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Review of Hurricane Debby: First Street Re-creation Finds Majority of Damaged Homes Outside of FEMA Flood Zones

Summary of Findings

78%

Percentage of properties flooded by Hurricane Debby that are outside of a FEMA Special Flood Hazard Area

$12.3B

Damage caused by Hurricane Debby, with $9.7 Billion outside of a FEMA Special Flood Hazard Area

- First Street's re-creation of Hurricane Debby flooding accurately predicted impacted areas and water depths.
- Comparisons against First Street's probabilistic flood hazards align closely with observed flooding from media and homeowner reports.

This report provides preliminary insights into the impact of Hurricane Debby, measuring the extent of flooding, insurance coverage gaps, and damage estimates. Our early analysis reveals that our re-creation of Hurricane Debby effectively predicts flooded regions and water depths, aligning closely with media and homeowner reports. Notably, 78% of the properties affected by the hurricane were located outside of FEMA's designated Special Flood Hazard Areas.

The storm resulted in a staggering $12.3 billion in damages, with $9.7 billion occurring outside of FEMA's Special Flood Hazard Areas. These findings underscore the necessity for a reevaluation of flood risk assessments and preparedness strategies in vulnerable areas.

Hurricane Debby Flooding Simulation

Hurricane Debby began as a tropical depression on July 31, 2024 in the Atlantic, quickly intensifying into a tropical storm by August 1. The storm strengthened further into a Category 1 hurricane on August 3 as it approached the Florida coast. Debby made its first landfall near Steinhatchee in Florida's Big Bend region on August 5, bringing heavy rain, storm surges, and strong winds. After crossing Florida and weakening slightly, Debby made its second landfall as a tropical storm on August 6 near Hilton Head Island, South Carolina. The storm continued to move slowly inland, causing significant flooding in the southeastern U.S. before dissipating on August 9. The storm was characterized by its slow movement, which exacerbated its impacts, especially from heavy rainfall and storm surge in affected areas.

The hardest-hit areas in Florida included the Big Bend region, where Debby caused significant storm surge and flooding. Cedar Key experienced a storm surge of nearly 6 feet, leading to widespread coastal flooding. However, it was the precipitation in areas like Sarasota, regions along the Florida-Georgia border and coastal South Carolina where the biggest impacts were felt. In Georgia, the coastal areas, particularly around Savannah, also faced severe flooding due to the slow progression of the storm. South Carolina experienced less intense wind damage but still faced extensive flooding, particularly in the low-lying regions near Hilton Head and Charleston.

