Field and laboratory assessment of a flood site: An example of the flooding of the Mohawk River at Lock 12 in Fort Hunter, NY, during Hurricane Irene (August 28-29th, 2011)

Sisti, A.D.[1], Combs, E.L.[1] and Marsellos, A.E., Ph.D.[1]

[1]*Dept. of Geology, Environment and Sustainability, Hofstra University, Hempstead, NY, 11549 U.S.A.*

Abstract

During periods of increased precipitation, the regions surrounding the Mohawk River in upstate New York are known to experience flooding. This poses a great deal of potential flood-related damages to both residents and businesses located at the Mohawk River watershed area. Having a proper understanding of how floods behave in this region can help people and businesses to prepare for these events. This can be achieved by using both Global Positioning System (GPS) and Light Detection and Ranging (LiDAR) techniques in a Geographical Information System (GIS), where one can accurately reconstruct past flood events by referencing photographic records of the event. This study focuses on the town of Fort Hunter, New York that experienced flooding as a result of Hurricane Irene in August 2011. After compiling reference images of the flooding, LiDAR data was used to reconstruct a three-dimensional, Digital Surface Model (DSM) of the study area. With this high resolution data available, each of the represented flooded sites by the reference images were recreated in the Global Mapper software (GIS software), which allowed for an accurate simulation of flood-water levels. Each of the locations that were analyzed and visualized in a computer laboratory, were also surveyed in the field using a geocollector Trimble Geo7X in order to determine the flood elevation from the mean sea level (MSL) during the flood. Modelling of the complete flow network has taken place in a Digital Terrain Model (DTM), does not include structures such as buildings or trees that may artificially alter the flow network modeling. Overall, these two methodologies, and the results they produced showed that both are viable methods for analyzing past floods, and that the LiDAR methodology in particular can prove to be a highly efficient way of doing this remotely, without visiting the field.

Introduction

The Mohawk River in Upstate New York has been subjected to several floods throughout history. During August 28-29th, 2011, the Hurricane Irene, which had passed through the Albany-Schenectady region caused of a great deal of flood related damages throughout the New York State. This study will take a closer look at the extent of the flooding caused by this storm in Fort Hunter, NY, a small town situated along the Mohawk River, which is notorious for its frequent flooding. While previous work has examined Mohawk River's floods and its tendency to flood on a regular basis (Johnston & Garver, 2001) no previous work has been done in this town which utilizes high resolution spatial data (e.g. LiDAR) in conjunction with a GPS device and a GIS software to reconstruct a previous flood event along a 6 kilometers Mohawk River's river segment which crosses the Fort Hunter area. Our research examines a methodology of testing in a computer laboratory whether the affected area of a previously flooded site can be determined using a GIS software instead of physically going to the site and taking high accuracy of GPS measurements.

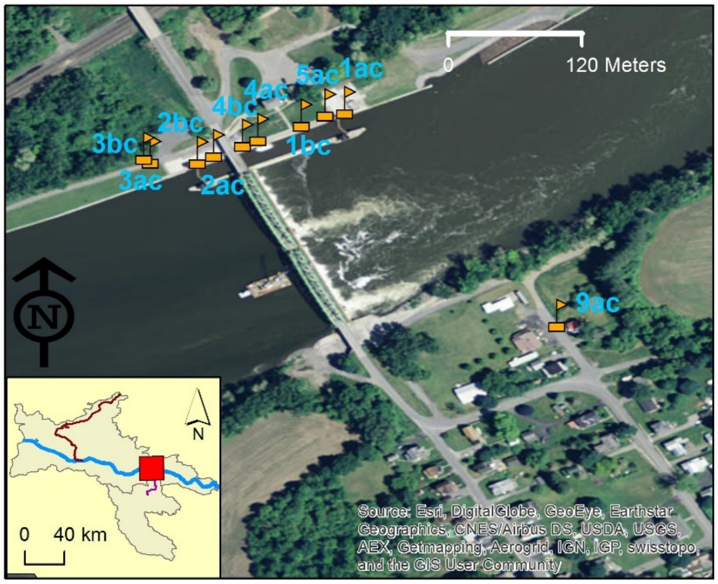

Figure 1: Lock Station 12 at Fort Hunter, NY with image locations at the study area.

