GLOBAL WEATHER AND CLIMATE CONSULTING, LLC

TODD MORRIS

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EXPERT WITNESS REPORT OF TODD MORRIS
CERTIFIED CONSULTING METEOROLOGIST (CCM)

Perez
V.
Town of Gila Bend, Arizona

Monsoon Flash Flood Incident
Aug 14, 2021

Dec 18, 2022

Date/Time of Incident:	Aug 14, 2021, at approximately 01:00 MST
Incident Location:	Gila Bend, AZ or 32.9440N/112.7140W
Prepared for:	Nathan Andrews, Partner Doyle Law Group

Compensation for my services in this matter are $290.00 per hour for report writing and records review, consultations, and other non-testimony services; $400.00 per hour for examination, deposition, arbitration and/or trial testimony; $150.00 per hour for travel.

My CV is attached hereto for the use of the reader and includes my publications over the past 10 years as well as the cases in which I have testified at trial or at deposition over the past 5 years.

Assignment

I was tasked with reviewing the weather events for the specific date of Aug 14, 2021, at the incident location. This report summarizes that review and also places the rainfall event in a climate perspective.

Forensic weather investigations are similar to performing a storm survey or damage assessment, something I did on a regular basis as a meteorologist with the National Weather Service during my 34.5 years of service. This process follows a strict methodology of collecting information, evaluating the merit of that information, comparing that information to normal, analyzing the pertinent data, and finally drawing a conclusion.

Methodology

I began by collecting and evaluating pertinent weather records for the date given and surrounding the subject location. These records included:

- National Weather Service (NWS) certifiable surface weather observations for all known observations within a 10-mile radius for Aug 13-14, 2021, if any
- NWS certifiable cooperative weather data for Aug 13-14, 2021, if any
- NWS certifiable Storm Data (including local storm reports) for Aug 2021
- NWS certifiable Climatological Data (CD) publications for Aug 2021 plus the Annual CD for 2021
- NWS certifiable Daily Weather Maps (surface and aloft) for Aug 13-14, 2021
- NWS certifiable forecasts for the incident location including any watches, warnings, or advisories plus statements for Aug 12-14, 2021
- NWS certifiable WSR-88D Weather Radar data (base reflectivity and velocity data) for Aug 13-14, 2021
- NWS certifiable NOAA visible and infrared satellite imagery for Aug 13-14, 2021
- NWS certifiable Advanced Hydrologic Prediction Service (AHPS) observed precipitation for Aug 13-14, 2021
- Maricopa County Regional Flood Control District certifiable hourly/sub-hourly ALERT rainfall data for nearby stations for Aug 13-14, 2021
- Citizen Weather Observer Program (CWOP) surface weather observations for all known observations within a 10-mile radius for Aug 13-14, 2021
- Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) surface weather observations for all known observations within a 10-mile radius for Aug 13-14, 2021
- NWS Storm Report for Aug 13-14, 2021 - dated Aug 19, 2021

I also examined related videos from network media as well as postings on social media such as Facebook and Twitter.

Background/Climatology

The incident location, located at the intersection of I-8 and State Highway 85, is in southwestern Maricopa County at an elevation of 745 ft MSL and just south of the Gila River as it enters the fertile Citrus Valley and Paloma area. While a full 50 miles from downtown Phoenix, it is considered part of the Phoenix/Scottsdale Metropolitan area and enjoys a variety of weather throughout the year. This includes both mild pleasant winters and very warm summers. Located between the Gila Bend Mountains to the north, the Maricopa Mountains to the east and the Sauceda Mountains well to the south, with the Gila River passing by to the immediate north, the weather is similar to that of Phoenix/Scottsdale but tends to experience slightly warmer daytime temperatures and less precipitation year-around (almost 14% less). There are two separate rainfall seasons. The first occurs during the winter months from December through March when the region is subjected to transitory large scale weather systems, often originating from the Pacific Ocean. Just 46% of the annual precipitation (both rain and snow) occurs during this period[1].

The second rainfall season occurs during mainly July-August when Arizona is subjected to widespread yet sporadic thunderstorm activity whose moisture supply originates in the Gulf of Mexico, in the Pacific Ocean off the west coast of Mexico and in the Gulf of California[2]. More commonly called Monsoon Season, August is climatologically in the heart of the annual North American Monsoon[3][4] season in central Arizona. Almost 24% of the annual precipitation (rainfall) received at the incident location occurs during this period[5].

Rainfall associated with monsoon thunderstorms can be very sporadic and short-lived with one location reporting an intense downpour for maybe 15-20 minutes and just 5 miles away it can be completely dry[6]. Primarily a rain-producing phenomena, capable of producing flash floods, monsoon thunderstorms are convective in nature and thus can be accompanied by strong and damaging winds, hail, dangerous lightning, and even occasional tornadoes.

On occasion, dissipating tropical weather systems from the eastern Pacific will bring substantial rainfall to the region, especially in October.

Figure 1 below provides the long-term climate monthly normal rainfall for this region and depicts the two distinct rainfall seasons.

[1] https://xmacis.rcc-acis.org/
[2] https://azclimate.asu.edu/climate/climate-of-phoenix-summary/
[3] https://www.wrh.noaa.gov/twc/monsoon/monsoon_whatis.php
[4] https://www.wrh.noaa.gov/twc/monsoon/monsoon_NA.php
[5] https://xmacis.rcc-acis.org/
[6] https://climas.arizona.edu/sw-climate/monsoon

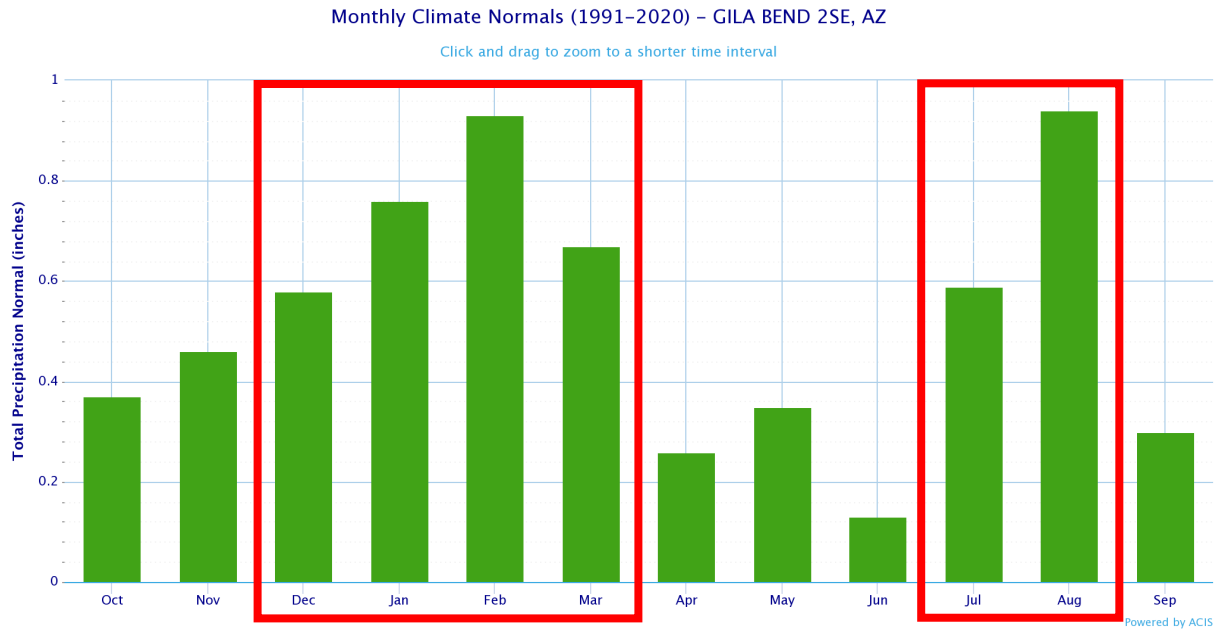

Figure 1 – Monthly Climate Normal Rainfall for Gila Bend, AZ

For climate purposes, the long-term climate station in Gila Bend, AZ (Station ID – 23393) was used given this station is the only climate station in a 20-mile radius and has one of the longest records of any active rain gauge in not only Maricopa County but all of Arizona with a complete record dating back to 1892. The station itself is 2.0 miles east of the incident location and is located at an elevation just 50 feet higher than the incident location.

For my actual hourly observational rainfall analysis, several other rain gauges within a 11-mile radius were used. See both Table 1 and Fig. 2 for reference. The Sand Tank Wash @ I-8 and Sauceda Wash rain gauges, owned, and operated by the Maricopa County Flood Control District (FCDMC), proved most useful given these stations provide data at 5-min intervals and the rainfall at these 2 locations drain directly into Gila Bend. Both stations are within a 5-mile radius of the incident location.

Metadata								
ID	Station Name	Type	Lat	Lon	Elev	Dist	Obs Time	Min Freq
Incident Location			32.9440	-112.7140	744	0		
40000	Sand Tank Wash @I-8	MCFCD	32.9331	-112.7058	765	0.9SE	NA	5 Mins
23393	Gila Bend 2SE	COOP	32.9380	-112.6811	794	2.0E	Daily	NA
42500	Gila Bend Landfill	MCFCD	32.9893	-112.6751	750	3.9NE	NA	5 Mins
KGXF	Gila Bend AF Auxiliary Field	NWS	32.8875	-112.7200	859	3.9S	NA	10 Mins
71000	Sauceda Wash	MCFCD	32.8804	-112.7543	850	5.0SW	NA	5 Mins
KAZGILAB2	Paloma Ranch	WxU	32.9380	-112.8120	709	5.7W	NA	5 Mins
40500	Bender Wash	MCFCD	32.9067	-112.5516	1200	9.8E	NA	5 Mins
AZM19	Paloma	UofA	32.9271	-112.8967	725	10.7W	NA	60 Mins
43000	Maricopa Mtns	MCFCD	32.9906	-112.5228	1210	11.6E	NA	5 Mins

NOTES
COOP = NWS Cooperative Observation Program
MCFCD = Maricopa County Flood Control District
NWS = National Weather Service
UofA = University of Arizona Met Network
WxU = Weather Underground
NA = Not Applicable