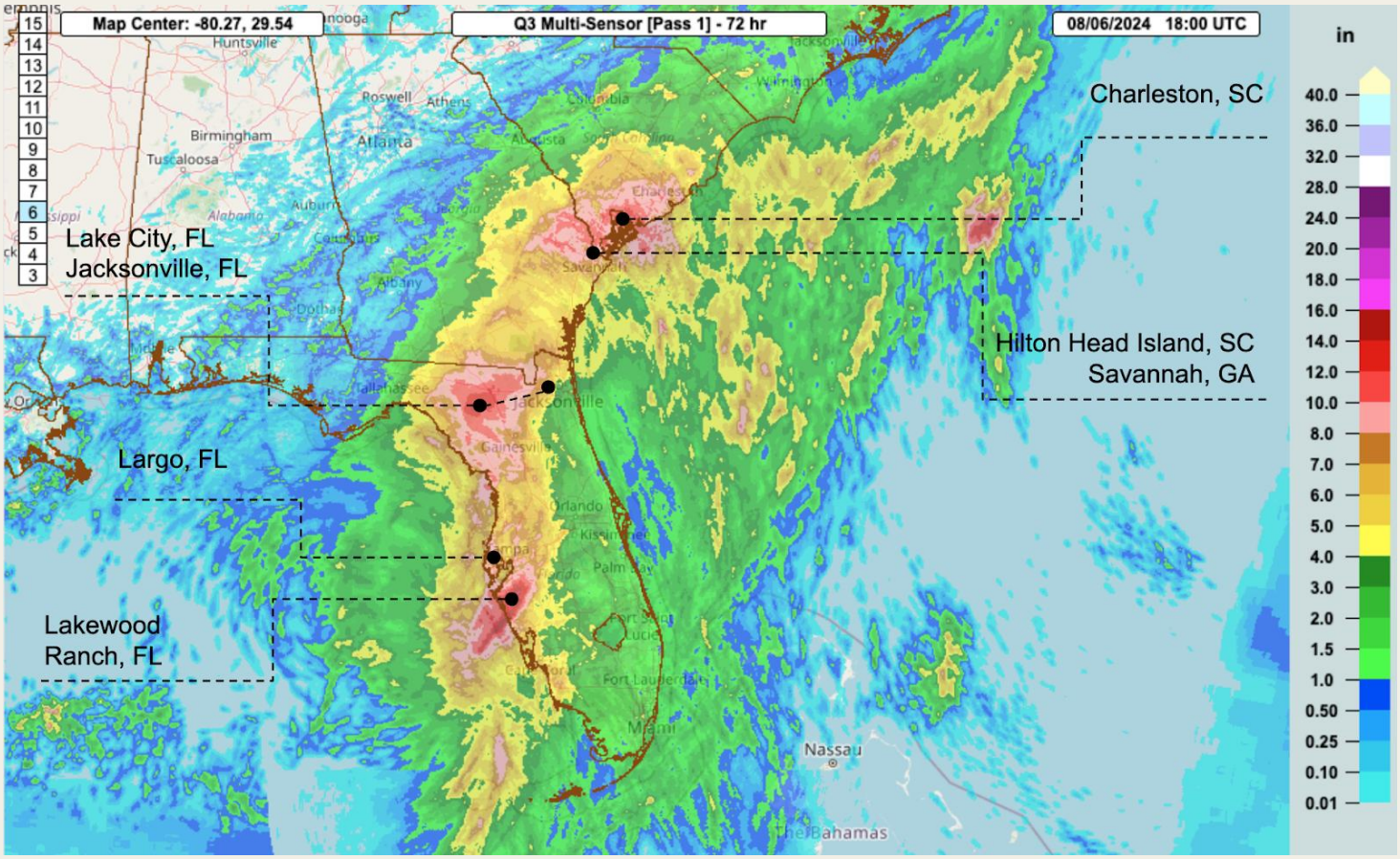


FIGURE 1. A MAP OF TOTAL RAINFALL ACCUMULATION OVER 72 HOURS (AUGUST 4TH TO 6TH), HIGHLIGHTING CITIES EXPERIENCING FLOODING DUE TO HURRICANE DEBBY.

As Debby moved inland, the storm's slow pace allowed it to drop significant amounts of rain over the southeastern United States. This led to catastrophic flooding, particularly in parts of Georgia and South Carolina, where several rivers overflowed their banks.

The impact was compounded by the storm's slow movement, which prolonged the exposure of these areas to heavy rains and high winds, resulting in widespread power outages and significant damage to infrastructure.

Hurricane Debby Flooding Re-creation

In order to understand the impact of Hurricane Debby, First Street simulated flooding from the event using observed rainfall rates and the pluvial components of the First Street Flood Model, which provides climate-adjusted return period estimates of rainfall rates and on-the-ground flooding from those rainfall rates (Kim et al, 2023; First Street 2023). The analysis found that large areas of Florida's West Coast, much of the Southeastern Atlantic Coast, and inland North Carolina, Virginia, Maryland, and Pennsylvania all saw some level of flooding from the heavy rainfalls associated with the events. The areas that saw the highest rate of rainfall were south of Tampa in the Sarasota area (~ 200 year return period which corresponds to a 0.5% annual likelihood), just northeast of Gainesville, FL (~ 240 year return period), and on the Georgia-South Carolina border (~ 200 year return period) where Savannah, Hilton Head, and Charleston were all impacted.

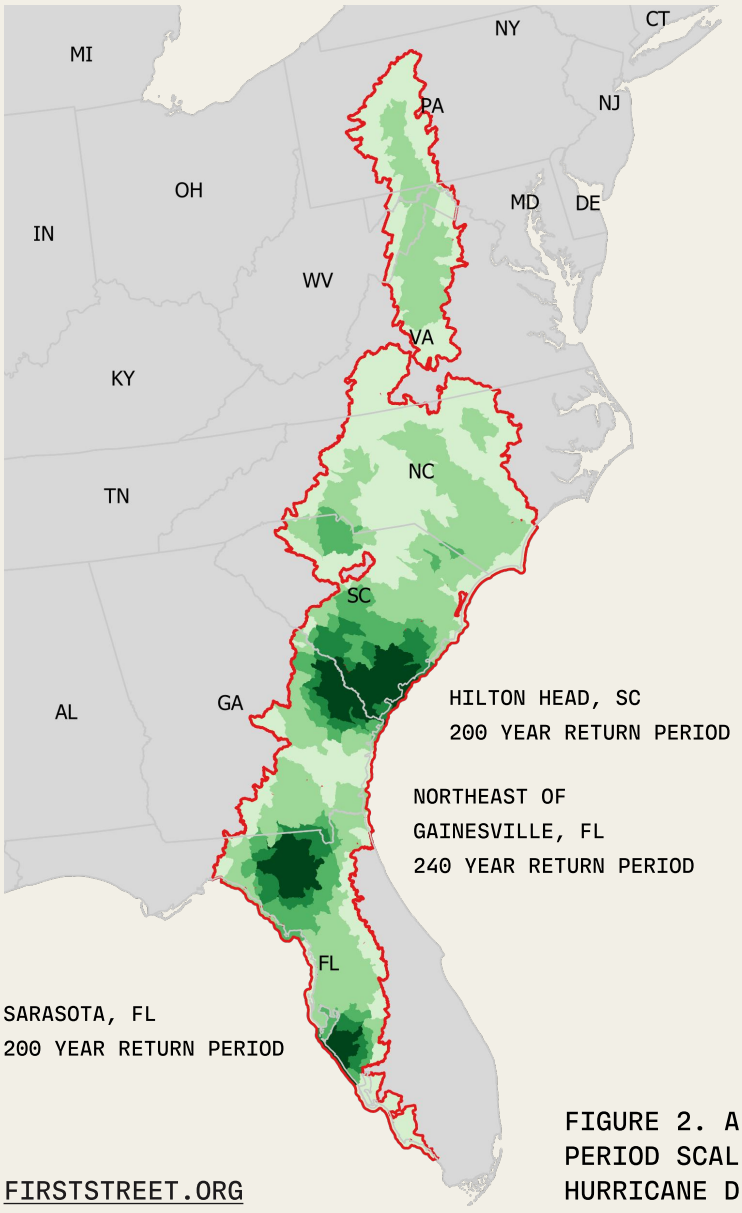
In order to simulate the flood hazard data and inundation maps for Hurricane Debby, First Street generated a combination of fluvial (riverine) and pluvial (rainfall) simulations, grounded in a physical hydraulic model and the latest high-resolution topographic data, such as the USGS standard one-meter digital elevation model (DEM) based on lidar observations of ground elevations, in order to accurately capture surface water dynamics. For the fluvial component, we utilize USGS streamflow data to simulate riverine flooding, ensuring the model aligns with actual hydrologic conditions. For the pluvial component, addressing local flood risks from rainfall, we rely on meteorological input data derived from weather radar and stream gauge adjusted precipitation products. This data integrates weather radar and gauge-driven rainfall observations, providing a robust basis for simulating flood events caused by rainfall.