Methodology

A laboratory and fieldwork method was used to determine various elevations at the flooded study area. The laboratory processing determined the water level of the flood and the geographic locations of the available images depicting the water level of the flood. Ten images of the flooding were found in the internet and other scenes were extracted from YouTube video files documenting the flood event. Google Earth was used to determine the geographic locations of the images (Fig. 1) at the study area. The georeferenced points were imported into a GIS software. Using the GIS software program and the available images the elevations of the water level were extracted showing the water level of the flood. A fieldwork methodology was followed using a GPS high accuracy survey (Fig. 2) in order to determine accurate elevations of the flood. GPS points were collected of the flood, and some erroneous positions were discarded from the Global Navigation Satellite System (GNSS) session and subsequent differential correction. Multiple GPS points were collected for each image (Fig. 1). GPS points were also obtained along a line to create a short topographic section. This section was used to correlate the GPS corrected elevation data with those derived from the LiDAR Digital Elevation Model (DEM).

The images georeferenced location was digitized and imported into the GIS software. A high resolution satellite imagery of the study area was also imported as an overlay image in conjunction with the high resolution LiDAR DEM in order to simulate the flood in a Three Dimensional (3D) mode of the study area. The digital elevation model utilized all LiDAR points with tight constraints to create a DTM with a minimum elevation to avoid pseudo structures such as trees showing as buildings. A DSM was avoided for the above reason. This procedure has facilitated the flood reconstruction and visualization of the flooded structures.

Visiting the study area has allowed us to GPS survey and obtain accurate elevation data by differentially corrected using a GPS reference station Continuously Operating Reference Station (CORS) from a less than 100 kilometers radius. A transect profile was also made to compare the GPS corrected data with the LiDAR data for the locations at Lock 12 (Fig. 1).

A flood modeling using a flow simulation has taken place to map the flooded areas at 86.35 meters (Fig. 3). This elevation was chosen as the maximum obtained elevation from the GPS survey that approaches the peak water level of the flood. A value of 0.5 meters of depth has been assigned to fill depressions in the terrain data and facilitate the flow network construction for the flow modeling. The water flow simulation has been set up to initiate from the Mohawk River's water surface under normal flow conditions.

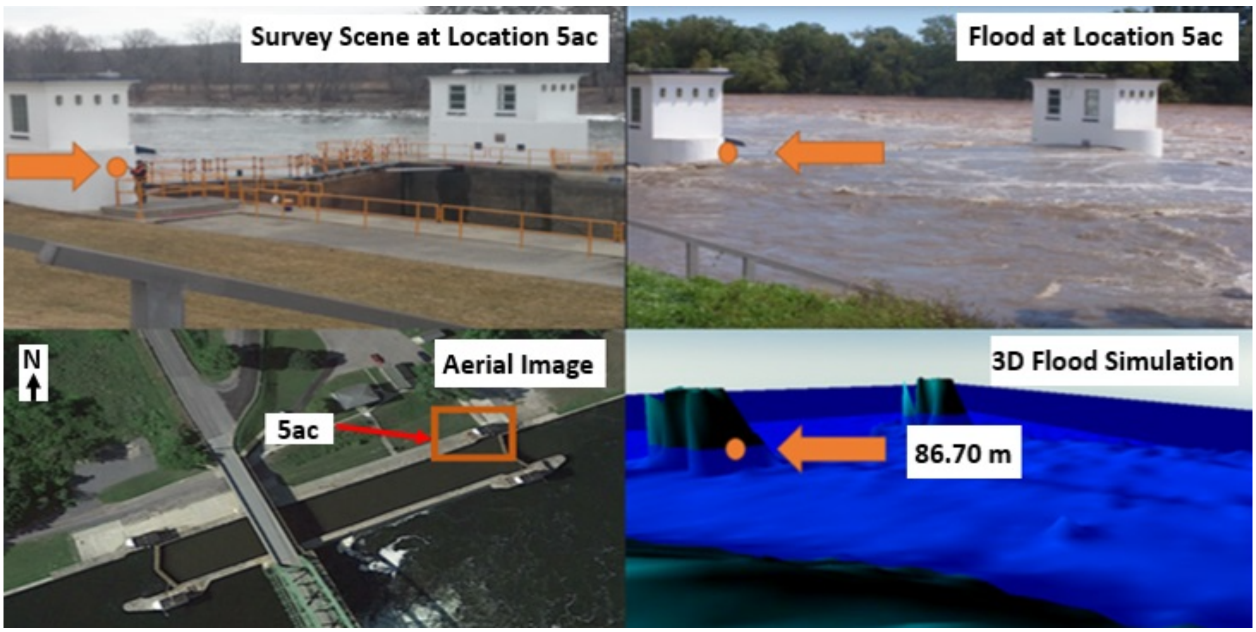

Figure 2: Lock Station 12 where flood simulation and GPS measurements were taken. (A): location 5ac during the GPS survey; (B): image of the flooding occurring at location 5ac (YouTube, 2011); (C): aerial view of flood location 5ac; (D): 3D simulated flood model of location 5ac.

