Final Report

Future Conditions 100-Year Flood Elevation Map

February 2021

BROWARD COUNTY FLORIDA

Geosyntec consultants

Future Conditions 100-Year Flood Elevation Map

FINAL REPORT

Prepared for

Broward County
Environmental Protection and Growth Management Department
ENVIRONMENTAL PLANNING AND COMMUNITY RESILIENCE DIVISION
115 S Andrews Ave, Room 329-H
Fort Lauderdale, Florida 33301

Prepared by

Geosyntec Consultants, Inc.
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Orlando, FL 32817

Project Number: FW3359

County Contract R2114367P1

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Project Manager – Senior Principal

The engineering material and data contained within the enclosed report was prepared by Geosyntec Consultants, Inc. for sole use by the Broward County Environmental Planning and Community Resilience Division. This report was prepared under the supervision and direction of the respective undersigned, whose seal as a registered professional engineer is affixed below.

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Project Number: FW3359

February 2021

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1. INTRODUCTION AND BACKGROUND

This report provides a final compendium of efforts performed on behalf of Broward County for the Future Conditions 100-Year Flood Elevation Map study. Geosyntec Consultants was tasked by the Broward County Environmental Planning and Community Resilience Division to perform this effort under contract #R2114367P1.

The Future Conditions 100-Year Flood Elevation Map is intended to advance the resiliency efforts in Broward County by setting the foundation to improve standards for flood protection. The Future Conditions 100-Year Flood Elevation Map was developed through integrated hydrologic modeling of surface and groundwater, using DHI's MIKE SHE/MIKE Hydro River model tools. This model accounted for future land use changes and the effects of projected sea level rise and precipitation changes on predicting future flood conditions. The results of this project will serve as a regulatory basis for establishing future finish floor elevations for new buildings and major redevelopments in the County.

The overall project included the following major elements leading up to the final project deliverables:

- Data Collection from the County, South Florida Water Management District (SFWMD), and other regulatory, municipal, and water control district sources to support the development of the flood models.
- Development of current conditions flood modeling using the MIKE SHE/MIKE Hydro River computer model to simulate design storms including the 10, 25, 50, 100, and 500-year 3-day storms and the 25 and 100-year 1-day storms. A June 2017 extreme storm event was chosen to calibrate and confirm the reasonableness of model results. The details of this model development process and results are summarized in the July 2020 Final Modeling Report included as Appendix A of this report. Current conditions modeling rainfall data resources are summarized in the January 2019 memorandum included as Appendix A.
- Development of future conditions rainfall depth change factors for the design storm events. This relied on the use of statistically downscaled global climate data and a process of developing an ensemble approach to leverage various datasets into reasonable future rainfall depth change factors. These increased change factors were used in the future conditions modeling. This collaborative process to develop the future rainfall change factors is captured in the June 2020 Technical Memorandum included as Appendix B.
- Development of a future conditions model building on the calibrated current conditions model. This model version took into consideration future projections of sea level rise, increased groundwater table, increased rainfall depth, changes in future landuse and consideration of future drainage structure operations. The details of this model development are summarized in the July 2020 Final Modeling Report included as Appendix C of this report.
- Workflows and GIS tools were developed to facilitate future model parameterization and results processing. A workflow to translate groundwater model results into the MIKE SHE model is captured in a January 2020 memorandum included as Appendix D. A memorandum summarizing the application of a GIS tool to translate model results into flood area mapping data is included in Appendix E.
- An evaluation of the County's Community Rating System (CRS) was performed to provide recommendations on possible enhancement based on the results of this project. This was intended to benefit not only the County but other municipal stakeholders in the County. This January 2020 Technical Memorandum is included as Appendix F.

- A stakeholder involvement process was engaged to educate County interests on the goals and outcomes of the project as well as to solicit their input and involvement in the process. Initial meetings were held in June 2018 focused on soliciting input and data. Interim meetings were held in January/February 2020 to present preliminary project results and solicit final input. A final community workshop was held in October 2020 to present final project results. Summary information from these meetings including presentations are included in Appendix G.

The above referenced efforts are detailed in the respective reports and memorandums issued previously, which are captured in the appendices to this report.

In addition to the above project elements, supplemental future model runs were conducted to provide the basis for flood mapping. These efforts are summarized in the following report Section 2.

As a final step of the project, a detailed flood mapping process was developed, and results compiled for the proposed future community flood elevation map. These efforts are summarized in Section 3 of this report.

2. FUTURE 100 YEAR FLOOD MODEL RESULTS SUMMARY

The future conditions design storm scenarios were run, and results processed for County use. This included the 10, 25, 50, 100, and 500-year 3-day storms and the 25 and 100-year 1-day storms. The future model included consideration of numerous future conditions including sea level rise, rise in groundwater tables, increased rainfall depth, changes in land use, and future control structure operational changes. In addition, model runs simulated conservative seasonal conditions reflecting king tide tailwater at the coastal boundaries and wet season soil saturation conditions. This is detailed in the final model report in Appendix C.