The likelihood (return period or recurrence interval) of rainfall and flood hazards is then estimated using the First Street Precipitation Model, which assesses the frequency and intensity of rainfall events by analyzing historical records and factoring in changes in rainfall patterns due to climate change. For instance, a 1-in-100-year recurrence interval signifies that a flood of that magnitude has a 1% chance of occurring in any given year, meaning there is a 1 in 100 probability that the water depth will reach the 100-year flood height this year. These return periods are presented in the map to highlight the area most directly affected from the heavy rainfall produced by Hurricane Debby.

Hurricane Debby Damage Assessment

To assess the damages from the storm simulation, inundation from the flood model was compared to the property-specific building characteristics and fragility curves which underlie First Street's damage calculations. Information on the likelihood of building-specific insurance coverage was integrated into the analysis to understand the likely impact of uninsured damages.

When integrating the fluvial model simulation with the rainfall rates that were produced by the event, there were 385k properties with some level of water reaching the building footprint in the Hurricane Debby re-creation. Of those, approximately 160k were calculated to have experienced some level of damage from the event, accounting for 42% of all properties impacted with preliminary damages ranging from $9.5 - $15.8 Billion. Of properties that were estimated to be damaged, 124k, roughly 78%, are outside of a FEMA Special Flood Hazard Area (SFHA) and are likely not subject to the mandatory flood insurance purchase requirement. Under the assumption that most of these properties likely do not have flood insurance, the estimated preliminary uninsured damage of Hurricane Debby ranges between $7.6 - $12.6 Billion.



385K
TOTAL PROPERTIES AFFECTED

≈160K (42%)
AFFECTED PROPERTIES WITH FLOOD DAMAGE

≈124K (78%)
DAMAGED PROPERTIES OUTSIDE OF SFHA

$9.5-$15.8B
TOTAL PROPERTY DAMAGE

$7.6-$12.6B
UNINSURED PROPERTY DAMAGES

FIGURE 2. A MAP OF RAINFALL FREQUENCY IN RETURN PERIOD SCALE FOR A 24-HR MAXIMUM RAINFALL FROM HURRICANE DEBBY AND ASSOCIATED DAMAGES

Losses from Hurricane Debby were disproportionately centered in the state of Florida. The results of the First Street flood model simulation found $2.6 - $4.5 Billion in losses from the event, of which $1.9 - $3.3 Billion (~70%) is likely to be uninsured and occurred outside of FEMA's SFHA. Among the counties hit hardest were Hillsborough, Duval, Pasco, and Marion counties in Florida, which are all located in regions of the state that saw rainfall rates above the 200 year return period and have a high density of buildings in the affected areas. Other areas of note are Charleston County, SC which saw rainfall rates near the 200 year return period during the 2nd landfall of Debby.

COUNTY	DAMAGES (MILLIONS)	PROPERTIES IMPACTED	FLOOD REPORTS IN MEDIA
HILLSBOROUGH, FL	$810	11,877	Widespread Flooding Was Reported Across The Tampa Bay Area Due To Debby, Leading To Flash Flood Warnings And Significant Impacts On The Hillsborough River (Source).
SARASOTA, FL	$1,099	8,586	Hurricane Debby Brought Record-Breaking Rainfall Of Up To 17.78 Inches In Some Parts Of Sarasota And Resulted In Widespread Inland Flooding And Significant Property Damage (Source).
DUVAL, FL	$426	8,336	Flooding And Power Outages Were Significant Issues In Jacksonville As The Storm Passed Through (Source)
PASCO, FL	$299	7,185	Pasco County Experienced Severe Flooding, Particularly In Low-Lying Areas, Prompting Evacuations (Source).
MARION, FL	$421	5,540	The County Saw Flash Floods In Ocala And Other Areas, Disrupting Traffic And Causing Property Damage (Source).
FAIRFAX, VA	$540	4,233	Heavy Rainfall Led To Flooding In Parts Of Fairfax County, Affecting Roads And Neighborhoods (Source).
NEW HANOVER, NC	$283	4,128	Wilmington And Surrounding Areas Experienced Coastal Flooding And Road Closures (Source).
MANATEE, FL	$597	4,052	Officials Were Forced To Strategically Release Water From The Lake Manatee Dam To Prevent A Structural Failure, Which Further Contributed To Downstream Flooding. By The Time The Storm Had Passed, Over 55 Water Rescues Had Been Performed, And Many Roads Remained Closed Due To The High Water Levels (Source).
CHARLESTON, SC	$123	3,860	The City Faced Significant Flooding, Especially In The Downtown Area, Due To High Tides And Storm Surge (Source).
WAKE, NC	$295	2,731	Raleigh And Surrounding Areas Dealt With Street Flooding And Downed Trees (Source).

