending from the Top Event corresponding to Form AF-8. For each year, show the value of each event separately.

    Reviewed the tables of 1,000 years descending from the Top Event which showed agreement to Form AF-8.

55. AF-4.3, page 179: Explain in detail the demand surge model. Provide a copy of the documented procedure, and its implementation in the code.

    Reviewed the documented procedure for the demand surge model, and calculation of the demand surge factors.

Reviewed the formula for estimating losses including the demand surge factor multiplier.

**Audit**

1. How the flood model handles expenses, risk load, investment income, premium reserves, taxes, assessments, profit margin, economic inflation, and any criteria other than direct property flood insurance claim payments will be reviewed.

   Discussed that no assumptions for expenses, risk load investment income, premium reserves, taxes, assessments, profit margin, economic inflation, or any other criteria other than direct property flood insurance claims payments are made. The individual claim amounts received exclude all of the items listed.

2. The method of determining flood probable maximum loss levels (PML) will be reviewed.

   Reviewed the method for determining flood PML.

3. The uncertainty in the estimated annual flood loss costs and flood probable maximum loss levels will be reviewed.

   Reviewed the new method for calculation of uncertainty intervals.

4. The data and methods used to incorporate individual aspects of demand surge on personal residential coverages for coastal and inland flooding, inclusive of the effects from building material costs, labor costs, contents costs, and repair time will be reviewed.

   Reviewed the demand surge procedure and implementation.

5. How the flood model accounts for economic inflation associated with past insurance experience will be reviewed.

   Discussed that no adjustments were made to the exposure or loss data when validating the model using claims data because the claims could be matched to their contemporaneous exposure data.

6. The treatment of wind losses in the determination of flood losses will be reviewed.

   Reviewed the documented procedure for distinguishing flood losses from other peril losses.

7. How the flood model determines flood loss costs associated with coastal flooding will be reviewed.

   Discussed how annual flood loss costs are calculated.

8. How the flood model determines flood probable maximum loss levels associated with coastal flooding will be reviewed.

   Discussed how PML is calculated at an occurrence level and at an aggregate level.

   Reviewed an example calculation for PML associated to the 1% exceedance probability.

9. How the flood model determines flood loss costs associated with inland flooding will be reviewed.

   Discussed that the method for estimating losses is the same for inland and coastal flooding.

10. How the flood model determines flood probable maximum loss levels associated with inland flooding will be reviewed.

    Discussed that the method for estimating PML levels is the same for inland and coastal flooding.

11. The methods used to ensure there is no systematic over-estimation or under-estimation of flood loss costs and flood probable maximum loss levels from coastal and inland flooding will be reviewed.

    Reviewed a historical loss comparison to modeled losses for coastal, inland, and combined events. The comparison demonstrated that there is no systematic over-estimation or under-estimation of flood loss costs and flood probable maximum loss levels from coastal and inland flooding.

12. All referenced scientific and technical literature will be reviewed, in hard copy or electronic form, to determine applicability.

    All references were available electronically and were reviewed as necessary.

## AF-5 Flood Policy Conditions*

*(*Significant Revision)*

***A. The methods used in the development of mathematical distributions to reflect the effects of deductibles, policy limits, and flood policy exclusions shall be actuarially sound.***

***B. The relationship among the modeled deductible flood loss costs shall be reasonable.***

***C. Deductible flood loss costs shall be calculated in accordance with s. 627.715, F.S.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. The extent that historical data are used to develop mathematical depictions of deductibles, policy limits, policy exclusions, and loss settlement provisions for flood coverage will be reviewed.

   Discussed that no mathematical depictions of deductibles, policy limits, policy exclusions or loss settlement provisions are used in the model.

2. The extent that historical data are used to validate the flood model results will be reviewed.

   Discussed that policy terms included in historical data used to validate the flood model were handled in accordance with industry practices.

3. Treatment of annual deductibles will be reviewed, if applicable.

   Reviewed the calculation and implementation of annual aggregate deductibles.

4. Justification for the changes from the currently accepted flood model in the relativities among corresponding deductible amounts for the same coverage will be reviewed.

   Discussed that there were no changes from the current accepted model in the relativities among corresponding deductible amounts for the same coverage.

## AF-6 Flood Loss Outputs and Logical Relationships to Risk*

*(Significant Revision)*

***A. The methods, data, and assumptions used in the estimation of flood loss costs and flood probable maximum loss levels shall be actuarially sound.***

***B. Flood loss costs shall not exhibit an illogical relation to risk, nor shall flood loss costs exhibit a significant change when the underlying risk does not change significantly.***

***C. Flood loss costs cannot increase as the structure flood damage resistance increases, all other factors held constant.***

***D. Flood loss costs cannot increase as flood hazard mitigation measures incorporated in the structure increase, all other factors held constant.***

***E. Flood loss costs shall be consistent with the effects of major flood control measures, all other factors held constant.***

***F. Flood loss costs cannot increase as the flood resistant design provisions increase, all other factors held constant.***

***G. Flood loss costs cannot increase as building code enforcement increases, all other factors held constant.***

***H. Flood loss costs shall decrease as deductibles increase, all other factors held constant.***

***I. The relationship of flood loss costs for individual coverages (e.g., personal residential structure, appurtenant structure, contents, and time element) shall be consistent with the coverages provided.***

