The NHWC Transmission

October 2017

CONTENTS

Click on hyperlinks located throughout this newsletter for more information.

The Untold Story of Hydrologic Data Collection for the Harris County Flood Control District during Hurricane Harvey

Mark Moore, Harris County Flood Control District

The Harris County Flood Control District (HCFCD) fully converted to ALERT2 in December of 2015, and since then has presented several articles describing the success of the new technology and its implementation. Repeating the same statistics and figures would only provide so much value, so instead we would like to focus on sharing some lessons we have learned from Hurricane Harvey.

ALERT2

For the full story on the HCFCD conversion process to ALERT2, reference *Harris County Flood Warning System 2016 Tax Day Flood Test – Passed!*[1] The analysis from Harvey shows similar success for the 154 gages in the system. Over the five days around the event, the ALERT2 network collected 250,000 data points with over 99% of incoming data successfully received. The system sent out over 500 valid alarms indicating intense rainfall rates or flooding conditions.

System Hardware

Over half of Harris County's 22 watersheds experienced record breaking flood levels, and as expected for such an epic event the gage network suffered damage. To put into perspective the magnitude of rainfall that Harvey produced, an average of 33.7 inches of rainfall occurred across Harris County's 1,777 square miles – equaling 1 trillion gallons of water and produced 68% of the annual average rainfall for the City of Houston in a four-day period. Only seven of the 154 gages sustained flood damage. In addition, five other sites had damaged water level sensors and two additional sites reported unreliable rain. All major repairs were completed by September 14th (14 days after rain stopped) due to the hard work of David Haynes, Don Van Wie, and HCFCD Technicians, restoring the system to full functionality to be prepared for the next flood event. Flooding from previous storm events encouraged HCFCD to raise gages to higher locations, and two of the three sites that flooded during Harris County's last storm did not flood during Hurricane Harvey. However, some of the damage may have been prevented with better installation procedures.

Two of the flooded sites are located close to the banks of the San Jacinto River, and have had consistent issues with flooding in past events. Repair work included elevating both stations and installing all equipment as high as possible (Figure 1). Every site that flooded was modified in some way to make the system more flood resilient for future storm events.

[1] M. Moore, S. Fitzgerald, J. Lindner. *Harris County Flood Warning System 2016 Tax Day Flood Test – Passed!* The NHWC Transmission, October 2016

Figure 1. Flood gage along the banks of the San Jacinto River. Storm debris can be seen all the way to the top of the antenna mast. Repair work involved elevating equipment to prevent damage from future minor floods.

HCFCD Servers

The flood gages themselves were not the only part of the network that experienced issues during Harvey's flooding. During the event HCFCD was informed that Harris County IT might be forced to change the network pathways for our primary server location due to flood damage. This would potentially stop the ability to transfer data to the Flood Warning System (FWS) website from the data collection point (Figure 2, Point A). At 10:30 AM August 28th, a conference call was held to ensure that vital processes could be handled by the backup server at a separate location. At 11:05 AM August 28th, 35 minutes later, the backup server failed due to internet connection issues at the unmanned secondary receive site due to storm damage (Figure 2, Point B). This was the only backup for the threatened primary server.

Fearing loss of data connections from the primary and backup servers, we contacted OneRain, HCFCD IT staff, and Harris County IT staff. We proposed a cloud hosted server as a "third" backup location. At 3:32 PM August 28th (~4.5 hours after our backup site failed), OneRain completed setup of a cloud sever that connected to the primary data collector located at the radio tower. All data from other servers was transferred over to the cloud hosted server, and redundancy was successfully restored thanks to the diligent work of OneRain staff.

The Public Website

The HCFCD maintains and operates our FWS website to provide accurate and reliable real-time rainfall, flood stage, and other data. This information is used by the HCFCD and by Harris County's Office of Homeland Security and Emergency Management to inform the public of imminent and current flooding conditions along watercourses. The website serves as a direct access point for public users, and was heavily utilized during the event.