Table 1 – Metadata for Rain Gauges Used in Analysis

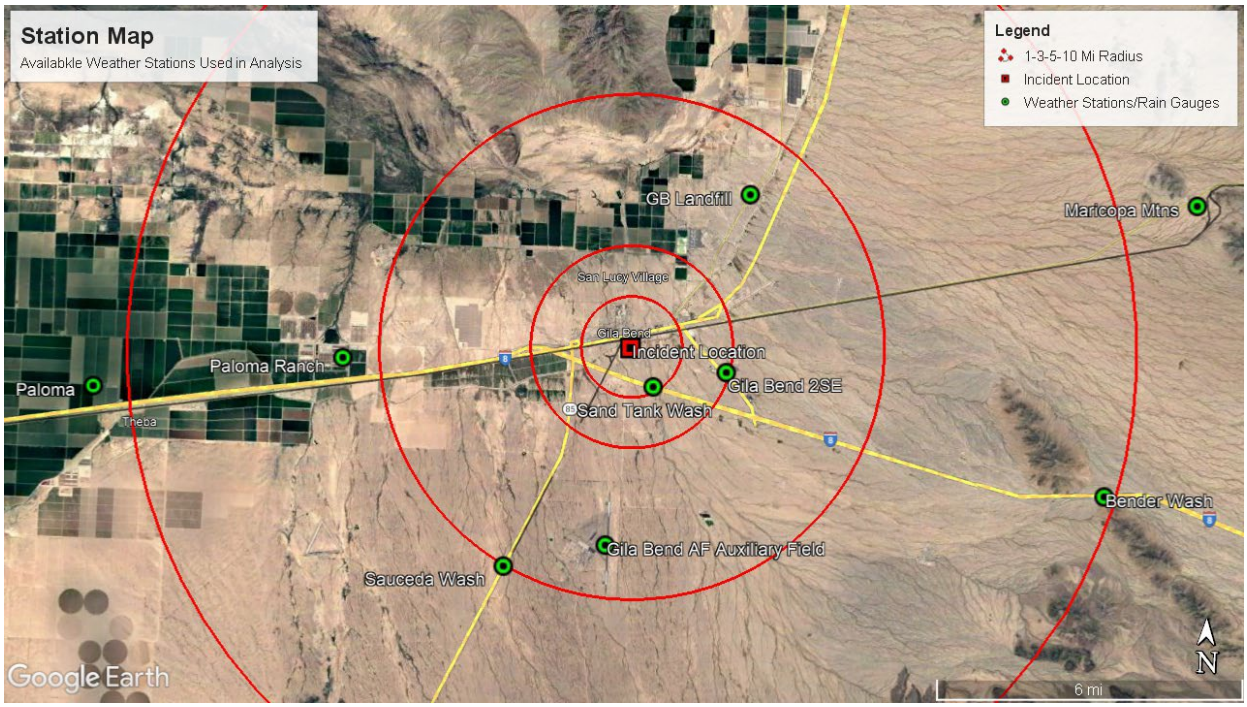

Figure 2 – Mapped Rain Gauges Used in Analysis

Analysis

Weather in the southwest is highly influenced by the position and strength of a dome of warm high-pressure in the upper levels of the atmosphere during the monsoon months. Small movements or relocations of this high-pressure center can mean the difference between a day ripe for thunderstorms and a day of hot dry sunshine. In addition, the amount and distribution of low-level moisture across the desert southwest is the other factor important for general thunderstorm development. In the non-monsoon months, rain versus no rain is highly predicated on the existence and strength of passing weather systems.

Prior to Aug 14, 2021, much of Arizona and especially the incident location had seen well below normal rainfall during the 2021 summer monsoon months as well as the monsoon months of 2020 and 2019. Only the period from Jul 21-26, 2021, did the Greater Phoenix Area see any substantial rain to this point in the season with Gila Bend receiving less than one inch during the 6-day period[7]. Thus, when a return to a more normal summer monsoon pattern was advertised by weather computer models, the National Weather Service in Phoenix, AZ, that serves the incident location, was quick to begin getting the message out to the public and the media. See Fig. 3 below.

[7] https://www.ncdc.noaa.gov/IPS/coop/coop.html?_finish=0.014277155992461044

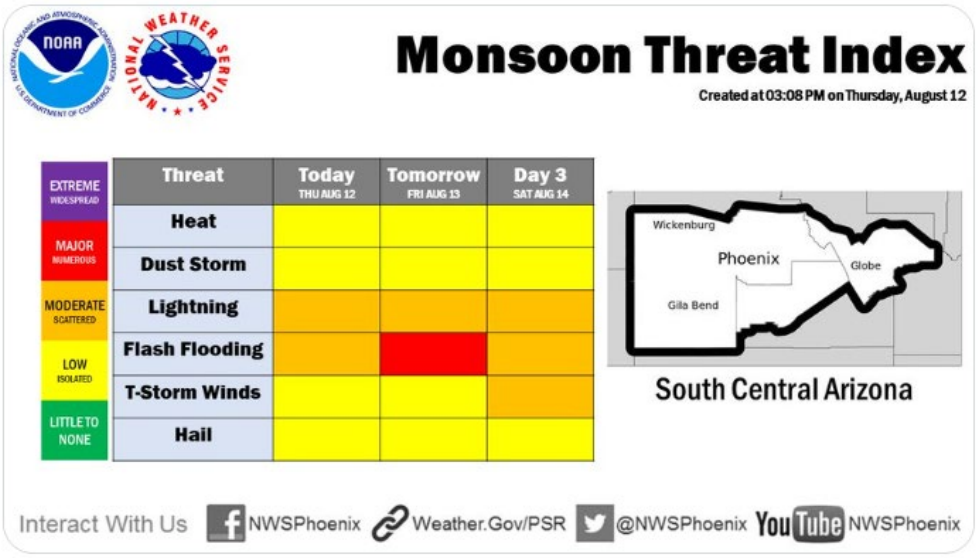

Figure 3 – NWS Messaging on Twitter – 3:08 PM MST 12 Aug 2021

This social media messaging by the NWS in Phoenix, AZ continued for the next several days. In fact, confidence was high enough that the NWS office in Phoenix, AZ issued a flash flood watch later in the afternoon of Aug 12, 2021, for Maricopa County, including the incident location, beginning at 5:00 PM on Aug 12, 2021, and continuing through Aug 15, 2021. It emphasizes the threat of flooding and heavy rainfall in the watch area. See Figure 4.

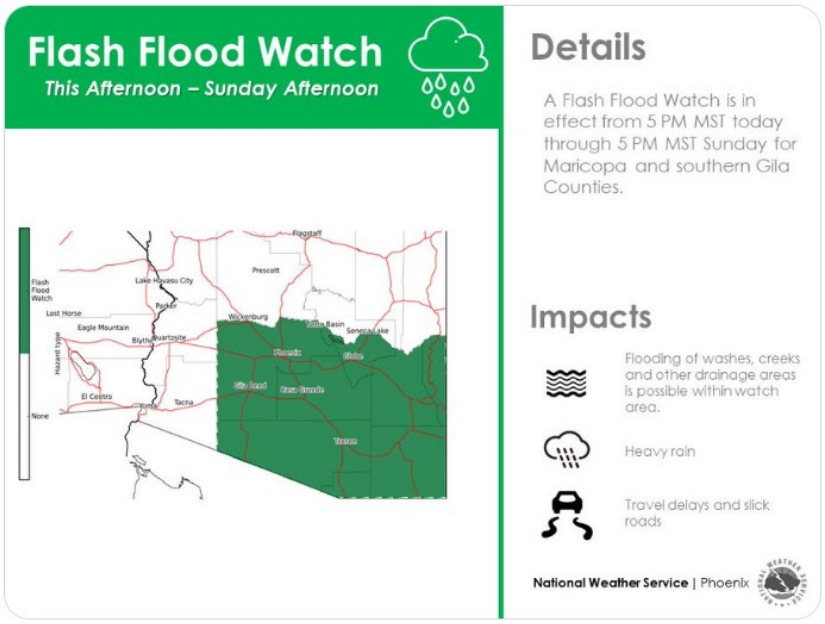

Figure 4 – NWS Messaging on Twitter – 4:30 PM MST 12 Aug 2021

Figure 5 is the social media messaging issued early on Aug 13, 2021. It addresses the active monsoon conditions expected each of the next several days with emphasis placed

on heavy rainfall and flash flooding that evening (8/13) that would naturally carry into the following day.

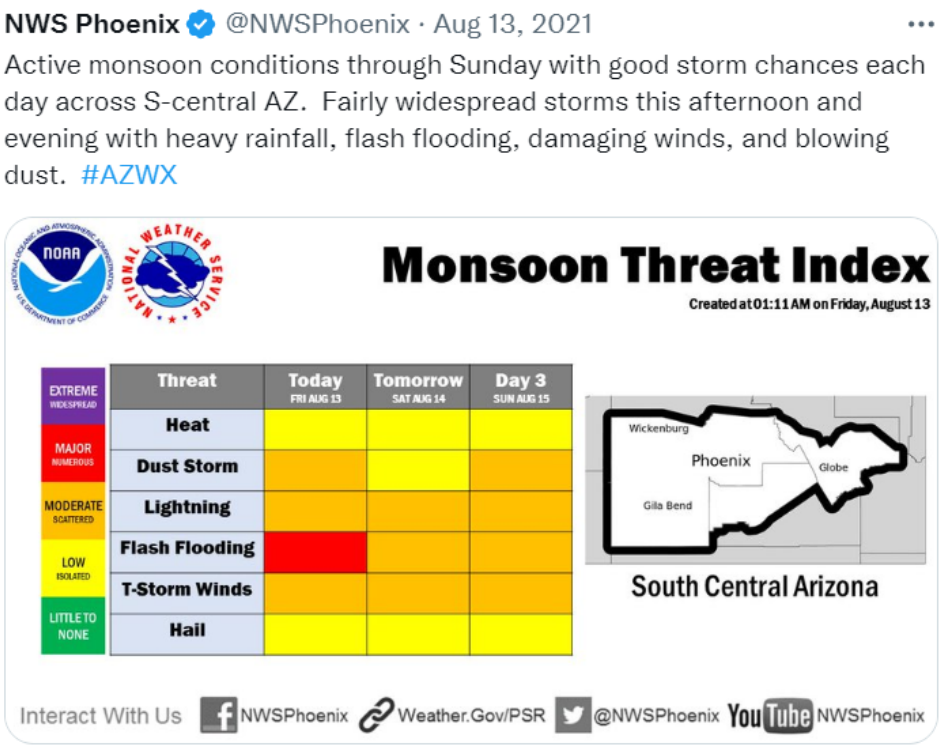

Figure 5 – NWS Messaging on Twitter – 1:11 AM MST 13 Aug 2021

Weather maps from the NWS's Weather Prediction Center[8] (WPC) set the stage for the weather activities for the day and overnight into Aug 14, 2021. The upper atmosphere weather map on the morning of Aug 13, 2021, showed the upper level high-pressure centered over Utah. See Fig. 6(L). At the surface, a weak low-pressure system was centered near Needles, CA while an area of high pressure was located near Flagstaff, AZ. Another critical piece of the weather puzzle was a weak surface front identified by the orange line extending from the AZ/NM border to near Phoenix, AZ. See Fig. 6(R). It would be along and just west of this weak surface front where later in the day storms would focus and then be directed by the atmospheric flow around the surface high pressure toward the surface low pressure. This ultimately would track the majority of storms from east to west and mainly just south of the incident location.

[8] https://www.wpc.ncep.noaa.gov

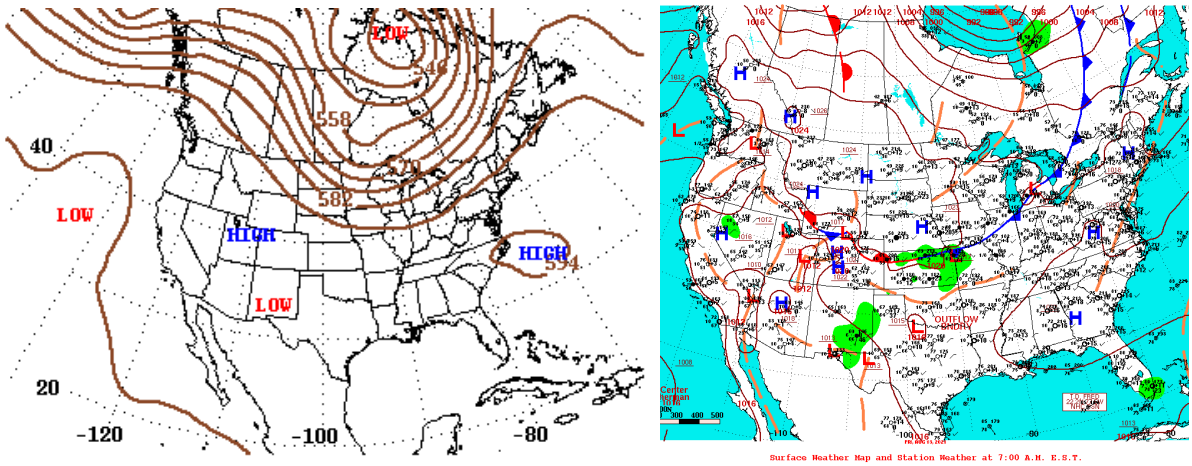

Figure 6 – Upper Air Chart (L) & Surface Weather Map (R) for 0500 on 13 Aug 2021

Satellite imagery from the National Environmental Satellite Data and Information Service[9] (NESDIS) in the late afternoon of Aug 13, 2021, showed considerable convective clouds already widespread across the mountains of east-central Arizona from northeast to east of Phoenix, AZ. See Fig. 7 (Red star depicts the incident location).