***J. Flood output ranges shall be logical for the type of risk being modeled and apparent deviations shall be justified.***

***K. All other factors held constant, flood output ranges produced by the flood model shall in general reflect lower flood loss costs for personal residential structures that have a higher elevation versus those that have a lower elevation.***

***L. For flood loss costs and flood probable maximum loss level estimates derived from and validated with historical insured flood losses or other input data and information, the assumptions in the derivations concerning (1) construction characteristics, (2) policy provisions, and (3) contractual provisions shall be appropriate based on the type of risk being modeled.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

56. Form AF-1, pages 247-249: Explain how ZIP Code 00042 in Brevard County is being handled.

    Discussed how the modeler-created ZIP Code 00042 in Brevard County is handled in the model.

57. Form AF-1, pages 247-249: Explain the difference in Frame Owners rates between the low of 0.0003 (32323) and the high of 27.690 (32102). Explain why the maximum of 27.69 appears to be in the midst of low loss costs and the minimum of 0.0003 appears to be in the midst of high loss costs in Figure 82.

    Discussed the locations and elevations in Franklin County ZIP Code 32323. Reviewed the DEM for the ZIP Code. Discussed the reasons for the lower losses compared to surrounding towns, and determined that their losses were reasonable.

    Discussed the locations and elevations in ZIP Code 32102 which are adjacent to the St. Johns River. Discussed the reasons for the higher flood loss costs from other ZIPs in the area which were reasonable.

58. Form AF-1, pages 247-249: Explain why the Frame Owners rate changes from the current accepted model by ZIP Code range from an increase of 914% (32631) and a decrease of 99% (e.g., 32009).

    Discussed the changes in ZIP Codes 32631 and 32009 from the current accepted model. Reviewed the exposure and ground elevation in both ZIP Codes.

    The flood risk and resulting loss cost in ZIP Code 32631 increased as a result of the updated soil and land surface characteristics. Discussed that despite the large percentage change, the change in gross AAL is only $1.26 per $1,000.

    Established that loss cost in ZIP Code 32009 decreased as a result of the updated dynamic floodplain width along the St. Mary's River.

    Discussed that changes in loss cost are driven by changes to the inland flood hazard analysis methodology.

59. Form AF-1, pages 247-249: Explain why the Frame Owners rate changes from the current accepted model by County range from an increase of about 48% (Jefferson County) and a decrease of 99% (Lafayette County).

    Reviewed the exposure and elevations in Jefferson and Lafayette Counties.

    Discussed that the increase in loss costs in Jefferson County results from a combination of greater coastal flooding in Apalachicola Bay due to climate change impacts and the updated land surface and sub-surface characteristics.

    Discussed that the decrease in loss costs in Lafayette County is due to the updated dynamic floodplain width at locations along the Suwannee River.

60. Form AF-1, pages 247-249: Explain why a significant number of Manufactured Homes losses per 1,000 are lower than Wood Frame, by ZIP Code. Explain why the ratio of Manufactured Homes rates to Frame Owners rates ranges from 0.083 in Broward County (32907) to 5.16 in Seminole County (32732).

    Discussed the assumptions made for calculating first floor height for manufactured homes and for wood frame homes on slab foundations.

    Discussed the intensity of flooding in ZIP Codes 32732 and 32907. Reviewed a comparison of the frequency of events by flood inundation height for both ZIP Codes.

    Discussed how lower flood depths can cause more damage to wood frame structures versus manufactured homes in some locations.

61. Form AF-2, pages 250-252: Describe in detail the modeling-organization-specified, predetermined and comprehensive exposure dataset. Provide the total value of the exposures and the number of exposures by type (frame, masonry, manufactured homes).

    Reviewed the exposure dataset breakdown by occupancy and construction type for single-family homes, rental units, and condo units.

    Discussed that no change was made in the exposure, other than updated ZIP Code data.

62. Form AF-2, pages 250-252: Explain the large changes in the historical storm modeled losses compared to the current accepted model. In particular, explain the changes in TampaBay06-1921, GreatMiami07-1926, LaborDay03-1935, Andrew-1992, Wilma-2005, and Matthew-2016.

    Discussed that changes in historical losses from coastal flooding events changed due to incorporation of sea-level rise, the updated treatment of storm surge for exiting hurricanes, and updates to the relationship between central pressure and peak storm surge.

63. Form AF-3, pages 253-259: Explain the relatively extreme nature of Collier County ZIP Codes 34102 and 34145 and Lake County ZIP Code 32102, particularly for Tropical Storm Fay (2008) and Unnamed Storm in East Florida (May 2009).

    Discussed that the historical loss percentage in Collier County ZIP Codes 34102 and 34145 were highest for Hurricane Wilma (2005). Discussed how inland flood losses, especially for low-lying areas, drive larger changes in losses.

64. Form AF-3, page 257: Explain why there are losses on the Gulf Coast for Atlantic by-passing Hurricane Matthew (2016) in Figure 92.

    Discussed how Hurricane Matthew (2016) created coastal flood damage on the West Coast of Florida.