Over 1 million unique users visited the website during Harvey, with over 6.3 million different page views (6x higher than any previous event). This load on the website caused the entire page to crash several times during the event even with

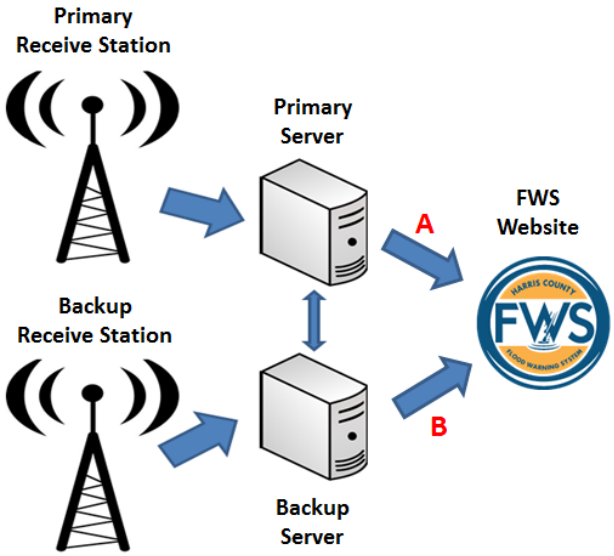


Figure 2. Diagram of flood warning data after it has arrived at the radio towers. Concerns were raised about the connection at Point A. Point B failed 35 minutes later.

preventative measures. A review of the statistics from the FWS website revealed a few key pieces of information that all flood warning system operators should be aware of:

1. 65% of users went to the website on a tablet or mobile device.
2. 35% of visitors were new users.
3. Most users went to the website directly or from a google search (70%), but other websites such as news agencies (20%) and

social media (10%) sent a significant amount of website traffic to the website.

4. Over 100 comments and questions were received by the FWS website alone.

Conclusions

In 2009, the HCFCD began a deliberate effort to restore the Harris County FWS into a source of reliable and accurate real-time hydrological data. By 2016 the HCFCD had achieved those goals and tested the newly upgraded system through a major storm event. However, Hurricane Harvey was on a scale that has never been seen in Harris County, the state of Texas, or the entire nation. The system performed exceptionally, but important lessons were discovered. We strive to share these lessons as the hydrologic warning community continues to be an improving and advancing field, and can only do so with the sustained cooperation of system owners, operators, vendors, and users.

The Development of a Flood Warning System for the City of Salem, Oregon

Justin Boyington, City of Salem, Oregon
Ken Puhn, WEST Consultants, Inc.

The City of Salem, Oregon began monitoring stream flows in 2006 with the installation of 6 near real-time continuous stream gauging stations, and by 2008 the program was built out to 11 stations. The objective of the program was to provide data to inform future stormwater master planning efforts and development of construction design standards. Then, in January 2012, the Salem area experienced a nearly 50-yr flood event on Mill Creek, which caused extensive damage to personal property and public infrastructure. While the real-time data from these gauging stations provided the City with critical information regarding stream trending, there wasn't anything in place to provide an understanding of impending flood severity or stream crest timing. This was particularly true for Mill Creek, which has 90% of its 111 square mile watershed outside of Salem city limits.

North access to the Salem Hospital was lost during January 2012 flooding.

Soon after the 2012 flood event, a group of stakeholders[1] within the Mill Creek watershed began to meet with the goal of achieving a common objective; the creation of an early Flood Warning System (FWS). Significant milestones have been reached since those initial meetings, most notably:

- Formation of an operational partnership consisting of local municipalities, state agencies, businesses, and critical facility managers (2012);
- Application and implementation of a FEMA Hazard Mitigation Grant Program (HMGP), 5% Initiative to expand the monitoring infrastructure within the Mill Creek Watershed (2013-2014);
- Creation of a data dissemination website and automated alerting system (2014) – Mid Willamette Valley High Water Watch - https://hww.onerain.com;
- Development of a hydrologic model for flood forecasting (2016); and
- Significant revisions to Salem's Flood Response Operations Plan as each milestone was met (2015-2017).

