Strategies to Establish Flood Frequencies Associated with Flood Event High Water Marks

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FMA 2015 Conference
September 11, 2015
The goal of this study was to document best practices in computing or estimating flood frequencies associated with high water marks (HWMs) on ungaged streams.

The report also provides a comprehensive background on: the various types of HWMs; the use of HWMs to reduce uncertainty in floodplain studies; and, flood discharge and frequency concepts.

Presentation Overview

- Why are HWMs important?
- Project objectives
- Project approach
- High water mark (HWM) characteristics
- Flood discharge and frequency
- Estimation of flood frequencies for HWMs
- Recommendations
- Q&A
Why are HWMs Important?

- HWMs are excellent for risk communication; “here’s how high it flooded in the past”.
- HWMs can augment the Nation’s stream gage system by providing valuable data on ungaged stream reaches.
- ASFPM estimates that a majority of flood insurance study models (~90%) are not calibrated against stream gage or high water mark data.
- HWMs can be used to improve the calibration of hydraulic engineering models and reduce error and uncertainty.
- An increased use of HWMs will result in more accurate and credible model results...and ideally less appeals to proposed BFEs.
Project Objectives

- Acknowledge the inherent uncertainty and error in streamflow estimation.
- Interview floodplain managers to understand current practices and needs related to HWMs.
- Establish a reasonable and repeatable methodology to assign a flood frequency to a given HWM.
Project Approach

• Perform agency interviews and incorporate interview findings in study process.
• Provide context for how HWMs can reduce uncertainty in flood studies and provide flood awareness.
• Provide an overview of HWM characteristics, collection and documentation methods, and their accuracy and reliability.
• Provide an overview of flood discharge and frequency concepts.
• Develop a method for estimating the flood frequency of a high water mark on gaged and ungaged streams.

HWM in San Anselmo, CA
https://www.fema.gov/hwm-project-summary-san-anselmo-ca
 Agency Interviews

• The ASFPM team interviewed personnel at agencies across the country that are responsible for collecting HWM data from federal, state and local governments.

• Interview questions
  - Collection procedures?
  - Storage methods?
  - Dissemination of data?
Interview Results

• Collection procedures - Most agencies use the Lumia et al. (1987) methodologies to collect and rate HWMs and reference HWMs to surveyed benchmarks.

• Storage methods – Typically paper field sheets or digital databases.

• Dissemination of data – We can do better!
  – There is no system for coordinating the collection and dissemination of HWM data nationally.
  – Consequently, HWM data resides at individual agencies and in some cases on the standalone computers of individuals at these agencies. Because of this limitation, HWMs are not being used to their full potential.
  – To rectify this, the USGS has recently begun to develop a centralized system for disseminating HWM data and is seeking to expand the capacity of this system.
High Water Mark (HWM) Characteristics

- Mud or silt lines – lines of sediment left on trees, structures, streambanks, or buildings.
- Debris lines – lines or piles of debris such as leaves and sticks.
- Debris snags – debris left in trees or shrubs.
- Ice debris – ice remnants that can mark high water.
- Seed lines – lines of seeds, fibers, and other miniscule debris that were floating on the water.
- Wash lines – lines where soil has been washed away from banks.
- Eroded banks – where the top of the erosion area approximates the highest water level.
Velocity head \((V^2/2g)\) is the height water will rise to, in the absence of velocity (i.e., a HWM).

So, HWMs can provide estimates of velocity!

\[
V = \sqrt{2gh}
\]

\(h = 3.0\text{-ft}\)?

Telephone pole 18-inches wide
Accuracy and Reliability of High Water Marks

- Excellent and good HWMs – Seed line and HWMs protected from post-flood rains...silt line in moss on north side of tree trunk (anecdote).
- Fair HWMs – Debris and mud lines.
- Poor HWMs – Irregular patterns (see photo below), HWMs on flexible plants, tupperware container on lawn (anecdote).

![Image of water marks]

<table>
<thead>
<tr>
<th>HWM classification</th>
<th>Coastal storm surge HWM uncertainty (ft.)</th>
<th>Upland rivers HWM uncertainty (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Good</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Fair</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Poor</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Very poor</td>
<td>&gt;0.40</td>
<td>&gt;0.20</td>
</tr>
</tbody>
</table>

*Table 1. Uncertainties of high water mark ratings. (Rydlund and Densmore, 2012)*
For a given stage, discharge tends to be greater as the flood wave arrives and less as it passes, tracing a closed loop that is generally centered along the uniform flow rating curve.

Stage differences are caused primarily by the return of overbank flow to the main channel.

Therefore, there is uncertainty in translating HWMs to discharges on natural streams and it is important to record the time of a HWM observation during a flood event.
Estimation of Flood Frequencies for HWMs

- Challenges are twofold:
  1) the need to relate the HWM to a discharge; and,
  2) then relate the discharge to a flood frequency or annual exceedance probability.

- This approach is straightforward where HWMs have been observed at or near a streamgage; however, for older HWMs at ungaged locations the approach is more complicated.
Estimation of Flood Frequencies for HWMs

1. Obtain a HWM.
2. Associate the HWM to a gaged or ungaged location; estimate stage and discharge for the HWM.
3. Develop a gaged or ungaged flood frequency curve.
4. Estimate a Flood Frequency for the HWM Discharge.
5. Perform an Independent Check.

Figure 24 - Generalized approach for estimating flood frequencies of a HWM.
Recommendations

• A nationwide geospatial database for archiving high water mark data should be developed and made available to the public.

• Guidance on methods to estimate the flood frequency for a high water mark at a given site should be made available with any High Water Mark database developed.

• Training associated with collecting high water mark data should be provided to federal, state and local entities.

• Training should be provided to state and local officials for estimating and understanding uncertainty in flood frequency estimates and how HWMs can be used to reduce this uncertainty.
Acknowledgements

• The Association of State Floodplain Managers (ASFPM) produced this report with funding from the Federal Emergency Management Agency (FEMA).

• The ASFPM is deeply grateful for the time and effort contributed by all the interview participants:
  – U.S. Geological Survey - Robert R. Holmes, Marie Peppler, Dave Eash
  – U.S. Fish and Wildlife Service - Brian Huberty
  – Federal Emergency Management Agency - Vincent Brown
  – U.S. Army Corps of Engineers - Terry R. Zien, Richard Pruitt
  – Indiana Department of Natural Resources - Dave Knipe
  – Texas Water Development Board - Melinda Luna
  – Johnson County, Iowa - Ed Bartels, Greg Parker, Rob Winstead
The ASFPM’s project team consisted of:

- Alan Luloff and Jeff Stone of the ASFPM Executive Office
- John Buechler, Laura Danielson, and Shane Hubbard of The Polis Center at Indiana University-Purdue University Indianapolis
- Kevin Coulton of cbec eco engineering, inc.
- Scott Morlock of the USGS Indiana Water Science Center
• This is one of my favorite flood HWMs; i.e., the two HWMs shown in the photo are from beaver gnawing on the tree limb during a prolonged flood event on Sacramento River (photograph courtesy of Tom Griggs, River Partners).

• Do you have a favorite HWM story? Please let me know; I’d like to compile a companion report that provides real-life observations, anecdotes, and experiences with HWMs.

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