    Reviewed the Hurricane Matthew (2016) storm surge footprint and the storm surge that was observed at the Cedar Key tide gauge.

65. Form AF-3, pages 253-259: Explain why the totals for storms are different than those given in Form AF-2.

    Discussed how Forms AF-2 and AF-3 ask for data differently. The losses reported in Form AF-3 are standard losses (Coverages A and C) while the losses reported in Form AF-2 are total losses (Coverages A, C, and D).

66. Form AF-4, page 261: Explain the zeros for Condo Unit (e.g., Brevard County Low).

    Discussed how a low number of condo units in a ZIP Code versus NFIP exposure data volatility showing no condo policy impact on the loss data.

    Reviewed an example condo unit exposure in a ZIP Code illustrating the scenario.

67. Form AF-4, page 262: Explain the Franklin County Low values 0.000 for all coverage types, and likewise, Flagler County Low values 0.001 or 0.000 where other counties have much larger values. Explain the situation with these two counties compared to potentially similar counties.

    Discussed the difference in Franklin County elevation compared to other coastal counties. Reviewed the exposure and loss costs by occupancy type in ZIP Code 32323.

    Reviewed comparison of loss cost by occupancy type of lowest loss cost ZIP Codes near Franklin County.

    Reviewed the exposure and loss cost by occupancy type in Flagler County and lower loss cost in ZIP Code 32164.

Reviewed the exposure and loss cost by occupancy type in Volusia County and lower loss cost in ZIP Code 32128.

68. Form AF-4, pages 261-267: Explain the differences in Average loss costs between the highest counties (Monroe, Gilchrist, Dixie) and the lowest counties (Baker, Clay). The high counties show loss costs over 5.88 for Owners and over 6.00 for Manufactured Homes, while the low counties are less than 0.025 for Owners and 0.006 for Manufactured Homes.

    Discussed how changes in coastal and inland flooding analysis generated higher loss costs, and how areas affected primarily by surface flooding generate lower loss costs.

69. Form AF-4, pages 261-267: Explain the very large range in the changes in Average Frame Owners loss costs from the current accepted model. The largest increases are +288% (Lake County) and +158% (Jefferson County). The largest decreases are -95% (Lafayette County), -93% (Baker County), and -90% (Duval County).

    Discussed how changes to riverine/inland flooding analysis drive higher losses. Discussed how changes in inland/surface flooding analyses drive larger changes in loss costs.

70. Form AF-4, pages 261-267: Explain the very large range in the changes in Average Manufactured Homes loss costs from the current accepted model. The largest increase is +290% (Lake County). The largest decreases are -99% (Madison County), -98% (Holmes County), and -94% (Baker County).

    Discussed how changes to modeled riverine/inland flooding drive higher losses in Lake County. Discussed how changes in modeled inland/surface flooding drive larger changes in loss costs.

71. Form AF-4, 0% Deductible, pages 261-267: Explain, in general, how apparent anomalies were resolved. In particular, explain the following cases for Frame loss costs less than Masonry loss costs:
    a. Owners: DeSoto County Average, Indian River County Average, Marion County Average,
    b. Renters: Brevard County Average, Jefferson County Average, St. Lucie County Average, and
    c. Condo Unit: Brevard County Average, Broward County Average, St. Lucie County Average.

    Discussed how proportionately larger masonry exposure affects loss costs and explains the apparent anomalies.

72. Form AF-4, page 262: With Form AF-1 having only two ZIP Codes for Glades County (33471 and 33944), explain the values given in Form AF-4 in Glades County Low, Average, and High for Frame Owners, Masonry Owners, and Manufactured Homes.

    Discussed that the AAL for a given county is calculated as a weighted average of ZIP Code loss costs divided by TIV. Reviewed the formula for calculating the weighted average.

    Reviewed a frame owner average example calculation.

    Reviewed table of Form AF-4 loss cost categories for all ZIP Codes in Glades County.

    Discussed how a low number of ZIP Codes in a county, and the related weighting of the exposure and losses, explain the results.

73. Form AF-4, page 262: With Form AF-1 having only two ZIP Codes for Gulf County (32456 and 32465), explain the values given in Form AF-4 in Gulf County Low, Average, and High for Frame Owners, Masonry Owners, and Manufactured Homes.

    Followed the same process as for PVL #72.

    Reviewed the frame, masonry, and manufactured homes exposure mix for Gulf County.

74. Form AF-4, page 263: With Form AF-1 having only one ZIP Code in Lafayette County (32066), explain the values given in Form AF-4 in Lafayette County Low, Average, and High for Frame Owners, Masonry Owners, and Manufactured Homes.

    Followed the same process as for PVL #72.

    Reviewed the frame, masonry, and manufactured homes exposure mix for Lafayette County.

75. Form AF-4, page 265: With Form AF-1 having only two ZIP Codes for Okeechobee County (34972 and 34974) with similar loss costs, explain the values given in Form AF-4 in Okeechobee County Low, Average, and High for Frame Owners, Masonry Owners, and Manufactured Homes.

    Followed the same process as for PVL #72.

    Reviewed the frame, masonry, and manufactured homes exposure mix for Okeechobee County.