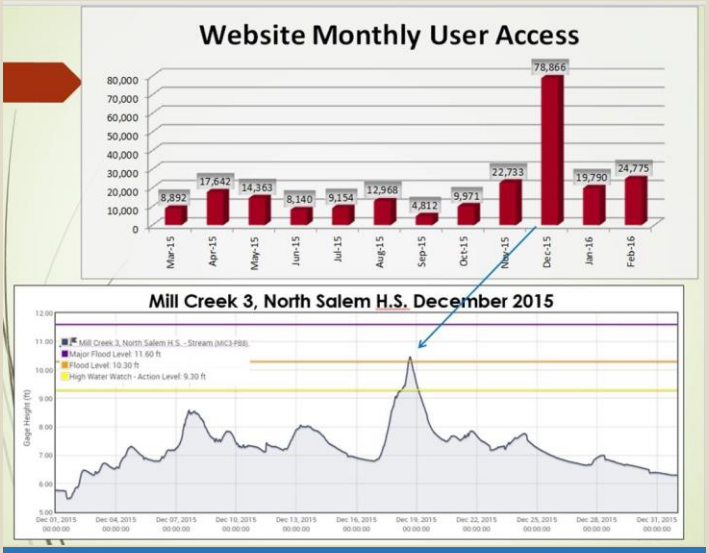
As stakeholders within the Mill Creek Watershed began to meet, it became apparent that a partnership should be developed to ensure ongoing communication, dissemination of historical and future data, collaboration on future mitigation efforts, and funding for grant matching dollars. The latter of which was significant in the successful application of the FEMA HMGP 5% initiative awarded to the City of Salem in 2013.

The FEMA grant provided funding for the purchase and installation of one additional stream gauging station, and five new rain gauges in the upper Mill Creek Watershed. It also provided funding for the conversion of eight existing City of Salem rain gages to report in real time. In addition to the FEMA grant expenditures, the City of Salem financed and installed one new stream gauging station in the upper Mill Creek watershed, and the City of Turner financed and installed one new gauging station within Turner city limits. The construction of this new monitoring infrastructure was completed in the fall in 2014. The expansion and upgrades to the existing gaging network were critical to the development of the automated alerting system and hydrologic forecasting model.

While the monitoring infrastructure was being installed, work began on the development of the "Mid-Willamette Valley High Water Watch" data dissemination website, which was completed in the fall of 2014. The website was developed to provide the Partners and the public with a central location to access local rainfall and stream data, weather forecasts, and quick links to the Partners' websites and/or emergency pages. One notable feature within the website software is the ability to easily write data driven automated alerts which are triggered based on the gaging system observations, to be received via email or text message. The ease of writing such alerts allows for specific alerts to be based on each partner's response plan. This feature has turned out to be one of the more essential components of the system.

Put to the Test in 2015

During December 2015, the Salem area was hit by a series of Pacific storm events. During this month, the new website was viewed almost 79,000 times. This was 50,000 more views than any other month since the website's inception in the fall of 2014. The December storm events also triggered 120 data driven automated alerts, which were received by 100% of the intended recipients. These alerts played a significant role in helping operational response staff and emergency managers for all the partners to make critical time sensitive decisions that were unique to their individual response plans.



Website analytics during December, 2015.

After the initial phases of the system had been developed, the City of Salem contracted with the engineering firm, WEST Consultants, Inc., to develop a stream forecasting system for the Mill Creek Watershed. The forecasting system is based on the US Army Corp's HEC-RTS (Real Time System) and HEC-HMS (Hydrologic Modeling System). HEC-RTS allows the operator to feed observed streamflow and precipitation data, along with National Weather Service forecasted precipitation, into the hydrologic model to predict timing and magnitude of peak stream levels on Mill Creek. Automated scripts were developed to feed the model the relevant observed stream and rainfall data along with National Weather Service 72-hour quantitative precipitation forecast data. The City of Salem operates the forecast model during large precipitation events and in turn shares the model output to FWS Partners, thus providing more time and confidence in initiating the appropriate level of response for future flood events.