First Street's Hurricane Debby Flood Model Review

First Street's Flood Model (FS-FM) performance was assessed by comparing the simulations of Hurricane Debby flooding with reference data from media sources for spot accuracy. The review of flood hazard data and inundation maps is critical for understanding flood risk representation and ensuring the accuracy of data used by various stakeholders. Social media offers a rich repository of information, including articles and photos, which can be utilized to identify flood locations and estimate water depths. This review leverages social media data to overcome the limitations of traditional validation methods in a data-scarce environment during and immediately following an event. By integrating social media data, this review provides insights into the model's effectiveness and the reliability of hazard data in representing the actual flood risks during the event.

This process focuses on assessing the accuracy of FS-FM's fluvial and pluvial modeling performance to provide real-world evidence of model skill in some of the areas most impacted, and publicly covered, during the flood event.

One such area was around the Manatee River beneath the Manatee Dam. Due to capacity concerns during the storm, water was released from the dam, which typically holds around 44 feet of water. However, during the storm water rose to 48 feet and public officials made the decision to release the pressure to avoid a larger flooding disaster. However, once the water was released, significant flooding downstream occurred in areas not usually prone to flooding, such as parts of Bradenton, leading to over 200 rescues and numerous emergency calls. The images below highlight the focus of media attention on the topic.