76. Form AF-5, pages 287-288: Explain the regional percentage changes from the current accepted model for the various policy types.

    Reviewed the drivers for regional percentage changes versus the current accepted model, in the Panhandle, North Florida, Southwest Florida, East Florida, and Southeast Florida.

77. Form AF-5.D, pages 289-292: Justify the large ranges from minima to maxima in Figures 95-101.

    Reviewed maps of the minimum and maximum county percentage change in flood output ranges.

    Reviewed the large ranges between minima to maxima in Lake, Jefferson, and Sumter Counties, and the maximum for Lafayette, Washington, and Duval Counties.

78. Form AF-8, pages 304-305: Explain why the uncertainty ranges are much narrower than the current accepted model.

    Reviewed the change in methodology for calculating uncertainty ranges that resulted in narrower ranges.

**Audit**

1. The data and methods used for flood probable maximum loss levels for Form AF-8, Flood Probable Maximum Loss for Florida, will be reviewed. The Top Event and Conditional Tail Expectations will be reviewed.

    Reviewed the top coastal and inland flood events at the occurrence level.

    Reviewed the top year and 500-year return period events at the aggregate level.

    Reviewed maps of the top events from an occurrence level and from an aggregate level.

2. The frequency distribution and the individual event severity distribution, or information about the formulation of events, underlying Form AF-8, Flood Probable Maximum Loss for Florida, will be reviewed.

    Reviewed the event frequency and intensity distributions for inland flood and for coastal flood.

3. All referenced scientific and technical literature will be reviewed, in hard copy or electronic form, to determine applicability.

    All references were available electronically and were reviewed as necessary.

4. Graphical representations of flood loss costs by rating areas and geographic zones (consistent with the modeling-organization grid resolution) will be reviewed.

   Reviewed maps of flood loss costs by ZIP Code and by County for frame owners, masonry owners, and manufactured homes.

5. The procedures used by the modeling organization to verify the individual flood loss cost relationships will be reviewed. Methods (including any software) used in verifying Flood Standard AF-6, Flood Loss Outputs and Logical Relationships to Risk, will be reviewed. Forms AF-1, Zero Deductible Personal Residential Standard Flood Loss Costs; AF-2, Total Flood Statewide Loss Costs; AF-3, Personal Residential Standard Flood Losses by ZIP Code; and AF-6, Logical Relationships to Flood Risk (Trade Secret Item); and AF-7, Percentage Change in Logical Relationships to Flood Risk, will be reviewed to assess flood coverage relationships.

   Discussed that a series of checks were performed to verify the individual loss cost relationships. Reviewed a graphical representation of the relationships that were used to confirm reasonability.

6. The flood loss cost relationships among deductible, policy form, construction type, coverage, year of construction, foundation type, number of stories, and lowest floor elevation will be reviewed. For coastal flooding, the flood loss cost relationship with distance to the closest coast will be reviewed.

   Reviewed Form AF-6 graphical representations of the flood loss costs relationships and confirmed reasonability.

7. The total personal residential insured flood losses provided in Forms AF-2, Total Flood Statewide Loss Costs, and AF-3, Personal Residential Standard Flood Losses by ZIP Code, will be reviewed.

   Reviewed Form AF-2 as revised during the review to add storms previously omitted, to match those in Standard SF-5.

   Discussed the differences in losses between Forms AF-2 and AF-3 being a result of the forms reporting losses differently. Form AF-2 is based on total losses for all coverages (A, C, and D) where Form AF-3 is based on standard losses that only include coverages A and C.

8. Form AF-4, Flood Output Ranges, and Form AF-5, Percentage Change in Flood Output Ranges, will be reviewed, including geographical representations of the data where applicable.

   Forms AF-4 and AF-5 were reviewed in detail. See the associated pre-visit letter questions.

9. Justification for all changes in flood loss costs from the currently accepted flood model will be reviewed.

   Reviewed the underlying reasons for the changes in loss costs from the current accepted model.

   For differences due to changes in hazard, general increases are along the Gulf Coast, decreases in some East Coast counties, and variable loss changes for inland counties. The maximum percent difference is in Lake County, and the minimum difference is in Lafayette County.

   The overall change in loss costs decreased 1.9% due to changes in vulnerability,

10. Form AF-4, Flood Output Ranges, will be reviewed to ensure appropriate relativities among deductibles, coverages, and construction types.

    Reviewed Form AF-4 for consistency in relativities.

11. Apparent reversals in the flood output ranges and their justification will be reviewed.

    Discussed that all cited anomalies in the flood output ranges were reviewed and are consistent with the distributions of exposures and TIV within each county.

12. Details on the calculation of uncertainty intervals and their justification will be reviewed.

    Reviewed the new uncertainty interval calculation.

