Flash Flooding Events Across the Mount Holly County Warning Area Amid the Evolving Landscape of Science, Technology, and Society

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Introduction

The National Weather Service (NWS) in Mount Holly (PHI) experiences a variety of weather threats throughout the course of each year. Flash flooding is becoming one of the greatest warm-season threats across the county warning area (CWA), as the frequency and severity of these events have noticeably increased for various reasons (including broadening urbanization, more frequent occurrences of anomalous tropospheric moisture content during the warm season, etc). Research-to-operations advances in flash flood forecasting, warning operations, media and technological innovation has allowed for flash flood warning operations at NWS PHI to rapidly evolve. Much of this modernization has occurred in concert with the storm-based warning era in the NWS; however, integration of media and technological advances into the warning process has been a more recent focus (especially in the past three years). We examine the state of flash flood verification for the office in an effort to determine and quantify the effects such modernization has had on warning operations.

Flash Flood Climatology and Verification in the NWS PHI County Warning Area

Flash flooding in the NWS PHI CWA tends to occur primarily in two favored corridors (Fig. 1a). The first is located within the greater Philadelphia metropolitan area northeastward toward the Trenton and New Brunswick areas in New Jersey. The second stretches from Reading to Allentown in eastern Pennsylvania. These two corridors are highly urbanized and are becoming increasingly so in the past two decades (Fig. 1b) with subtle but observable increases in flood frequency at many gauges in these areas (e.g., Fig. 3).

The most noticeable trend in warning verification over the past decade has been a recent large increase in lead time (Fig. 2a). Other statistics exhibit little trend through the period [as these values appear to be more closely tied to annual variations in flash flood events and warnings issued (Fig. 2e)]. However, the probability of detection has also increased noticeably in the past three years, suggesting a potential association with the office integration of media/technological advances. Several examples are provided in Figs. 4 and 5. A common theme among these is the promotion of situational awareness: combining a high volume of data into simple, comprehensible, and immediately actionable displays of information to promote fast and effective decision-making.

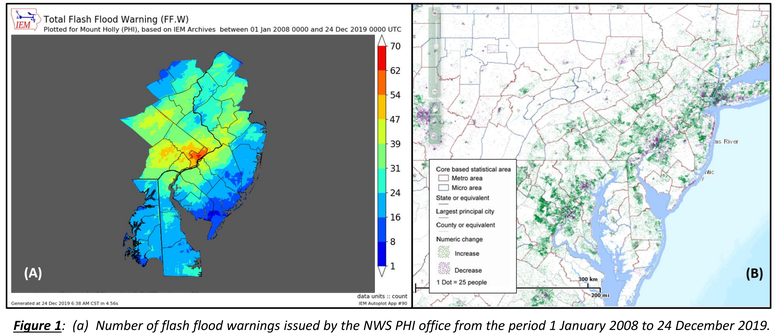

Figure 1: *(a) Number of flash flood warnings issued by the NWS PHI office from the period 1 January 2008 to 24 December 2019. Image courtesy of the Iowa Environmental Mesonet at Iowa State University. (b) Population increase (green) and decrease (purple) between the 2000 and 2010 census. Image courtesy of United States Census Bureau.*

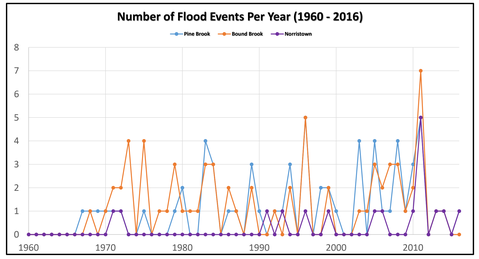

Figure 3: *Number of distinct flood events per year from 1960 to 2016 for the Pine Brook gauge on the Passaic River (blue), the Bound Brook gauge on the Raritan River (orange), and the Norristown gauge on the Schuylkill River (purple).*

Figure 4a (right): *Example of a social media page that reports (in near real-time) county dispatches. These pages have been instrumental in (1) the identification of multiple and distinct flash flood events within single warnings, (2) faster verification of warnings, ultimately providing more informed decisions with subsequent warnings, and (3) receipt of events in less-populated areas that may otherwise have been unknown, even well after the event. Example from the 11-12 July 2019 flash flood event.*