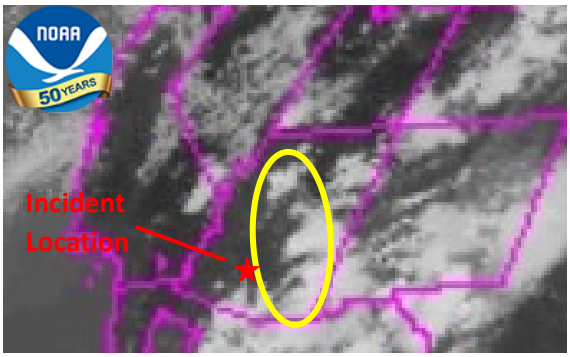

Figure 7 – Visible Satellite Imagery for 5:00 PM MST on 13 Aug 2021

Showers and thunderstorms were well underway by 9:00 PM MST over the higher terrain, well north through east of the incident location. This was more than 140 miles northeast of the incident location. See Fig. 8 (Red star depicts the incident location).

The NWS had already issued several flash flood warnings for these thunderstorms during the evening hours of 13 Aug 2021, in Gila County and eastern Maricopa County with several eyewitness reports of flooding in these areas.

While there were other severe weather threats expected by the NWS with these storms as they marched across the state, such as hail and strong damaging winds, the primary advertised threat was flash flooding.

[9] https://www.nesdis.noaa.gov

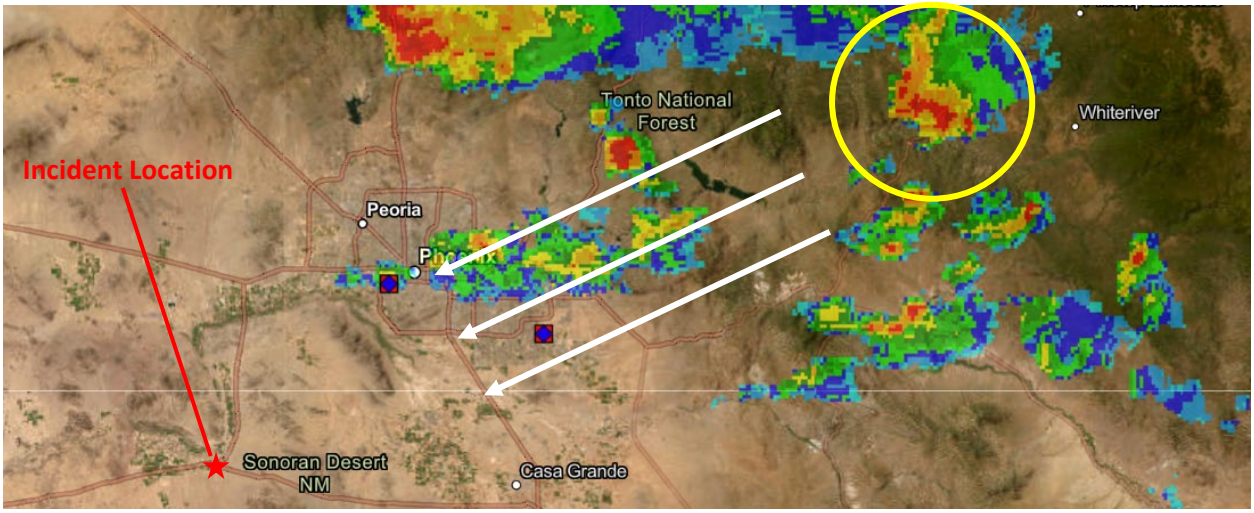

Figure 8 – NWS WSR-88D Radar Image for 9:00 PM MST on 13 Aug 2021

The storm motion with these storms was reported as moving southwest at 20-25 mph. Emphasis by the NWS in Phoenix, AZ was placed on the flash flood potential although "up to quarter size hail and wind gusts to 60 mph" was mentioned as occurring with these storms[10].

By 11:00 PM MST on 13 Aug 2021, radar showed these storms continuing to develop and march southwest off the higher mountains and into the lower valleys toward Gila Bend. Several more flash flood warnings had been issued for the Phoenix metro area with several reports of flooding due to very heavy rainfall. See Fig. 9.

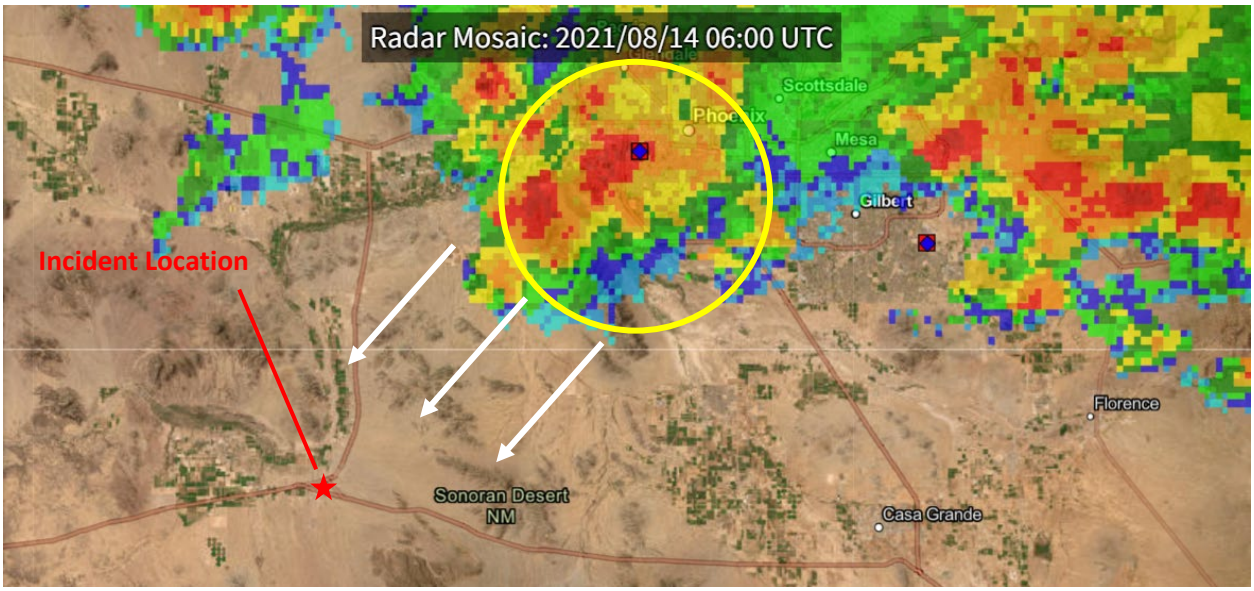

Figure 9 – NWS WSR-88D Radar Image for 11:00 PM MST on 13 Aug 2021

[10] https://mesonet.agron.iastate.edu/wx/afos/p.php?pil=SVSPSR&e=202108140045

By 12:20 AM MST on 14 Aug 2021, radar showed an intense storm beginning to move over the Maricopa Mountains to the east of Gila Bend, AZ. See Fig. 10. It is at this time that one of the Maricopa County Flood Control District (MCFCD) rain gauges (Maricopa Mtns) began reporting very heavy rain.

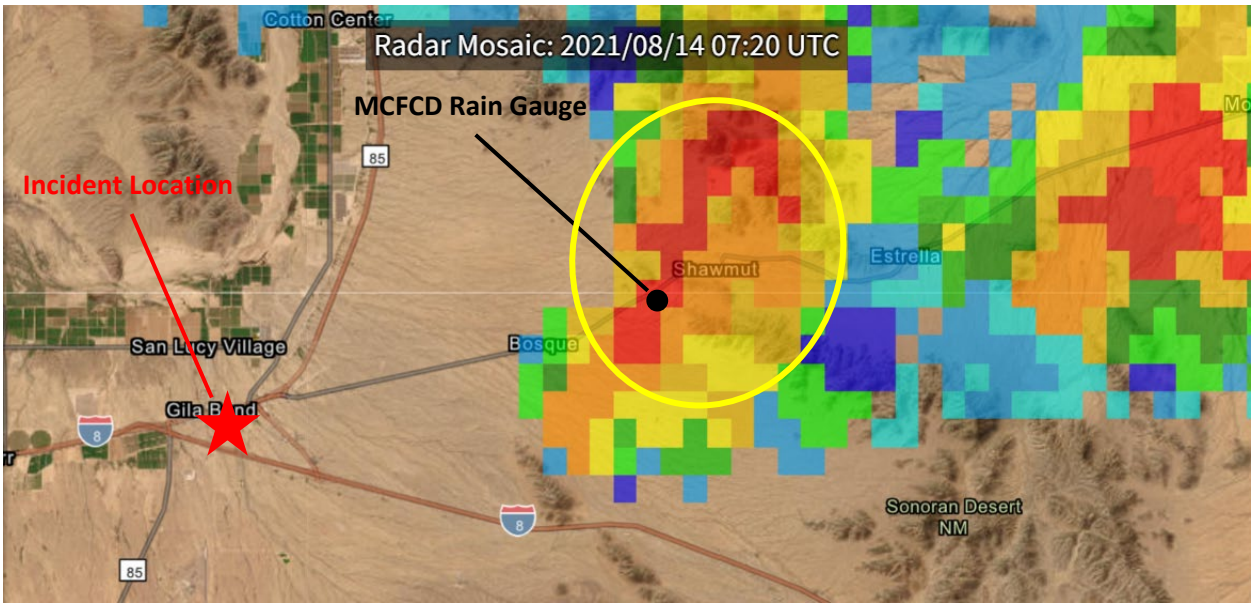

Figure 10 – NWS WSR-88D Radar Image for 12:20 AM MST on 14 Aug 2021

This storm would continue to track to the southwest, expand in areal size, and increase in intensity over the next 20-30 minutes. See Fig. 11.