## COMPUTER/INFORMATION FLOOD STANDARDS – PAUL FISHWICK, LEADER

### CIF-1 Flood Model Documentation*

*(*Significant Revision)*

***A. Flood model functionality and technical descriptions shall be documented formally in an archival format separate from the use of correspondence including emails, presentation materials, and unformatted text files.***

***B. A primary document repository shall be maintained, containing or referencing a complete set of documentation specifying the flood model structure, detailed software description, and functionality. Documentation shall be indicative of current model development and software engineering practices.***

***C. All computer software (i.e., user interface, scientific, engineering, actuarial, data preparation, and validation) relevant to the flood model shall be consistently documented and dated.***

***D. The following shall be maintained: (1) a table of all changes in the flood model from the currently accepted flood model to the initial submission this year, and (2) a table of all substantive changes in the flood model since this year's initial submission.***

***E. Documentation shall be created separately from the source code.***

***F. A list of all externally acquired currently used flood model-specific software and data assets shall be maintained. The list shall include (1) asset name, (2) asset version number, (3) asset acquisition date, (4) asset acquisition source, (5) asset acquisition mode (e.g., lease, purchase, open source), and (6) length of time asset has been in use by the modeling organization.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

79. CIF-1.D, page 186: Provide the table required by Standard CIF-1, Audit item 7.

Reviewed the summary of changes table.

80. CIF-1.F, page 186: Provide the list of all externally acquired flood model-specific software and data assets as described and required by Standard CIF-1, Audit item 6.

Reviewed the list of all externally-acquired flood model-specific software and data sources.

**Audit**

1. The primary document repository, containing or referencing full documentation of the software in either electronic or physical form, and its maintenance process will be reviewed.

Discussed the use of Microsoft Team Foundation Server (TFS) as the primary document repository.

Reviewed the KCC server management and data management policy.

2. All documentation should be easily accessible from a central location in order to be reviewed.

Reviewed numerous examples of accessing documentation from the TFS system.

3. Complete user documentation, including all recent updates, will be reviewed.

Reviewed the process document for modeling surface water flooding.

Reviewed the documented procedure for the demand surge model.

Reviewed examples of RiskInsight update and release notes.

Reviewed the Database Schema and Results Database Guide. Reviewed additional documentation contained in User Guides.

4. Modeling organization personnel, or their designated proxies, responsible for each aspect of the software (i.e., user interface, quality assurance, engineering, actuarial, verification) should be present when the Computer/Information Flood Standards are being reviewed. Internal users of the software will be interviewed.

All subject matter experts and personnel involved in software implementation were available and participated throughout the review.

5. Verification that documentation is created separately from, and is maintained consistently with, the source code and data will be reviewed.

Discussed the process for creating documentation.

Reviewed examples illustrating that documentation is created separately from the source code and maintained within a combination of TFS and GitHub.

6. The list of all externally acquired flood model-specific software and data assets will be reviewed.

   Reviewed the list of all external acquired flood model-specific software and data sources.

7. The tables specified in Flood Standard CIF-1.D that contain the items listed in Flood Standard GF-1, Scope of the Flood Model and Its Implementation, Disclosure 8 will be reviewed. The tables should contain the item number in the first column. The remaining five columns should contain specific document or file references for affected components or data relating to the following Computer/Information Flood Standards: CIF-2, Flood Model Requirements, CIF-3, Flood Model Organization and Component Design, CIF-4, Flood Model Implementation, CIF-5, Flood Model Verification, and CIF-7, Flood Model Maintenance and Revision.

   Reviewed the summary of changes for all the model changes since the current accepted model.

8. Tracing of the flood model changes specified in Flood Standard GF-1, Scope of the Flood Model and Its Implementation, Disclosure 8 and Audit 9 through all Computer/Information Flood Standards will be reviewed.

   Reviewed the demand surge factor update through CIF Standards 1-5.

## CIF-2 Flood Model Requirements*

*(*Significant Revision)*

***A complete set of requirements for each software component, as well as for each database or data file accessed by a component, shall be maintained. Requirements shall be updated whenever changes are made to the flood model.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

### Pre-Visit Letter

81. CIF-2, page 187: Provide requirements documentation that specifically relates to each model change identified in Standard GF-1.8.

    Reviewed software requirements documentation for updates made in the model under review:

    - Event catalog module updates
    - Intensity footprint module updates
    - Vulnerability module updates
    - Other changes impacting loss costs (ZIP Code updates, demand surge factors)

### Audit

1. Maintenance and documentation of a complete set of requirements for each software component, database, and data file accessed by a component will be reviewed.

   Reviewed requirements specifications.

   Reviewed database or data file schemas.

   Reviewed the requirements document for demand surge adjustments to loss.

   Reviewed the demand surge multipliers file schema.

## CIF-3 Flood Model Organization and Component Design*

*(*Significant Revision)*

***A. The following shall be maintained and documented: (1) detailed control and data flowcharts and interface specifications for each software component, (2) schema definitions for each database and data file, (3) flowcharts illustrating flood model-related flow of information and its processing by modeling organization personnel or consultants, (4) network organization, and (5) system model representations associated with (1)-(4) above. Documentation shall be to the level of components that make significant contributions to the flood model output.***

***B. All flowcharts (e.g., software, data, and system models) in the submission or in other relevant documentation shall be based on (1) a referenced industry standard (e.g., UML, BPMN, SysML), or (2) a comparable internally-developed standard which is separately documented.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

82. CIF-3.B, page 188: Provide the documents for flowcharting standards.

Reviewed the ISO 5807 standard used as a reference guide for all flowcharts. Reviewed KCC's appendix to the ISO 5807 standard. Further refinements were made to KCC's appendix during the review.

