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CE 394K.3  
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## Coastal Flooding in Brevard County, Florida

### **Introduction**

My project was to create a model of the coastal flooding that occurred in Brevard County, Florida in August 2008 as a result of Tropical Storm Fay. To do that, I used precipitation data, soil water storage data, flowlines, and Florida subwatersheds to map in GIS where flooding would be most likely. While this approach was reasonably successful, it was not a truly accurate model of the mechanism of flooding. In an attempt to capture that behavior, I created a HEC-HMS model to examine the time-series response of the Brevard surface water system to different amounts of precipitation.

The results obtained from both of these models gave me a good idea of where and how flooding occurred. When compared to published data about the storm, my model results match fairly well, but many more factors could be incorporated into both models. I learned a lot from the analyses performed while doing this project so I think it was worth doing, but to make a truly accurate flood model for Brevard, more work needs to be done.

### **Background**

I chose to do this project on the effects of Tropical Storm Fay in Brevard County primarily because Brevard, in addition to being the home of Kennedy Space Center and Cocoa Beach (Figure 1), is where my hometown, Indian Harbour Beach, is located. I was a sophomore in high school when Fay hit, and I remember it well because the first week of school was cancelled and there was widespread flooding. This personal interest is what first inspired me to start researching this topic.



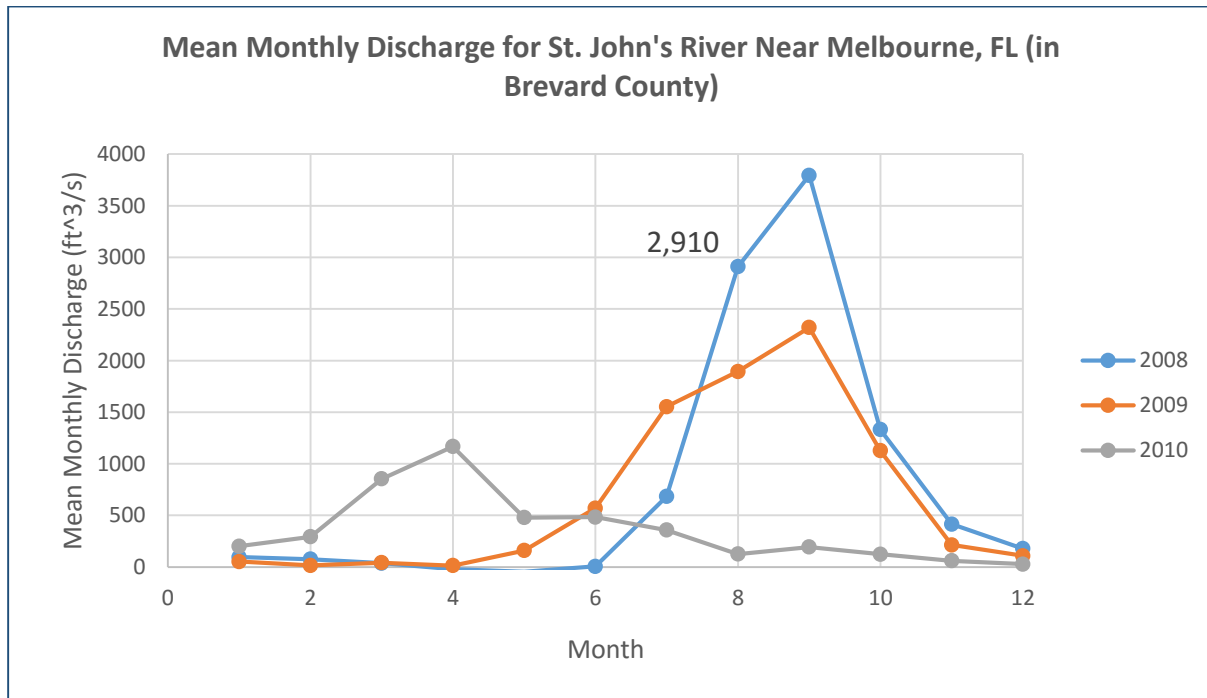
**Figure 1:** (Left) Vehicle Assembly Building at Kennedy Space Center, Brevard. (Right) Ron Jon surf shop<sup>[2]</sup> in Cocoa Beach, FL

While researching this topic, I learned how devastating Tropical Storm Fay had been to Brevard. The storm remained over central Florida for several days, and poured over 25 inches of rain into some areas of Brevard County<sup>[1]</sup>. The incredibly high amounts of precipitation caused massive flooding throughout the county, resulting in five deaths and over 12 million dollars' worth of damage<sup>[1]</sup>. Images flooding in my local streets can be seen in Figure 2 below. Realizing the amount of damage Fay did to my home county is what convinced me to analyze this storm for my project.