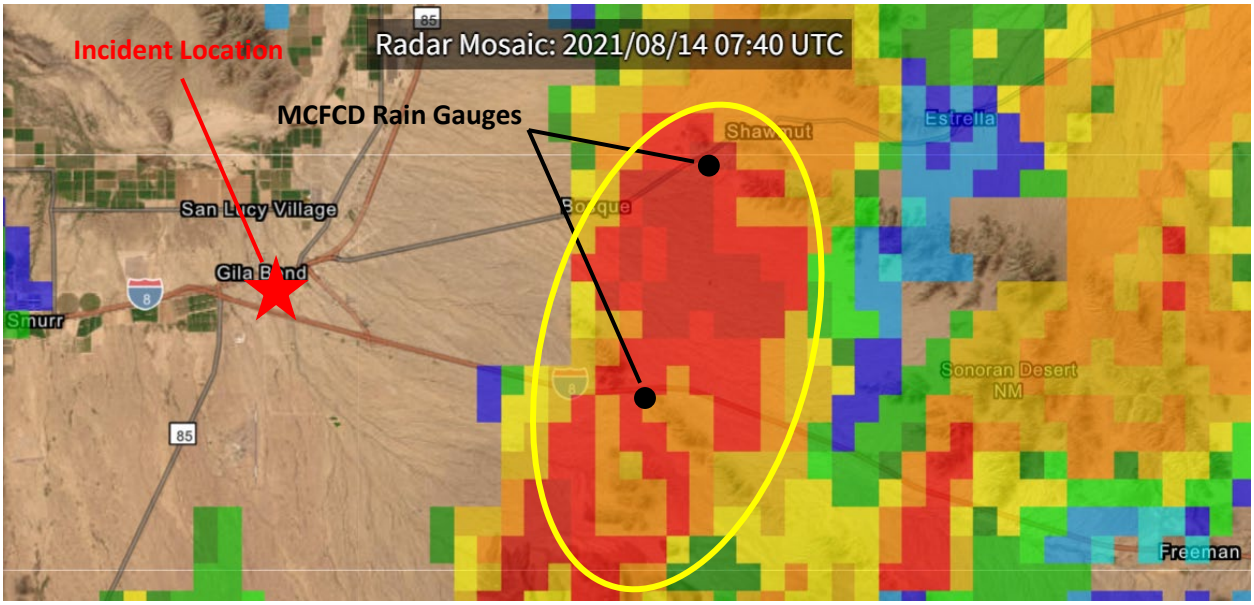

Figure 11 – NWS WSR-88D Radar Image for 12:40 AM MST on 14 Aug 2021

By 12:40 AM MST on 14 Aug 2021, very heavy rain was being reported at 2 MCFCD rain gauges, east of Gila Bend, AZ with rain continuing to expand west and south toward the Incident Location. It is shortly after this time that the NWS in Phoenix, AZ issued a flash flood warning for southern Maricopa County, including Gila Bend, AZ, and the Incident Location[11]. See Fig. 12. This warning was issued to the public, federal/state/local emergency management and response agencies, and also was received by local and national media.

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BULLETIN - EAS ACTIVATION REQUESTED
Flash Flood Warning
National Weather Service Phoenix AZ
1253 AM MST Sat Aug 14 2021

The National Weather Service in Phoenix has issued a

* Flash Flood Warning for...
  Maricopa County in south central Arizona...

* Until 500 AM MST.

* At 1253 AM MST, Doppler radar indicated thunderstorms producing
  heavy rain across the warned area. Between 0.5 and 1.5 inches of
  rain have fallen. Additional rainfall amounts up to 1 inch are
  possible in the warned area. Flash flooding is ongoing or expected
  to begin shortly.

  HAZARD...Life threatening flash flooding. Thunderstorms
           producing flash flooding.

  SOURCE...Radar.

  IMPACT...Life threatening flash flooding of creeks and streams,
           urban areas, highways, streets and underpasses.

* Some locations that will experience flash flooding include...
  Gila Bend, Estrella, Sonoran National Monument, Bosque and Mobile.