Beyond what was described in the final model report in Appendix C, an additional scenario was run for each design storm to approximate a condition where the shallow soil profile is fully saturated, and no significant soil storage is available to absorb rainfall before runoff occurs. This "Limited Infiltration Scenario" consisted of starting the simulations with the initial groundwater head levels in the model at ground surface (using the ground topographical data as data surface reference). For this scenario, the topo surface representing ground surface was made equivalent to the initial head conditions for the groundwater (i.e., water table). In theory, this puts the groundwater table at ground surface at the start of the simulation, effectively approximating a situation where there is no available soil storage. This is a conservative generalization that does not necessarily correspond with initial stage assumptions in some waterbodies in the model which may be overridden by their initial water elevation settings. Also, as the model approaches the onset of the storm event, this initial water table elevation may fluctuate in some areas through some localized head equalization, so the result may not be "full" saturation of the soil storage at the beginning of the storm.

The results of this scenario for the 100-Year 3-day design storm are shown on the following pages. It is noted that this model scenario was considered reasonably conservative by the authors for the purpose of approximating future flood risk and served as the basis for developing the future conditions community flood mapping product detailed in report Section 3.

Figures depicting maximum flood elevation and depth for the 100-year 3-day design storm for this Limited Infiltration Scenario are shown below as Figures 2-1 and 2-2, respectively.

