Dewberry

# 2015 Flood Threat Bulletin – Final Report

## Colorado Water Conservation Board

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## Submitted To:

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

# 2015 Colorado Flood Threat Bulletin

Final Report

## INTRODUCTION

During the warm season, Colorado is threatened by a variety of different forms of flooding including ice jams, flash floods, spring snowmelt and river. As the state has a storied history of volatile swings in year to year precipitation, some years can have very limited flooding while others see consistent flood threats through the entirety of the warm season. This project is design to (i) provide Colorado emergency managers and first responders with a daily county-specific assessment of flood and flash flooding threat in their county, and (ii) provide a longer-term precipitation outlook geared towards water supply planning.

In 2012, a competitive award of the Colorado Flood Threat Bulletin was made to Dewberry. As in previous years, the program runs from May 1 through September 30 and requires the daily issuance of a Flood Threat Bulletin (FTB) describing the flood threat in Colorado and the issuance of a 15-day Flood Threat Outlook (FTO) to identify periods of rapid snowmelt, locally heavy rainfall, or conversely the development of drought conditions due to lack of precipitation. In addition, a daily Storm Total Precipitation (STP) product is issued to recap the daily hydrologic conditions across Colorado. In 2015, Dewberry meteorologists Brad Workman (FTB, FTO, STP) and Dmitry Smirnov (FTB, FTO, STP) developed all of the forecasts. The forecasts were made available on the website www.coloradofloodthreat.com.

### Daily Flood Threat Bulletin (FTB)

The Daily Flood Threat Bulletin (FTB) is designed for daily issuance during the contract period by 11:00 AM. The FTB outlines the daily threat of flooding across the State, the nature of the threat and the time period in which the threat of flooding would be the greatest in County-specific manner. Additional information includes a characterization of the threat of attendant severe weather (tornadoes, high winds, hail) and the probability of thunderstorm hourly rainfall rates and/or amounts.

The threat of flooding is conveyed to the user community through the use of graphics and text. The graphical component to the product includes a map of the State of Colorado with county boundaries and a color coded threat to succinctly illustrate the range of flooding threats across Colorado. The evolution of this presentation to a more communicative graphical form enhanced the spatial and temporal threat areas visualization.

The spatial coverage of the threat was available by clicking on a threat icon at the top of the page. The resulting graphic showed the areas of highest threat and a forecasted approximation of the temporal distribution associated with the type of thunderstorm/general storm system forecast. The spatial threat graphic is issued to users on days of high threat or when the National Weather Service issues either Flash Flood or Flood Watches.

### Flood Threat Outlook (FTO)

The second product is a bi-weekly FTO issued to address the 7 to 15 day threat of flooding across the state on Mondays and Thursdays by 300PM. This product addresses both the extended threat of flooding and a precipitation outlook by river basin.

### Storm Total Precipitation (STP)

For 2014, Dewberry provided a continuation of the STP service through use of MapBox web mapping tools and a website based in Google Sites. The STP product was updated this year to use gridded Stage 2 precipitation obtained by merging NWS WSR-88D Storm Total Precipitation products from Boulder, Grand Junction, Pueblo, Cheyenne and Goodand sites so that point-by-point comparisons of the STP/observed data can be assessed. Additionally, Dewberry forecasters often used CoCoRaHS and NWS reports to supplement textual discussion with any notable weather events, such as extreme rainfall, flooding, debris slides, hail, wind and tornadoes.

## 2015 UPDATES

There were three updates to the FTB at the start of the 2015 season:

1. The most significant update was a completely redesigned website mainly to add the capability of archiving all FTB/FTO/STP maps and text. This was not available in previous years. This allowed the user to easily find past rainfall amounts (STP) as well as evaluate FTB and FTO performance from past dates. In fact, we found the archiving capability quite useful for our own validation as well.
2. The presentation of the FTO was substantially redesigned to transition to an "event-based" forecasting system, as opposed to the 5-day periods that were used through 2014. Additionally, the visual presentation of the FTO was improved, in concert with the website redesign. The new FTO layout allowed the user to access all content without a single click. In contrast, previous years required five clicks in order to see all precipitation and threat maps.
3. The three-tier threat system (Low, Moderate, High) for the FTB was slightly reworked to add a fourth "High Impact" threat category. This allowed for a more localized depiction of the threat in the situation where there was a particularly high risk such as a population center or an already high river flow that could experience additional rainfall.

Additionally, building off of the 2014 effort to incorporate state-of-the-art objective Quantitative Precipitation Forecast guidance, Dewberry transitioned from using "medium" resolution (12-16km) to high resolution (<=4km) weather model data. Although we have not done a comprehensive comparison of the transition, we have strong reason to believe the higher resolution guidance is much more realistic. For example, Figure 1 shows the comparison between the two systems for July 21, 2015. On that particular day, rainfall exceeding 1.5 inches was observed over northeast Colorado. However, this was only captured by the high-resolution guidance.

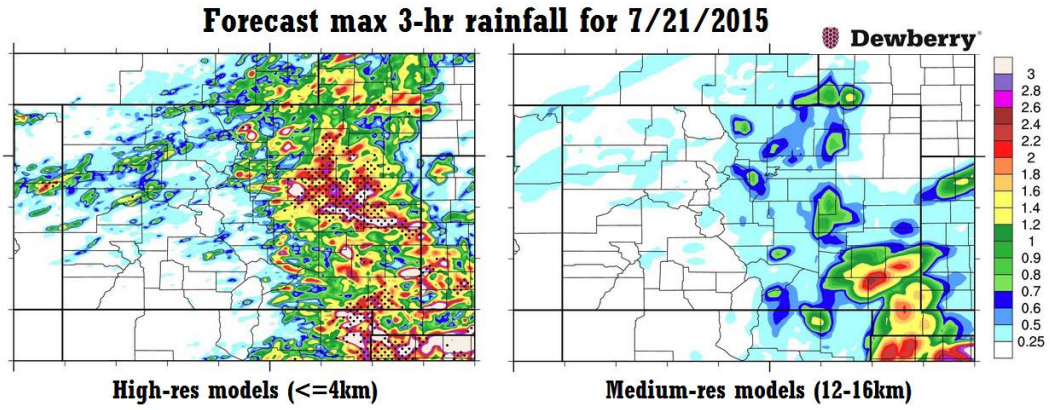


**Figure 1**: Comparison of high-resolution and medium-resolution rainfall guidance for July 21, 2015. This figure was tweeted to the public during the day.