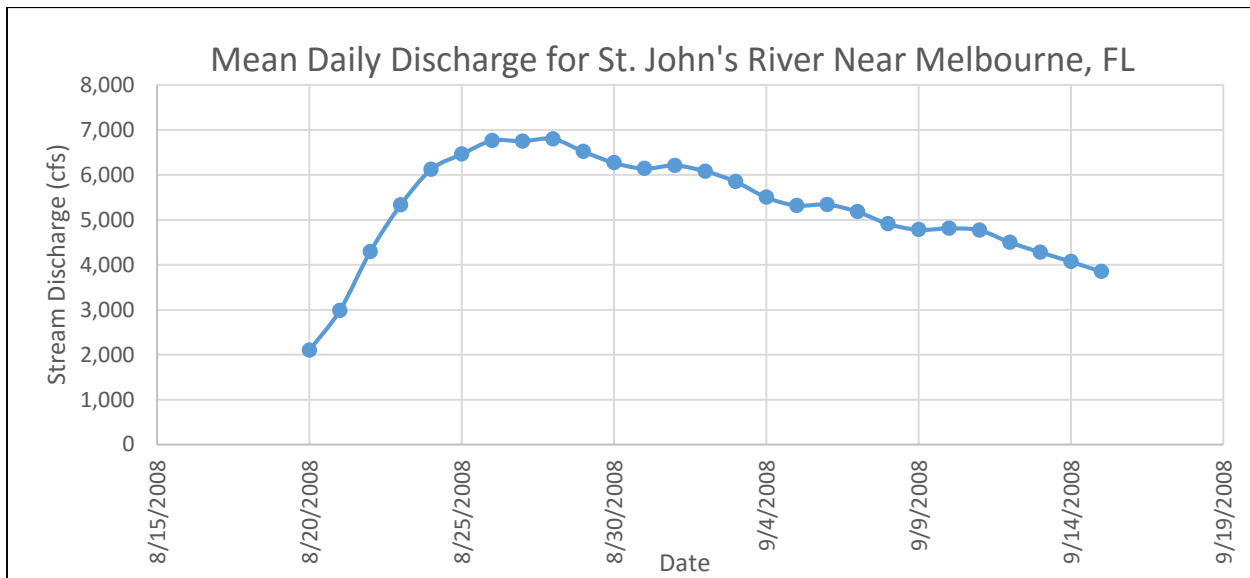


**Figure 2:** (Left) A street in Brevard during Tropical Storm Fay. (Right) The same street in November, 2015.

Tropical Storm Fay, in addition to affecting me personally, was a record storm in many ways. It was the first storm to make landfall in Florida four times, and its zigzag path meant it stayed over the same area of Florida much longer than the average tropical storm or hurricane. This long residence time resulted in record rainfall amounts, noted above. Figure 3 shows a graph depicting how much higher the streamflow was as a result of Fay when compared to other years in Florida. Figure 4 depicts the daily mean streamflow before and after Fay.



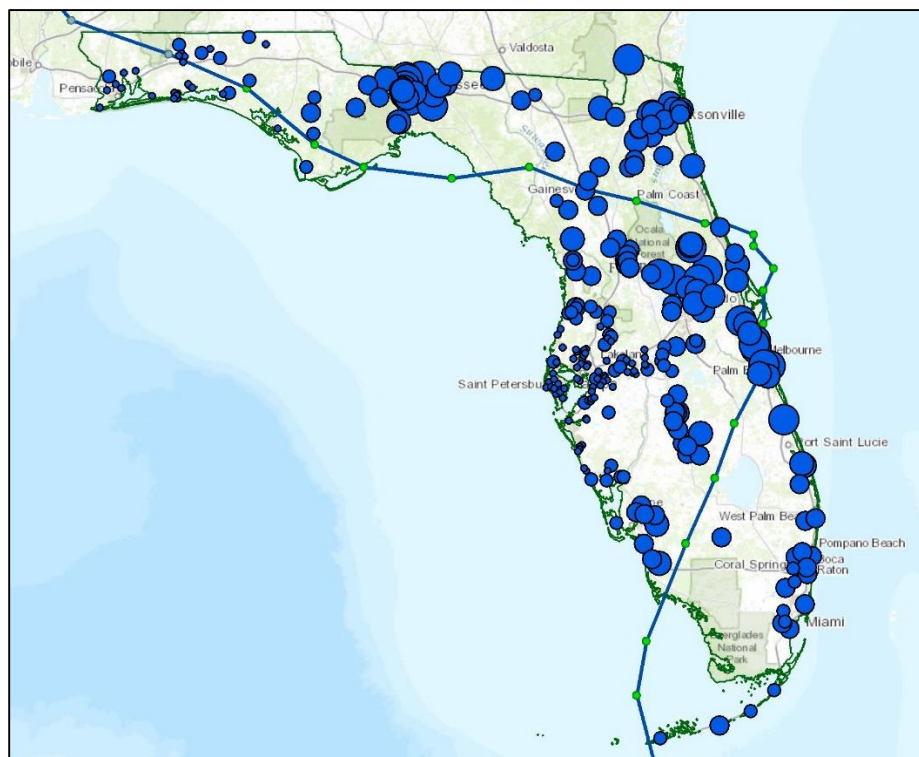
**Figure 3:** Graph of mean monthly discharge for 3 years; the discharge for Fay (in August 2008), is much higher than in other years (the discharge is even higher in September because two more hurricanes hit Brevard that year after Fay).



**Figure 4:** Plot of mean daily discharge before, during, and after Fay (note that the discharge after the storm would normally have decreased more quickly, but Brevard was hit with another storm)