Figure 2-1: Future Flood Elevation Map – Limited Infiltration Scenario

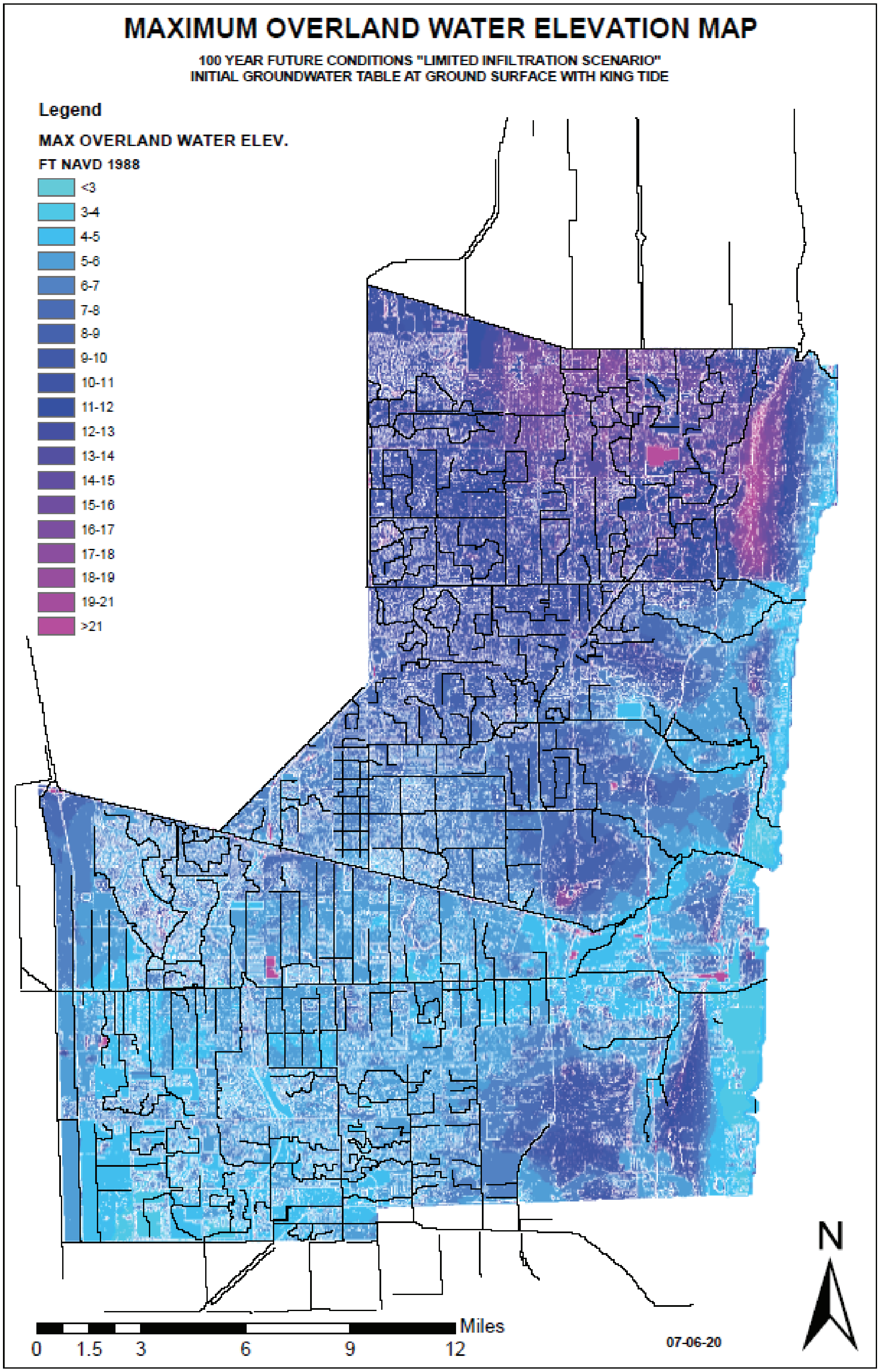

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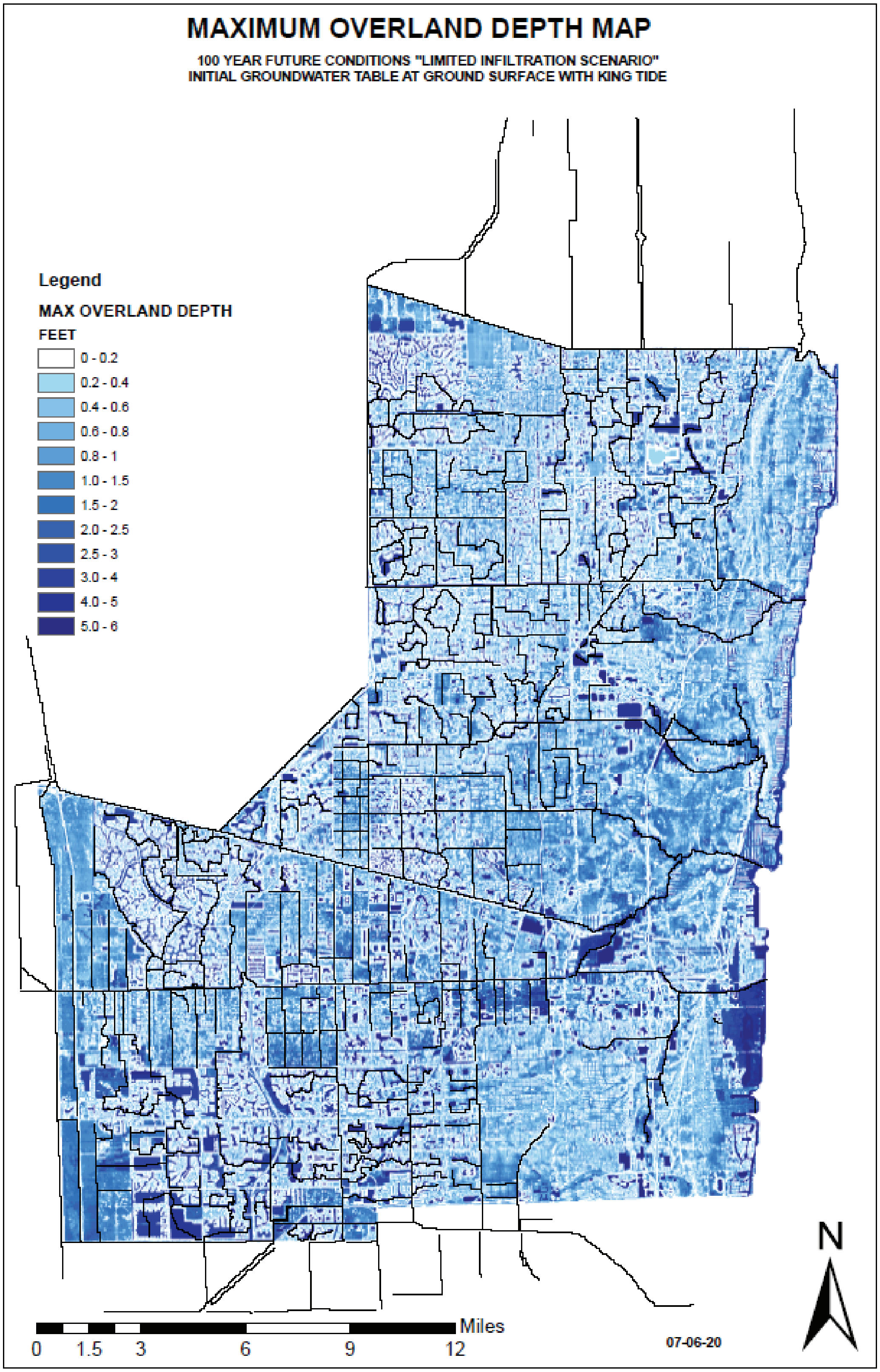
Figure 2-2: Future Flood Depth Map – Limited Infiltration Scenario



3. FUTURE 100 YEAR FLOOD MAPPING

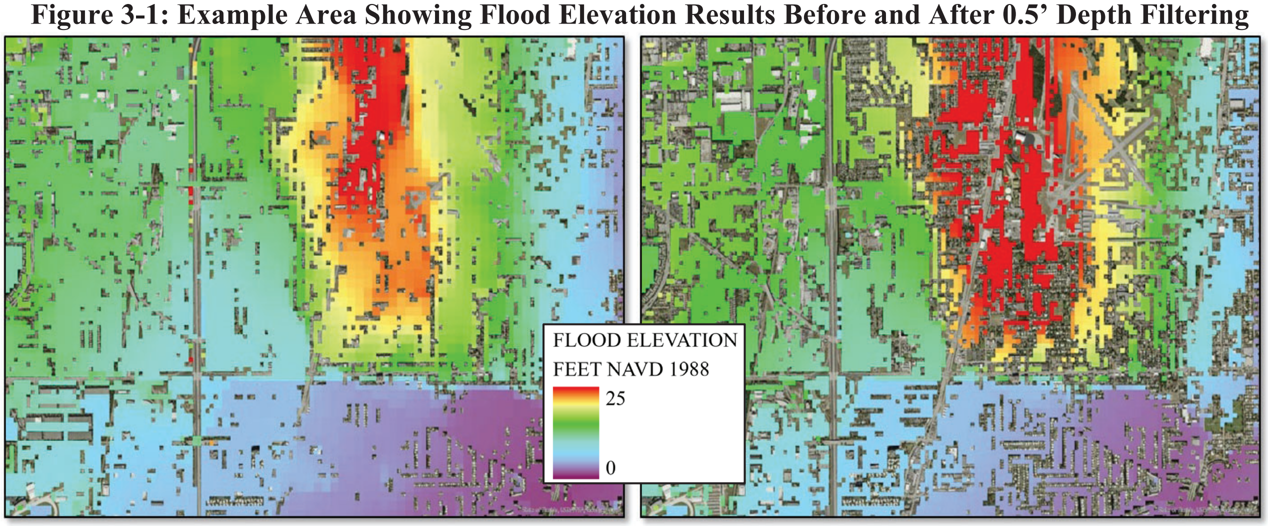
This section summarizes the efforts to develop a process by which the future 100-year 3-day flood elevation results derived from the project model were refined into a representation suitable for the final community future flood map product. It is noted that the eventual community-based map product would be consumed by interested parties in both a static map format (i.e., PDF) and a web based interactive platform (similar to the current future groundwater map). Also, considerations of the repeatability of the overall model-to-map data process was necessary to leave the County with a viable process for future mapping based on changes and/or evolution in model assumptions.