**Audit**

1. The following will be reviewed:
   a. Detailed control and data flowcharts, completely and sufficiently labeled for each component,
   b. Interface specifications for all components in the flood model,
   c. Documentation for schemas for all data files, along with field type definitions,
   d. Each network flowchart including components, sub-component flowcharts, arcs, and labels,
   e. Flowcharts illustrating flood model-related information flow among modeling organization personnel or consultants (e.g., BPMN, UML, SysML, or equivalent technique including a modeling organization internal standard), and
   f. If the flood model is implemented on more than one platform, the detailed control and data flowcharts, component interface specifications, schema documentation for all data files, and detailed network flowcharts for each platform.

Reviewed the flowchart defining the process for developing building vulnerability functions.

Reviewed the flowchart of major model components in the flood model (Figure 3) revised during the on-site review to correct dataflows in accordance with KCC's flowcharting standards appendix.

Reviewed the flowchart of KCC network organization (Figure 4) revised during the on-site review to correct the control transfer representation in accordance with the updated KCC flowchart standards appendix.

Reviewed the flowchart describing the processes of the coastal flood model (Figure 14) revised during the on-site review to correct inconsistencies with KCC's flowchart standards.

Reviewed the flowchart defining the process for selecting the Florida Flood Rate Filing Template and exposures for loss analysis.

Reviewed the flowchart for retrieving first floor height (FFH) value during damage function assignment.

Reviewed the flowchart for applying demand surge factors.

Reviewed flowcharts used to:

- Prepare input exposure files
- Load exposure data and to validate and geocode exposure data
- Create the exposure database
- Generate the import log and transfer data into the exposure database
- Prepare and submit analysis requests
- Apply coverage-specific damage functions
- Distribute event catalog to workers
- Determine intensity for each affected location
- Estimate ground up and gross losses for each event
- Prepare and save losses in results database
- Generate and view modeled results
- Generate model output reports
- Review results: ELT, YLT, EP Curves, EP Summary, and Event Footprints.

Reviewed interface specifications for the model components listed in the flowcharts above.

Reviewed RiskInsight results database schema.

Reviewed the schema reference for flood intensity tiles, the schema reference for flood hazard, and the RiskInsight model definition schema.

Reviewed an illustration of the network flows.

Reviewed workflow of KCC professionals involved in development of the flood model. Reviewed an example of flow among KCC personnel for the formula development process.

Discussed that the flood model can only be used within the RiskInsight platform.

2. A flood model component custodian, or designated proxy, should be available for the review of each component.

   All subject matter experts and personnel involved in software implementation were available and participated, as needed, throughout the review

3. The flowchart reference guide or industry standard reference will be reviewed.

   Reviewed the ISO 5807 standard used as a reference guide for all flowcharts. Reviewed KCC's appendix to the ISO 5807 standard. Further refinements were made to KCC's appendix during the on-site review.

## CIF-4 Flood Model Implementation*

*(Significant Revision)*

***A. A complete procedure of coding guidelines consistent with current software engineering practices shall be maintained.***

***B. Network organization documentation shall be maintained.***

***C. A complete procedure used in creating, deriving, or procuring and verifying databases or data files accessed by components shall be maintained.***

***D. All components shall be traceable, through explicit component identification in the flood model representations (e.g., flowcharts) down to the code level.***

***E. A table of all software components affecting flood loss costs and flood probable maximum loss levels shall be maintained with the following table columns: (1) component name, (2) number of lines of code, minus blank and comment lines, and (3) number of explanatory comment lines.***

***F. Each component shall be sufficiently and consistently commented so that a software engineer unfamiliar with the code shall be able to comprehend the component logic at a reasonable level of abstraction.***

***G. The following documentation shall be maintained for all components or data modified by items identified in Flood Standard GF-1, Scope of the Flood Model and Its Implementation, Disclosure 8 and Audit 9:***

***1. A list of all equations and formulas used in documentation of the flood model with definitions of all terms and variables.***

***2. A cross-referenced list of implementation source code terms and variable names corresponding to items within G.1 above.***

***H. Flood model code and data shall be accompanied by documented maintenance, testing, and update plans with their schedules. The vintage of the code and data shall be justified.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

83. CIF-4.H, page 189: Provide the information as noted.

Reviewed the code and data update plans.

Reviewed the schedule for model and software updates which are assessed during planning sessions throughout the year.

Discussed the frequency of the recurring software scoping meetings, their format and procedures.

Reviewed the KCC model update plan.

**Audit**

1. Sample code and data implementations will be selected and reviewed, for at least the meteorology, hydrology and hydraulics, vulnerability, and actuarial components.

Reviewed selected samples of the urban drainage code.

Reviewed a mapping created during the on-site review between the variables given in the urban draining runoff equation to the implementation variables in the source code.

Reviewed implementation of surface water flooding in the code.

Reviewed implementation of the pre-FIRM updated FFH assignments when FFH and foundation type are unknown for both coastal and inland flooding.

Reviewed portions of the hydrology and hydraulics code.