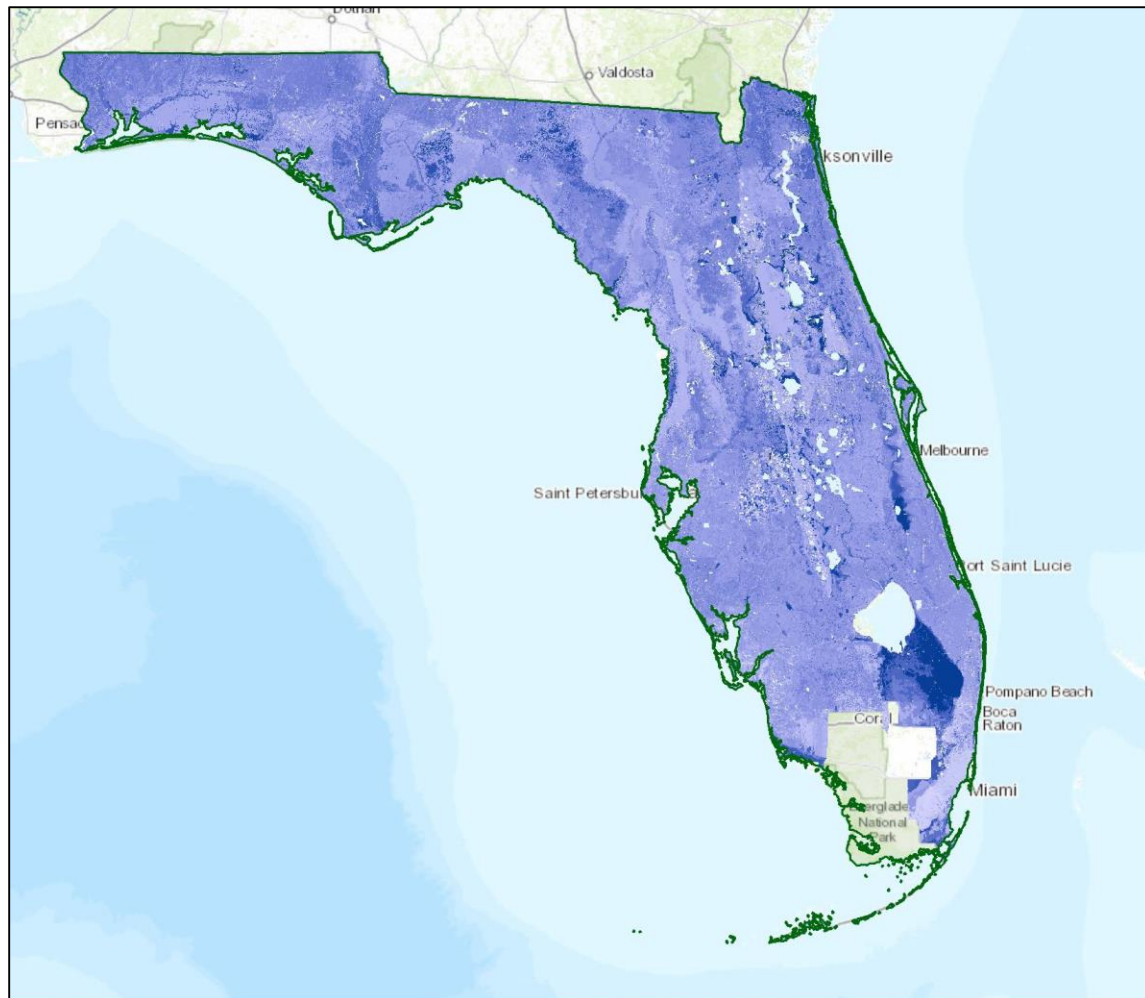
### Analysis and Results

To start my analysis, I needed to gather several different data sets. I began my search with NFIE’s database, where I was able to get information on Florida flowlines, catchments, subwatersheds, and basins. After that, I downloaded precipitation data for Fay from the NWS and Fay’s path from NOAA. These two datasets are shown in the map below; as you can see from Figure 5 the larger precipitation symbols (indicating heavier rainfall) follow the path of the storm through Florida.



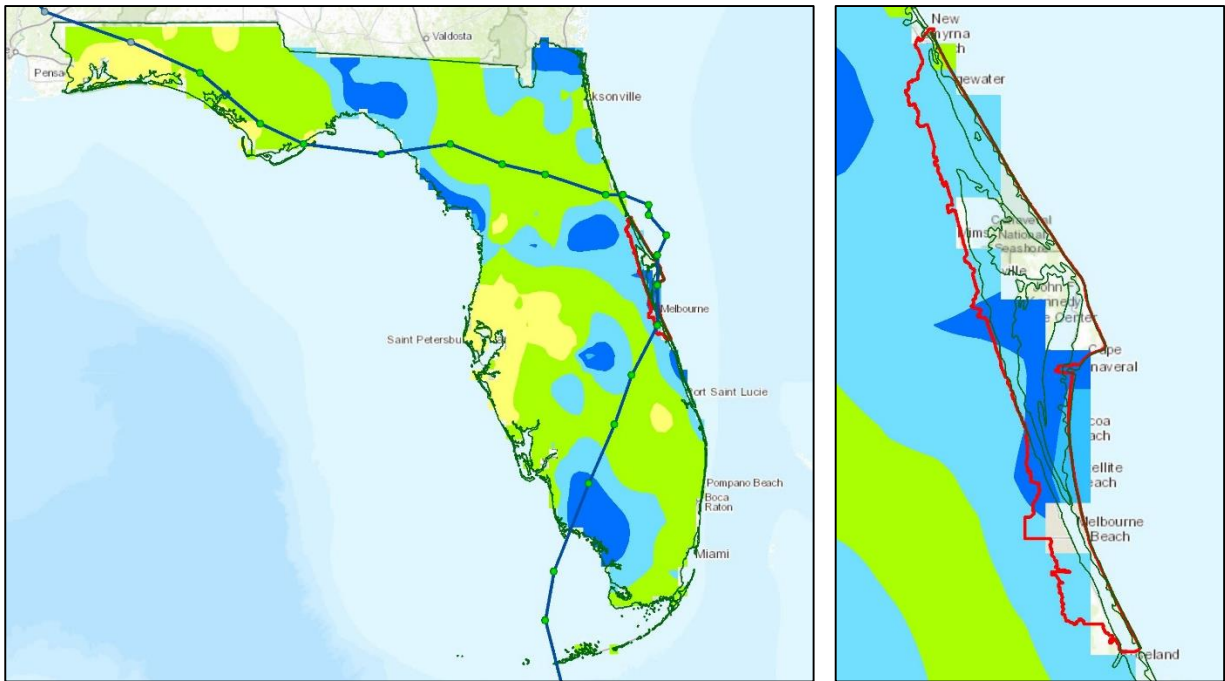
**Figure 5:** Map of Fay’s path with graduated symbols representing the amount of rainfall received over the course of the storm.

In addition to the hydrologic and storm data, I needed soil water storage data to begin my analysis. I was able to access the national dataset for available soil water storage (ASW) using the ESRI online server, and then extract just the data for Florida. This map is shown in Figure 6.