The flood elevation mapping was based on an area weighted approach. This approach was developed by the project technical team to provide a reasonable interpretation of the detailed grid-based flood elevation data from the project model, into an easily digestible format for stakeholders. This as opposed to a contouring approach which based on initial attempts proved to be problematic. This approach was vetted through consistent coordination with County representatives to develop a reasonable and defensible approach to the final flood mapping product. The general approach to the development of this process is summarized as follows.

To represent flood risk mapping in Broward County, the results of the future conditions 100 year 3-day storm simulation with the limited soil storage scenario was used. Flood elevation results were exported from the project MIKE SHE/ MIKE Hydro River model as raster data. These results were further processed in GIS to be formatted for mapping purposes as follows:

- First, a conversion from the model units of meters into feet.
- Second, flood elevations were then converted from the NGVD 1929 vertical datum to the NAVD 1988 vertical datum using the Countywide conversion factors.
- Third, the flood results were then clipped to the established Broward County urban boundary.
- Finally, the flood results raster was filtered to a threshold of only data from areas exhibiting more than one half foot of flood depth. This was performed using raster processing referencing a model results depth raster with values less than half a foot filtered out. An example area showing the flood elevation data before and after filtering is shown below in Figure 3-1.

Figure 3-1: Example Area Showing Flood Elevation Results Before and After 0.5' Depth Filtering



Full Flood Elevation Results

Flood Elevation Results with Depths less than 0.5' Filtered Out

Areas with a half a foot or more of flood depth was considered a reasonable representation of flood risk for the purposes of the future flood map.

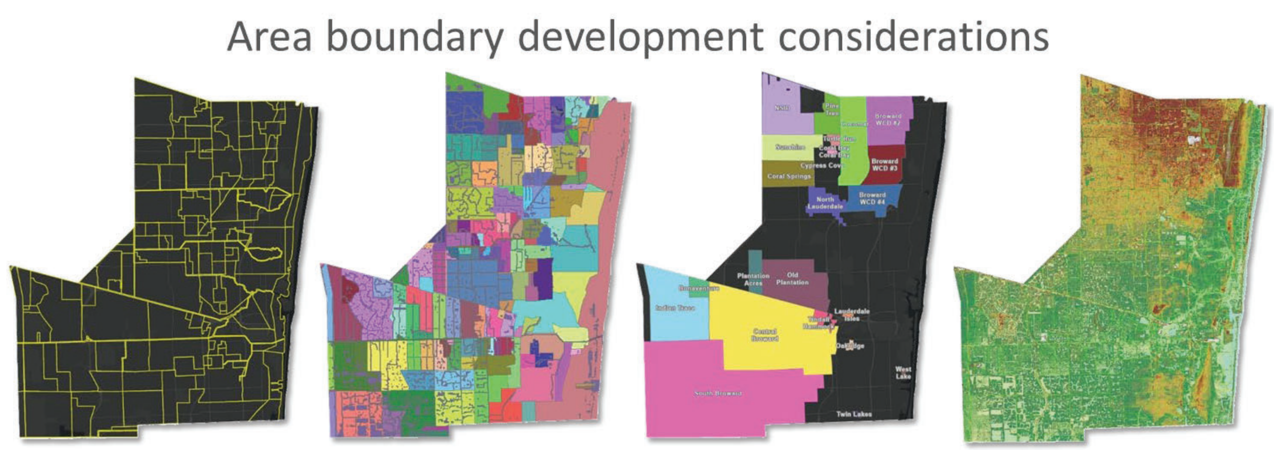
Next, the application of a “Flood Elevation Area Based Approach” was established, and datasets developed. The rationale behind the area based approach is mainly that areas of the County are topographically flat and/or elevations are controlled by pumps or control structures that outfall to major canals. Although flood elevations are expected to vary in these areas during the course of storms as the water progresses though uplands to the receiving bodies, past experience in observations of peak model stage results indicate that an approximation of average extreme elevation within control areas can be used to reasonably represent risk. This approach also facilitates interpretation of the results by stakeholders and for use in development decisions. In areas with consistent topography, it is expected that these common flood areas may be able to encompass significantly large areas. However, there are many areas in the County where the topographic relief changes over short distances, for example ridge lines in the southeast and northeast areas of the County. In these locations, the representative flood elevation areas would be expected to be much smaller addressing localized changes in topography (which drive more spatial variation in the flood elevations).

