Use of Watermarks for Discerning Hurricane-Induced Flood Levels

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Abstract

Property damage attributable to hurricane-induced floods can be difficult to discern once flooding has subsided; however, flood levels can be estimated by measuring watermarks left by standing water on interior and exterior finishes including glass, gypsum board, exterior siding, fences, landscaping, etc. This paper illustrates how field measurements of watermarks can be used reliably, along with other field observations, to assess structure distress related to flood.

A particular application of this can be seen in a dispute stemming from property damage related to Hurricane Katrina, in which the author was posed the task of determining if commonality existed to qualify for a class-action lawsuit. During site visits to putative class properties in the city of New Orleans, watermarks were field-measured to establish an estimated flood level, and the causes of various distress to each structure were analyzed including wind and flood. The field-measured watermark data were compared to the Interagency Performance Evaluation Taskforce (IPET) reported levels and revealed good correlation. The damage attributable to flooding was then compared across properties resulting in a conclusion that each property sustained significantly differing levels of damage, including some with no flooding above the finished floor; and thus did not meet commonality.

Introduction

A hurricane is defined by the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center (NHC) as a tropical cyclone in which the maximum sustained surface wind is 74 mph or more. Due to the elevated wind speeds associated with hurricanes, widespread property damage related to wind pressures is common; however, hurricanes are also accompanied by significant rainfall, storm surge and subsequent flooding, which results in additional distress and degradation of construction materials.

Identifying distress related to hurricane-induced flooding begins with observations of site conditions and the determination of maximum floodwater elevation experienced at the structure of interest. The focus of this paper relates to observations and measurements of watermarks as they pertain to the evaluation of distress and determination of the extent of hurricane-induced flood damage.

A storm which demonstrated the reliability of watermark measurement in the determination of flood distress occurred on August 29, 2005, when Hurricane Katrina made landfall and produced widespread damage across the majority of the city of New Orleans, including damage related to levee failures. The author's involvement in the evaluation of incurred damage, as it pertained to the validity of a class-action lawsuit, included the use of field-measured watermarks for cross-comparison of the extent of flood distress to putative class properties.

Forensic Method

Post-hurricane data collection for use in the evaluation of structural and non-structural component distress involves site observations, documentation, and a variety of forensic measurements. The data collected are used in the determination of overall extent of distress and for the delineation of wind, water and flood damage.

In the case of the post-Hurricane Katrina assessment, the author collected the following forensic data specific to the evaluation of flood damage:

Elevations: The elevation of each structure relative to the North American Vertical Datum of 1988 (NAVD 88) was determined by a surveying company using a global positioning device. NAVD 88 is the vertical control datum of orthometric height established for vertical control surveying in North America (National Geodetic Survey, NGS).

Watermarks: The author estimated the maximum flood level within the structures by measuring stains/watermarks left by standing water and debris on interior and exterior finishes including glass window panes, gypsum board, exterior siding, etc. All watermark data were referenced to NAVD 88. Typical watermarks found on these and other structures in the New Orleans area can be viewed in **Figure 1 through Figure 6**, below.

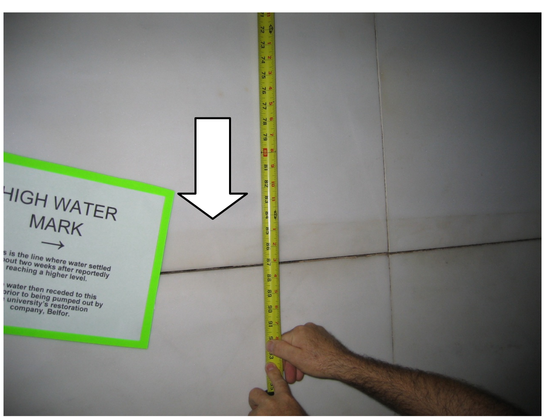

Figure 1: Tulane University Library Basement

Figure 2: Tulane University Center

Figure 3: Glass Paneled Door

Figure 4: Unfinished Water Heater Closet

Figure 5: Residential Living Room Window

Figure 6: Residential Door

It was the author's experience that the clearest watermarks appeared along vertical glass surfaces, such as window panes or storefronts. Watermarks along organic materials, such as wood and gypsum board, were often accompanied by fungal growth that masked a clear line of previous flood water elevations. Masonry materials found along the exterior of structures were less conclusive in the discovery of a clear watermark due to the cleansing of the masonry surfaces during rain storms.