Lastly, it should be noted that the completion of each FWS milestone mentioned above required a revision to Salem's Operation Flood Response Plan; and as each reiteration of the plan was made it became more and more clear that creation of this system will undoubtedly make a difference for the communities it serves. In fact, even though there has only been one minor flood event (2015) since the system has been in place, the system has already recognized many "non-flood" events that before the system's inception would have resulted in needless worry and response.

CoCoRaHS

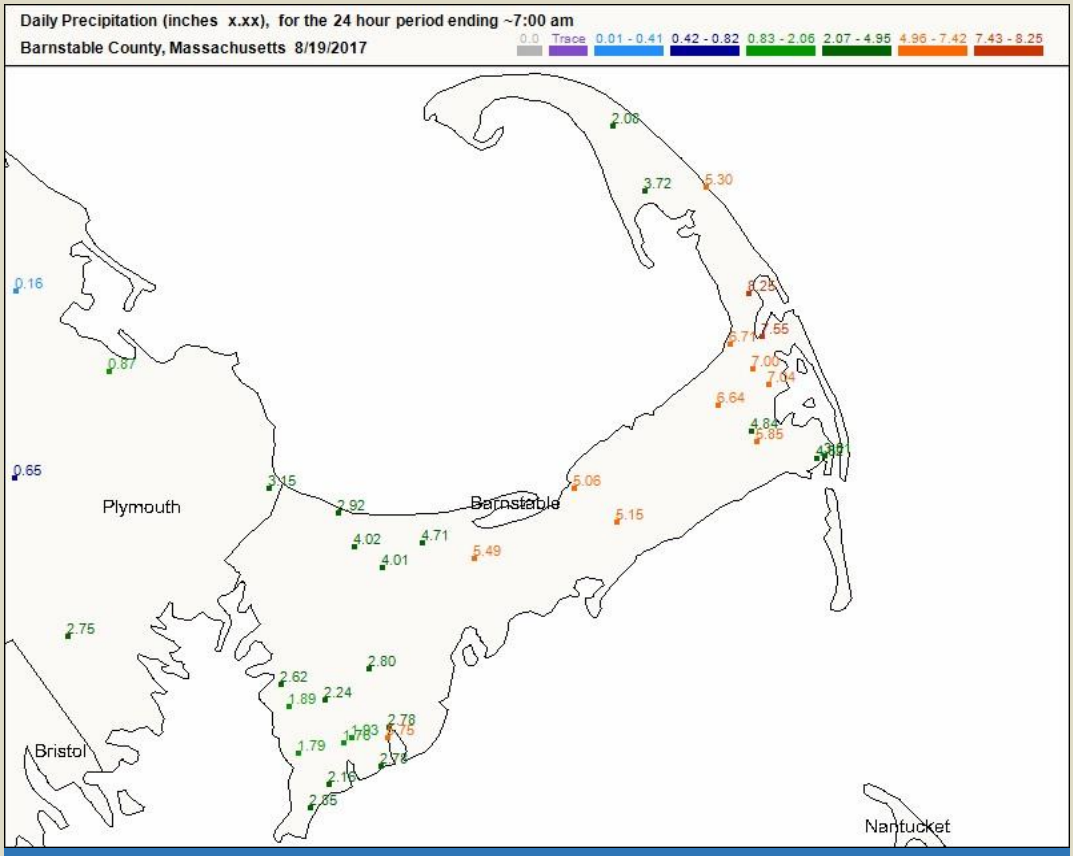
providing important precipitation data documenting heavy rain events for 19 years

Henry Reges, Colorado State University
CoCoRaHS U.S. National Coordinator

CoCoRaHS, the Community Collaborative Rain, Hail and Snow network, turned nineteen years old in June. With over 20,000 active volunteers in all fifty states, Canada, Puerto Rico, the U.S. Virgin Islands and the Bahamas, it continues to provide important daily and often real-time reports of precipitation. When heavy rain falls, an observer can file a "significant weather report" which goes immediately to the local National Weather Service Office's AWIPS workstations, sounding an alarm for the forecasters to view. These reports provide critical real-time precipitation information that may lead to the issuance of warnings and help save lives in flash floods as well as tropical rainfall events.