Establishing the initial target flood area boundaries was an iterative process and relied upon several sources of available data as well and engineering judgement. These included:

- The County’s GIS feature of major drainage basins was considered for formation of flood areas. Where possible, consistency with these boundaries was used or they were at least used as guidelines for refinement.
- Drain code boundaries from the project model were reviewed. These generally represent areas of common drainage somewhat analogous to subbasins, however more directly applicable as hydraulic pathways.
- The County's water control district boundaries were also considered in developing flood area boundaries. The purpose of this was consideration of jurisdictional boundaries that may benefit from specific area interpretation of elevation data.
- Topography was considered to account for areas where the surface elevation changes over short distances which would warrant some smaller refinement of common flood elevation areas.

These datasets are shown graphically in Figure 3-2 below.

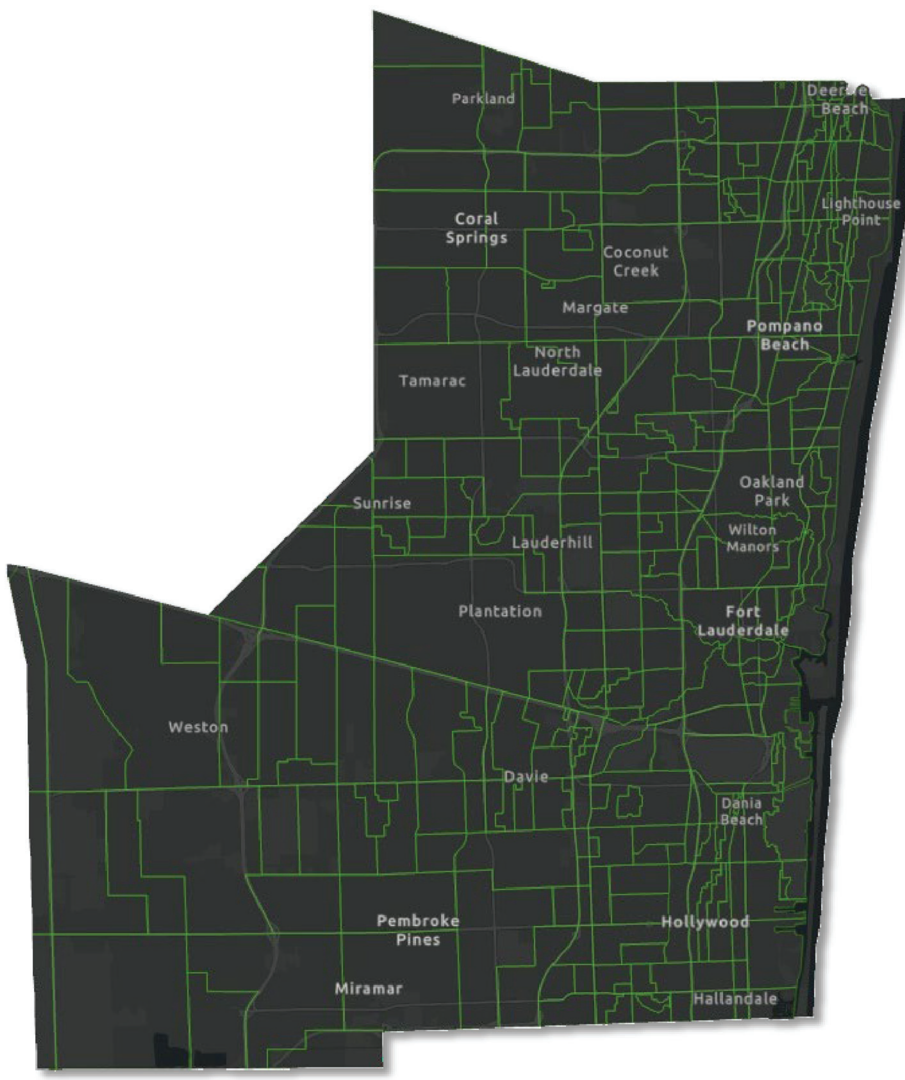
Figure 3-2: Flood Area Boundary Dataset Considerations



County Major Drainage Basins **Model Drain Code Designations** **Water Control District Boundaries** **Topography**

In other areas where refinement was necessary, boundaries between flood areas generally were established along transportation corridors or obvious major development boundaries or interfaces between developed and undeveloped parcels. In many cases these act as topographical divides reflected in the model results. In some cases, because of the highly variable topography, areas required refining to best represent the flood areas. In these cases, boundaries within urbanized areas needed to be bisected. Attempts were made to follow property boundaries or other obvious related features to minimize the possibility of flood elevation data being split at structures.