## FTB PERFORMANCE METRICS

Dewberry provides several performance metrics related to both the forecasting of the flood threat and the delivery of the forecasts. Table 1 shows both the final year to date number of all products provided, and the percent provided on time. In each case, on-time products were delivered over 97% of the time, meeting the CWCB-established metrics.

## VERIFICATION METRICS

The daily FTB flood threat forecasts were verified on their ability to both (i) identify days when flood threats were realized and (ii) specify the approximate location of the potential flooding. As in 2014, Dewberry continued to place substantial effort on data collection to increase validation and verification robustness. Here are the information sources and methodology used to verify this year's forecast:

**TABLE 1: PRODUCT DELIVERY PERFORMANCE FOR 2015 FLOOD THREAT BULLETIN PRODUCTS.**

| Product | Total Products | Products on Time | Percent on Time |
|---|---|---|---|
| STP | 153 | 152 | 99.3% |
| FTB | 153 | 152 | 99.3% |
| FTO | 44 | 43 | 97.7% |
| **Total** | **350** | **347** | **99.1%** |

*Information sources*

1) 24-hour accumulated precipitation reports from about 850 CoCoRaHS observers across Colorado. This data is generally collected between 6AM-8AM.
2) Gauge-adjusted radar estimated gridded precipitation data (4 kilometer grid) prepared daily by NWS's River Forecast Centers (RFC). This is very similar to the quality controlled Stage 4 product provided by NOAA.
3) Storm reports obtained daily from the Boulder, Pueblo, Goodland (KS) and Grand Junction NWS offices. Reports were only included if they contained the following phrases: "heavy rain", "flash flood", "flood" or "debris slide". Reports involving the term "heavy rain" are retained only when the magnitude of rainfall exceeds 0.75 in.

*Verification methodology*

A "flood day" is hereby defined when <u>any one of the following</u> criteria is met:

1) Gridded or CoCoRaHS rainfall exceeds:
    a. 1.00 in. west of 104˚W
    b. 1.50 in. east of 104 ˚W
2) An NWS storm report described in (3) above is received that day
3) If a "flood day" is based solely on CoCoRaHS reports, at least 2 reports satisfying the criterion (1) above must be received. This eliminates days with localized, marginal rainfall that is unlikely to cause substantial flooding. Note that this kind of situation rarely occurs.
4) Additionally, subjective analysis of a "flood day" may overwrite the objective procedure above based on:
    a. a day with significant snowfall that results in "flood day" precipitation totals, but is not an actual flood threat, and/or,
    b. a day where no rainfall occurs but flooding occurs due to strong snowpack melt and/or,
    c. high antecedent river levels that are causing flooding even in the absence of additional rainfall.

In all, these corrections are applied on 13 days in May through early June. Appendix A contains the daily forecast observations used for verification, while Appendix B shows all NWS storm reports according to the FTB threat level during their occurrence. Tables 2 and 3 shows a breakdown of the daily forecasts made for the 2015 FTB season. Table 2 is for the entire season, while Table 3 shows the month by month statistics. Four categories of daily forecast verification are presented:

1) No flood forecast and no flood observed
2) No flood forecast and flooding observed
3) Flooding forecast/flooding observed
4) Flooding forecast and no flooding observed

**TABLE 2: FORECAST METRICS BY TYPE OF FORECAST FOR THE 2015 FORECASTING PERIOD.**

| | Forecast Flood Day | Forecast No Flood Day | **Total** |
|---|---|---|---|
| Observed Flood Day | 69 (a) | 19 (b) | **88** |
| Observed No Flood Day | 16 (c) | 49 (d) | **65** |
| **Total** | **85** | **68** | **153** |

**TABLE 3: FORECAST METRICS BY MONTH FOR THE 2015 FORECASTING PERIOD.**

| Forecast / Observed | May | June | July | August | September | Total |
|---|---|---|---|---|---|---|
| **No Flood / No Flood** | 3 | 1 | 7 | 14 | 24 | **49** |
| **No Flood / Flood** | 5 | 3 | 3 | 3 | 2 | **16** |
| **Flood / Flood** | 22 | 20 | 18 | 8 | 1 | **69** |
| **Flood / No Flood** | 1 | 6 | 3 | 6 | 3 | **19** |
| **Total** | **31** | **30** | **31** | **31** | **30** | **153** |

The overall FTB accuracy can be calculated by adding the number of correct forecasts (refer to Table 2; a + d = 118) and dividing by number of forecasts (153) resulting in a 77% "hit rate", slightly higher than 2014's 76% but lower than the 84-86% reported in 2012 and 2013. We continue to maintain that the decrease in the hit rate from 2012-2013 is mostly attributed to a substantially enhanced validation effort, notably the inclusion of statewide gridded precipitation estimates that capture precipitation even without nearby gauges. The probability that a flooding day was forecasted correctly is determined by dividing the number of correct flood days forecast (69) by the number of flood days observed (88) or 78%, which is an improvement from last year's 73%.

The false alarm rate of flood day forecasts is found by dividing the number of incorrect flood day forecasts by the total number of non-flood days, or 25% (16/65), which is slightly higher than last year but in line with the program's goal of 25%. Finally, the miss rate can be found by dividing the number of unforecasted flood days by the total number of flood days, or 22% (19/88). This represents a decrease from last year, even though there were more flood days this year.

**TABLE 4: ACCURACY AS A FUNCTION OF THREAT LEVEL**

| | Observed Flood Day | Observed No Flood Day | Total |
|---|---|---|---|
| LOW | 28 | 14 | **67%** |
| MODERATE | 37 | 2 | **95%** |
| HIGH | 3 | 0 | **100%** |
| HIGH IMPACT | 1 | 0 | **100%** |
| **Total** | **69** | **16** | **81%** |

Similar to last year, most "miss days" involved very localized heavy rainfall. For example, 11 of the 19 miss days had less than 200 square miles of "flood-day" rainfall. On the other hand, a notable miss day was June 4th when downtown Denver received over 3 inches of rainfall. No flood threat was forecasted at the 11AM normal issuance. However, our meteorologists posted a special late afternoon update to provide awareness of the situation.

Table 4 provides a new statistic: a comparison of hit versus false alarm rate as a function of each threat category. In theory, we would expect higher threat days to be realized more than lower threat days since the latter have more uncertainty in the forecast. Indeed, Table 4 shows this to be the case. Low threat forecasts verified about 67% of the time, Moderate threats 95% and High/High Impact threats verified on each of the four days they were forecasted. Table 4 shows that the amount of confidence in our forecast is well captured by the threat level.

