Improving Situational Awareness of Flash Flooding in a Small Urban Catchment by Integrating Meteorological Analysis into a Geospatial Framework

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Susceptibility of Flooding Within Urban Environments

- A long known phenomenon
- Urban risk often > rural risk
- Compounding factors of:
 - impervious surfaces
 - channeled flow via stormwater/drainage systems
 - enhanced runoff



Burlington, VT not a Stranger to Flooding

- Six discrete events since 2012, most notably:
 - July 4, 2012
 - May 22, 2013
 - June 29, 2013
- Resulting from intense convective rainfall bursts



Why Here?

- Burlington, VT watershed as defined by NWS Flash Flood Monitoring and Prediction (FFMP) software
- Most reports occur along a subtle, largely buried natural drainage



Methodology

- GIS mapping
- Historical Content Analysis
- Radar and Hydrometeorology
- Human contributions



GIS Analysis

- Hillshade layer derived from 3.2m DEM reveals enhanced detail along the drainage (black outline)
- Notice the several small depressions (arrowed)
- Some of these areas served as foci for areas of flooding during the 2012 & 2013 events



GIS Analysis

- 2 foot contours reveal greater detail
- Overlay of the 4 July, 2012 and 22 May, 2013 flooding locations highlights the importance of the drainage and natural depressions



Presdee & Edwards Map from 1853



The Story of Burlington's Lost Ravine

- A natural northeast -> southwest oriented drainage clearly evident on early maps from the 1800s.
- Was an early impediment to eastward development of the city.
- Served as a conduit for the Vermont Central Railroad (m. 1800s), and the city's primary sewerage conduit by the late 1800s into the 20th century before modernization.
- Largely filled/buried by the 20th century, though evidence remains.

Coast Survey Map of 1872



The King Street Dip



Flood Frequency Analysis

- Warm season heavy rainfall events (Apr. Sep.) tallied from the early 20th century through Sep. 2013
 - Burlington Free Press archives
 - NWS Storm Data
 - Search technique \rightarrow examine all 25.4mm (1.0")+ rainfall days (@ KBTV)
 - Additional criteria to search days where <u>hourly rates</u> > 25.4mm (1.0")
- 67 heavy rainfall days identified
- Hourly constraints limited search to 1948 onward
- Flooding was reported on 28 of the 67 days (42%).
- Flooding reports were not completely coincident with hourly rates > 25.4mm (1.0") -> (cross-hour totals)

Meteorological Analysis – Hourly Rates

- Of the 67 heavy rainfall events, rates mainly ranged from 0.15 to 0.35 mm, or 0.75 to 1.5 inches per hour.
- Right hand tail

 more extreme events.



Sub-Hourly Precipitation Data



- Sub-hourly precipitation data available from 1971 onward, limiting cases to 44.
- Only slightly greater totals noted between flood and null events
- F-test data showed near equal variances of short term precipitation rate between flood and null events.

Precipitation Intensity Frequency Duration Plots for Burlington



- 2 and 5 year return period data show sub-hourly rates in excess of 1 inch, matching the box and whisker plots.
- These intense sub-hourly rates likely play a large role in the city's flood episodes

Antecedent Precipitation

- Slightly higher for flood vs. null events
- Greater differences at 1 week time frame
- Results inconclusive though antecedent precipitation likely plays a role in some events (August 1955)



Radar Case Studies

- 4 July, 2012 → No dual-polarization data
- 22 May, 2013 → Dualpolarization data available
- All data from KCXX WSR-88D in Colchester, VT



22 May, 2013 Dual Polarization Data

- Short term intense convective rainfall burst 2130-2215 UTC.
- An impressive 0.96 inches observed in 14 min. at KBTV
- DP instantaneous rates up to 6 inches per hour and short term estimates of 1-2 inches in 30 min.
- DP data performed better than legacy WSR-88D precipitation estimates.



Human Contributions to Flooding

- Clogged drains/catchment basins
- Modern sewer lines intersecting with ravine sewer → more crisscrossing lessens slope of water drainage and slows flow
- Feedback via Burlington Public Works Stormwater staff



Summary

- Burlington remains prone to urban flood events.
- High intensity, short duration convective rainfall bursts > 1 inch in < 1 hour most problematic.
- Variability in convective rainfall rates over short distances likely responsible for some of the data disparities.
- WSR-88D dual-polarization precipitation estimates and instantaneous precipitation rates more valuable than legacy radar estimates.
- Higher density rain gauge network would add considerable value and enhance S/A for potential and early detection of flood events.
- Human contributions to the urban flood phenomenon is an important consideration.

Thank You