To determine the appropriateness of the use of consistent flood elevations within delineated areas, a statistical analysis was performed in GIS using zonal statistics. The developed flood areas were compared to the flood elevation raster data from the model, and statistics such as maximum, minimum, mean, standard deviation values were calculated for each area. As the statistical standard deviation is a key indicator of the similarity of data values and generally shows how spread out the values are within a dataset (i.e., consistency of flood elevation data within an area), standard deviation was used as an indicator of the representativeness of the flood elevations in each area. In other words, where standard deviations are minimal, it would be expected the flood elevation data would also reflect general consistency in values. For the deviations that are extreme, it would indicate a wide variation in elevations which would then make the development and use of a consistent elevation over a given area somewhat problematic and dictate further refinement. Initial trial runs were evaluated with various areas to refine this process. In the end, a reasonableness target was determined as achieving less than ~1 to 1.5 standard deviations. It is noted that for areas with steeply varied topography and other areas where only a minimal flood data within a particular area boundary was available, the imposition of the target standard deviation range was not achievable. The outliers that do exist were examined more detail to ensure their reasonableness in the context of this analysis, and further adjustments made as applicable. The process resulted in the development of 368 discrete flood areas. These areas are shown on Figure 3-3.



During the refinement process, it was noted that areas with steeply changing topography over small areas were skewing the area statistics significantly. After analysis of various combinations of topographic anomalies, it was considered appropriate to focus attention to large transportation corridors with elevated overpasses and also several of the large landfill sites in the County with extremely high elevations. Other topographic anomalies such as berms and small hills associated with golf courses, material stockpiles or other localized small instances were not considered to significantly influence flood elevation statistics in areas. Based on this identification, a GIS feature was developed for the purpose of masking out flood elevations in areas with large or extreme changes in topography over short distances. This feature was used in processing to create another flood elevation raster version on which the above-mentioned statistics were run for the area based flood elevation analysis. It is noted that this results in no flood elevations reflected in these masked out areas. For the purposes of the new community map, application of the GIS feature layer was considered a reasonable concession as major transportation corridors and waste disposal facilities generally have detailed site-specific flood plans which would drive design decisions. The masking areas are shown on Figure 3-4 with a detailed area shown on Figure 3-5.

Figure 3-4: Topographic Masking Areas

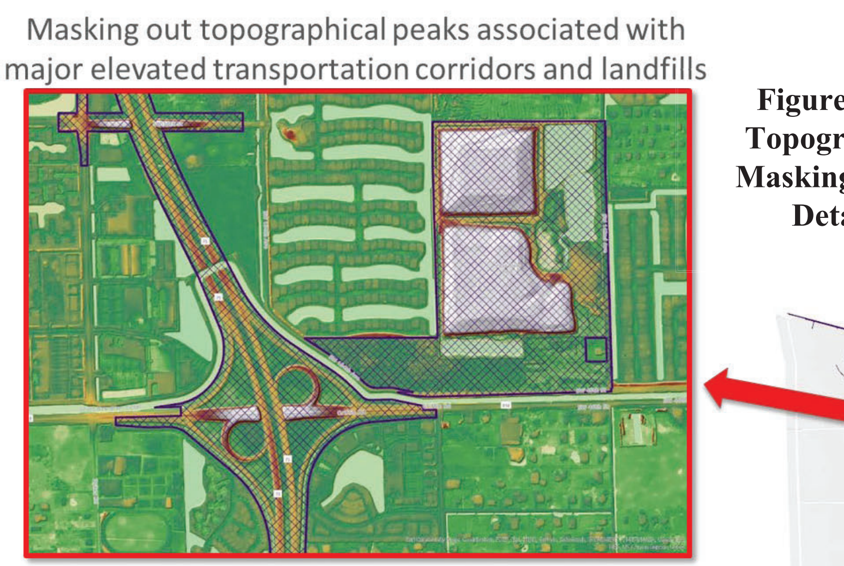
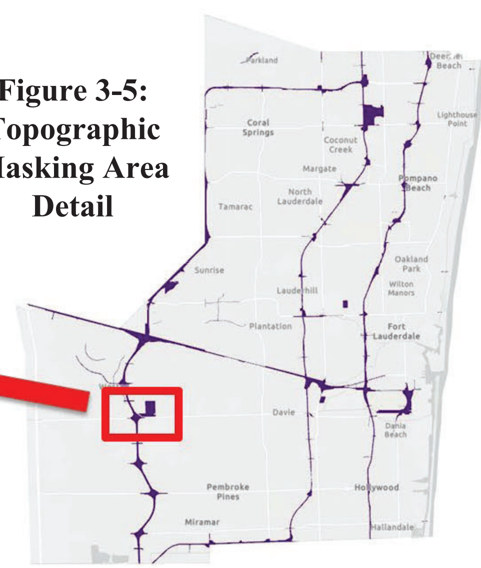


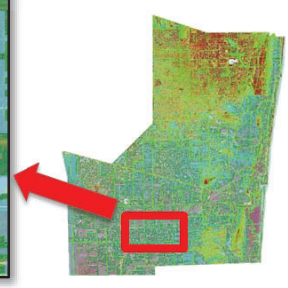
Figure 3-5: Topographic Masking Area Detail



The next step was to determine what an appropriate regulatory flood risk guidance elevation would be for each of areas using the statistical data developed. Based on comparison of the data in representative locations and data histogram analysis, it was determined using a flood elevation derived from the flood area statistical mean plus 2 standard deviations would appropriately capture a reasonable flood risk value. Assuming a normal distribution, 2 standard deviations captures approximately 95% of the values within distribution. Although the flood area data is not consistently normally distributed, and often right leaning to higher elevations, most areas approached a reasonable approximation of this distribution. Some examples of flood areas with derived statistics are shown below in Figures 3-6 and 3-7.