Results

The simulated water elevation is based on the reference images used for this study and the determined elevations are cited in Table 1. A high level of accuracy (±0.1 meter) was obtained from the laboratory and field work data analysis. The high resolution of the LiDAR imagery was able to depict various structures and high water marks of the flood which aided in determining the elevation of the water levels at the various points. The maximum water level elevation through the pictures and associated water rise simulation was determined to be 86.80 meters (±0.1 meter). The 3D reconstruction model of the flood constructed in GIS has provided an accurate simulation of the flood levels using the LiDAR DEM. The 3D reconstructions and water flood simulations provided a no more than ±0.1 meter error of the flood water levels given the reference images that were used. High water marks located or captured by the images on flooded structures facilitated the water flood level determination. Marks were located on various structures included but not limited to fences, brick walls, carbs, streets, house doors or windows and other structures. This is illustrated (Fig. 2), where the same location (5ac) is viewed at the time of the flood, time of the GPS survey, and the 3D LiDAR DEM reconstruction of the flooded scene.

The maximum elevation value derived from the differential GPS survey is 86.35 meters (MSL), and it approaches the flood levels of the August 28th -29th of 2011. The simulation of the water rise including the flow river network and flood modeling has shown a reconstruction of the flood's boundaries (Fig. 3). The GPS corrected elevation data were collected at the same points where images locations were georeferenced (Fig. and Table 1). The locations at Lock 12 indicate the flood boundary on that side of the river. Location 9ac is used to indicate the flood boundary at Brown Place, on the opposite bank of Lock 12. Figures 4a and 4b indicate the accuracy seen between the GPS elevation data and the LiDAR simulated flood levels data.

Table 1: Water flood elevations (MSL) derived from images and water flood simulations using LiDAR DEM in the lab and GPS measurements at the field.

		Coordinates		Elevation (meters)			Accuracy (meters)			
No.	Address	Latitude	Longitude	GPS Data (MSL)	Simulation & Pictures	Simulation Estimated Error	GPS Uncorr. Horiz.	GPS Cor. Horiz.	GPS Uncorr. Vert.	GPS Cor. Vert.
1ac	Lock 12	42 56' 45.260" N	74 17' 16.726" W	85.04	85.40	± 0.1	±6.34	±0.20	±8.36	±0.25
1bc	Lock 12	42 56' 44.909" N	74 17' 18.003" W	85.42	85.60	± 0.1	±5.17	±0.45	±6.77	±0.66
2ac	Lock 12	42 56' 43.988" N	74 17' 20.607" W	84.74	85.70	± 0.1	±12.65	±0.18	±14.40	±0.25
2bc	Lock 12	42 56' 43.747" N	74 17' 21.010" W	85.89	85.70	± 0.1	±6.30	±0.10	±10.52	±0.14
3ac	Lock 12	42 56' 43.783" N	74 17' 22.365" W	85.24	85.50	± 0.1	±7.18	±0.37	±9.43	±0.62
3bc	Lock 12	42 56' 43.936" N	74 17' 22.659" W	84.68	85.50	± 0.1	±11.59	±0.45	±18.48	±0.64
4ac	Lock 12	42 56' 44.488" N	74 17' 19.288" W	85.67	86.80	± 0.1	±14.63	±0.26	±25.18	±0.31
4bc	Lock 12	42 56' 44.265" N	74 17' 19.659" W	86.35	86.80	± 0.1	±9.38	±0.29	±13.51	±0.42
5ac	Lock 12	42 56' 45.145" N	74 17' 17.283" W	86.11	86.70	± 0.1	±5.00	±0.15	±6.42	±0.26
9ac	Brown Place	42 56' 39.002" N	74 17' 10.525" W	85.87	86.80	± 0.1	±5.79	±0.17	±6.16	±0.27