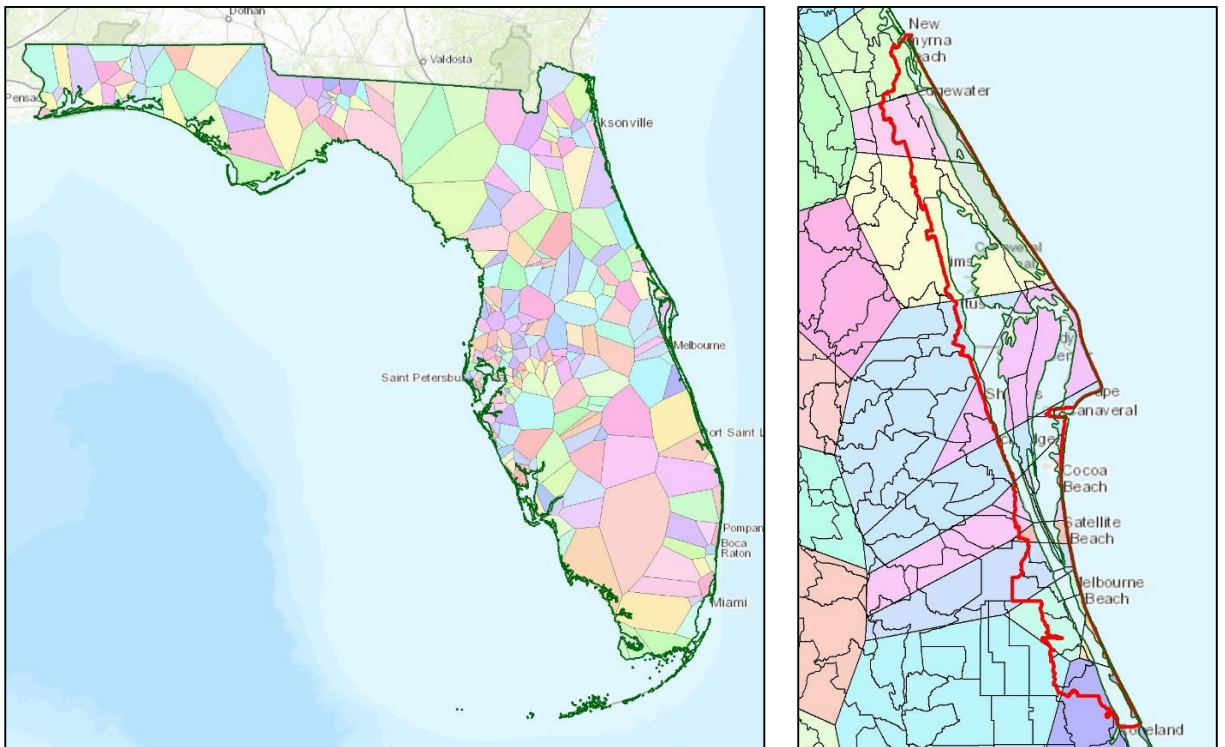
**Figure 6:** Map of AWS for Florida, clipped from the national dataset. Note: there is no available data for the Everglades.

After gathering all my data, I could begin my analysis. In brief, my goal was to take the point precipitation data I had for Fay and spatially interpolate it over all of Florida. I would then assign each subwatershed in Florida a precipitation value based on this interpolation, and then spatially average each of the results. The resulting polygons were then transformed to a raster data set. After correcting for unit conversions and differences in cell size, I could then subtract the AWS value to get a prediction of which areas would flood. To put it simply: the amount of water that fell minus the amount of water that the ground could hold would equal the amount of flooding. Even though this is a rather simplistic view of the mechanism of flooding, I felt that this analysis would be a good place to start. To that end, my first step was to interpolate the precipitation data. I initially used ArcMap's "Spline" tool, to get the results shown in Figure 7. While the results for the whole state of Florida look pretty good, zooming in on Brevard county shows that the resolution is not good near the coast. This is partly due to the fact that there were only four precipitation gauges in that area, and partly because the spline interpolation breaks up near the boundary, which in this case is the ocean.



**Figure 7:** Total precipitation from Fay as determined by the Spline tool in ArcMap. Dark blue corresponds to heavier rainfall.