Type	Description	State	County	Lat	Lon	Report Time
damaged roadway	FIVE POINTS RICHMOND RD / RICHMOND RD	PA	Northampton County	40.8594679501334	-75.1580097443795	2019-12-23 18:24
US 46 eastbound : Watermain break	NJ DOT - STMC: Watermain break on US 46 eastbound area of CR 618/Mountain Lakes Blvd (Mountain Lakes) right lane closed use caution	NJ	Morris County	40.8838665938	-74.4576424293	Tue, 24 Dec 2019 06:24:02 -0500

Figure 4b (left): *Snapshot of the automated, real-time situational awareness display of DOT reports obtained via RSS feed for the NWS PHI.*

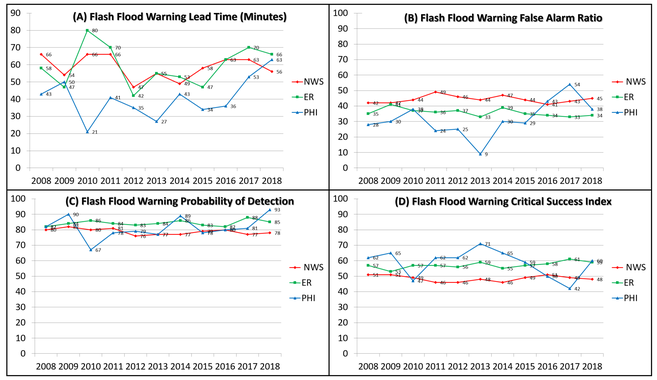

Figure 2: *Flash flood warning lead time in minutes (a), false alarm ration (FAR); (b), probability of detection (POD); (c), and critical success index (CSI); (d) during the storm-based polygon warning era. Statistics for the National Weather Service as a whole are in red, for all Eastern Region offices are in green, and for the NWS PHI office are in blue. Note that 2019 data are not shown (preliminary) but continue to indicate an increasing trend in lead time and POD and a decrease in FAR from the previous year.*

Type	Description	County	Lat	Lon	Report Time
Flood	River/Creek overflowing; Cropland/Yard/Basement Flooding	Chester County PA	40.032383434466102	-75.630223485696812	2019-07-11T22:21:59Z
Rain/Snow	Rain	Chester County PA	40.032373338819128	-75.630161857191103	2019-07-11T22:21:21Z
Rain/Snow	Rain	Morris County NJ	40.91278299840659	-74.351875042082212	2019-07-11T22:18:33Z
Rain/Snow	Rain	Chester County PA	39.926870875097774	-75.573001496400028	2019-07-11T22:11:51Z
Flood	Street/road flooding; Street/road closed; Vehicles stranded	Somerset County NJ	40.662159654811276	-74.428975686470795	2019-07-11T22:10:11Z
Rain/Snow	Rain	Hunterdon County NJ	40.546399526634097	-74.820419818124444	2019-07-11T22:00:57Z
Flood	Street/road flooding; Street/road closed; Vehicles stranded	Berks County PA	40.409695	-75.580287	2019-07-11T21:37:31Z
Rain/Snow	Rain	Bucks County PA	40.3923235	-75.1420983	2019-07-11T21:33:48Z
Flood	Homes or buildings filled with water	Berks County PA	40.433254	-75.562479	2019-07-11T21:20:42Z
Flood	Street/road flooding; Street/road closed; Vehicles stranded	Montgomery County PA	40.249595866824681	-75.645504958551684	2019-07-11T20:59:57Z
Flood	Street/road flooding; Street/road closed; Vehicles stranded	Berks County PA	40.44178	-75.555316	2019-07-11T20:58:58Z
Flood	Street/road flooding; Street/road closed; Vehicles stranded	Cecil County MD	39.677798640875196	-76.160028055852211	2019-07-11T20:50:33Z
Rain/Snow	Drizzle	Somerset County NJ	40.532841802462	-74.502186620634005	2019-07-11T20:50:01Z
Flood	River/Creek overflowing; Cropland/Yard/Basement Flooding	Warren County NJ	40.925216	-74.993613	2019-07-11T20:42:29Z
Flood	River/Creek overflowing; Cropland/Yard/Basement Flooding	Warren County NJ	40.706779462255574	-74.999344919982214	2019-07-11T20:39:26Z
Rain/Snow	Drizzle	Middlesex County NJ	40.501072458703641	-74.456832458570849	2019-07-11T20:38:41Z
Rain/Snow	Drizzle	Middlesex County NJ	40.497879898213331	-74.449729255377221	2019-07-11T20:36:55Z
Rain/Snow	Rain	Hunterdon County NJ	40.546369097662254	-74.820217974833989	2019-07-11T20:34:41Z
Rain/Snow	Rain	Cecil County MD	39.586569813857051	-76.076677159214443	2019-07-11T20:33:19Z
Flood	Street/road flooding; Street/road closed; Vehicles stranded	Lehigh County PA	40.555623	-75.488726	2019-07-11T20:27:16Z
Rain/Snow	Drizzle	Middlesex County NJ	40.496654073663805	-74.444636152863391	2019-07-11T20:20:22Z
Rain/Snow	Rain	Morris County NJ	40.912656687901	-74.351613699367335	2019-07-11T20:20:17Z
Rain/Snow	Drizzle	Middlesex County NJ	40.497571694046424	-74.444431792339916	2019-07-11T20:19:52Z
Flood	River/Creek overflowing; Cropland/Yard/Basement Flooding	Northampton County PA	40.931388854980047	-75.151046752929969	2019-07-11T20:18:28Z
Rain/Snow	Rain	Lehigh County PA	40.697368441396655	-75.705006796621866	2019-07-11T20:00:45Z
Flood	River/Creek overflowing; Cropland/Yard/Basement Flooding	Lehigh County PA	40.697389545310165	-75.705033856222274	2019-07-11T20:00:33Z
Rain/Snow	Rain	Mercer County NJ	40.2218138	-74.6390521	2019-07-11T19:53:06Z
Rain/Snow	Rain	Bucks County PA	40.0977277	-74.9225434	2019-07-11T19:52:52Z
Rain/Snow	Rain	Burlington County NJ	39.908164	-74.728339	2019-07-11T19:42:21Z