Finally, Appendix B shows all of the flood-related storm reports received by the National Weather Service. Of the 356 total reports, 281 (79%) were correctly anticipated by the FTB. It is notable that this captures not only whether or not a flood threat verified anywhere across Colorado, but also that the report fell within a threat area. This represents an encouraging improvement from last season's 73% accuracy.

## CHARACTERIZATION OF FORECAST PERIOD WEATHER

Continuing the streak of relatively active years in 2013 and 2014, the current year was even more active. Figure 2 shows the number of daily CoCoRaHS reports exceeding 1 inch, 2inches as well as the spatial area of precipitation exceeding the "flood day" standards established in the previous section. Of the 153 days of the FTB season, 107 (70%) experienced at least 1 inch of rainfall somewhere in the state. An equally impressive 44 days (29%) saw a location experience rainfall of 2 inches or more. While these numbers are comparable to 2014, the seasonal evolution was quite different. In 2014, rainfall was relatively evenly distributed across the entire period. In 2015, most of the activity was early in the season (May-July) with August and September being significantly drier.

The 2015 warm season began in an incredibly active fashion with 49 flood threats being issued during May and June. Fortunately, although heavy rainfall did certainly occur, it was generally very short-lasting avoiding the state any significant/widespread flooding issues. On May 8th and 9th, an intense late spring storm left as much as 6 inches of rainfall over the Palmer Divide. Over 500 CoCoRaHS observers reports over 1 inch of rainfall during that span and the "flood-day" area exceeded 15,000 square miles. May 18th continued a string of rainy days in Colorado Springs and El Paso County. Over 2 inches of rainfall was measured by many observers. Additional widespread

heavy rainfall was noted in the Raton Ridge near the New Mexico border. Cool temperatures provided late-season boosts to high-elevation Snow Water Equivalent depths, with many locations erasing drought conditions to end the season near average. Altogether, May 2015 turned out to be the wettest May in Colorado history. At one point, we noted that Denver had 10 days in a row with measurable precipitation, only being second to the 11 day streak recorded in July 2011.

Rainfall activity continued right through June, with about 10 days of 2+ inch rainfall being observed somewhere in the state. The character of the rainfall was more intense, but less widespread in nature. On June 4th and 5th, the Front Range and the Northeast Plains experienced severe weather with hail over 2 inches in diameter reported on both days causing substantial damage to several communities. Additionally, two impressive (and photogenic!) tornadoes were observed on June 4th in the Front Range, leading to national news coverage as storm chasers converged into the Denver metro area. Drier conditions increased in frequency during the latter part of June, but not before an impressive rainstorm on June 24th led to over 3 inches of rainfall near downtown Denver. Localized but intense flooding accompanied this rainfall as the South Platte River was already at elevated levels from the rainy May.

July saw a downtick in rainfall activity, though many days still experience a short-lasting torrential downpour somewhere in the state. For example, on July 13th, one inch of rain fell in 15 minutes in Durango and Cortez. Additional localized heavy rainfall fell in the far eastern Plains near the Kansas border. Later in the month, the southwest monsoon began to deliver more widespread rainfall west of the Continental Divide. The monsoon was especially active in the last week of August and early September with consecutive days of 0.5-1.0 inch rainfall falling across many locations west of the Continental Divide.

September was generally dry across most of the state, especially east of the Continental Divide. Many observers experienced 2 to 3 week periods without any rainfall. However, the southwest monsoon still provided some rainfall in the typically favored San Juan Mountains. But just as the season came in on an active note, rainfall and even some severe weather were back in the picture the last few days of the month. Hail up to 1.5 inches was observed on September 29th, which is not unheard of but certainly rare that late in the season.

In summary, 2015 continued a streak of rainy warm seasons in Colorado. However, unlike the significant flooding in 2013, most rainfall fell in orderly fashion with only localized flooding issues. Otherwise, from a water supply standpoint, the state ended September in excellent shape with many reservoir levels well above average.

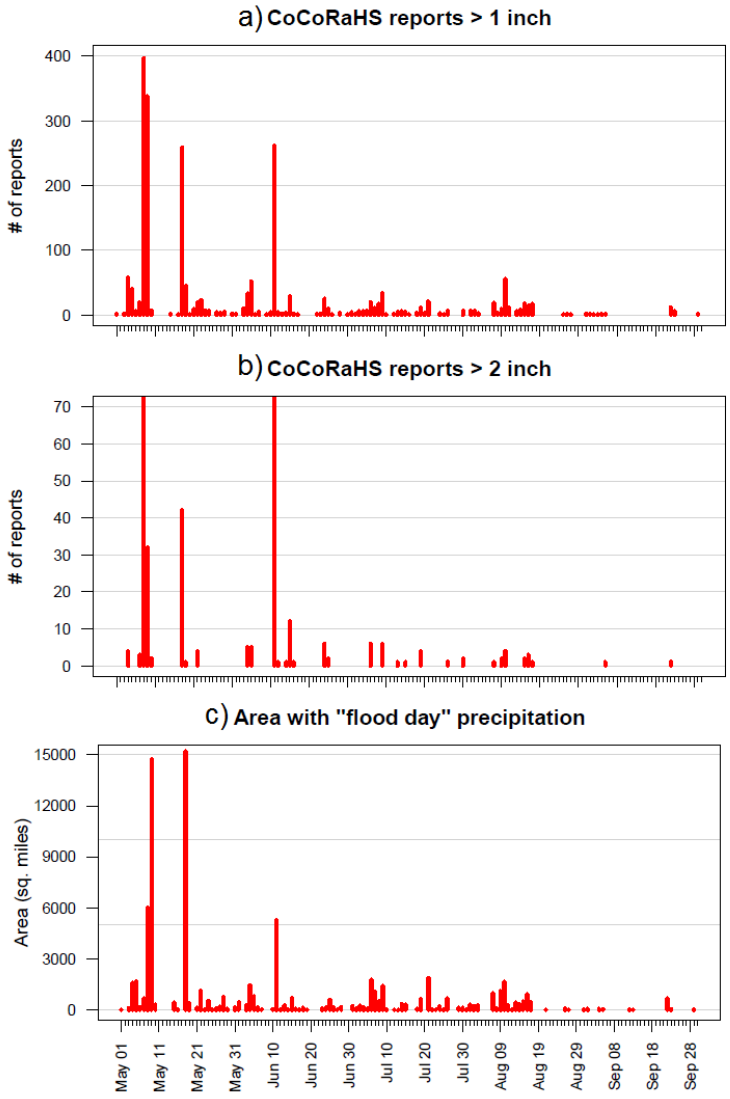


**Figure 2** – The number of daily CoCoRaHS reports exceeding 1 in. and 2 in. is shown in panels (a) and (b), respectively. Panel (c) shows the coverage of "flood day" precipitation, in sq. miles, from the gridded precipitation product. For reference in (c), the total area of Colorado is about 104,000 sq. miles.