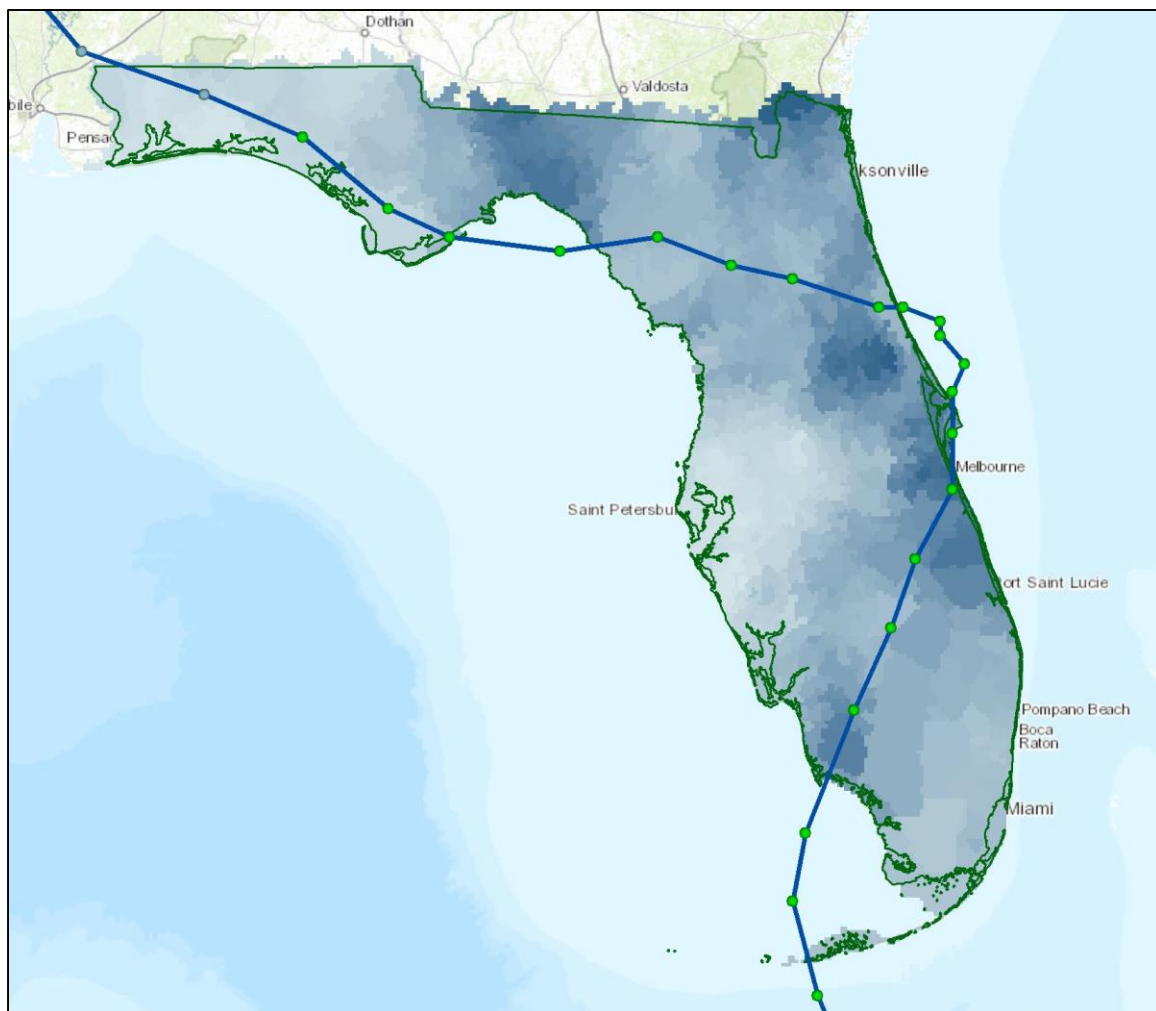
To improve the results for precipitation along the coast, I decided to try a different method of spatial interpolation—ArcMap’s “Thiessen Polygons” tool. Using this, I was able to obtain a map of polygons with a precipitation value associated with each one, as shown in Figure 8. When looking at Brevard, it is clear to see that this method yields a much better result than the spline tool. Each Thiessen polygon was then intersected with a Florida subwatershed, shown in Figure 8 for Brevard.



**Figure 8:** (Left) Thiessen polygons for Florida. (Right) Polygons intersected with Florida subwatersheds for Brevard

The next step in my analysis was to spatially average all of the precipitation data according to the subwatersheds. This was done using the equation for average precipitation provided to the class in Exercise 5 and shown below. The results of this calculation were then converted to a raster using ArcMap, and the resulting map is shown in Figure 9. Note that the areas of high precipitation follow the path of the storm, as was seen in the graduated precipitation data.

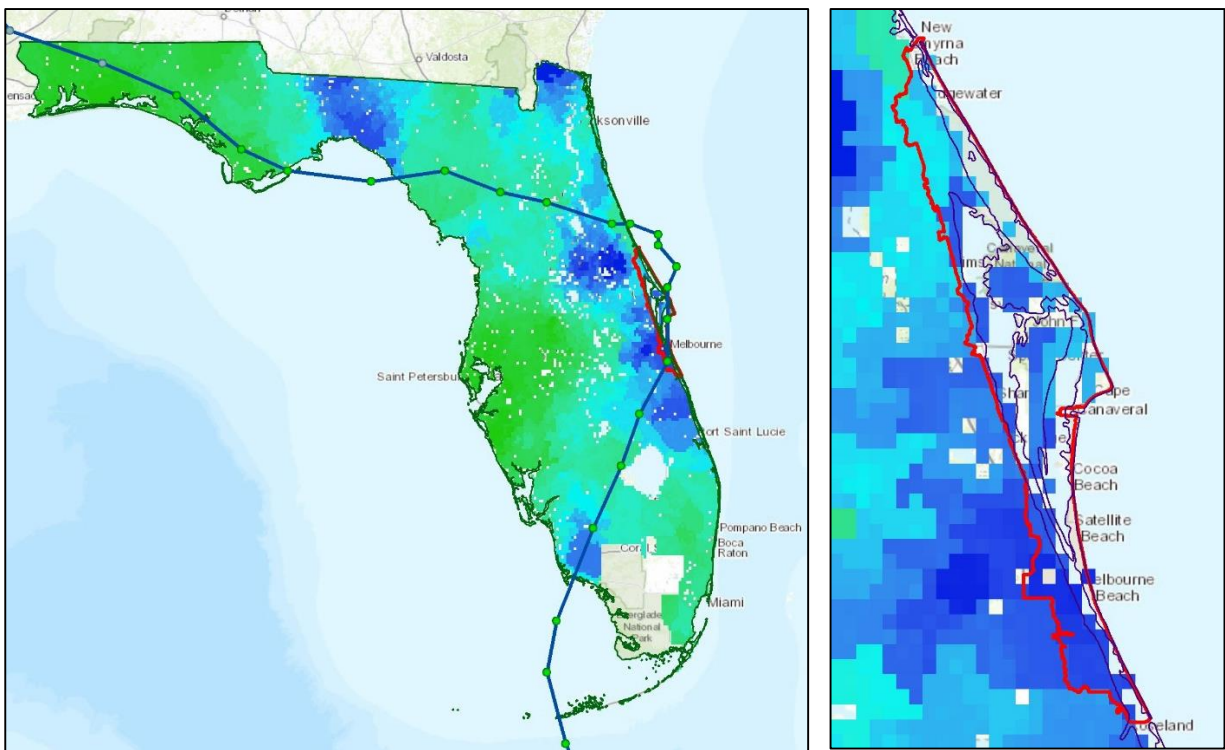
$$P_i = \frac{\sum_k A_{ik} P_k}{\sum_k A_{ik}} \quad (1)$$