Flood Elevation = 5.39 (mean) + [2 x 0.46 (StdDev)] = 6.31

Rounded to 6.5



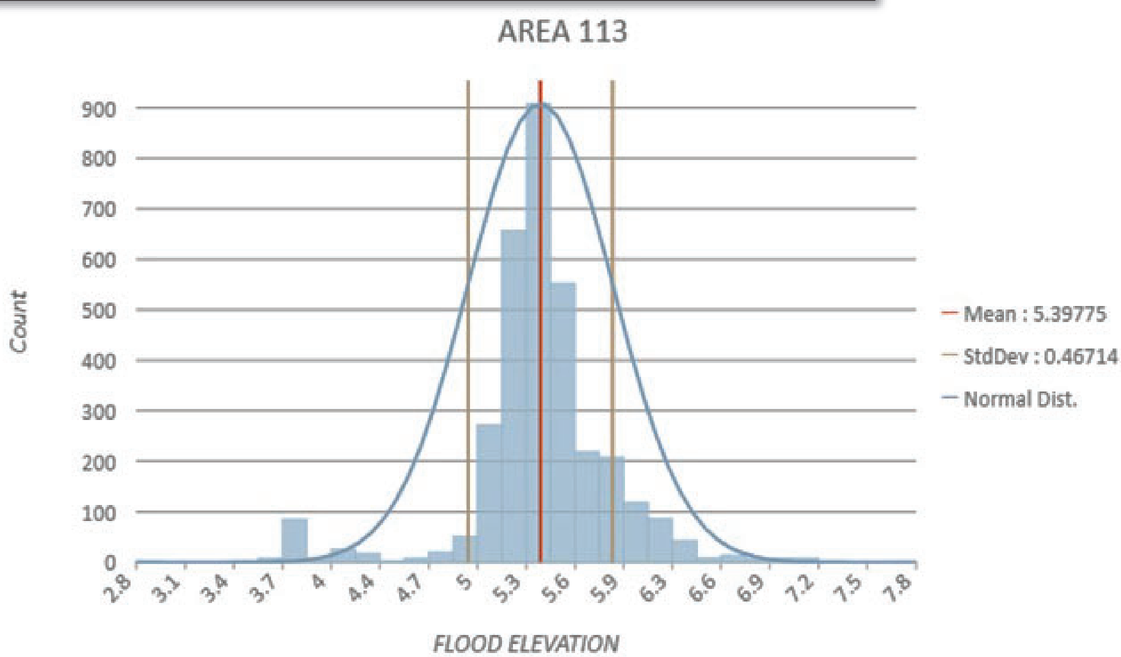
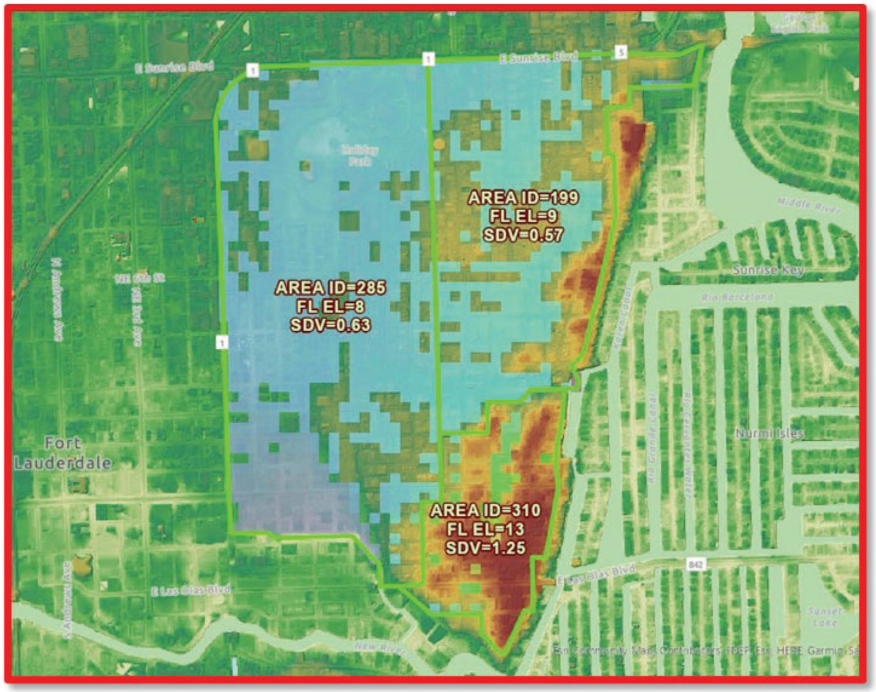
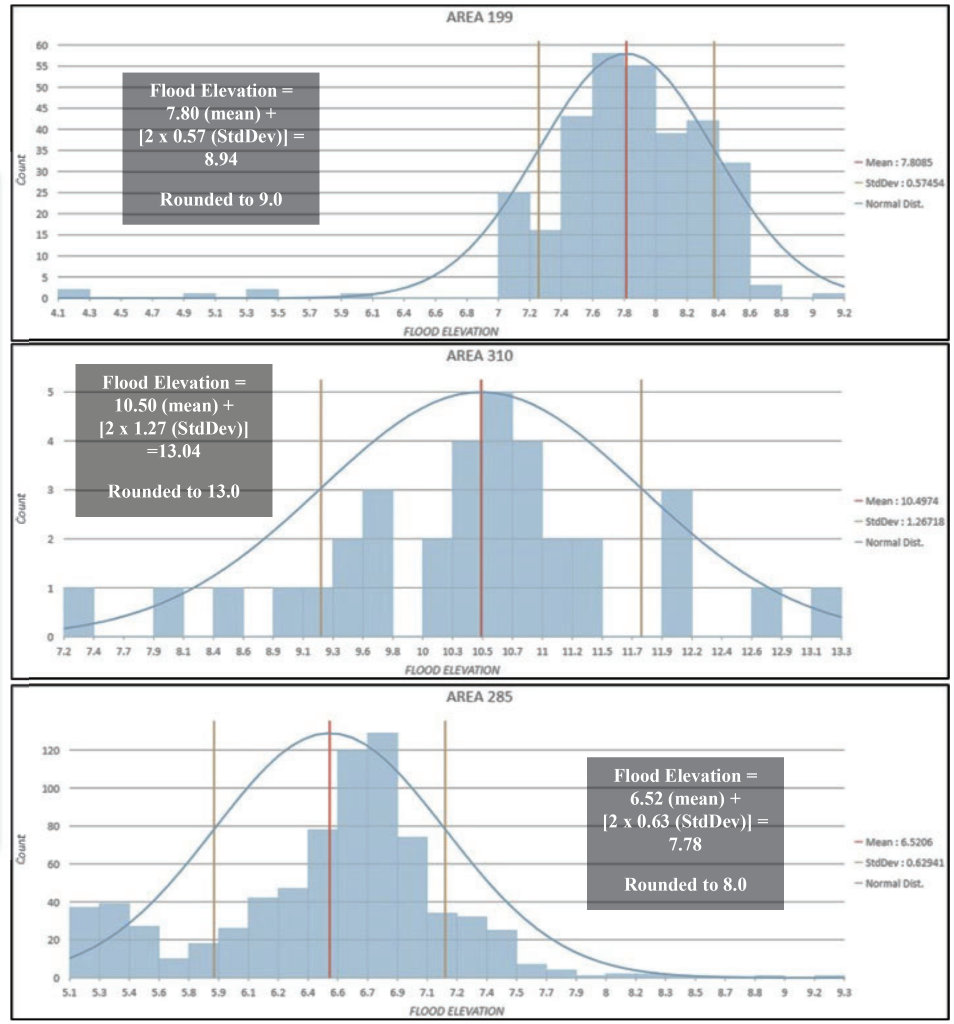