## WEBSITE AND SOCIAL MEDIA

During the historic floods of September 2013, we identified an opportunity to expand the outreach of the Colorado FTB and inform the public at large regarding ongoing flood threats. This unique opportunity was identified as a Twitter account with which to provide updates on meteorological conditions. The Twitter account was a great success during the September floods, so it was installed as a season-long tool in 2014 (and continued in 2015) to provide meteorological information in the form of links to our forecast products (FTB and FTO), "nowcasts," and the most current heavy rain/flooding reports from the public and National Weather Service offices.

The Twitter account, @COFloodUpdates, has gained followers since its inception, with the total number of followers up to 757. This can be attributed to the amount of retweets a few of our tweets received, especially from accounts like Colorado Emergency Management's Twitter feed, which has over 35,000 followers. This exponential increase of viewership of our tweets played a large role in expanding our outreach to those who may not have

known about the @COFloodUpdates account and the FTB website otherwise. The use of specific hashtags also played a large role in expanding viewership; hashtags are searchable through Twitter, and using relevant hashtags such as #COwx or #COFlood allows people looking for specific information to be directed to our tweets. The following is a bullet point summary on how our season progressed in terms of followers:

- **May**: 667 followers (an increase of 290 followers over May 2014)
- **June**: 721 followers
- **July**: 734 followers
- **August**: 750 followers
- **September**: 757 followers

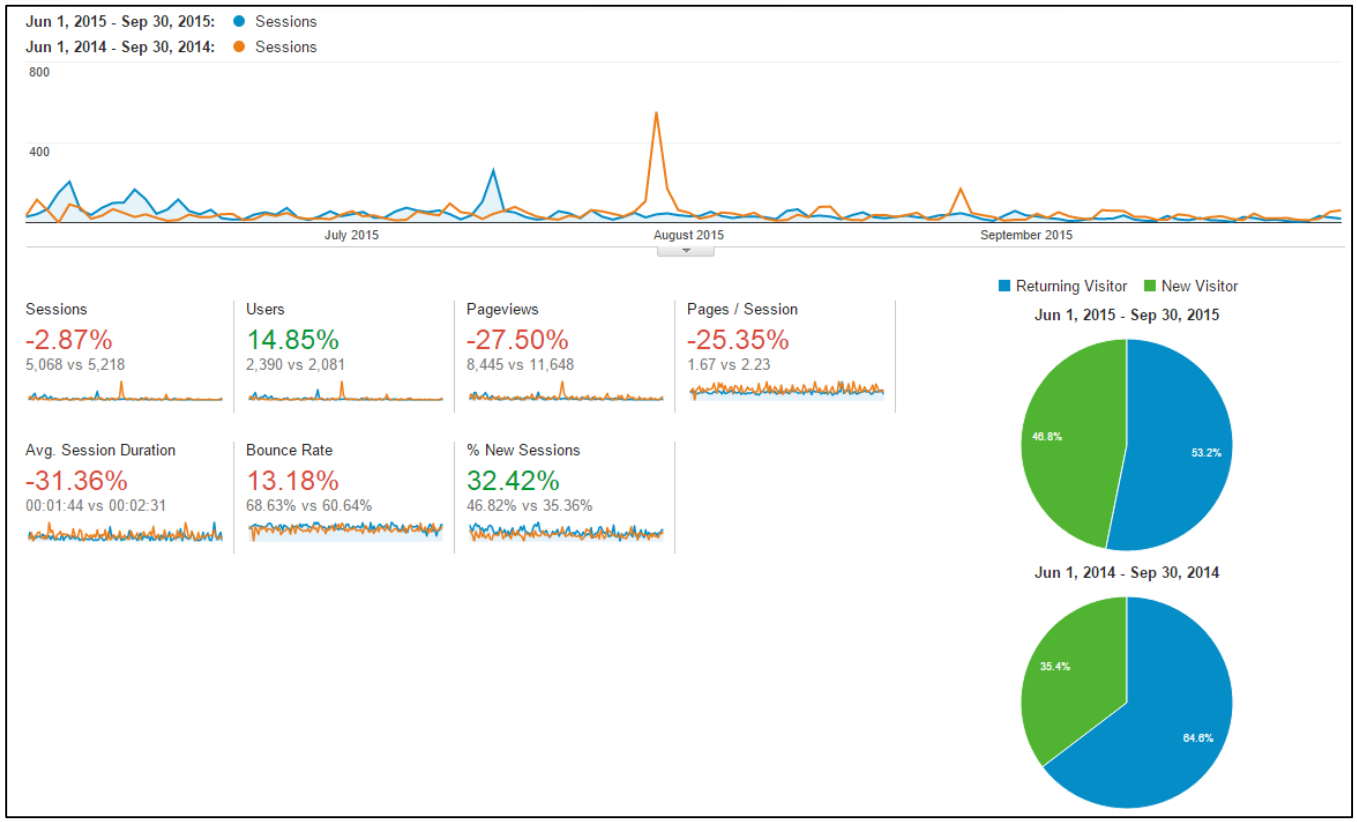


**Figure 3** – Visits to the ColoradoFloodThreat.com site in 2014 (orange line) vs. 2015 (blue line), including usage statistics. Note that May 2014 and 2015 have been removed. With the transition to the new website, analytics were unavailable for May 2015, so in order to create a comparable relationship, only the time period of June through September is considered.

A graphical representation of site viewership shows the continued success of site viewership into 2015, with the primary catalyst remaining the use of the Twitter Account. Site visits (sessions) remained nearly identical, with 5,068 during June 1 – Sept 30 2015 compared to 5,218 for the same period in 2014. This represents a slight decrease in the number of sessions, but the real growth during 2015 occurred in two important categories: Users, and the Percent New Sessions (percentage of first time visits). The Colorado Flood Threat Bulletin experienced a 14.9% increase of unique users in 2015, as well as a 32.4% increase in the Percent New Sessions. It is important to note that with the transition to the new website and format, Pageviews, Pages/Session, and Bounce Rate are down significantly. This is due to the reduction in the number of pages on the website. For example, every Flood Threat Outlook product from 2014 included six different pages, whereas in 2015 all information was contained on one

page. This change can also be noted in the average session duration where a significant decrease occurred due to the streamlining of the website.