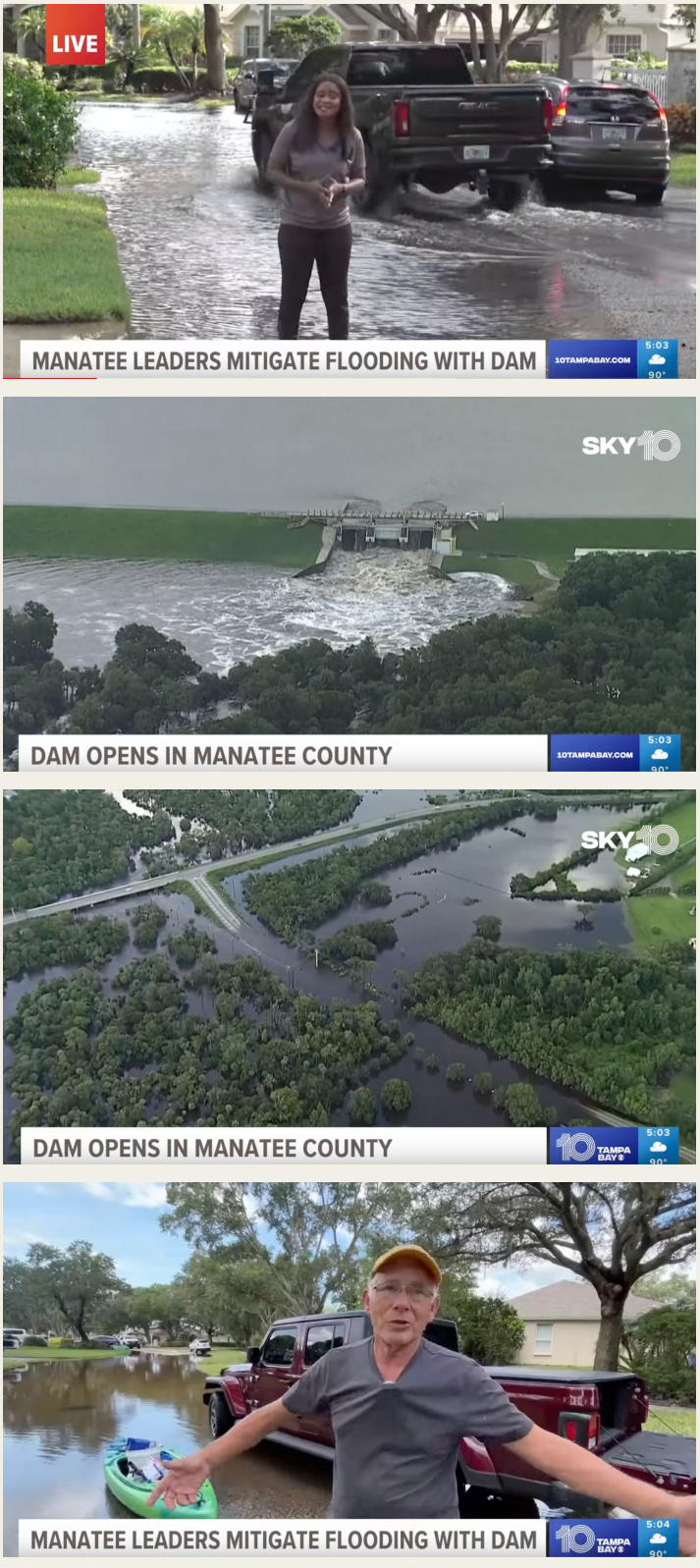


FIGURE 3. IMPACTS OF THE EXTENSIVE WATER FROM MANATEE DAM DUE TO HURRICANE DEBBY

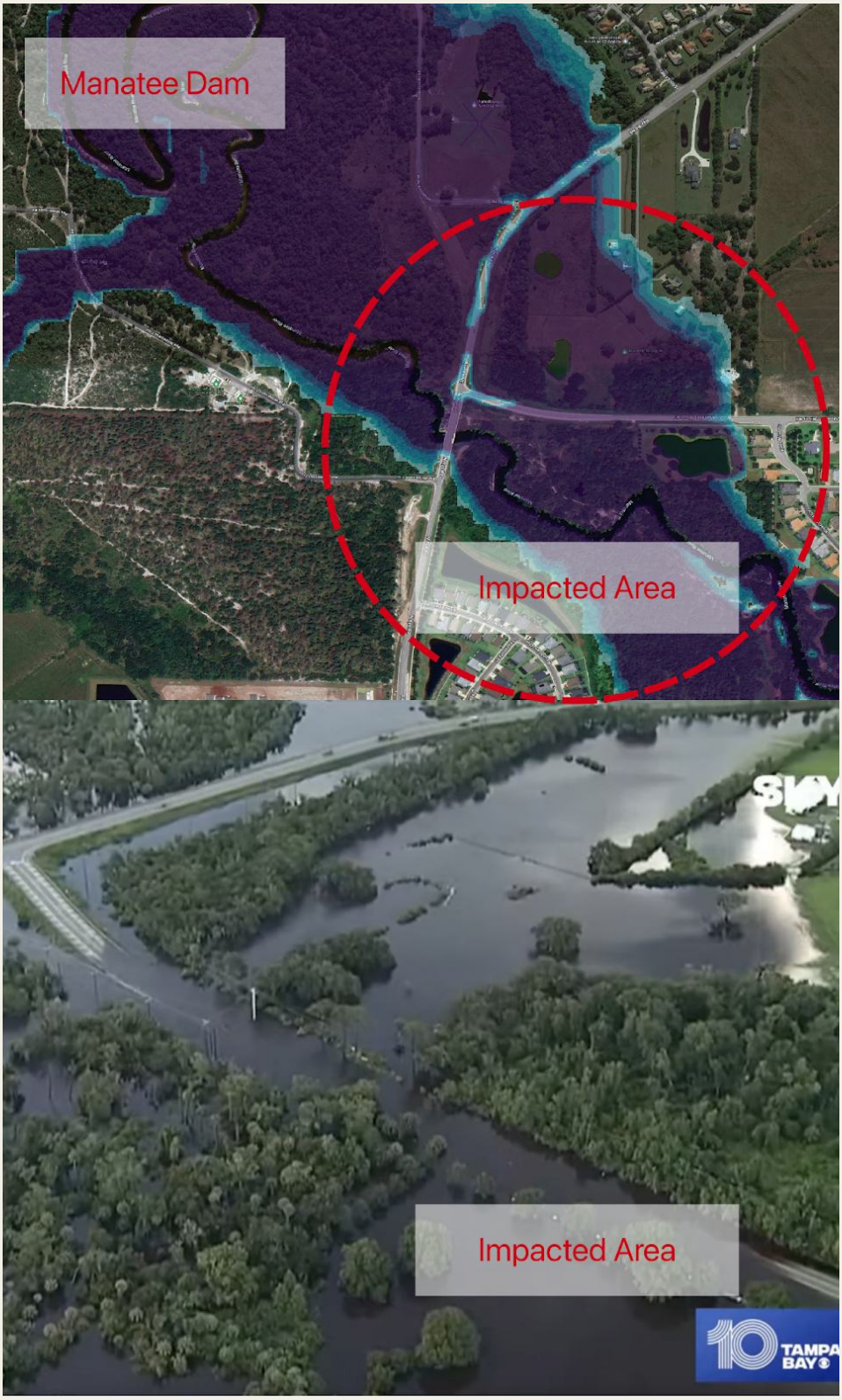


FIGURE 4. RESULTS OF THE FLUVIAL FLOODING CAUSED BY THE EXTENSIVE HEAVY RAINFALL AND WATER RELEASE FROM THE MANATEE DAM

One particular intersection was covered repeatedly during the event and was used as a test case for visual spot accuracy. From spot accuracy coverage of the east-west street (Upper Manatee River Rd), the image aligns exceptionally well with complete inundation of that street and water also inundating the areas under the north-south street (Rye Rd ME) as shown on the flood hazard map.