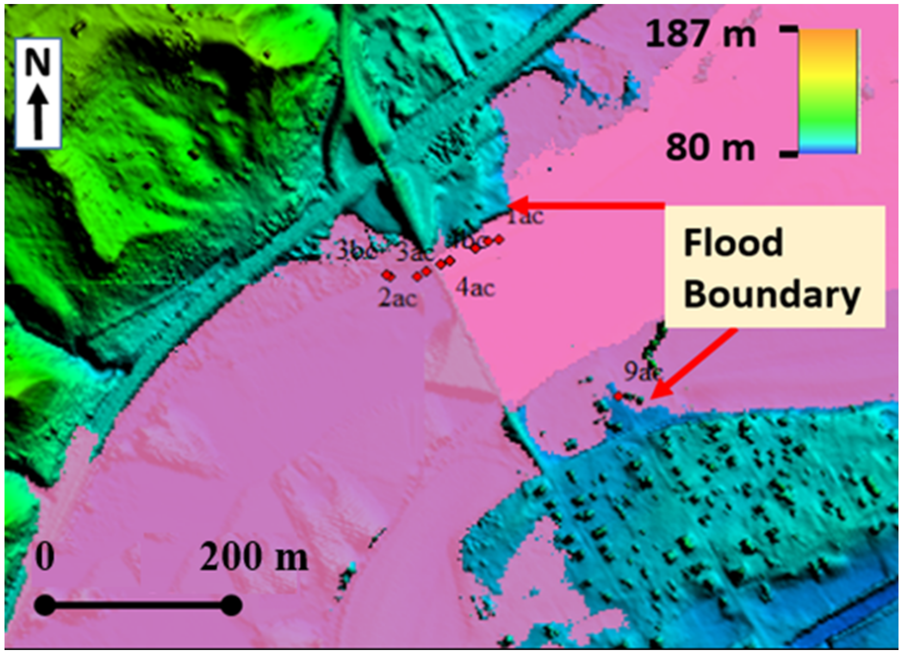

Figure 3: Reconstruction of the flood using a LiDAR DEM and the water level at 86.35 meters.

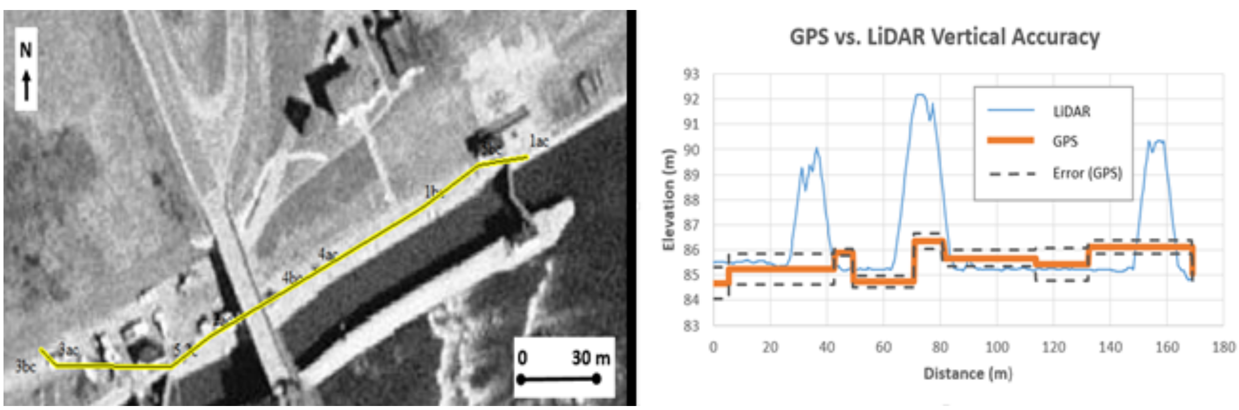

Figure 4: (Right) Comparison of GPS and LiDAR vertical accuracy. Large spikes in LiDAR data represent buildings/structures found on this transect. The LiDAR error is not shown on the graph because the error is too small to be seen properly. The error for the LiDAR is ± 0.1 meters. (Left) Transect at Lock 12 to extract the LiDAR elevation data from the DEM.

Discussion

This study focused on a small region, especially with regards to the LiDAR flood simulations. This allowed for a high level of accuracy. The lab simulation and GPS survey methods show that these methods are capable of producing results with a high level of precision and accuracy on simulating a flood event remotely or visiting the study area. By having reference images, which show water levels during the flood, multiple methods can be utilized for an accurate reconstruction of the past floods. The LiDAR flood analysis method produced an error of ±0.1 meter. This is a high enough level of accuracy and allows for a proper reconstruction of past floods. By comparing the LiDAR to the GPS elevation data that were collected, the results were able to be cross referenced in order to determine their accuracy.

Conclusion

Our tested site at Fort Hunter has shown that river floods can be observed using laboratory simulation techniques without requiring to visit the flood site. This means that an evaluation of a flood event in this region can be assessed by looking at past flood records from images and analyze them in a computer laboratory. Understanding how water elevations increase and interact with the topographic anaglyph of this region, efficient decision making and appropriate measures can be taken to prevent the spread and severity of floodwaters in Fort Hunter, NY at the Mohawk River or in other areas as well.

References

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