**Figure 9:** Raster of average precipitation for each Florida subwatershed.

Once I had a raster of precipitation data, all I needed was to subtract the raster of AWS. This was slightly complicated by the fact that the soil data set had a larger cell size and different units than my precipitation raster. Additionally, there is no soil data for several areas in Florida (especially around the Everglades), which meant that I could not model flooding there. After correcting for the differences in cell size and units, I was able to use ArcMap's "Raster Algebra" tool to subtract the AWS raster from the precipitation raster, which resulted in the flood raster shown in Figure 10. As is seen from the map, the areas of highest flooding (dark blue) occur along the path of the storm, which makes logical sense. There are a few issues with the flood raster. The resolution of the flood raster is worse than the precipitation raster because the AWS data was in a lower resolution. Also, because the AWS data was incomplete for some areas in Florida, the

flood data is necessarily also incomplete. Despite these drawbacks, I think overall the flooding model gives a good—if overly simplistic—indication of areas of likely flooding during Tropical Storm Fay. Looking more closely at Brevard shows that while the resolution is not great, it is still much better than what would have been achieved using the spline tool.

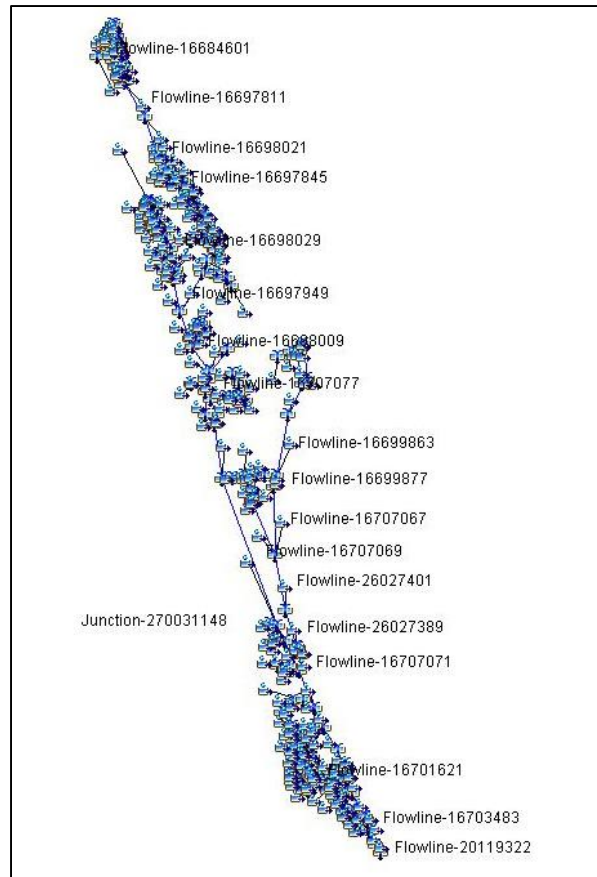


**Figure 10:** (Left) Flood raster for the state of Florida. (Right) Flooding in Brevard; resolution is poor due to the low resolution of the AWS data

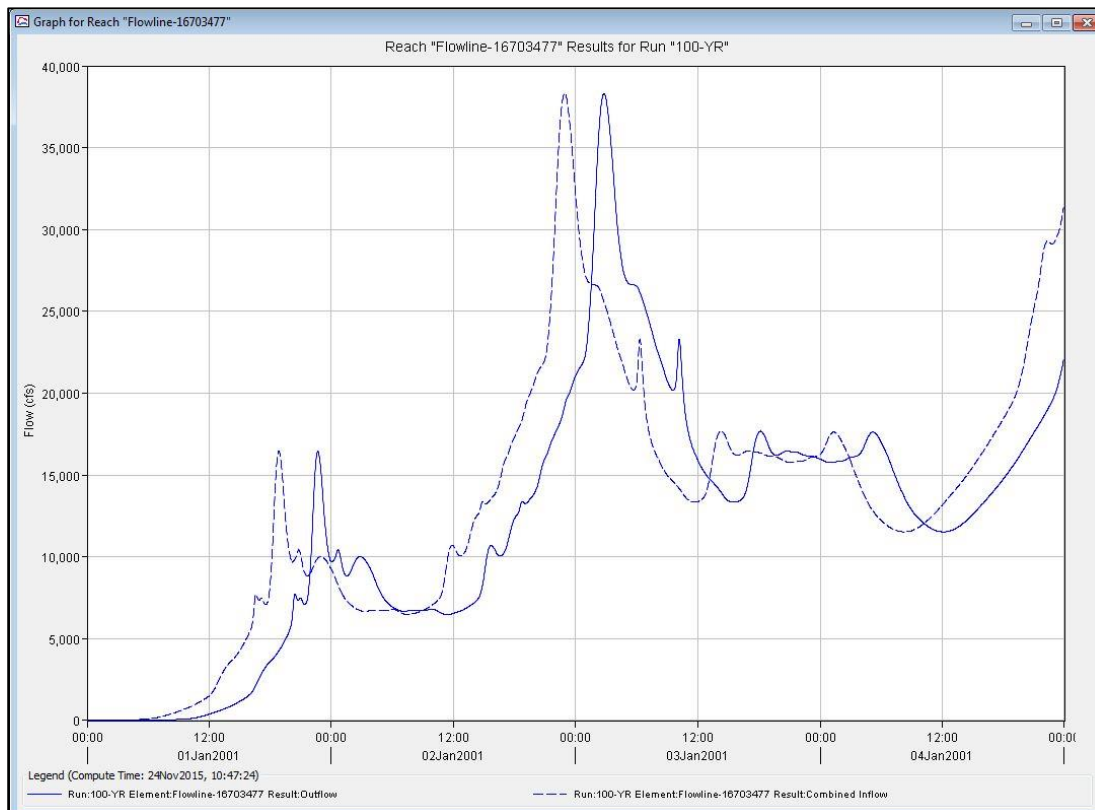
The next step of my project was to try to make a time-sensitive flood model to look at flooding throughout the storm, rather than just cumulatively. To do this, I wanted to find or create a HEC-HMS model for Brevard and create a storm similar to Tropical Storm Fay to run. I initially looked for an available model for Brevard, but could not find anything. I then attempted to create this model using tools from the lectures on HEC-HMS, but did not have much luck. Cynthia Castro was able to help me with HEC-HMS, and created the model of Brevard’s watershed shown in Figure 11. Several important assumptions were made to create this model based on the available data:

1. All reservoirs were removed, since there was not detailed enough data to model these.
  - a. Instead, the model used the lag method over the watersheds, which accounted for some of the retention.
2. I could not find any good time-dependent precipitation data, only cumulative results for the whole storm, so the HMS model just uses the available 100-year storm event data from the NOAA gauge in Brevard.
3. No baseflow was modeled.

Running the 100-year storm event yielded data similar to what occurred during Tropical Storm Fay. The predicted streamflow for one flowline in central Brevard is shown in Figure 12, which shows an increase and decrease like to the actual streamflow, shown Figure 4 (the patterns look different because Florida had several hurricanes that summer, rather than one 100-year storm).



**Figure 11:** HEC-HMS watershed model for Brevard County



**Figure 12:** Streamflow in one flowline of the HMS model for a 100-year storm event



Results for a catchment and junction are presented in Figure 13. The graphs show the same pattern that would be expected from the flowline data: a large peak at the time of maximum rainfall and a gradual tapering off.

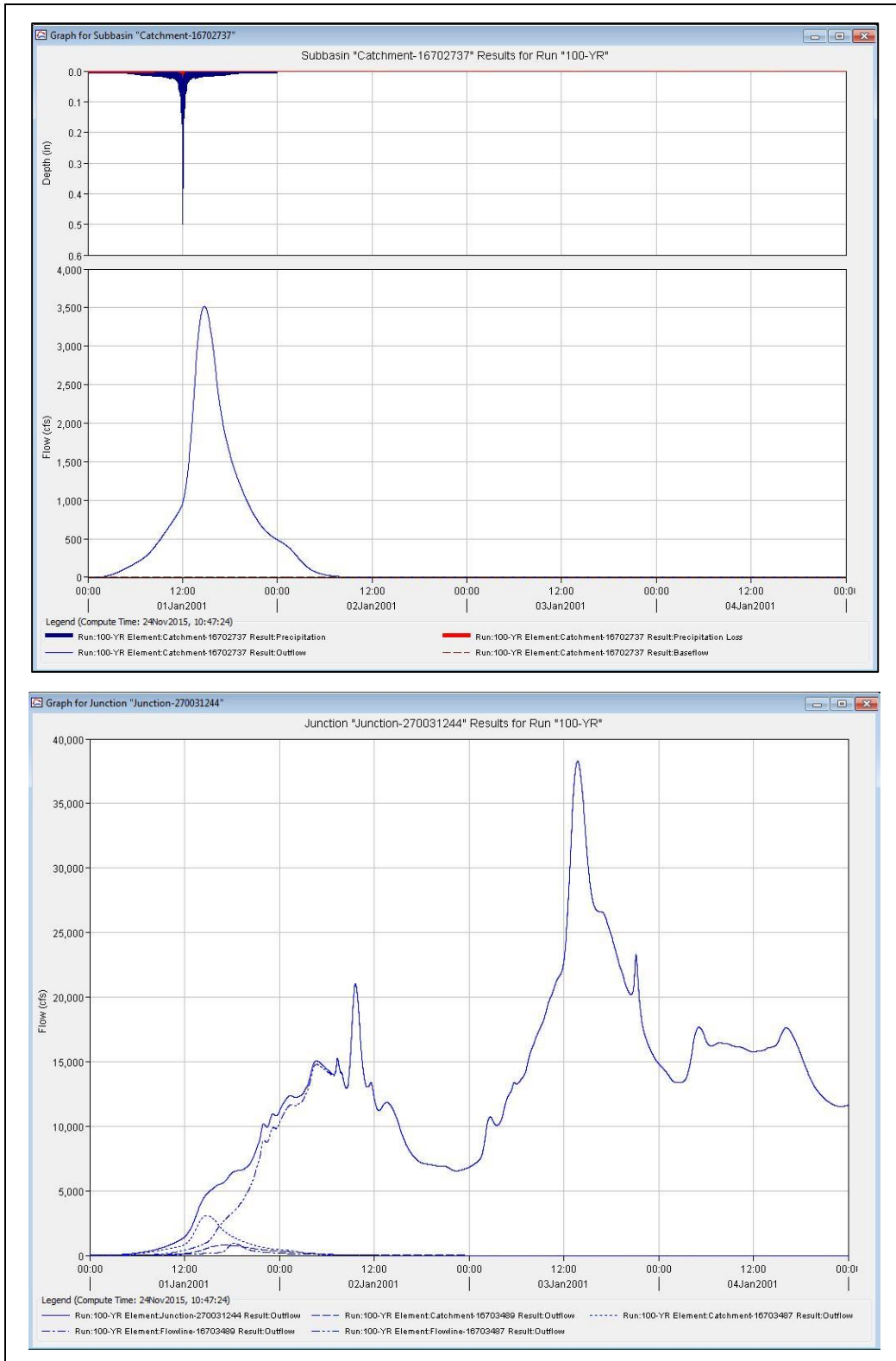
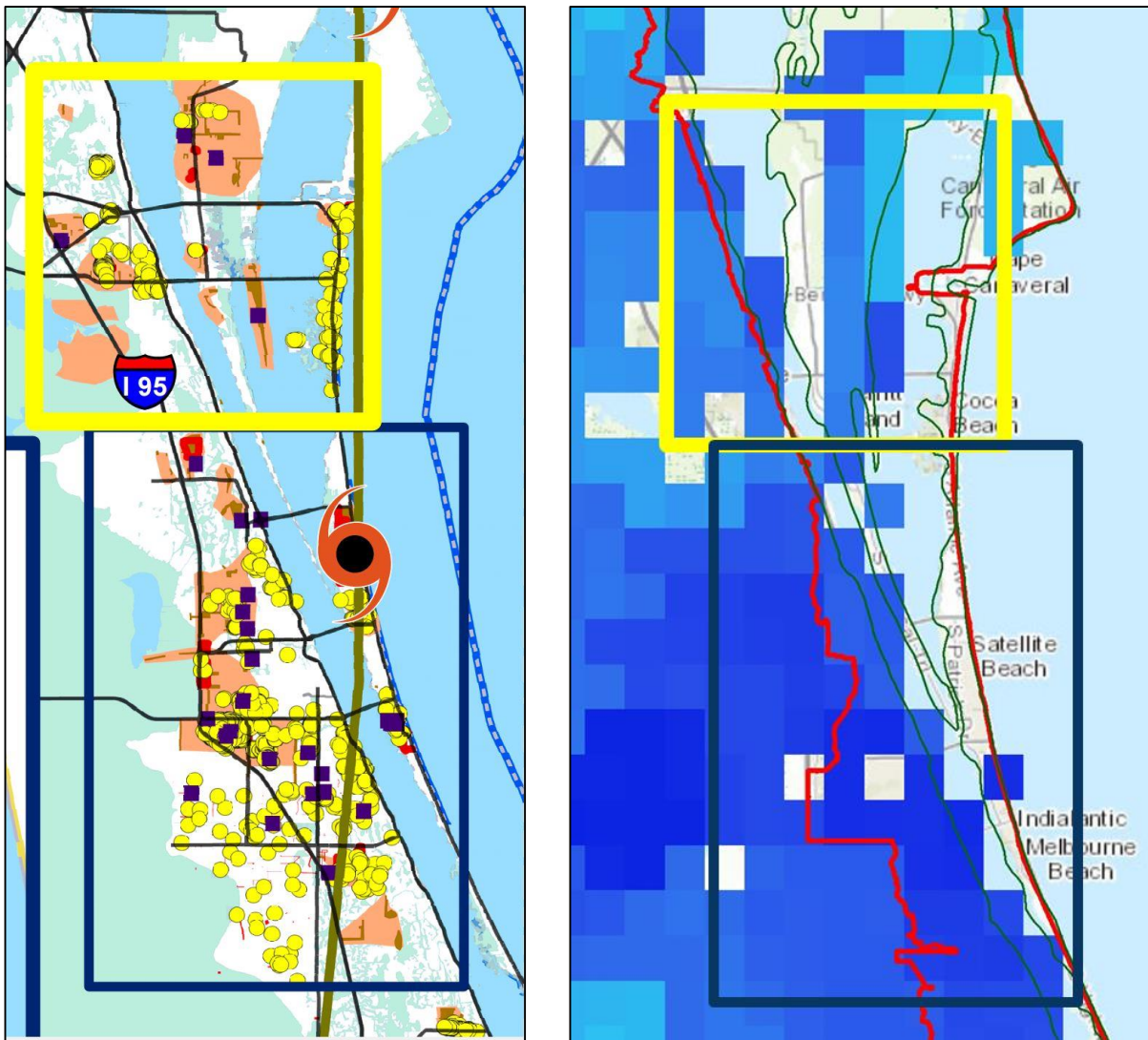