Watermark Data

The Interagency Performance Evaluation Taskforce (IPET) was established by the U.S. Army Corps of Engineers in the fall of 2005 to provide scientific and engineering answers to questions about the performance of the New Orleans and Southeast Louisiana Hurricane Protection System during Hurricane Katrina. As part of its evaluation, IPET documented flood water elevations throughout New Orleans. The author found reasonable correlation between watermark data and IPET published data as illustrated in **Figure 7** and the graph of author-observed watermarks versus IPET-reported elevations in **Figure 8**.

Figure 7: Watermark Data

The author estimated damage to interior finishes using the field-measured watermark elevations, when available. In some instances, due to the perishable nature of watermarks, the author estimated damage to interior finishes using water elevations above finished floor (A.F.F.) based on the IPET high water elevations (IPET, 2006). However, with an instinct for knowing where to look, such as unfinished spaces, crawl spaces or basements; watermarks could be located on most of the structures, even years later.

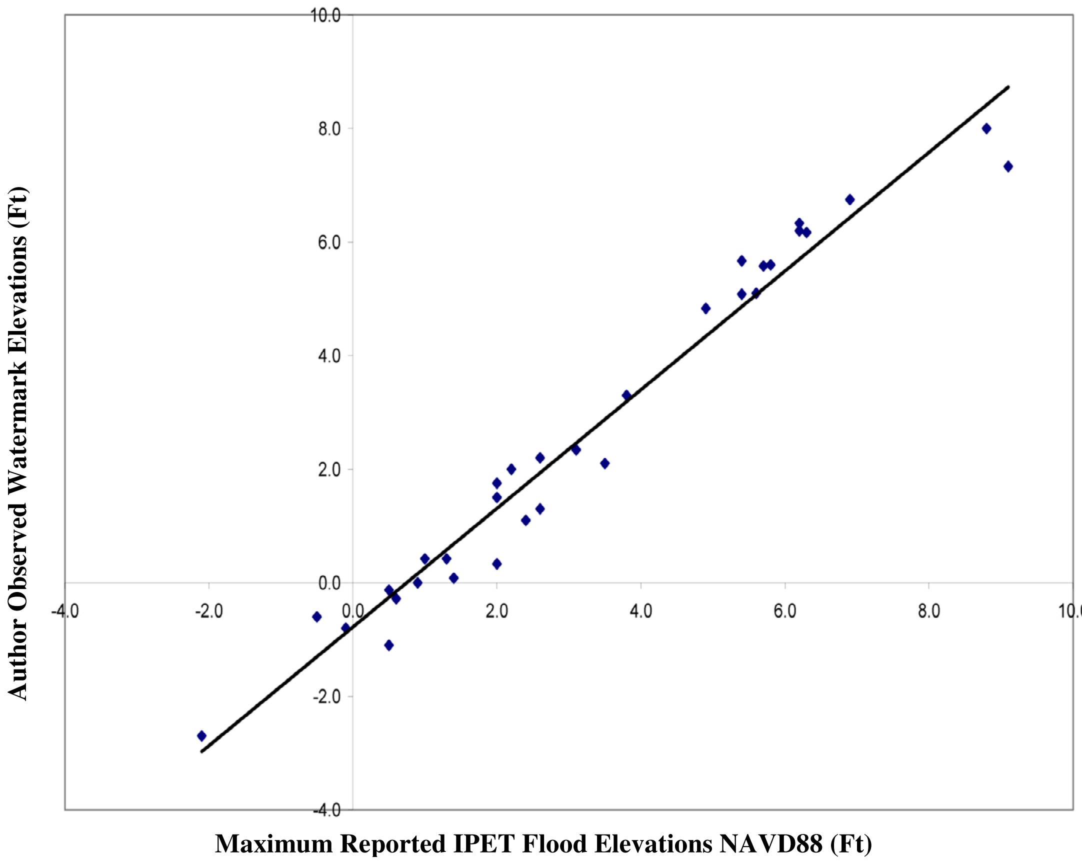

Figure 8: Author- Observed Watermark vs. IPET Reported Flood Elevations

Discussion

Degradation of a structure's architectural finishes is a function of exposure to flood water, wind driven rain, and wind forces. The resistance of a structure's finishes to water and wind is determined by its unique characteristics, including its property topography, age, height, design, and its material water resistive properties. For example, an increase in the flood water exposure height (**E**) or immersion time (**T**), or a decrease in the building material's water resistance (**R**), increases the flood damage (**D_f**) to an individual structure. The relationship for material degradation damages can be described by the following equation:

$$D_f \text{ (finish degradation)} = f\begin{bmatrix} E \text{ (water exposure height)} \\ T \text{ (immersion time)} \\ R \text{ (topography, age, height, design, and material water resistance)} \end{bmatrix}$$

As the height of the flood water rises within a structure, the greater the exposure of building materials and electrical and mechanical systems to flood water and the greater the magnitude of damage. The height of flood water above a given structure's finished floor was a distinct and variable parameter in the flooded structures in New Orleans. The water level A.F.F. varied due to four conditions:

> **Subclass Basin –** A subdivision of the global putative class of properties defined by average finished grade elevation. A lower finished grade elevation has the effect of increasing the height of the flood water relative to the first finished floor.
>
> **Site Topography** – Localized grading that affects the elevation of the structure's foundation, as situated on the site relative to the surrounding properties contained within the same subclass basin. Structures which are situated higher or lower on their individual plot of land will experience lower and higher relative flood levels, respectively.
>
> **Type of Foundation System** – Concrete slab-on-grade and pier and beam foundation systems were observed. In general, structures with concrete slab-on- grade foundations have first floor levels at or near the surrounding grade, thus increasing the height of flood water relative to the finished floor. Pier and beam systems are elevated above the adjacent grade, which reduces the relative height of flood water with respect to the first finished floor elevation.
>
> **Number of Stories** – Flood levels observed at all two-story structures did not affect the second level; therefore, the height of flood water of the second level finished floor was zero regardless of the immersion height experienced by the first level. This is applicable when considering the percentage of livable space affected by the flood waters.

The author found a wide range of variability in the subject structures' resistances to water, which resulted in a wide range of variability in damages observed.

For this reason, the author concluded that there was no commonality of flood related distress that validated the applicability of a class action lawsuit (Nelson, et. al., 2011).

The author notes the following two examples, which illustrated the large variation in relative flood levels, and the conclusions made using the data collected:

> The maximum riverine type flood water level recorded by IPET was approximately 2'-1" *below* the finished floor elevation of a structure which exhibited tilted foundation piers (placing the water level near grade). Through use of the IPET data (correlated by field-measurement of watermarks at other

properties) and field observed distress, the author concluded that the riverine flood waters were unlikely to have caused the tilting of the piers.

The IPET data at a structure which exhibited scouring and undermining of its wooden pile foundation system indicated a water level 5’-1” A.F.F. The magnitude of observed scouring and the known elevation of flood levels indicated damage consistent with flood and/or surge; therefore, the author attributed the distress to Hurricane Katrina.

Conclusions

The observation and measurement of watermark elevations play an important role in the overall assessment of the effect of flood waters on a community. Use of watermarks in conjunction with the observed physical characteristics of construction materials make it possible to opine on the commonality of flood damage within a defined class. The author found vertical glass surfaces to offer the clearest watermarks for accurate documentation of flood water elevations experienced at the evaluated properties.

Correlation of field-measured watermark elevations with the IPET flood elevation data made it possible to accurately quantify flood damage to a given property. IPET data was used to verify field-measurements and was used in the absence of a distinct watermark.

The study of the effects of Hurricane Katrina flood levels indicated a large variance in the amount of damage sustained by the properties evaluated within the putative class. Variable factors, such as flood elevation, topography, water resistance of construction materials and age also affected the magnitude of distress.

References

Interagency Performance Evaluation Task Force (IPET)/US Army Corps of Engineers, "Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System," dated June 1, 2006.

Nelson, Erik L., DeLeon, Marco A., Schober, Gregory G., “Commonality Test Methodology for Residential Structures in Katrina Canal Breaches Class Action”, Proceedings of the 2011 Structures Congress, Las Vegas, Nevada, April 14-16, 2011.

National Geodetic Survey (NGS), http://www.ngs.noaa.gov/faq.shtml#WhatVD29VD88.