Reviewed script for generating Form AF-1. Updates were made to the script during the on-site review to add comments and variable names.

Reviewed the component method code for wave loads on buildings.

Reviewed the demand surge model code.

2. The documented coding guidelines, including procedures for ensuring readable identifiers for variables, constants, and components, and confirmation that these guidelines are uniformly implemented will be reviewed.

Reviewed the updated coding guidelines documentation.

Discussed the reasons for the updated coding guidelines.

3. The procedure used in creating, deriving, or procuring and verifying databases or data files accessed by components will be reviewed.

   Discussed that the software team has processes and procedures for automated and manual validation of flood model development.

   Reviewed an interactive map tool used to visually inspect an event footprint.

   Reviewed an interactive tool used to visually inspect damage functions and secondary uncertainty distributions.

   Reviewed an interactive model definition viewer used for model validation.

4. The traceability among components at all levels of representation will be reviewed.

   Reviewed the process used to ensure traceability among model components.

5. The following information will be reviewed for each component, either in a header comment block, source control database, or the documentation:
   a. Component name,
   b. Date created,
   c. Dates modified, modification rationale, and by whom,
   d. Purpose or function of the component, and
   e. Input and output parameter definitions.

   Discussed that all source code for the RiskInsight platform is under source control.

   Reviewed an example in the source control system.

6. The table of all software components as specified in Flood Standard CIF-4.E will be reviewed.

   Reviewed table of software component metadata and subsequent code breakdowns.

7. Flood model components and the method of mapping to elements in the computer program will be reviewed.

   Discussed that the model definition file provides the primary means of mapping damage functions, hazard events, and other model details.

   Reviewed an example from the model definition file that provides the primary means of mapping damage functions, hazard events, and other model details.

8. Comments within components will be reviewed for sufficiency, consistency, and explanatory quality.

   Reviewed a mapping created during the on-site review between the variables given in the urban drainage runoff equation to the implementation variables in the source code.

   Comments in selected source codes examined were reviewed.

   Reviewed examples of code comments for methods and description comments for statements in the code.

   Reviewed the script for generating Form AF-1 updated during the on-site review to add comments and variable names.

9. Unique aspects within various platforms with regard to the use of hardware, operating system, and essential software will be reviewed.

   Reviewed the hardware and operating system requirements for the flood model and RiskInsight platform for each tier.

10. Network organization implementation will be reviewed.

    Reviewed the network organization diagram in Figure 4 that was revised during the on-site review to correct the control transfer representation in accordance with the updated KCC flowchart standards appendix.

11. Code and data maintenance plans, testing plans, update plans, and schedules will be reviewed. Justification for the vintage of code and data will be reviewed.

    Reviewed the code and data update plans described in the Model Software Update Guidelines.

    Reviewed the schedule for model and software updates which are assessed during planning sessions throughout the year

## CIF-5 Flood Model Verification*

*(Significant Revision)*

***A. General***

***For each component, procedures shall be maintained for verification, such as code inspections, reviews, calculation crosschecks, and walkthroughs, sufficient to demonstrate code correctness. Verification procedures shall include tests performed by modeling organization personnel other than the original component developers.***

***B. Component Testing***

***1. Testing software shall be used to assist in documenting and analyzing all components.***

***2. Unit tests shall be performed and documented for each updated component.***

***3. Regression tests shall be performed and documented on incremental builds.***

***4. Integration tests shall be performed and documented to ensure the correctness of all flood model components. Sufficient testing shall be performed to ensure that all components have been executed at least once.***

***C. Data Testing***

***1. Testing software shall be used to assist in documenting and analyzing all databases and data files accessed by components.***

***2. Integrity, consistency, and correctness checks shall be performed and documented on all databases and data files accessed by the components.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Pre-Visit Letter**

84. CIF-5, pages 191-195: Provide complete and thorough verification procedures and output from the model changes identified in Standard GF-1.8.

Reviewed the procedure to ensure complete and accurate implementation of model updates.

**Audit**

1. Procedures for unit conversion verification will be reviewed.

   Reviewed procedures for 1) flood conversion constants and code usage, 2) currency unit conversion, 3) percent of fraction conversion to dollars, and 4) test for latitude longitude to grid index and grid index to latitude longitude.

2. The components will be reviewed for containment of sufficient logical assertions, exception-handling mechanisms, and flag-triggered output statements to test the correct values for key variables that might be subject to modification.

   Discussed that RiskInsight source code is properly and appropriately coded for logical assertion and exception-handling.

   Discussed the defensive coding practices used by the software development team.

   Reviewed examples of defensive coding and error code tracking practices.

3. The testing software used by the modeling organization will be reviewed.

   Discussed the testing software and automated testing process.

   Reviewed code used to perform specific automated tests and a list of sub-projects in the testing framework.

   Discussed that unit and regression tests are performed after every merge.

   Discussed that the frequency of integration tests run to confirm losses have not changed.

4. The component (unit, regression, integration) and data test processes and documentation will be reviewed including compliance with independence of the verification procedures.

   Reviewed an example unit and regression tests run after every code check-in.

   Reviewed the automated test for applying demand surge factors. Reviewed a demand surge loss test example.