This includes the following highways...
▫AZ Route 238 between mile markers 10 and 19.
▫AZ Interstate 8 between mile markers 124 and 132.
```

Figure 12 – NWS Flash Flood Warning for Gila Bend, AZ Area Issued at 12:53 AM MST on 14 Aug 2021

Over the course of the next 2 hours, thunderstorms with heavy to very heavy rainfall moved from northeast to southwest, overspreading the entire Gila Bend, AZ area. See Fig. 13 – a collection of 4 radar images taken every 30 minutes from 1:00 AM MST to 2:30 AM MST on 14 Aug 2021. The defined Incident Location is identified by the red star symbol in each of the 4 images.

[11] https://mesonet.agron.iastate.edu/wx/afos/p.php?pil=FFWPSR&e=202108140753

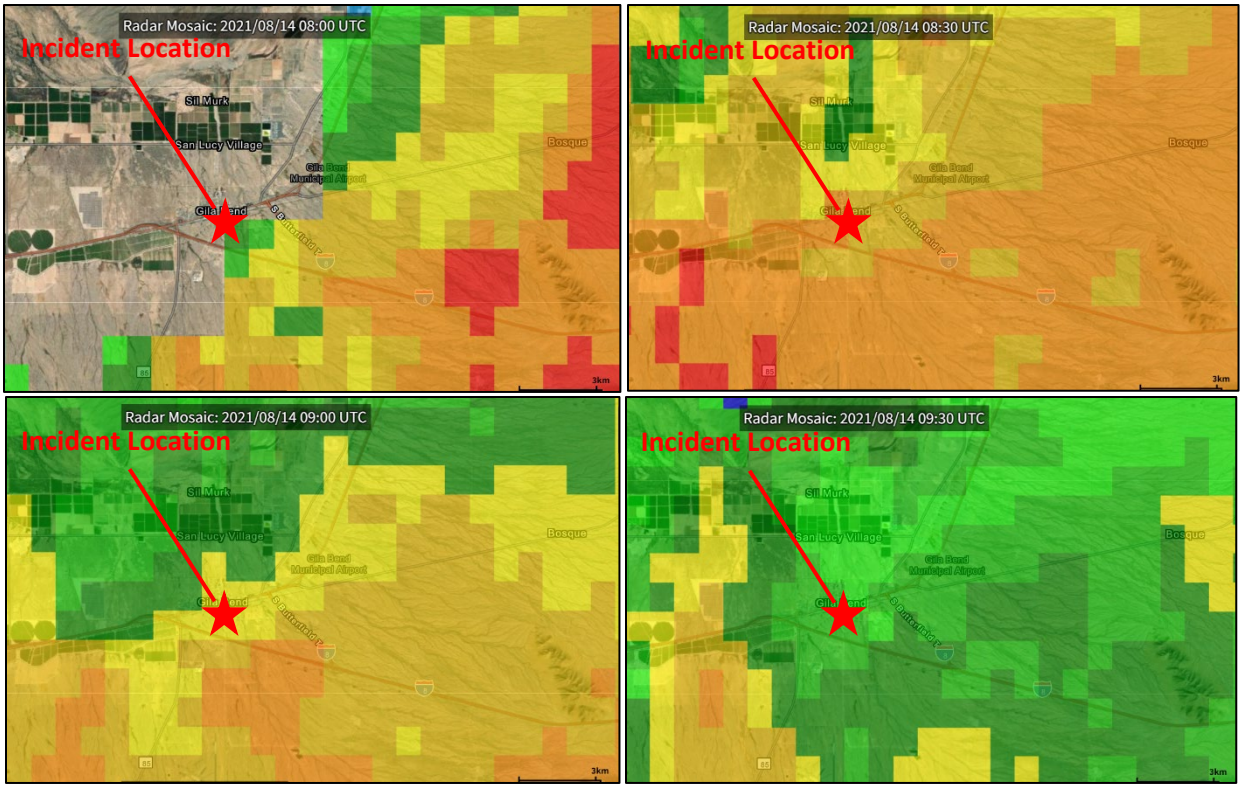

Figure 13 – NWS WSR-88D Radar Imagery for 1:00 AM/1:30 AM/2:00 AM/2:30 AM MST on 14 Aug 2021

The heaviest rainfall amounts were east and south of the Incident Location. Table 2 lists the stations used in the analysis and their corresponding hourly rainfall amounts in inches.

Gila Bend AZ Incident Hourly Rainfall (MST)

Station Name	8/14/2021																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily
Sand Tank Wash @ I-8	0.00	1.00	0.28	0.08	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48
Gila Bend 2SE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.32
Gila Bend Landfill	0.00	0.32	0.00	0.79	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23
Gila Bend AF Auxiliary Field	T	0.91	0.24	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22
Sauceda Wash	0.00	1.92	0.40	0.16	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60
Paloma Ranch	0.00	0.92	0.91	0.12	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02
Bender Wash	0.39	2.68	0.71	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.94
Paloma	0.00	0.68	0.05	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83
Maricopa Mtns	1.85	1.89	0.04	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.90

Notes:
Values in **Green** are at/above 0.01 inches
Values in **Blue** are at/above 0.25 inches
Values in **Orange** are at/above 0.50 inches
Values in **Red** are at/above 1.00 inches
Daily Values in **Purple** are at/above 3.00 inches
Values are in inches

Table 2 – Hourly Rainfall for Rain Gauges Used in Analysis on 14 Aug 2021

It is worth noting that several of the gauges analyzed reported hourly rainfall values well in excess of 1.5 inches between midnight and 2:00 am on 14 Aug 2021. These types of

hourly values are more than 5 times the minimum definition of heavy rain and represent as much as 43% of the normal annual rainfall for the area[12].

A closer examination of the MCFCD Maricopa Mtns rain gauge reveals that the highest rainfall rate in a 5-min period was 0.55 inches between 1240–1245 AM MST on 14 Aug 2021[13]. See Fig. 14.

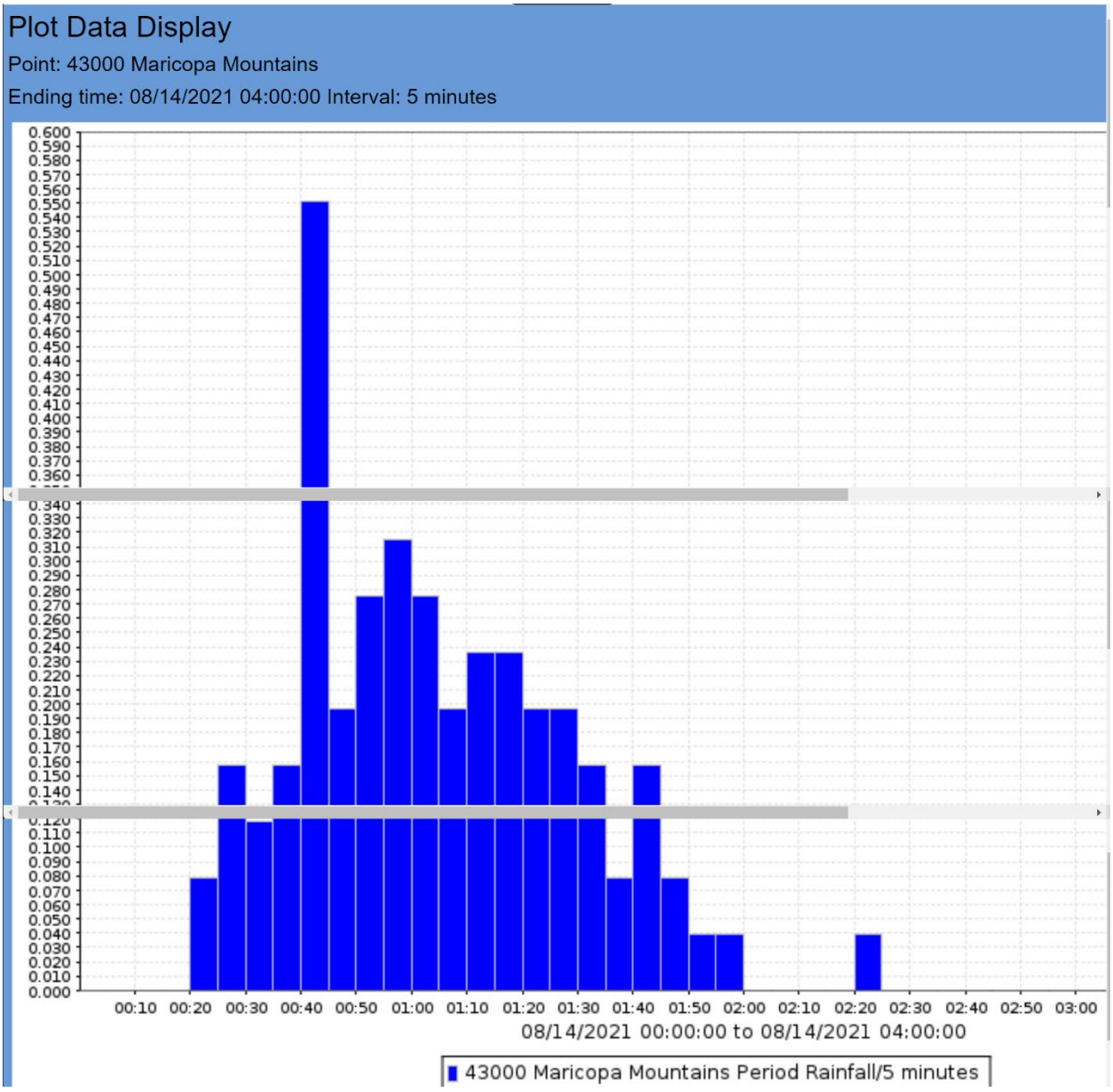

Figure 14 – MCFCD Maricopa Mtn 5-Min Rain Gauge Data for 14 Aug 2021

[12] https://www.maricopa.gov/625/Rainfall-Data
[13] https://www.maricopa.gov/625/Rainfall-Data

In addition, the highest instantaneous rainfall rate at the MCFCD Maricopa Mtns rain gauge was in excess of 9.5 inches per hour between 1240–1245 AM MST on 14 Aug 2021[14], indicative of how torrential the rain was at times. See Fig. 15.

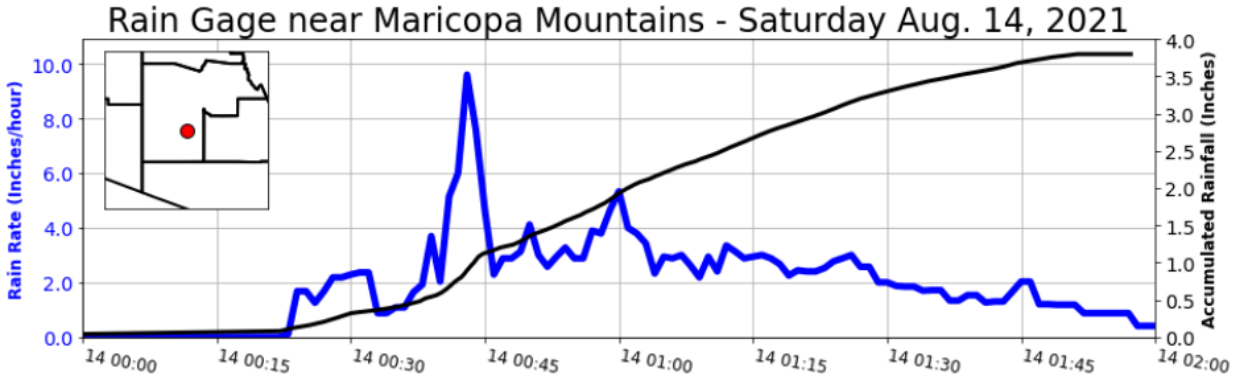

Figure 15 – MCFCD Maricopa Mtn Instantaneous Rain Gauge Data for 14 Aug 2021

On a broader scale, this rainfall event was widespread across not only Gila Bend, AZ, and the rest of Maricopa County but nearly state-wide. Multi-Sensor rainfall estimates[15] from 6:00 PM MST on 13 Aug 2021 to 6:00 PM MST on 14 Aug 2021 showed widespread heavy rainfall in several areas across southern Arizona with 24-hour rainfall estimates in excess of 4.00 inches. See Fig. 16.

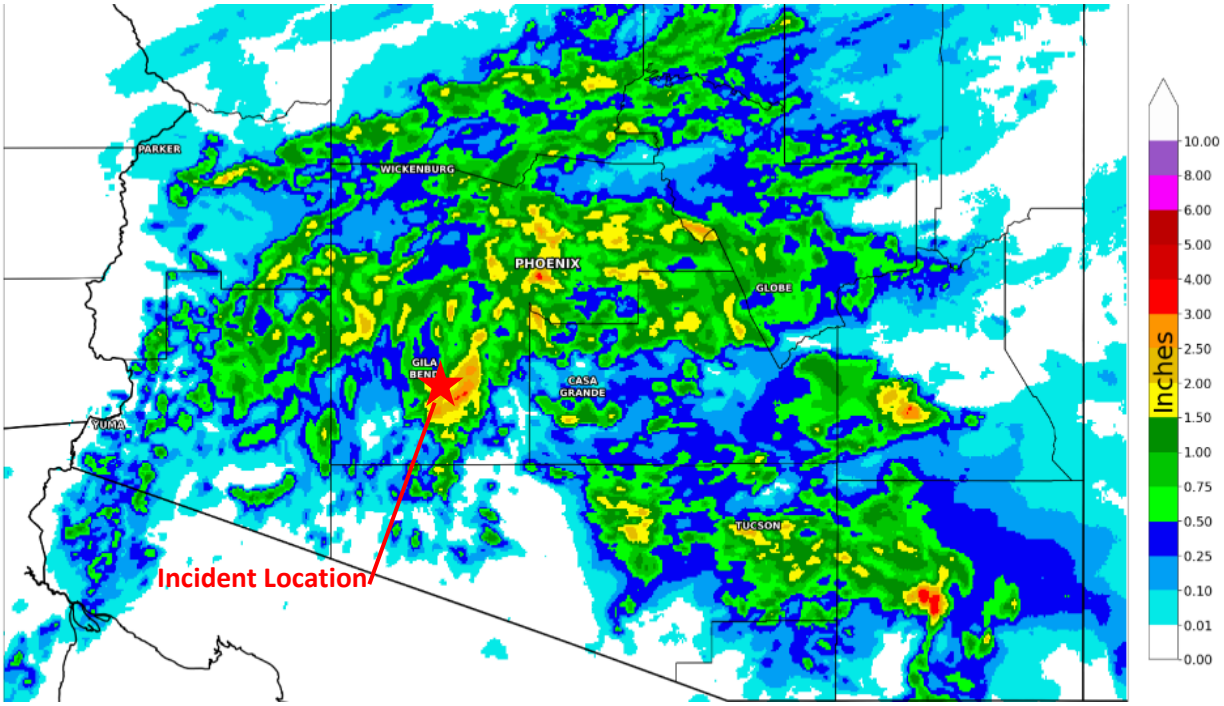

Figure 16 – Multi-Sensor Rainfall Estimate from 6:00 PM MST 13 Aug 2021 to 6:00 PM MST 14 Aug 2021

[14] https://www.maricopa.gov/625/Rainfall-Data
[15] https://www.weather.gov/psr/StormReportfor1314August2021

While localized flooding would have begun shortly after the onset of the heavy rain, the large-scale widespread flash flooding that ultimately inundated the community of Gila Bend, AZ, took a bit longer. The MCFCD stream gauge at the Sauceda Wash showed a gradual rise in the water level beginning at 2:09 AM MST on 14 Aug 2021, but saw a dramatic rise, almost 1.3 ft., between 2:25 AM MST and 3:16 AM MST on 14 Aug 2021 and peaking at 4.1 ft. at 5:09 AM MST[16]. See Fig. 17.

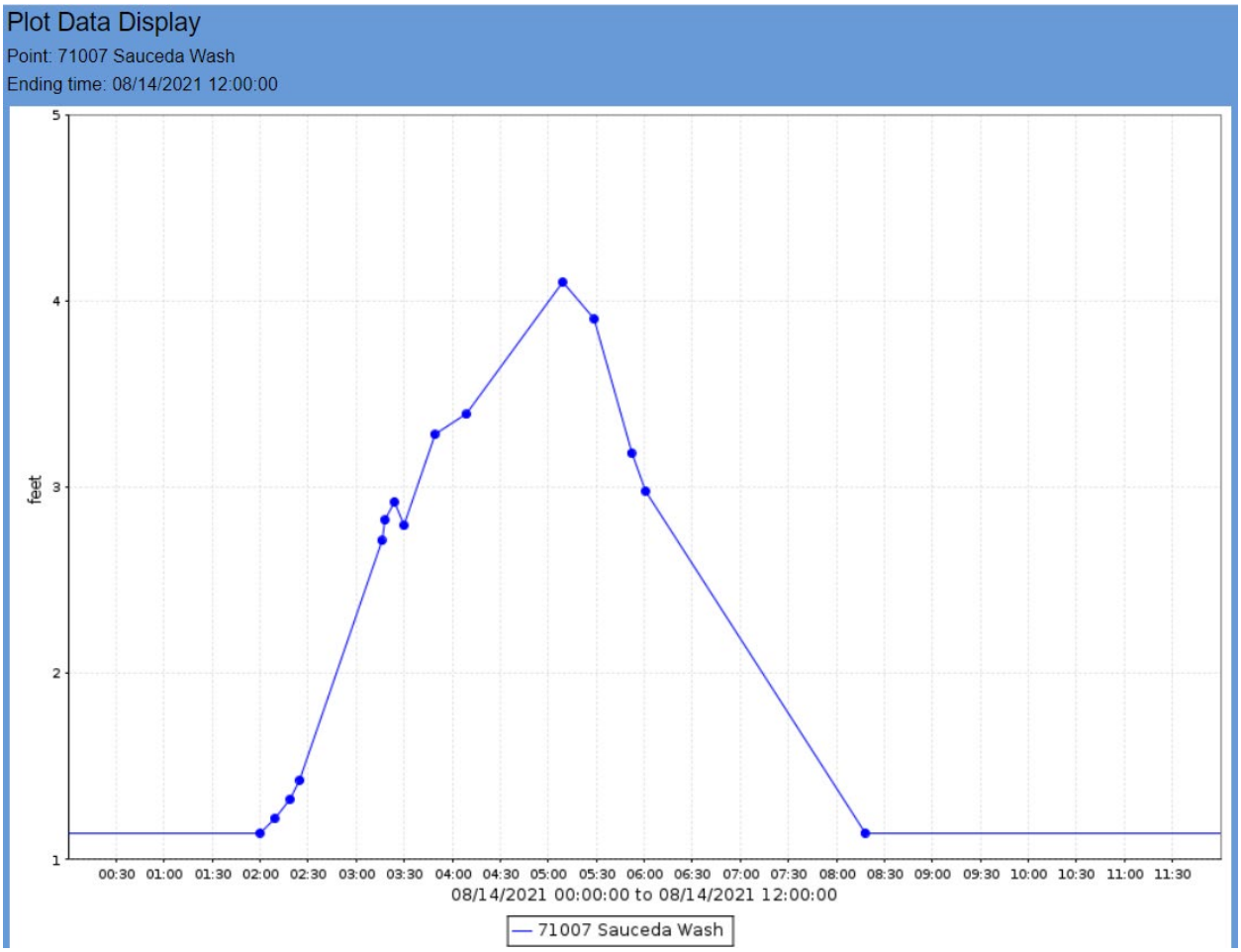

Figure 17 – MCFCD Stream Gauge Readings at the Sauceda Wash Location on 14 Aug 2021

An examination of the stream gauge at the Sand Tank Wash showed a sharper rise in the water level beginning at 1:49 AM MST on 14 Aug 2021, with a substantial rise of almost 6.4 ft. between 1:49 AM MST and 4:08 AM MST on 14 Aug 2021[17]. See Fig. 18.

[16] https://alert.fcd.maricopa.gov/php/plot_stream.php
[17] https://alert.fcd.maricopa.gov/php/plot_stream.php

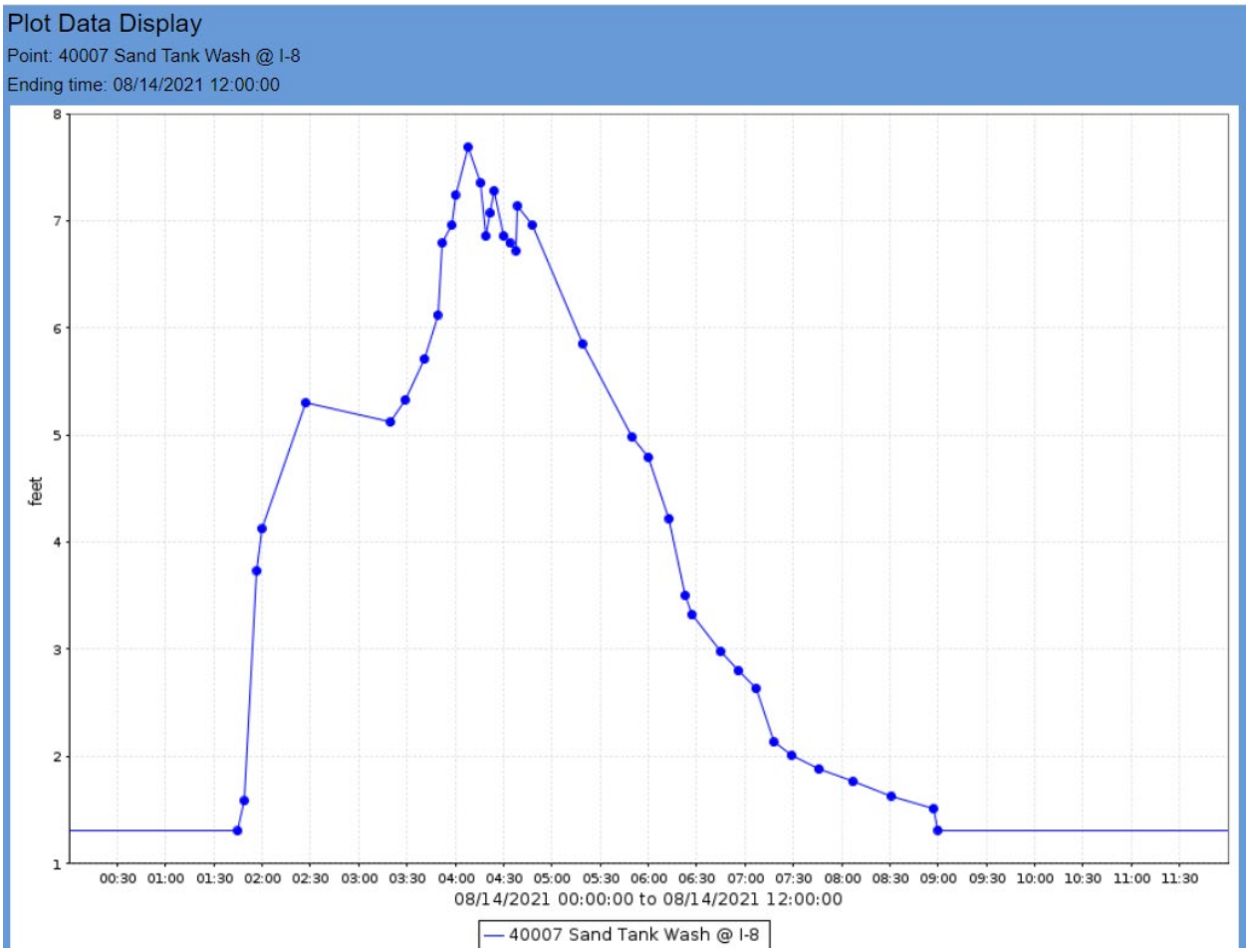

Figure 18 – MCFCD Stream Gauge Readings at the Sand Tank Wash Location on 14 Aug 2021

Also worth noting, per the NWS Local Storm Reports Database[18], the Arizona Department of Transportation (ADOT) reported that at 2:02 AM MST on 14 Aug 2021, State Route 238 was closed in both directions due to flooding - 7 miles WSW of Mobile, AZ.

Thus, the NWS flash flood warning lead time (given that the warning was issued at 12:53 AM MST) can be safely calculated to range from between 56 minutes and 1 hour and 32 minutes.

One might ask “if the heaviest rainfall was to the east and south of Gila Bend, why was the majority of the flooding in Gila Bend, AZ?” To answer this question, one only needs to examine the MCFCD Gila Bend Area Drainage Master Plan[19]. In this document you will find that the natural washes to the east flow west into the Gila Bend Canal which then flows into Gila Bend and the natural washes to the south flow north into the Gila Bend Canal in the town of Gila Bend. Essentially, all the heavy/copious amounts of rainfall to

[18] https://mesonet.agron.iastate.edu/wx/afos/p.php?pil=LSRPSR&e=202108140930
[19] https://apps.fcd.maricopa.gov/fcdprojects

the east and south of Gila Bend, AZ in the early morning hours of 14 Aug 2021 flowed right into town, adding to the already 1-2 inches of onsite rainfall. See Fig. 19.

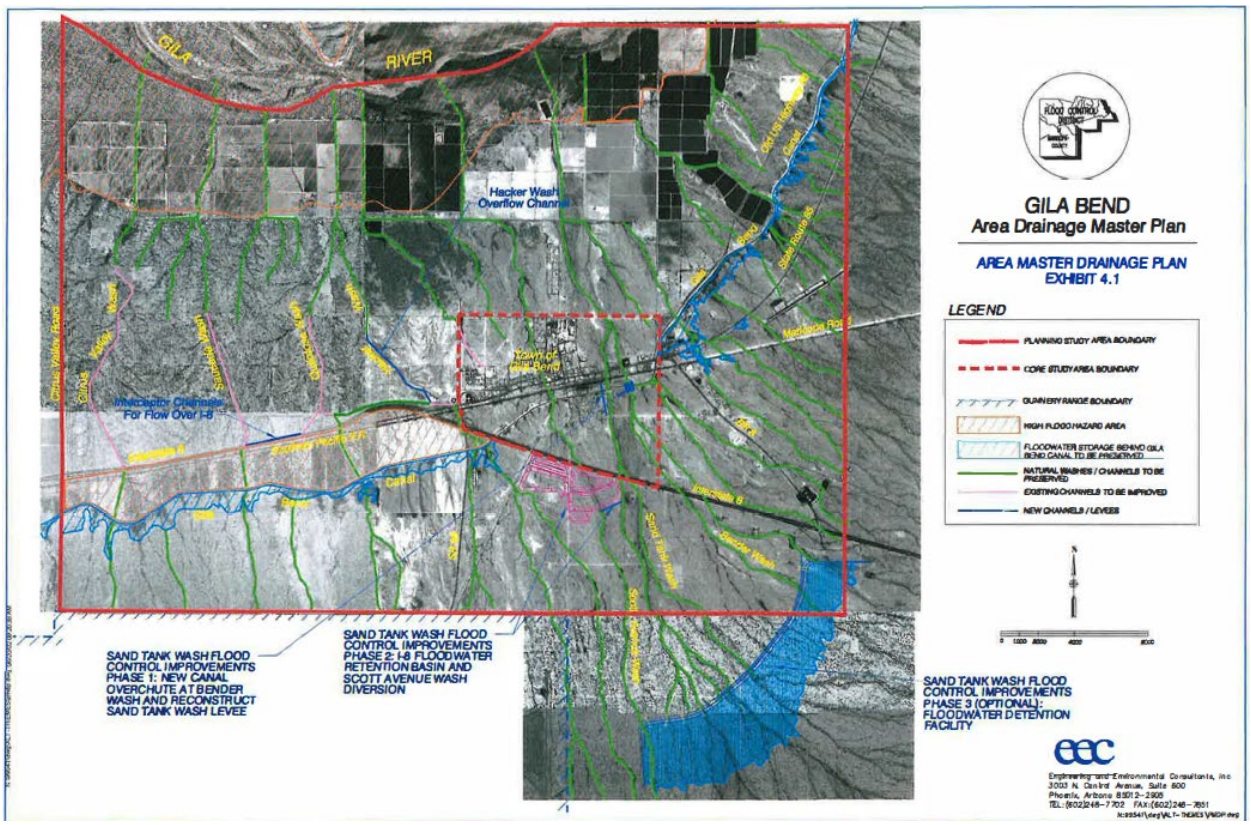

Figure 19 – MCFCD Gila Bend Area Drainage Master Plan Overview

One might also ask how common is it for a certain amount of rain to fall in one hour or two hours or even three hours in a given location? The National Oceanic and Atmospheric Administration (NOAA), the parent agency for the NWS, provides point precipitation frequency estimates for all USA locations with 90% confidence.[20] Table 3 below is the point precipitation frequency estimate for the MCFCD Maricopa Mtn rain gauge location. It shows for 3.03” of rainfall in a period of 1 hour, the off-hour amount on 14 Aug 2021, a recurrence interval of more than 1000 years. For 3.74” of rainfall in a period of 2 hours, a recurrence interval of more than 1000 years. For 3.78” of rainfall in a period of 3 hours, a recurrence interval of again more than 1000 years.

[20] https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=az

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 1, Version 5

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.183** (0.154-0.215)	**0.239** (0.203-0.284)	**0.331** (0.280-0.390)	**0.397** (0.332-0.465)	**0.485** (0.402-0.568)	**0.550** (0.453-0.645)	**0.615** (0.499-0.723)	**0.681** (0.544-0.804)	**0.765** (0.596-0.910)	**0.827** (0.633-0.992)