Figure 13: Brevard HMS model results from the 100-year storm event for a catchment (Top), and a junction (Bottom).

## Conclusions

I feel that my analysis of Tropical Storm Fay, even if grossly oversimplified, was fairly accurate. My flood model predicts that basically all of Brevard County was flooded, which I know was true from personal experience. My flooding results can also be compared with published reports on the storm, as shown in Figure 14, where it is seen that the areas of worst flooding predicted by my model correspond to those in the report. As discussed in the “Analysis and Results” section, the HEC-HMS model, although not using actual Fay data, followed the same pattern that was seen during the storm.



**Figure 14:** (Left) Published report of flooding in Brevard County, where heaviest flooding is indicated by orange. (Right) My model for flooding in Brevard, with dark blue corresponding to heaviest flooding.

Although the results I obtained match logical assumptions of where and when flooding would occur, this model definitely needs to incorporate more factors to increase accuracy and usefulness. One easy improvement that could be made to the model would be to get better AWS data; either a dataset with better resolution or one that includes information from the Everglades. In the future, I would also like to use the DEM for Florida, landcover data, and percent impervious data to construct an even better model for flooding. To improve the HEC-HMS

model, I need to find a time series of precipitation data for Tropical Storm Fay, which I am sure exists somewhere.

This project helped me improve my understanding of the ArcMap and HEC-HMS programs and the different tools they offer. Using them, I was able to create an accurate, if simplistic, map of where flooding occurred in Brevard County due to Tropical Storm Fay. In addition to that flood map, I was able to create a HEC-HMS model with the help of Cyndi Castro that lets me look at the response of Brevard waterbodies to different storm events. Though there is plenty of room for improvement if I wish to continue working on this model, I was able to accomplish the basic goal of this project and model coastal flooding during Tropical Storm Fay.

### **Citations**

1. "Tropical Storm Fay (2008)." Wikipedia. Wikimedia Foundation, n.d. Web. 10 Nov. 2015.
2. "World Famous Ron Jon Surf Shop." ActiveRain. ActiveRain Inc, 6 May 2009. Web. 10 Nov. 2015.