Figure 4c: *Automated, real-time situational awareness display of mPING reports within the NWS PHI CWA during the 11-12 July 2019 flash flood event. A flash flood emergency was issued for Berks County during the height of the event, with receipt of these reports one of the first indications regarding the severity of flash flooding occurring.*

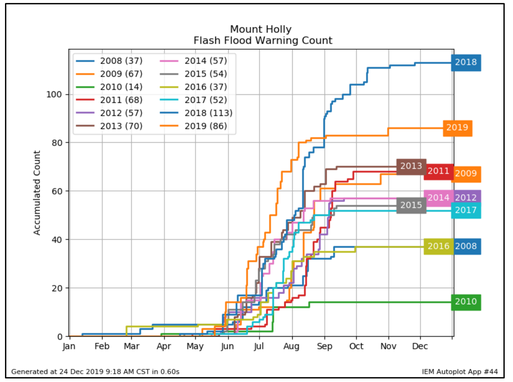

Figure 2e: *Number of flash flood warnings issued per year by NWS PHI from 2008 to 2019 (shown as accumulated totals through the year). Image courtesy Iowa Environmental Mesonet at Iowa State University.*

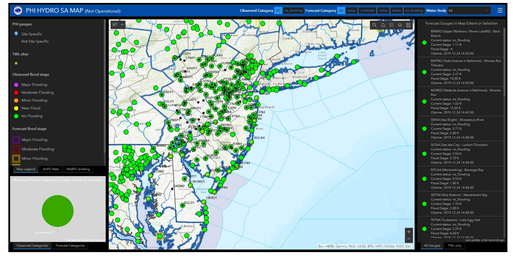

Figure 5: *Internal situational awareness page providing color-coded flood information for gauges within and surrounding the PHI CWA. Each gauge is interactive, providing gauge information and instructions for product issuance when operational needs arise.*

Current Operational Philosophy

NWS PHI has implemented a modernized approach to flash flood warning operations in the storm-based warning era. The approach has several key features:

- Integration of media and technological advances [e.g., RSS (Fig. 4b), mPING (Fig. 4c), ArcGIS (Fig. 5), and others]
- Emphasis on situational awareness (Figs. 4 and 5)
- Incorporating research-to-operations advances to facilitate improved decision-making [including the Multi-Radar/Multi-Sensor (MRMS) system, Flooded Locations and Simulated Hydrographs (FLASH), Flash Flood Monitoring and Prediction (FFMP), among many others]