10-min	**0.278** (0.234-0.328)	**0.364** (0.309-0.432)	**0.504** (0.425-0.593)	**0.604** (0.506-0.708)	**0.738** (0.613-0.865)	**0.837** (0.690-0.982)	**0.936** (0.759-1.10)	**1.04** (0.828-1.22)	**1.16** (0.908-1.39)	**1.26** (0.963-1.51)
15-min	**0.345** (0.290-0.406)	**0.452** (0.383-0.535)	**0.624** (0.527-0.735)	**0.749** (0.627-0.877)	**0.915** (0.759-1.07)	**1.04** (0.855-1.22)	**1.16** (0.941-1.36)	**1.28** (1.03-1.52)	**1.44** (1.13-1.72)	**1.56** (1.19-1.87)
30-min	**0.464** (0.391-0.547)	**0.608** (0.515-0.720)	**0.841** (0.710-0.990)	**1.01** (0.845-1.18)	**1.23** (1.02-1.44)	**1.40** (1.15-1.64)	**1.56** (1.27-1.84)	**1.73** (1.38-2.04)	**1.94** (1.52-2.31)	**2.10** (1.61-2.52)
60-min	**0.575** (0.484-0.677)	**0.753** (0.638-0.891)	**1.04** (0.879-1.23)	**1.25** (1.05-1.46)	**1.53** (1.26-1.79)	**1.73** (1.43-2.03)	**1.93** (1.57-2.27)	**2.14** (1.71-2.53)	**2.40** (1.88-2.86)	**2.60** (1.99-3.12)
2-hr	**0.632** (0.546-0.738)	**0.824** (0.711-0.964)	**1.13** (0.973-1.31)	**1.36** (1.16-1.58)	**1.68** (1.42-1.94)	**1.93** (1.61-2.23)	**2.19** (1.79-2.54)	**2.45** (1.96-2.87)	**2.82** (2.19-3.34)	**3.11** (2.35-3.73)
3-hr	**0.660** (0.575-0.769)	**0.854** (0.746-0.992)	**1.16** (1.01-1.34)	**1.40** (1.21-1.61)	**1.74** (1.48-2.00)	**2.02** (1.68-2.32)	**2.32** (1.89-2.68)	**2.64** (2.10-3.07)	**3.09** (2.36-3.65)	**3.46** (2.57-4.13)
6-hr	**0.780** (0.688-0.898)	**1.00** (0.885-1.15)	**1.33** (1.17-1.51)	**1.59** (1.39-1.81)	**1.96** (1.68-2.21)	**2.26** (1.90-2.56)	**2.57** (2.12-2.93)	**2.91** (2.35-3.34)	**3.39** (2.63-3.94)	**3.78** (2.84-4.46)
12-hr	**0.880** (0.785-0.998)	**1.12** (1.00-1.27)	**1.48** (1.31-1.66)	**1.76** (1.55-1.97)	**2.15** (1.87-2.41)	**2.46** (2.11-2.77)	**2.78** (2.34-3.16)	**3.12** (2.56-3.57)	**3.59** (2.86-4.18)	**3.98** (3.08-4.71)
24-hr	**1.06** (0.953-1.18)	**1.35** (1.21-1.51)	**1.78** (1.59-1.98)	**2.11** (1.88-2.34)	**2.58** (2.27-2.86)	**2.94** (2.57-3.27)	**3.32** (2.86-3.72)	**3.72** (3.15-4.20)	**4.27** (3.54-4.88)	**4.71** (3.83-5.44)

Table 3 – NOAA-Atlas 14 Point Precipitation Frequency Estimates for the MCFCD Maricopa Mtn Location

The same can be done for the MCFCD Bender Wash rain gauge. Table 4 below is the point precipitation frequency estimate for the MCFCD Bender Wash rain gauge location. It shows for 2.83” of rainfall in a period of 1 hour, the off-hour amount on 14 Aug 2021, a recurrence interval of more than 1000 years. For 3.39” of rainfall in a period of 2 hours, a recurrence interval of more than 1000 years. For 3.86” of rainfall in a period of 3 hours, a recurrence interval of again more than 1000 years.

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 1, Version 5

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.179** (0.151-0.208)	**0.235** (0.201-0.274)	**0.329** (0.280-0.381)	**0.393** (0.331-0.453)	**0.480** (0.401-0.554)	**0.542** (0.452-0.628)	**0.603** (0.495-0.701)	**0.664** (0.539-0.777)	**0.741** (0.587-0.876)	**0.796** (0.621-0.954)
10-min	**0.273** (0.229-0.316)	**0.358** (0.305-0.418)	**0.501** (0.426-0.580)	**0.598** (0.505-0.690)	**0.730** (0.610-0.844)	**0.825** (0.688-0.955)	**0.917** (0.754-1.07)	**1.01** (0.819-1.18)	**1.13** (0.894-1.33)	**1.21** (0.945-1.45)
15-min	**0.338** (0.285-0.391)	**0.444** (0.378-0.518)	**0.621** (0.528-0.719)	**0.741** (0.625-0.855)	**0.905** (0.757-1.05)	**1.02** (0.853-1.18)	**1.14** (0.935-1.32)	**1.25** (1.02-1.47)	**1.40** (1.11-1.65)	**1.50** (1.17-1.80)
30-min	**0.455** (0.383-0.527)	**0.598** (0.509-0.697)	**0.836** (0.711-0.968)	**0.998** (0.842-1.15)	**1.22** (1.02-1.41)	**1.38** (1.15-1.60)	**1.53** (1.26-1.78)	**1.69** (1.37-1.97)	**1.88** (1.49-2.23)	**2.02** (1.58-2.42)
60-min	**0.563** (0.474-0.652)	**0.740** (0.631-0.863)	**1.03** (0.880-1.20)	**1.24** (1.04-1.43)	**1.51** (1.26-1.74)	**1.70** (1.42-1.97)	**1.90** (1.56-2.20)	**2.09** (1.69-2.44)	**2.33** (1.85-2.76)	**2.50** (1.95-3.00)
2-hr	**0.611** (0.539-0.704)	**0.803** (0.702-0.923)	**1.11** (0.971-1.27)	**1.35** (1.17-1.54)	**1.67** (1.43-1.90)	**1.92** (1.63-2.19)	**2.19** (1.82-2.52)	**2.46** (1.99-2.85)	**2.84** (2.22-3.35)	**3.14** (2.38-3.76)
3-hr	**0.637** (0.565-0.724)	**0.827** (0.735-0.939)	**1.14** (1.01-1.29)	**1.38** (1.22-1.55)	**1.74** (1.50-1.96)	**2.02** (1.72-2.28)	**2.33** (1.93-2.66)	**2.67** (2.15-3.08)	**3.15** (2.43-3.70)	**3.54** (2.65-4.22)
6-hr	**0.752** (0.672-0.849)	**0.976** (0.872-1.10)	**1.31** (1.17-1.47)	**1.59** (1.40-1.76)	**1.98** (1.71-2.19)	**2.29** (1.95-2.56)	**2.63** (2.18-2.95)	**2.99** (2.42-3.39)	**3.51** (2.72-4.05)	**3.93** (2.95-4.62)
12-hr	**0.849** (0.768-0.951)	**1.09** (0.988-1.22)	**1.47** (1.32-1.62)	**1.76** (1.58-1.94)	**2.18** (1.92-2.40)	**2.52** (2.19-2.79)	**2.87** (2.43-3.22)	**3.23** (2.67-3.67)	**3.75** (3.00-4.35)	**4.18** (3.23-4.95)
24-hr	**1.00** (0.899-1.13)	**1.29** (1.15-1.44)	**1.71** (1.53-1.92)	**2.05** (1.82-2.28)	**2.52** (2.21-2.81)	**2.89** (2.50-3.22)	**3.28** (2.79-3.68)	**3.68** (3.06-4.18)	**4.24** (3.42-4.89)	**4.69** (3.69-5.49)

Table 4 – NOAA-Atlas 14 Point Precipitation Frequency Estimates for the MCFCD Bender Wash Location

The tragic result, as we now know, was a 1000-year flash flood throughout a good portion of Gila Bend, AZ. See Fig. 20.

Figure 20 – Post-Flash Flood Photo in Gila Bend, AZ – 14 Aug 2021
(Photo courtesy of NWS)

Conclusions/Opinions

Based upon the provided data and after reviewing all the information, it is my professional opinion that:

1. August 14, 2021, began as a typical summer monsoon day in central and southern Arizona but the strength of the storms and the amount of moisture in the atmosphere converted to rainfall by the end of the day and overnight was extreme.
2. The weather events that transpired in and around Gila Bend, AZ on 14 Aug 2021, were well-warned by the NWS by as much as 1 hour and 32 minutes in advance.

3. The storm that resulted in the flash flooding deposited as much as 4.00 inches of rain in less than 2 hours across the watershed that subsequently flowed down the washes and into Gila Bend early in the morning of 14 Aug 2021.
4. This amount of rainfall statistically has a recurrence interval of over 1000 years based upon NOAA's point-precipitation frequency estimates.
5. The potential for flash flooding to occur in Gila Bend, AZ, was made public more than 35 hours in advance of the event. This advance notice included all emergency response agencies as well as all county, state, and federally responsible agencies.

Certification

I certify that the above information contained in this report is true and accurate to the best of my ability and that all analysis and findings expressed in this report were made with accuracy as a professional meteorologist within a reasonable degree of meteorological certainty.

Todd Morris

Todd Morris, CCM
Global Weather and Climate Consulting, LLC

EXPERT QUALIFICATIONS

Professional Experience

President at Global Weather and Climate Consulting LLC

November 2013 – Present (9 years)

AMS Certified Consulting Meteorologist (CCM) providing expert witness testimony at trial and depositions as a subject matter expert (SME) on weather, water, marine & climate matters. Including data acquisition, analyses, and reports. Meteorological support to TV/film/commercial productions as well as insurance claims. Also, meteorological considerations for homeland security, counterterrorism, and emergency response.

- Recent clients include:

California Department of Forestry	Farmers Insurance Company
California Department of Transportation	State Farm Insurance Company
Long Beach Container Terminal	AmGUARD Insurance Company