Some interesting events during 2017 include over a 1,400+ observer reports each day from the Texas-Louisiana area during Hurricane Harvey, over 400+ daily reports throughout Puerto Rico, the Bahamas, Florida (while they still had power) and the southeast as Hurricane Irma wreaked havoc and helpful rainfall reports over the Virgin Islands and Puerto Rico proceeding Hurricane Maria until the power was knocked out and reports were unable to be sent in. Recent heavy rain events included eleven six-inch plus observations over Northeast Texas the night of August 12th; over six, six-inch plus reports on Cape Cod during the night of August 18-19th and five, five-inch plus reports (which your author drove through) in Southwest Ontario on the evening of August 29th. There were many more of these around the country throughout the summer months.

This year CoCoRaHS has added two new features for its observers to participate in. One is Soil Moisture Monitoring (https://cocorahs.org/Content.aspx?page=soilmoisture) and the other is Condition Monitoring (https://cocorahs.org/Content.aspx?page=condition) where an observer can help the US Drought Monitor authors with a report on whether their current landscape is wet, normal or dry. In addition to these new features, once the weather turns cold, observers can send in updates on the water content (SWE) of their snowpack, which provides valuable data to many municipalities and over half the annual reports received by NOAA's National Operational Hydrologic Remote Sensing Center (NOHRSC).



Map of significant event on Cape Cod, Massachusetts August 19, 2017

If you've yet to join the network, please consider taking a daily observation. You can find out more on our website: www.cocorahs.org

Registration is Open

for the

National Hydrologic Warning Council

9th Annual Texas Workshop

November 8-9, 2017

This 2-day interactive workshop will focus on hydrologic warning programs and systems in Texas, including flood warning system performance, flood forecasts and warnings, flood impacts, public communication, reservoir operations, and post flood activities. Other topics will include radio frequency encroachment, NOAA Atlas 14, and ALERT2 implementation.

The venue for this years' workshop will be the historic Menger Hotel located at 204 Alamo Plaza in San Antonio, Texas.

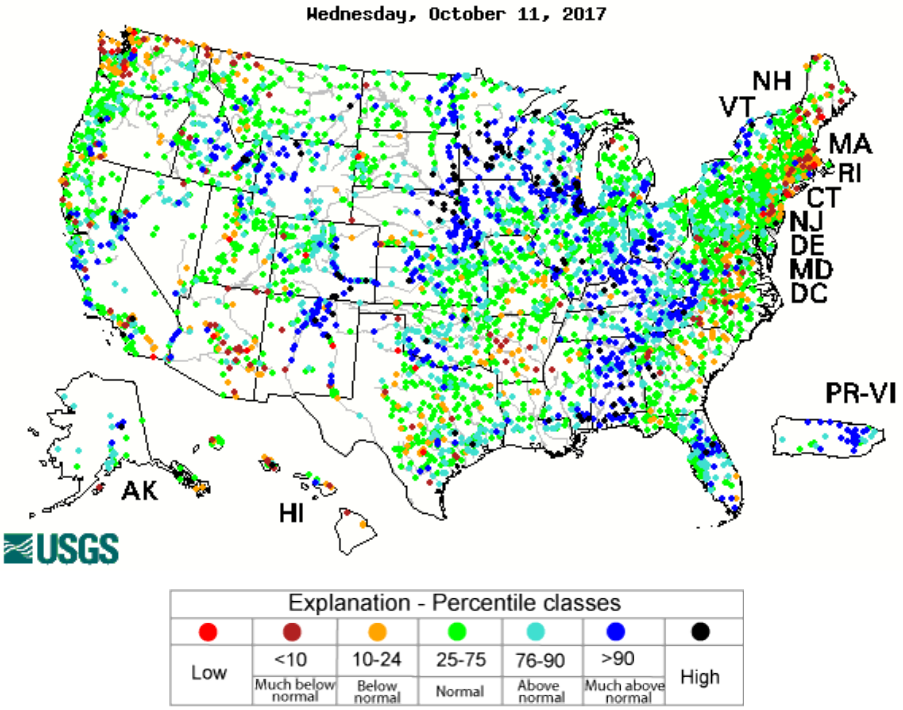
THE HISTORIC MENGER HOTEL

Visit the **NHWC** website to register.