Mentioned previously, the use of hashtags played a large role in expanding the outreach of our Flood Threat Bulletin products. The following bullet points show a list of common tags that were used, as well as unique tags that were used to target specific events with large audiences.

- Common hashtags: #FTB, #FTO, #STP, #COwx, #COFlood, #Colorado, #Weather, #Monsoon, #Summer, #Fire, #Severe
- Unique hashtags: #Wildfires, #LaborDay, #Colorado, #IndependenceDay, #JulyFourth, #July4th,

Twitter provides an Analytics website for all public Twitter accounts. Arguably the most useful data variable is "impressions." Impressions are defined as the number of times Twitter users saw a particular tweet and demonstrates the effectiveness of the use of specific hashtags and interactions (retweets) from other accounts that may have more followers. Average tweets received between 400-800 impressions, as this represents the base follower group of our account. The more engaging or important the content, the more impressions a tweet received as more people retweeted it. During the season, 39% of Tweets (91 out of 223 tweets) made over 1,000 impressions, with the best tweet making 5,647 impressions. That particular tweet was an image of the day's Flood Threat Map with a link to the Flood Threat Bulletin website is shown in Figure 4. It was retweeted 12 times, most notably by Colorado Flood DSS, KDVR FOX31 Denver, Channel 2 KWGN, Colorado Emergency Management, and Larimer County Long Term Recovery Group. In addition to tweets showing the daily flood threat map such as in Figure 5, we expanded our social media campaign by adding other flood and water-supply related information. For example, we tweeted monthly total precipitation volume maps, such as shown in Figure 4.

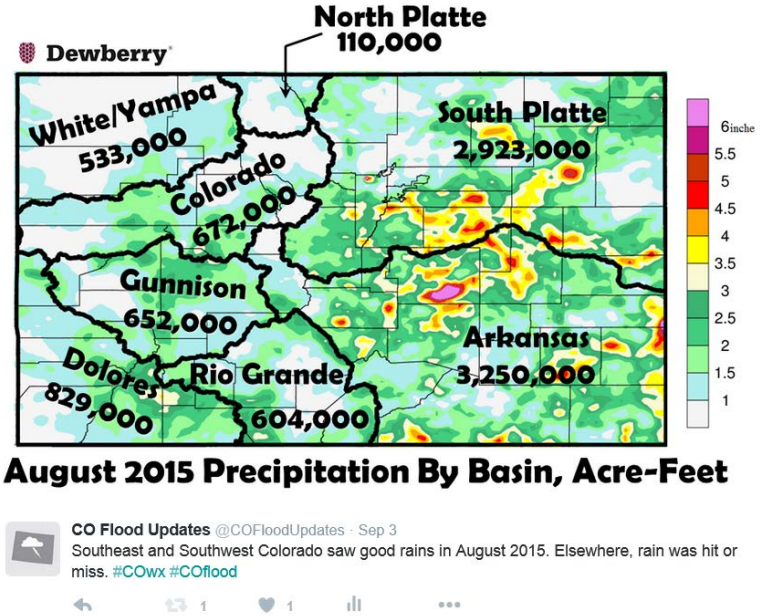


**Figure 4:** Example of tweet from September 3rd showing total precipitation in inches and acre-feet across major watershed boundaries.


**Figure 5** – Tweet with greatest amount of Twitter impressions (retweeted 12 times). August 8, 2015.

In total, the FTB Twitter handle produced 281,846 impressions over the course of the 2015 season. The relationship between retweets and total impressions is illustrated in Figure 6 below.

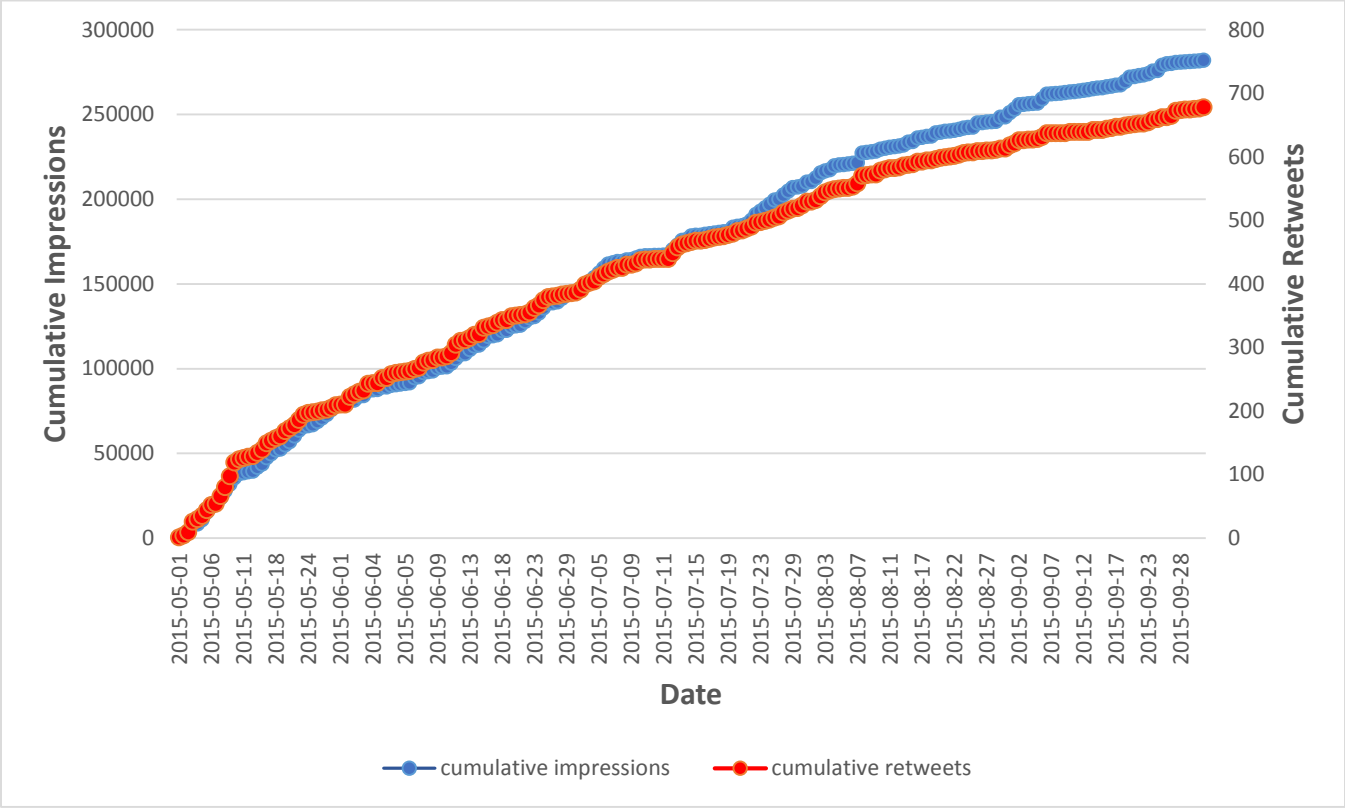


**Figure 6** – Relationship between cumulative retweets and impressions from Twitter Analytics. Note that in general, the pattern of impressions closely follows the pattern of retweets, showing the direct relationship between the two measures.