City of Santa Barbara	Hilton Hotel Company
City of Los Angeles	Old Dominion Freight Line
City of San Francisco	J.B. Hunt Company
Gila Valley Irrigation District	Toyota Motor Company
State of Arizona	Chevrolet Automobile Corporation
Arizona Department of Transportation	Bridgestone Corporation
Southern California Edison	Laguna Art Museum
Pacific Gas and Electric	Saatchi & Saatchi Advertising Company
Chevron Corporation	Believe Media Company
Signature Aviation	Nautilus International
Shea Homes	Copper State Home Builders

- Recent cases include:
  - United States of America v. Gila Valley Irrigation District – Defendant **(Deposition Given)**
  - Copperstate Home Builders v. Moto Holdings - Plaintiff
  - Burns v. AmeriTech – Defendant **(Deposition Given)**
  - Bauer v. Old Dominion – Defendant
  - Crocker v. CALTRANS – Defendant

- North Carolina Port Authority v. Nautilus – Defendant
- Larrabee Condo Owners Association v. Farmers Insurance – Defendant
- LHP Management LLC V. Empire Corporation of TN - Defendant
- Enami v. State of Arizona - Defendant
- Maddox v. Holderman – Defendant
- Vasquez v. Los Angeles Unified School District – Plaintiff **(Deposition Given)**
- City of Los Angeles v. Tetra Design Inc. – Plaintiff **(Deposition Given)**
- Ilg-Kucheran v. Port of Skagit, WA – Plaintiff **(Deposition Given)**
- Streightiff v. Hilton – Defendant
- Nuno, Alyssa v. City of Santa Barbara – Defendant
- Anderson v. State of Arizona & United States of America - Plaintiff
- AIG v. Signature Aviation – Defendant **(Deposition Given)**
- Dept. of Forestry & Fire Protection v. California Resources Corporation, et al - Plaintiff
- CalFire v. Southern California Edison Company – Plaintiff
- CalFire v. Aera et al - Plaintiff
- Bisogno, Robin, et al v. CA Dept. of Transportation – Defendant
- Valencia v. Farmers Insurance - Defendant
- Sliskovich v. Mid-Century Insurance Company - Defendant
- Noble Textile, Inc. v. United Specialty Insurance Company – Defendant
- Adlen v. Clubcorp - Defendant
- Lou v. Little Lake City School District – Defendant **(Deposition Given)**
- Valerie Meyers v. National Weather Service (NWS) – Defendant **(Deposition Given x 2)**
- More than 100 cases as an associate to Air, Weather and Sea Conditions, Inc.

Regional Coordinator for Impact-Based Decision Support Services at National Weather Service Western Region Headquarters (Retired) – Salt Lake City, UT

January 2011 – January 2016 (5 years)

Brought the weather decision needs of federal, state, local and tribal partners/stakeholders together with the services and capabilities of the NWS forecast offices in the western U.S. Supported NWS efforts in the west to create an Operational Decision Support Division and an enhanced Regional Operations Center function including the selection of staff, creating/modifying policy/procedures, and providing recommendations/ input to senior staff. Supported efforts to meet NWS Strategic Plan goals of a Weather Ready Nation.

Acting Meteorologist in Charge at National Weather Service - Phoenix, AZ

March 2015 - June 2015 (4 months)

Managed all weather forecast/support activities for central Arizona and southeast California including

WFO PSR. This included managing office operations and systems, managing observational networks, providing leadership and oversight to all staff and programs within area of responsibility and within the confines of the mission of the NWS. This included managing and directing day-to-day operations of the WFO including the issuance of forecasts, outlooks, watches, warnings, the oversight of the public service unit, cooperative observer program and NOAA Weather Radio Program.

Acting Deputy Regional Director at National Weather Service - Western Region Headquarters – Salt Lake City, UT
August 2012 - October 2012 (3 months)
Assisted in providing leadership, direction, management and supervision of NWS Western Region. Developed short and long-range plans, including new approaches to problems, and required resources given existing capabilities.

Physical Scientist at National Weather Service - Los Angeles/Oxnard, CA
2003 - 2011 (8 years)
Program management of several critical operational office programs within WFO Los Angeles/Oxnard.

Subject-Matter-Expert (SME) for Los Angeles Terrorism Early Warning Group (TEW) – Los Angeles, CA
2005-2009 (4 years)
Provided weather support/briefings to the TEW (run by Los Angeles County) for exercises and emerging threats. This included analysis of meteorological conditions and their impact on planning, preparedness, and emergency response.

Meteorologist in Charge (MIC) at National Weather Service - Los Angeles/Oxnard, CA
1994 - *2003 (9 years)*
Managed all weather forecast/support activities for southern California including WFO LOX and 1 CWSU. This included managing office operations and systems, managing observational networks, providing leadership and oversight to all staff and programs within area of responsibility and within the confines of the mission of the NWS. This included managing and directing day-to-day operations of the WFO including the issuance of forecasts, outlooks, watches, warnings, the oversight of the public service unit, cooperative observer program and NOAA Weather Radio Program.

Deputy Meteorologist in Charge (DMIC) at National Weather Service - Los Angeles, CA
1992 - 1994 (2 years)
Managed and directed day-to-day operations of the WSFO including the issuance of forecasts, outlooks, watches, warnings, the oversight of the public service unit and NOAA Weather Radio Program.

Meteorologist in Charge (MIC) at National Weather Service - Santa Maria, CA
1990 - 1992 (2 years)
Supervised all weather services/support at a small WSO whose primary responsibilities were agricultural forecasting, pilot briefings and surface observations.

Evaluations Officer at National Weather Service - Milwaukee, WI

1988 - 1990 (2 years)
Performed service evaluations of all FSS's and WSO's within the state of Wisconsin as well as forecast responsibilities on all forecast desks including public, marine, aviation and severe weather.

General Forecaster at National Weather Service - Milwaukee, WI
1985 - 1988 (3 years)

Meteorologist Intern at National Weather Service - Reno, NV
1981 - 1985 (4 years)

Certifications

Certified Consulting Meteorologist
American Meteorological Society License #702 February 2014

NWS Weather Observer
Department of Commerce National Weather Service June 1981

Private Pilot
Department of Transportation Federal Aviation Administration January 1978

Professional Affiliations

American Meteorological Society (AMS), Certified Consulting Meteorologist (CCM)
National Council of Industrial Meteorologists (NCIM), Full Member
American Meteorological Society (AMS), Full Member
National Weather Association (NWA), Full Member
Los Angeles Terrorism Early Warning Group (TEW)
National Weather Service (NWS) Weather Spotter
Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) Member
International Association of Emergency Managers (IAEM), annual Conference Member

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Honors and Awards

Bronze Medal Group Award
Department of Commerce
January 2015
For the provision of an integrated set of innovative decision support services during the on-going California Drought Emergency.

Bronze Medal Group Award

Department of Commerce
December 2008
For outstanding forecasting and briefing efforts over an extended period to the DHS/FEMA (JFO), established in response to the October 2007 southern CA fire siege.

Gold Medal Group Award
Department of Commerce
January 2005
For the service provided during the southern CA rain/floods of Jan. 2005.