Large swaths of water following the existing river channel to the northeast and southwest of the intersection align both in regard to extent and depth of water from the model simulation. Additionally, Figure 5 illustrates flooding caused by heavy rainfall and water release from the Manatee Dam in Manatee County, which is highlighted in the simulation model results as having extensive flooding in the exact area this image was taken.

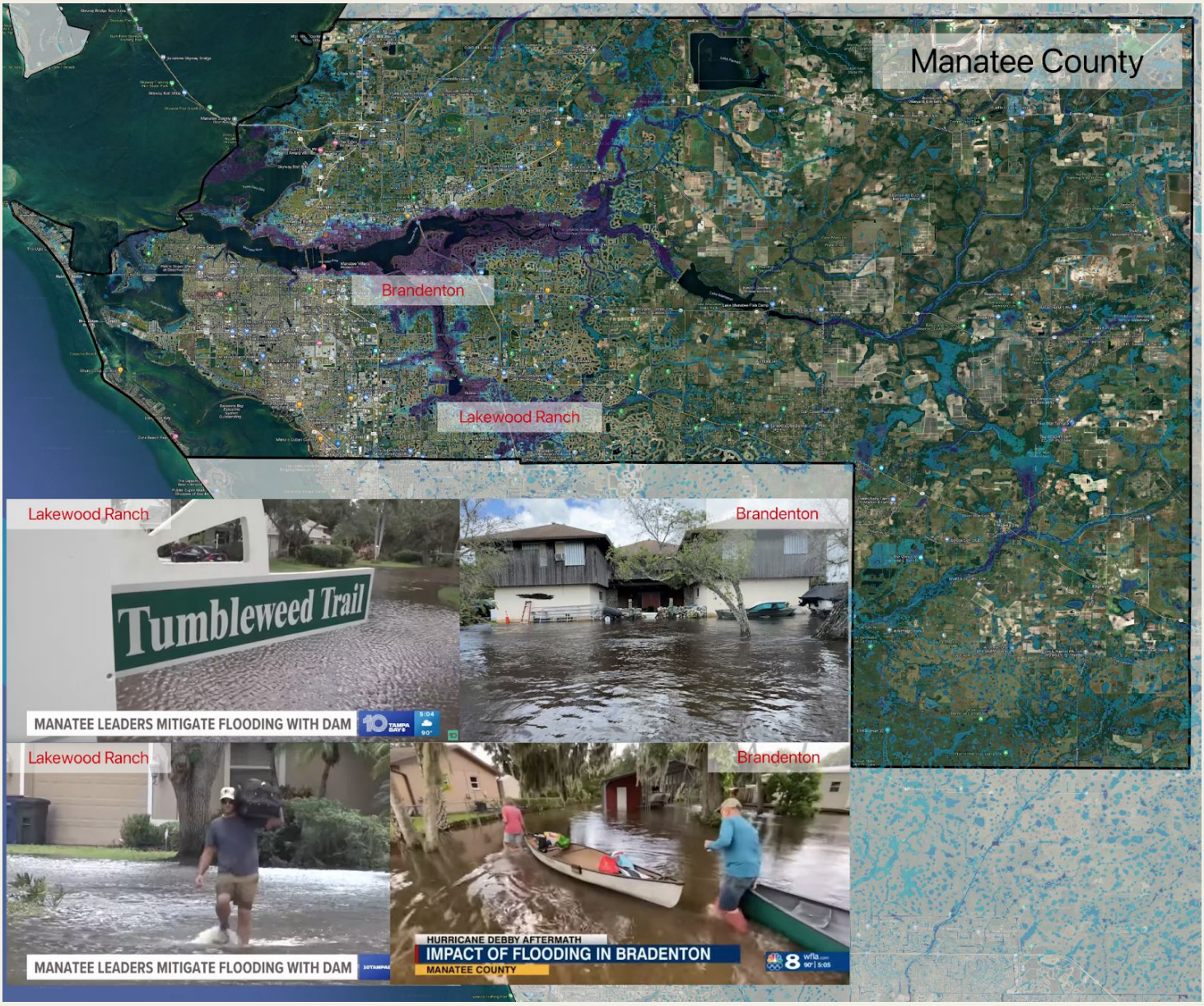


FIGURE 5. FLOODING IN MANATEE COUNTY DURING HURRICANE DEBBY COMPARED TO FIRST STREET'S SIMULATED FLOOD HAZARD

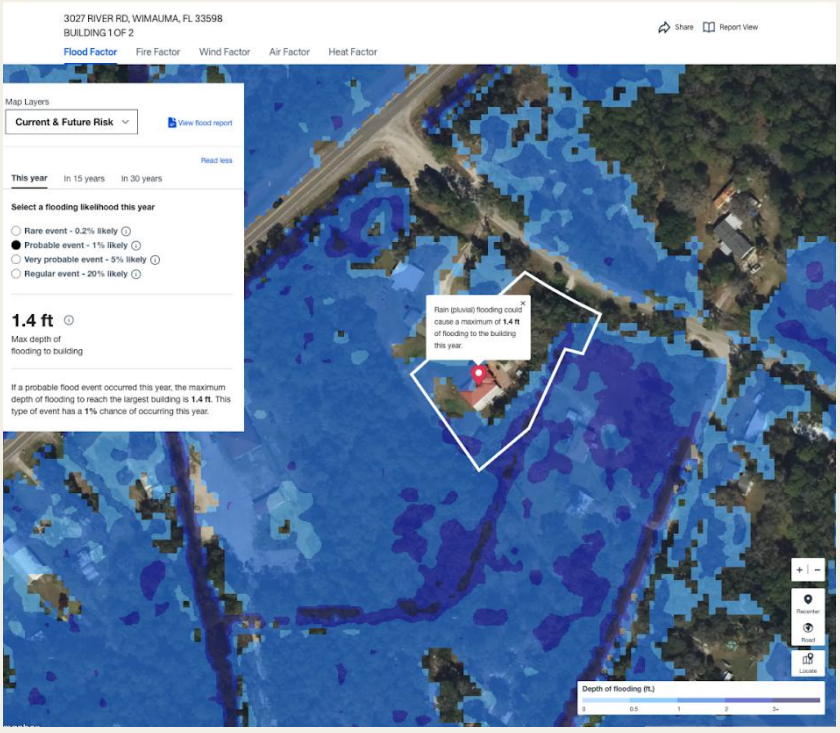
Most damaged areas experienced rainfall magnitudes corresponding to a 1-in-100-year return period during Hurricane Debby, allowing a comparison with the 1-in-100 year FS flood map with reference data from media sources. During this process, we identified specific inundation locations and verified their geographical features using Google Maps to ensure consistency between the areas depicted by the media and modeled by First Street. Selected inundation areas utilized include Lakewood Ranch, Sarasota, and Jacksonville, FL, where Hurricane Debby caused significant physical flood damage.