Currently, the most notable followers are the following: Colorado Emergency Management, Colorado Flood DSS, READY Colorado, AAA Colorado, Red Cross Denver, Colorado State Patrol Troop 1E, Colorado Wildfire Info, Dave Aguilera – CBS4 Meteorologist, Forest Service, ARP, KDVR FOX31 Denver, FOX31/CW Pinpoint Weather, CASFM, Pikes Peak Red Cross, Northern Colorado Red Cross, and Colorado Springs Gazette.

Various police precincts, city/county government offices, TV/newspaper reporters/meteorologists from across the state, academia meteorologists, individual citizens of Colorado, private meteorologists, fire and rescue units, etc. also follow the Twitter account.

# CONCLUSIONS/RECOMMENDATIONS

1. Following 2013 and 2014, 2015 continued a streak of very active rainfall activity during the May-September period of the Flood Threat Bulletin. Nearly 70% of the 153 operational days experienced rainfall exceeding 1

inch, and a total of 85 flood threats were issued. Although there were some localized flash flooding events, there were no significant/widespread floods during the season.

2. The FTB maintained or slightly increased its performance statistics from 2014. Overall accuracy was 77% (up from 76% in 2014), with a false alarm rate of 25% and a miss rate of 22%. Notably, almost all of the misses were from days with very localized activity where only 1 or 2 gages received heavy rainfall. The FTB correctly anticipated 79% flood-related NWS reports (see Appendix B).

3. The Twitter program continued to successfully expand, with the addition of nearly 200 followers to our Twitter handle and resulting in approximately 280,000 views of FTB flood threat information. We continued to see that interaction was most significant when we posted the threat map inside the Tweet, which overall expanded our view. This is consistent with online marketing trends that have clearly identified Twitter and other Social Media users as "content thirsty". More people are drawn to images and are likely to review this information when it presented to them in their Twitter feed. As a result, it leads to more impressions and greater overall awareness. This program has provided immense value to the State of Colorado and we recommend that it is continued during next year's FTB.

4. We completed a transition to high resolution weather model guidance that was started in 2014. We expect that this will allow us to improve the objective guidance going into the FTB, that will ultimately improve forecast accuracy by reducing both misses and false alarms.

# APPENDIX A – VERIFICATION WORKSHEETS

Column descriptions:

cocomax:

Maximum daily precipitation (in inches) from all available CoCoRaHS reports.

nstats:

Number of CoCoRaHS stations exceeding 1.00 in. (west of 104˚W) and 1.50 in. (east of 104˚W)

rfcmax:

Maximum daily precipitation from gridded River Forecast Center precipitation analysis

area:

Area of precipitation (in square miles) exceed 1.00 in. (west of 104˚W) and 1.50 in. (east of 104˚W) based on the River Forecast Center gridded precipitation analysis

obs:

Whether (1) or not (0) a "flood day" was observed (see page 3 for description of "flood day")

threat:

Maximum threat in Flood Threat Bulletin (0=None, 1=Low, 2=Moderate, 3=High, 4=High Impact)

remarks:

Indicates days where manual adjustment of observations was required, for one of the following reasons:
"SN": Snowfall resulted in precipitation exceeding "flood day" standards, but no flooding observed.
"MELT": Snowmelt induced flooding was noted despite no precipitation.
"RIV": Riverine flooding from antecedent rainfall, but no concurrent rainfall/snowfall.

| Date | cocomax | nstats | rfcmax | area | obs | threat | Remarks |
|---|---|---|---|---|---|---|---|
| 5/1 | 1.57 | 2 | 1.08 | 18 | 1 | 0 | |
| 5/2 | 0.8 | 0 | 1.4 | 0 | 0 | 0 | |
| 5/3 | 1.3 | 1 | 1.59 | 118 | 1 | 1 | |
| 5/4 | 3.14 | 51 | 2.96 | 1,604 | 1 | 1 | |
| 5/5 | 1.46 | 32 | 1.61 | 1,652 | 1 | 1 | |
| 5/6 | 1.49 | 5 | 1.45 | 171 | 1 | 1 | |
| 5/7 | 2.34 | 14 | 2.59 | 678 | 1 | 2 | |
| 5/8 | 3.99 | 382 | 5.69 | 5,981 | 1 | 2 | |
| 5/9 | 4.37 | 301 | 3.74 | 14,740 | 1 | 3 | |
| 5/10 | 3.32 | 7 | 1.66 | 319 | 1 | 2 | RIV |
| 5/11 | 0.3 | 0 | 0.51 | 0 | 1 | 2 | RIV |
| 5/12 | 0.59 | 0 | 0.8 | 0 | 1 | 2 | RIV |
| 5/13 | 0.87 | 0 | 0.67 | 0 | 1 | 1 | RIV |
| 5/14 | 0.64 | 0 | 1.33 | 0 | 1 | 1 | RIV |
| 5/15 | 1.96 | 2 | 1.85 | 431 | 1 | 1 | SN |
| 5/16 | 0.7 | 0 | 1.71 | 18 | 0 | 0 | |
| 5/17 | 1.33 | 1 | 0.7 | 0 | 0 | 0 | |
| 5/18 | 3.28 | 223 | 2.95 | 15,224 | 1 | 1 | |
| 5/19 | 2.06 | 19 | 1.57 | 407 | 1 | 2 | |
| 5/20 | 1.06 | 1 | 0.44 | 0 | 1 | 1 | RIV |
| 5/21 | 1.36 | 4 | 1.21 | 142 | 1 | 0 | |
| 5/22 | 2.7 | 10 | 4.45 | 1,109 | 1 | 1 | |
| 5/23 | 1.6 | 2 | 1.69 | 29 | 1 | 2 | |