Figure 3-6: Example of Statistically Derived Flood Area Elevations in Typical Area

Figure 3-7: Example of Statistically Derived Flood Area Elevations in Area of Steeply Changing Topography





It is noted that rounding elevation data is a common practice in flood mapping. For FEMA flood mapping purposes or other similar efforts, rounding (up or down) to the nearest 1 foot has traditionally been applied. Recent FEMA guidance has made allowances for decimal values (i.e., 0.5' or lower) as long as the hydraulic analysis supports such accuracies[1]. In the case of this Broward County map, the rounding interval desired was an even half-foot which is supported by the MIKE-SHE / MIKE Hydro River model and underlying topographical data accuracy. This interval is consistent with the County's previous 1977 Community Flood Map. Once the refined flood areas were established and final statistics calculated, the resulting flood elevation values were rounded to the nearest half-foot elevation using GIS calculation tools.

These resulting flood area results are shown on Exhibit 1 with an aerial background and on Exhibit 2 with a topographical background. It is the intention that these flood areas and respective elevations will be promulgated into the new future conditions 100-year community flood elevation map.

4. CONCLUSIONS

The Future Conditions 100-Year Flood Elevation Map project was intended to advance the resiliency efforts in Broward County by setting the foundation to improve standards for flood protection such as establishing future finish floor elevations for new buildings and major new redevelopments in the County. The Future Conditions 100-Year Flood Elevation Map was developed through integrated hydrologic modeling of surface and groundwater, using DHI's MIKE SHE/MIKE Hydro River model tools. This model incorporated future land use changes and the effects of projected sea level rise and precipitation changes on predicting future flood conditions.

This final report provides a compendium of previous project task submittals and stakeholder coordination efforts. This reports also provides a summary of final future flood modeling scenarios leading to the development of the final flood mapping data. The flood area approach for conveying the future 100-year flood elevation data for the updated community flood map was vetted through a collaborative process reflecting input from a Broward staff and key stakeholders. The model deliverables and results processing tools developed during this project will provide the County with a living toolset to leverage the project's technical data to inform future decisions where projections and assumptions on future changes may evolve.

[1] FEMA standards allow for the use decimal base flood elevations (BFEs) to supplement whole-foot rounded BFEs with consideration of the relative accuracy of the hydraulic analysis methods to support such usage. Reference: *Guidance for Flood Risk Analysis and Mapping, Mapping Base Flood Elevations on Flood Insurance Rate Maps, FEMA, December 2020.*