The following images provide further evidence of the utility of the First Street probabilistic flood hazard layers as tools for the assessment of risk aligned at return period-specific levels. The areas chosen for spot accuracy assessment are all equivalent to a 100 year return period event, and were compared to First Street's 100 year flood hazard predictions.

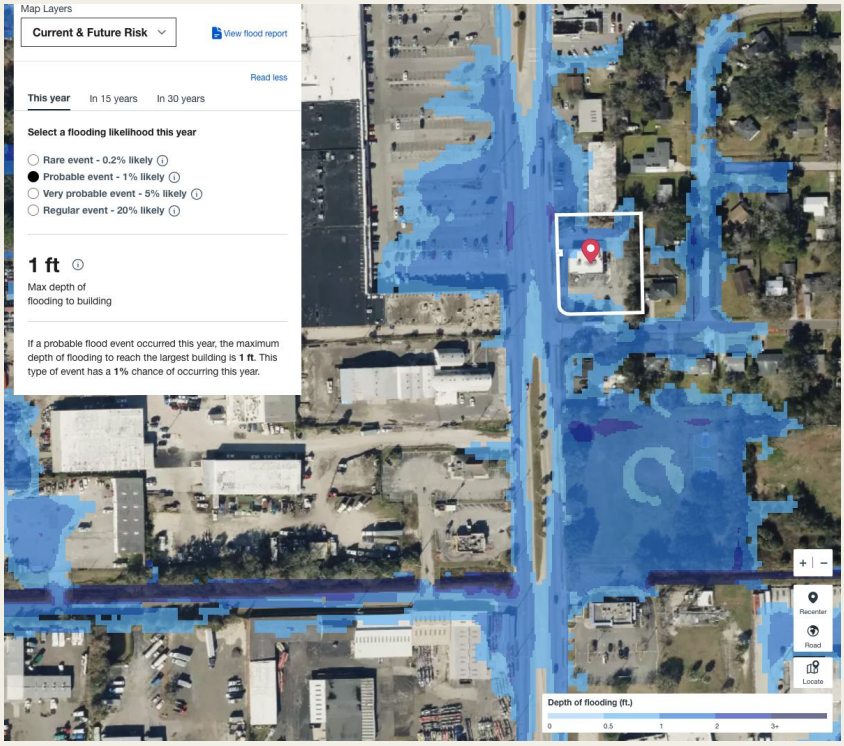
Accuracy Spot Checks of Observed Flooding from Hurricane Debby and Comparison to the First Street 100 Year Return Period Probabilistic Hazard on FirstStreet.org

An aerial drone captures a view of homes flooded off River Road and U.S. 301 in Wimauma on Monday, Aug. 5, 2024. Flooding was occurring from the nearby Little Manatee River. The river level was 15.83 feet at the time of this photo and classified as moderate flooding, with 17 feet considered

This comparison shows the skill of the model in incorporating high resolution elevation data. In the image of the predicted inundation around the home on firststreet.org, the home has less severe flooding than the surrounding land. This is apparent in the image above that shows flood waters on the property, but with the building and some surrounding areas sitting at or above the water level.