| Date | cocomax | nstats | rfcmax | area | obs | threat | Remarks |
|---|---|---|---|---|---|---|---|
| 5/24 | 1.51 | 2 | 2.35 | 537 | 1 | 1 | |
| 5/25 | 1.31 | 5 | 1.13 | 24 | 1 | 1 | |
| 5/26 | 0.81 | 0 | 1.67 | 88 | 1 | 1 | RIV |
| 5/27 | 1.44 | 4 | 3.63 | 189 | 1 | 1 | RIV |
| 5/28 | 1.68 | 3 | 3.56 | 779 | 1 | 1 | |
| 5/29 | 1.33 | 4 | 1.74 | 71 | 1 | 1 | |
| 5/30 | 0.05 | 0 | 0.33 | 0 | 0 | 1 | |
| 5/31 | 1.15 | 0 | 1.81 | 171 | 1 | 0 | |
| 6/1 | 1.34 | 0 | 2.29 | 466 | 1 | 0 | |
| 6/2 | 0.28 | 0 | 0.27 | 0 | 0 | 1 | |
| 6/3 | 1.28 | 9 | 1.57 | 283 | 1 | 0 | |
| 6/4 | 3.47 | 30 | 3.67 | 1,451 | 1 | 0 → 3 | PM Update |
| 6/5 | 2.63 | 48 | 2.69 | 802 | 1 | 2 | |
| 6/6 | 1.04 | 1 | 1.16 | 165 | 1 | 2 | |
| 6/7 | 1.82 | 4 | 1.47 | 35 | 1 | 1 | |
| 6/8 | 0.54 | 0 | 0.78 | 0 | 0 | 1 | |
| 6/9 | 1.01 | 1 | 0.88 | 0 | 0 | 1 | |
| 6/10 | 1.41 | 3 | 1.7 | 47 | 1 | 2 | |
| 6/11 | 4.76 | 239 | 3.97 | 5,273 | 1 | 2 | |
| 6/12 | 2 | 3 | 1.11 | 6 | 1 | 2 | |
| 6/13 | 1.74 | 2 | 2.94 | 271 | 1 | 1 | |
| 6/14 | 2.05 | 2 | 1.41 | 35 | 1 | 3 | |
| 6/15 | 3.94 | 29 | 4.15 | 714 | 1 | 2 | |
| 6/16 | 2.42 | 2 | 1.57 | 71 | 1 | 2 | |
| 6/17 | 1 | 0 | 1.36 | 35 | 0 | 2 | |
| 6/18 | 0.4 | 0 | 1.93 | 124 | 1 | 2 | RIV |
| 6/19 | 0.2 | 0 | 1.13 | 6 | 1 | 2 | RIV |
| 6/20 | 0 | 0 | 0.3 | 0 | 1 | 2 | RIV |
| 6/21 | 0.65 | 0 | 0.09 | 0 | 1 | 2 | RIV |
| 6/22 | 1.23 | 1 | 0.91 | 0 | 1 | 2 | |
| 6/23 | 1.2 | 1 | 1.44 | 71 | 1 | 1 | |
| 6/24 | 3.31 | 25 | 1.57 | 147 | 1 | 1 | |
| 6/25 | 2.18 | 5 | 2.55 | 590 | 1 | 2 | |
| 6/26 | 1.02 | 1 | 1.61 | 136 | 1 | 1 | |
| 6/27 | 0.9 | 0 | 1.34 | 24 | 0 | 1 | |
| 6/28 | 1.77 | 3 | 1.7 | 171 | 1 | 1 | |
| 6/29 | 0.55 | 0 | 0.92 | 0 | 0 | 1 | |
| 6/30 | 1.24 | 1 | 0.94 | 0 | 0 | 0 | |
| 7/1 | 1.22 | 2 | 1.77 | 236 | 1 | 3 | |
| 7/2 | 1.15 | 1 | 1.33 | 71 | 1 | 2 | |
| 7/3 | 1.33 | 6 | 1.73 | 242 | 1 | 1 | |
| 7/4 | 1.73 | 5 | 3.24 | 142 | 1 | 2 | |
| 7/5 | 1.15 | 6 | 1.91 | 77 | 1 | 2 | |
| 7/6 | 2.96 | 18 | 2.86 | 1,787 | 1 | 2 | |

| Date | cocomax | nstats | rfcmax | area | obs | threat | Remarks |
|---|---|---|---|---|---|---|---|
| 7/7 | 1.51 | 10 | 1.94 | 1,079 | 1 | 2 | |
| 7/8 | 1.88 | 14 | 2.31 | 513 | 1 | 2 | |
| 7/9 | 3.79 | 32 | 3.71 | 1,416 | 1 | 2 | |
| 7/10 | 1 | 0 | 1.24 | 24 | 0 | 1 | |
| 7/11 | 0.7 | 0 | 0.81 | 0 | 0 | 0 | |
| 7/12 | 1.27 | 2 | 1.08 | 18 | 1 | 1 | |
| 7/13 | 2.27 | 5 | 1.2 | 6 | 1 | 1 | |
| 7/14 | 1.2 | 0 | 2.2 | 354 | 1 | 2 | |
| 7/15 | 2.16 | 3 | 3.09 | 324 | 1 | 2 | |
| 7/16 | 1.25 | 1 | 1.13 | 0 | 0 | 0 | |
| 7/17 | 0.54 | 0 | 0.57 | 0 | 0 | 0 | |
| 7/18 | 1.25 | 0 | 1.96 | 59 | 1 | 2 | |
| 7/19 | 3.32 | 6 | 2.82 | 613 | 1 | 2 | |
| 7/20 | 1.2 | 2 | 0.81 | 0 | 1 | 2 | |
| 7/21 | 1.82 | 16 | 4.74 | 1,876 | 1 | 2 | |
| 7/22 | 0.55 | 0 | 1.54 | 47 | 0 | 0 | |
| 7/23 | 0.68 | 0 | 1.89 | 29 | 0 | 0 | |
| 7/24 | 1.66 | 1 | 2.81 | 212 | 1 | 0 | |
| 7/25 | 1.81 | 1 | 1.8 | 35 | 0 | 0 | |
| 7/26 | 2.15 | 4 | 2.35 | 678 | 1 | 0 | |
| 7/27 | 0.17 | 0 | 0.63 | 0 | 0 | 0 | |
| 7/28 | 0.33 | 0 | 0.42 | 0 | 0 | 1 | |
| 7/29 | 0.89 | 0 | 2.06 | 130 | 1 | 1 | |
| 7/30 | 3.56 | 4 | 2.1 | 130 | 1 | 0 | |
| 7/31 | 0.44 | 0 | 1.06 | 12 | 0 | 2 | |
| 8/1 | 1.91 | 3 | 1.99 | 319 | 1 | 0 | |
| 8/2 | 1.48 | 6 | 1.7 | 230 | 1 | 0 | |
| 8/3 | 1.26 | 1 | 2.59 | 254 | 1 | 2 | |
| 8/4 | 0.88 | 0 | 1.27 | 0 | 0 | 0 | |
| 8/5 | 0.83 | 0 | 0.79 | 0 | 0 | 0 | |
| 8/6 | 0.35 | 0 | 0.05 | 0 | 0 | 0 | |
| 8/7 | 2.67 | 11 | 3.18 | 1,003 | 1 | 0 | |
| 8/8 | 1.27 | 3 | 1.67 | 100 | 1 | 1 | |
| 8/9 | 7.29 | 8 | 5.71 | 1,109 | 1 | 1 | |
| 8/10 | 2.61 | 51 | 2.63 | 1,646 | 1 | 2 | |
| 8/11 | 1.66 | 11 | 1.97 | 265 | 1 | 4 | |
| 8/12 | 0.85 | 0 | 1.37 | 24 | 0 | 1 | |
| 8/13 | 1.33 | 5 | 2.52 | 436 | 1 | 1 | |
| 8/14 | 1.7 | 8 | 1.94 | 319 | 1 | 0 | |
| 8/15 | 2.49 | 8 | 3.28 | 490 | 1 | 0 | |
| 8/16 | 2.56 | 10 | 6.51 | 914 | 1 | 0 | |
| 8/17 | 2.02 | 6 | 2.35 | 478 | 1 | 2 | |
| 8/18 | 0.66 | 0 | 0.81 | 0 | 0 | 0 | |
| 8/19 | 0.37 | 0 | 0.15 | 0 | 0 | 0 | |