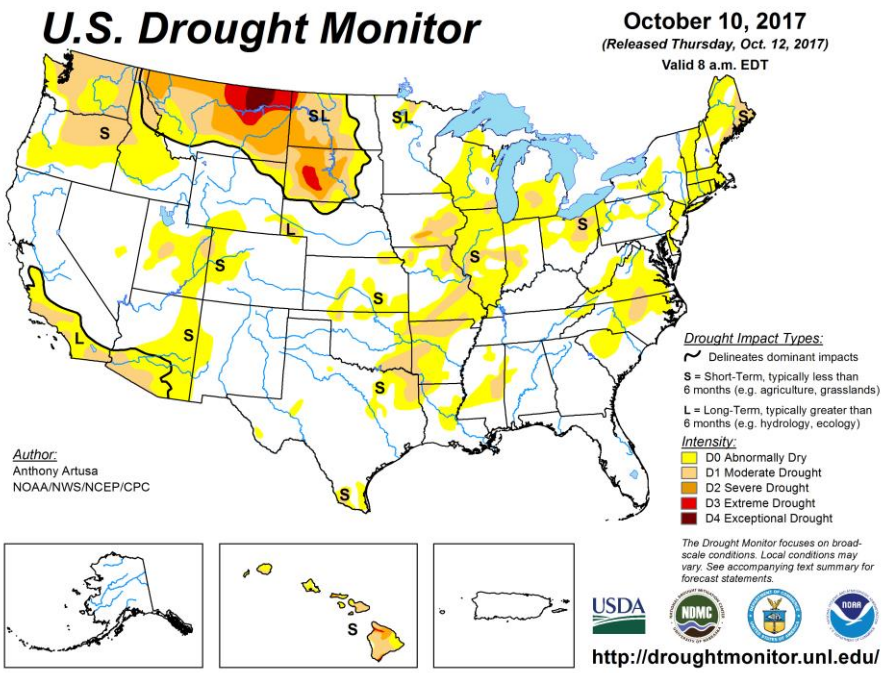
NATIONAL HYDROLOGIC WARNING COUNCIL

HARRIS COUNTY FLOOD CONTROL DISTRICT

Hydrologic Conditions in the United States
Through October 10, 2017



Latest stream flow conditions in the United States. (courtesy USGS)



Latest drought conditions in the United States. (courtesy National Drought Mitigation Center)

November Newsletter Articles Focus:

Hydrology

The NHWC is requesting articles that focus on hydrology - the science behind the work we do. Please consider preparing a short article about new methods, research, or discoveries in hydrology or a recent significant hydrologic event.

Submit your article to:

editor@hydrologicwarning.org

November 3rd is the deadline for inclusion in the November issue.

Future Newsletter Articles Focus

To give you more time to prepare articles, below is the article focus schedule for the next four months:

Nov - Hydrology
Dec - Hazard Communication & Public Awareness
Jan - Modeling/Analysis
Feb - Data Collection

NHWC Calendar

November 8-9, 2017 - 9th Annual Texas Workshop, San Antonio, TX

General Interest Calendar

October 19, 2017 – The ALERT Users Group Fall Meeting & Workshop, Sacramento, California

November 5-9, 2017 – AWRA Annual Conference, Portland Oregon

April 17-20, 2018 – The ALERT User's Group Training Conference and Exposition, Ventura, California

Jun 4-7, 2018 – 2018 ASCE Environment and Water Resources Institute International Congress, Minneapolis, Minnesota

(See the event calendar on the NHWC website for more information.)

Parting Shot

Who we work for – everyday!

Hurricane Harvey, Houston, Texas

Contributed by **Steve Fitzgerald**, Harris County Flood Control District, Texas
NHWC President

National Hydrologic Warning Council

Providing Timely, Quality Hydrologic Information to Protect Lives, Property, and the Environment

http://www.hydrologicwarning.org