River Road and U.S. 301, Wimauma, Florida, from SOURCE

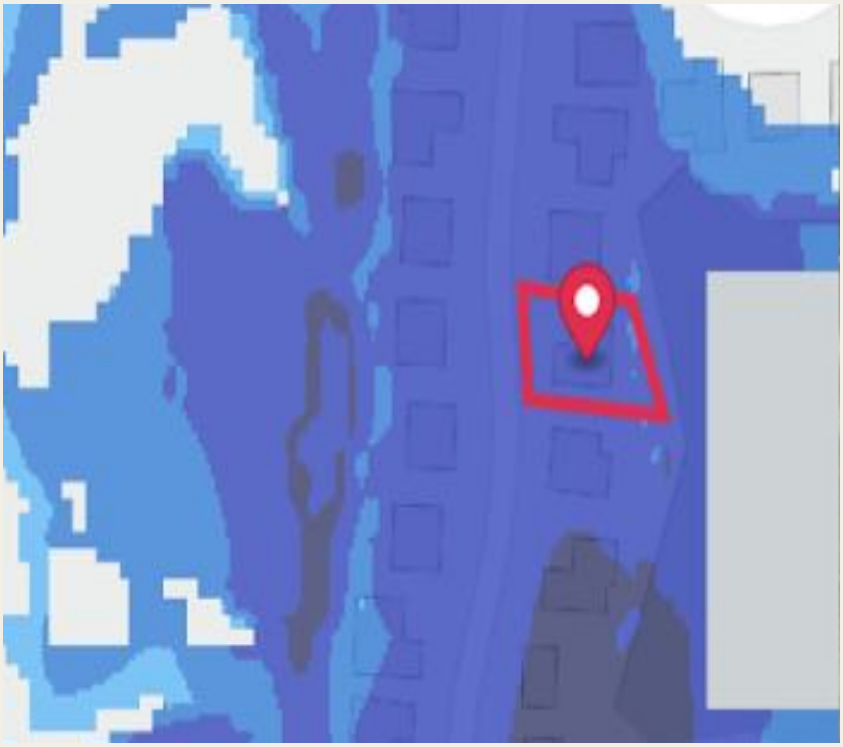


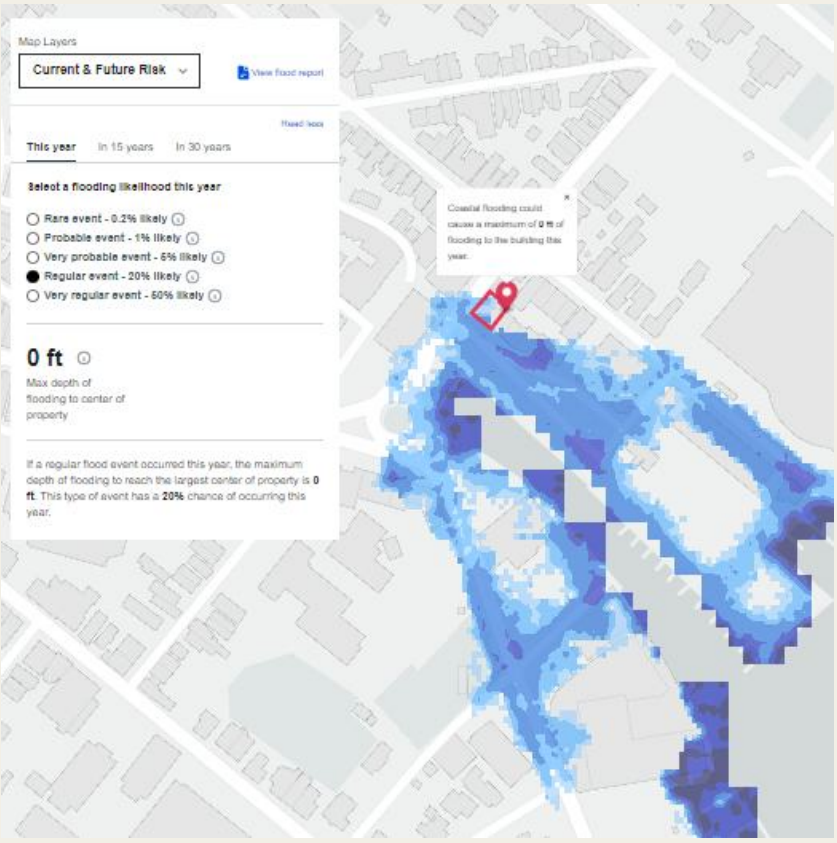
This comparison shows a commercial area in Jacksonville, FL that flooded during Hurricane Debby. Of particular interest is the area of standing water on the road near a commercial building, located at the same location as a depression in surface elevation whose impact on flooding is resolved by the First Street Flood Model.

711 Edgewood Avenue N, Jacksonville, Florida Flooding, from SOURCE

This comparison in Sarasota, FL, highlights the skill of the First Street Flood Model in predicting flood severity, with depths in this neighborhood consistent with the 1-2 foot flood depth model prediction.

Bahia Vista St and File ave, Sarasota, Florida, from SOURCE





This documented flooding at Dock Street, in Annapolis, MD, highlights the skill of the First Street Flood Model in coastal areas. In this instance, the model is able to resolve the flooding along a coastal street from a 1-in-20 return period event. The higher elevations at the end of the street, shown as dry in the image, have also been predicted to avoid flooding in this event.

142 Dock Street, Annapolis, MD, from SOURCE