5. Fully time-stamped, documented cross-checking procedures and results for verifying equations, including tester identification, will be reviewed. Examples include mathematical calculations versus source code implementation, or the use of multiple implementations using different languages.

   Reviewed an example code change history tracked and reported in TFS source control.

6. Flowcharts defining the processes used for manual and automatic verification will be reviewed.

   Reviewed flowchart of automated and manual testing processes.

7. Verification approaches used for externally acquired data, software, and models will be reviewed.

   Reviewed the general data verification process.

   Reviewed validation and quality checks on the exposure data points to ensure geo-points do not fall over water or other uninhabitable terrains.

## CIF-6 Human-Computer Interaction*

*(*New Flood Standard)*

***A. Interfaces shall be implemented as consistent with accepted principles and practices of Human-Computer Interaction (HCI), Interaction Design, and User Experience (UX) engineering.***

***B. Interface options used in the flood model shall be unique, explicit, and distinctly emphasized.***

***C. For a Florida rate filing, interface options shall be limited to those options found acceptable by the Commission.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

### Pre-Visit Letter

85. CIF-6.A, page 196: Provide the human interface guidelines.

Reviewed the human interface guidelines.

86. CIF-6.C, page 196: Provide and explain the analysis options related to Florida rate filings.

Reviewed the analysis options related to Florida rate filings. Reviewed the Florida Flood Rate Filing v2.0 template in user interface.

Discussed that the Florida Flood Rate Filing v2.0 template has pre-defined values that are required for rate filing in Florida. The template is encrypted and marked immutable so the selected options cannot be changed in the user interface.

Reviewed a live demonstration of the model execution.

### Audit

1. External and internal user interfaces will be reviewed.

Reviewed and discussed the use of the Florida Flood Rate Filing v2.0 template with read-only model options.

2. Documentation related to HCI, Interaction Design, and UX engineering will be reviewed.

Reviewed the documentation associated with HCI, interactive design, and UX engineering.

3. The decision process specifying the logic of interface option selections, when an acceptable flood model is selected, will be reviewed.

   Discussed that KCC has simplified the decision process by eliminating unacceptable options and only enabling relevant choices controlled by an immutable template.

   Reviewed the process for selecting the Florida Flood Rate Filing template and exposures for loss analysis.

## CIF-7 Flood Model Maintenance and Revision*

*(*Significant Revision)*

***A. A clearly written policy shall be implemented for review, maintenance, and revision of the flood model and network organization, including verification and validation of revised components, databases, and data files.***

***B. A revision to any portion of the flood model that results in a change in any Florida personal residential flood loss cost or flood probable maximum loss level shall result in a new flood model version identification.***

***C. Tracking software shall be used to identify and describe all errors, as well as modifications to code, data, and documentation.***

***D. A list of all flood model versions since the initial submission for this year shall be maintained. Each flood model description shall have an unique version identification and a list of additions, deletions, and changes that define that version.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

**Audit**

1. All policies and procedures used to review and maintain the code, data, and documentation will be reviewed. For each component in the system decomposition, the installation date under configuration control, the current version identification, and the date of the most recent change(s) will be reviewed.

   Reviewed the procedures to ensure complete and accurate completion of development projects including code reviews, testing, and documentation.

   Discussed the KCC protocol for model changes, including review, revision, or maintenance.

   Reviewed an example of a code review performed.

2. The policy for flood model revision and management will be reviewed.

   Reviewed modeler policy for model maintenance and revision.

3. Portions of the code will be reviewed.

   Code reviews were conducted as listed under CIF-4.

4. The tracking software will be reviewed and checked for the ability to track date and time.

   Discussed the use of TFS and GitHub as the source control system.

   Reviewed examples of source control explorer showing the date and time each change set was checked-in, and the GitHub web interface showing commits.

5. The list of all flood model revisions as specified in Flood Standard CIF-7.D will be reviewed.

   Reviewed a summary of code changes and the updated requirements documents for the flood model under review.

## CIF-8 Flood Model Security*

*(*Significant Revision)*

***Security procedures shall be implemented and fully documented for (1) secure access to individual computers where the software components or data can be created or modified, (2) secure operation of the flood model by clients, if relevant, to ensure that the correct software operation cannot be compromised, (3) anti-virus software installation for all machines where all components and data are being accessed, and (4) secure access to documentation, software, and data in the event of a catastrophe.***

**Verified: YES**

**Professional Team comments are provided in black font below.**

### Audit

1. The written policy for all security procedures and methods used to ensure the security of code, data, and documentation will be reviewed.

   Reviewed the policy on information security procedures.

2. Documented security procedures for access, client flood model use, anti-virus software installation, and off-site procedures in the event of a catastrophe will be reviewed.

   Discussed that written procedures are maintained for access, client flood model use, anti-virus software installation, and off-site procedures.

   Reviewed examples from the information security policy addressing the above.

3. Security aspects of each platform will be reviewed.

   Discussed that the flood model can only be used with the RiskInsight platform.

   Reviewed an example of the software operation management from the information security policy.

4. Network security documentation and network integrity assurance procedures will be reviewed.

   Reviewed an example of the network management from the information security policy.