| Date | cocomax | nstats | rfcmax | area | obs | threat | Remarks |
|---|---|---|---|---|---|---|---|
| 8/20 | 0.1 | 0 | 0.07 | 0 | 0 | 0 | |
| 8/21 | 0.1 | 0 | 1.72 | 12 | 0 | 0 | |
| 8/22 | 0.43 | 0 | 0.83 | 0 | 0 | 0 | |
| 8/23 | 0.58 | 0 | 0.9 | 0 | 0 | 0 | |
| 8/24 | 0.55 | 0 | 0.53 | 0 | 0 | 0 | |
| 8/25 | 1.4 | 1 | 0.97 | 0 | 0 | 0 | |
| 8/26 | 1.68 | 2 | 1.49 | 71 | 1 | 2 | |
| 8/27 | 1.03 | 1 | 1.1 | 24 | 0 | 0 | |
| 8/28 | 0.74 | 0 | 0.59 | 0 | 0 | 0 | |
| 8/29 | 0.11 | 0 | 0.36 | 0 | 0 | 0 | |
| 8/30 | 0.73 | 0 | 0.86 | 0 | 0 | 1 | |
| 8/31 | 1.14 | 0 | 1.69 | 29 | 0 | 1 | |
| 9/1 | 1.62 | 1 | 1.47 | 65 | 1 | 0 | |
| 9/2 | 1 | 0 | 0.55 | 0 | 0 | 1 | |
| 9/3 | 1 | 0 | 0.89 | 0 | 0 | 1 | |
| 9/4 | 1.17 | 2 | 1.11 | 65 | 1 | 0 | |
| 9/5 | 2.28 | 1 | 1.12 | 35 | 0 | 0 | |
| 9/6 | 0.33 | 0 | 0.26 | 0 | 0 | 0 | |
| 9/7 | 0.51 | 0 | 0.89 | 0 | 0 | 0 | |
| 9/8 | 0.21 | 0 | 0.3 | 0 | 0 | 0 | |
| 9/9 | 0.24 | 0 | 0.76 | 0 | 0 | 0 | |
| 9/10 | 0.11 | 0 | 0.84 | 0 | 0 | 0 | |
| 9/11 | 0.01 | 0 | 0.01 | 0 | 0 | 0 | |
| 9/12 | 0 | 0 | 1.72 | 35 | 0 | 0 | |
| 9/13 | 0.9 | 0 | 1.62 | 12 | 0 | 0 | |
| 9/14 | 0.75 | 0 | 0.73 | 0 | 0 | 0 | |
| 9/15 | 0.6 | 0 | 0.93 | 0 | 0 | 0 | |
| 9/16 | 0.34 | 0 | 0.83 | 0 | 0 | 0 | |
| 9/17 | 0.59 | 0 | 0.73 | 0 | 0 | 0 | |
| 9/18 | 0.19 | 0 | 0.2 | 0 | 0 | 0 | |
| 9/19 | 0 | 0 | 0.16 | 0 | 0 | 0 | |
| 9/20 | 0.03 | 0 | 0 | 0 | 0 | 0 | |
| 9/21 | 0.16 | 0 | 0.12 | 0 | 0 | 0 | |
| 9/22 | 3.35 | 8 | 3.08 | 690 | 1 | 1 | |
| 9/23 | 1.57 | 1 | 1.87 | 47 | 0 | 1 | |
| 9/24 | 0.1 | 0 | 0.03 | 0 | 0 | 0 | |
| 9/25 | 0.05 | 0 | 0 | 0 | 0 | 0 | |
| 9/26 | 0.01 | 0 | 0.08 | 0 | 0 | 0 | |
| 9/27 | 0.06 | 0 | 0.1 | 0 | 0 | 0 | |
| 9/28 | 0.53 | 0 | 0.55 | 0 | 0 | 0 | |
| 9/29 | 1 | 0 | 1.22 | 12 | 0 | 0 | |
| 9/30 | 0.33 | 0 | 0.94 | 0 | 0 | 0 | |

# APPENDIX B – NWS REPORT VERIFICATION

The figure below shows all NWS storm reports received from May 1 – September 30 (panel A) and an analysis of whether those reports fell within our threat area (panel B). Red crosses indicate the report did not fall into a threat region. Of the 356 qualifying reports (see page 3 for description), 281 (79%) were accurately anticipated by the FTB. It is notable that of the 75 reports that were not within our threat area, 23 of them occurred in or very close to El Paso County from 11PM-2AM on the night of August 9th, 2015. On August 9th, we issued a Low flood threat that included the extreme southern portion of El Paso County stating "*Storm coverage will likely be highest from mid-afternoon through around sunset. However, the flood threat will persist through the early morning hours due to anticipated upslope moving outflow boundary.*" Thus, despite the fact that the reports did not fall into our threat area, we believe there was at least some early warning of a possible flooding threat.