Silver Medal Group Award
Department of Commerce
November 2004
For weather support given to firefighting personnel during the wildfires of Oct./Nov. 2003.

Bronze Medal Group Award
Department of Commerce
December 1998
For public service performed resulting in lives/property saved during the El Nino events of 1997/98.

Isaac Cline Award
National Weather Service - Los Angeles
August 2008
For providing exceptional and dedicated support of operations over an extended period to the DHS/FEMA Joint Field Office, established in response to the October 2007 southern CA fire siege.

Certificate of Appreciation
Tri-Advisory Conference - National Ski Patrol, Far West Division
November 2006
In providing education in the name of service and safety.

30 Year Length of Service Award
Department of Commerce
February 2012
In recognition of 30 years of government service.

Projects

Climate Information for Disaster Management - Bridging the Weather and Climate Timescales
February 2015 to January 2016
Members: Todd Morris, Andrea Bair, Alison Meadows, Zack Guido, Mike Crimmins, Robert Scripp, Jonathan McLeod

Co-author The Federal Emergency Management Agency (FEMA) Region IX (CA, AZ, NV, and Pacific Islands) has based disaster management preparations on weather information for decades. Climate information, which conditions weather risk, however, has been underutilized. The Climate Assessment of the Southwest (CLIMAS), the National Weather Service (NWS) Western Region, and the Response Division of FEMA Region IX have co-designed a hydroclimate dashboard tool that is integrated into FEMA disaster management, stewarded by the NWS, and studied by CLIMAS. The hydroclimate dashboard includes a short narrative and supporting graphics and information that cover historical climate risk, current conditions, and climate outlooks. The dashboard provides an opportunity to leverage climate information to help FEMA Region IX better monitor, anticipate, and prepare for potential disaster.

Weather (and Decision Support) for Emergency Managers

October 2012 to January 2013

Members: Todd Morris, Jay Rosenthal

Co-author Basic meteorological concepts and understanding play a big role in the response to this nation's natural and man-made disasters, as well as planned responses to terrorist threats against urban and rural areas. Issues such as land-sea breeze circulations, mountain and valley winds, coastal cloud cover, vertical and horizontal wind shear, normal diurnal fluctuations, and the impact of certain predictable and terrain enhanced windstorms all play crucial roles in determining who is at risk, and what strategies are most effective in minimizing harm to people and structures. The ability of the National Weather Service, with its Incident Meteorologists and decision support services, together with rapidly advancing technology in assimilating data over small time and spatial scales, provides the emergency manager or incident commander with a host of essential real-time support capabilities. This paper attempts to identify and highlight the value of this real-time support capability.

Weather Support to FEMA/DHS Joint Field Office Established in Response to the Devastating Southern California Wildfires of October 2007

October 2007 to July 2008

Members: Todd Morris, Eric Boldt

Author An Incident Support Specialist Overview - On October 24, 2007, President George W. Bush, signed a Major Disaster Declaration for the State of California for severe wildfires affecting Southern California. The Disaster Declaration put into motion federally funded and state coordinated response and recovery efforts, including establishing a FEMA/DHS Joint Field Office. Weather support for this function was provided by an Incident Support Specialist (ISS) from the National Weather Service in Los Angeles/Oxnard, CA. This paper is an overview of those local efforts, including the products and services provided, and an examination of the complexities involved. It also discusses the lessons learned and the successes realized.

History of Weather Observations Los Angeles, CA 1847-1948

January 2006 to January 2006

Members: Todd Morris, Glen Conner, Curt Kaplan

Contributor The turbulent times in California brought the United States Army to the Los Angeles area. An Assistant Surgeon accompanied the small force to provide medical care for the 121 soldiers in Kearny's Dragoons. On the morning of 5 June 1847, duty required Assistant Surgeon, Dr. John S. Griffin of that unit, to record the weather conditions at his post in El Pueblo de Los Angeles. On 20 June 1847, he began recording the "clearness of the sky" and in July he recorded rainfall when it occurred. So began the first official weather observations in Los Angeles. From our vantage point one hundred sixty-nine years later, we are astounded by the survival of that record. Equally astounding is the succession of improvements in meteorology that have occurred between that first observation and the forecasts now being generated by the modern National Weather Service Forecast Office for the Los Angeles area.

NOAA Technical Memorandum NWS WR-261 - Climate of Los Angeles

January 1999 to October 2001

Members: Todd Morris, David Bruno, Gary Ryan, Curt Kaplan

Contributor and Editor We hope and trust that readers will find The Climate of Los Angeles, California to be both useful and informative, not only as a data source, but as an important document that broadens the understanding of weather and climate systems that affect southern California.

National Weather Digest, Volume 14, Issue 4, Pages 14-18 - "The Possible Influence of an Existing Snow Field on the Track of a Surface Low Pressure-A Case Study"

January 1989 to November 1989

Members: Todd Morris

Author One of the challenges for meteorologists who deal with winter storms is accurately forecasting the position and track of the surface low-pressure center. This can help determine not only precipitation type but also where the greatest amount of precipitation will fall. A case study was examined which fit an "old and unwritten" rule of thumb. This theory is that the surface low-pressure center will track along the southern edge of an existing snow field. The case study fit perfectly, physical reasoning is included, and further investigations are encouraged.

Skills & Expertise

Meteorology	**Coordination**	**Preparedness**
Weather	**Coaching**	**Air Quality**
Climatology	**Training**	**GIS**
Weather Forecasting	**Policy**	**CAMEO**
Environmental Science	**Government**	**Weather Radar**
Decision Support	**Remote Sensing**	**Environmental Policy**
Incident Command Sys/NIMS	**Weather Observing**	**Storm Surveys/Damage Assess**
Program Management	**Hydrology**	**Hazard Mitigation**

Project Management	**Severe Weather**	**Technical Writing**
Budget Monitoring	**Emergency Management**	**Technical Support**
Research	**Disaster Response**	**Strategic Planning**

Education

FEMA – Washington, D.C.
Occupational Certificates, Incident Command System/NIMS (ICS 300, 400, 700, 800), 2008-2010

Emergency Management Institute - Emmetsburg, MD
Occupational Certificate, Emergency Management, 2008 - 2008

Texas A&M University
Occupational Certificate, Emergency Management, 2006 - 2006

NTL Institute - Alexandria, VA
Occupational Certificate, Human Interaction, 2003 - 2003

Army Management Staff College - Ft. Belvoir, VA
Occupational Certificate, Personnel Management, 2001 - 2001

SUNY Albany
Coursework completed, Radar Meteorology/Hydrology, 1984 - 1984

University of Wisconsin-Madison
Bachelor of Science (BS), Meteorology, 1978 – 1982