1.54 A COMPARISON OF THE MAY 1990 AND MAY 2015 HIGH IMPACT RIVER FLOODING IN ARKANSAS

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1. INTRODUCTION

Spring flooding often occurs in the state of Arkansas during the months of April and May. During the months of May 1990, and May 2015, the river flooding that occurred was extreme. Each of the two events shared a number of similarities. Over 20 inches of rain fell in both May of 1990 and May of 2015 over parts of west central Arkansas. This lead to historical rises along the Arkansas River. The purpose of this study is to compare the similarities and differences of these two events using a variety of meteorological and hydrological parameters as well as the severity of the impacts.

2. WHAT OCCURRED

Several rounds of heavy rainfall and thunderstorms plagued Arkansas during the month of May 1990 and 2015. The vast majority of rain fell across the west central Arkansas and back into Eastern Oklahoma across the basins of the Arkansas River. The red-orange zone in Figure 1 highlights the hydrologic area where rainfall drains into the Arkansas River. As a result of the excessive rainfall over the western basin area, the Arkansas River recorded some of its highest crests on record in 1990 with locations all within the top 5 crests of all time for their respective locations. For May of 2015, most did not reach the top 5 category (Table 1)**.**

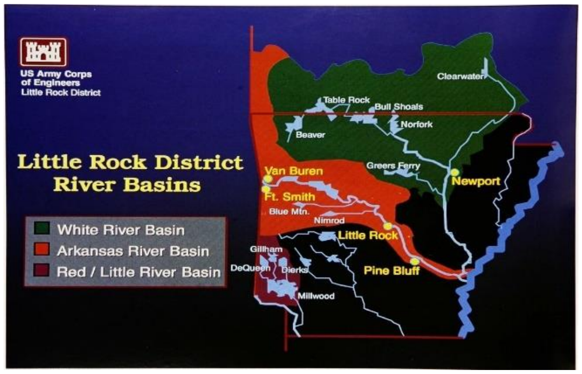

Figure 1. Arkansas River hydrologic area (courtesy of U.S. Army Corps of Engineers)

Arkansas River	May of 1990	Rank	May of 2015*	Rank
Toad Suck L&D*	282.90	1	280.45	2
Ozark L&D	370.00	2	367.71	4
Morrilton	41.30	2	38.64	9
Pendleton	33.70	2	31.90	6
Pine Bluff	47.70	4	45.96	5
Van Buren	36.10	5	33.53	10
Dardanelle	41.60	5	37.73	9
Little Rock*	27.70	5	22.89	11

Table 1 . Historical Crests and Rankings

Table 1 shows the historical river crests and where they rank for the forecast points along the Arkansas River that lie within the state of Arkansas. The significance of the May 1990 river flooding is that this was the first time the river reached these levels since the development of flood control systems that were built in the 1940s and 1950s. Even with the addition of flood control measures, Toad Suck Lock and Dam (L&D) still broke the all-time crest record in May 1990, with May 2015 following in second place Figure 2). It should be noted that the crest in 2015 at Toad Suck L&D actually occurred on June 3rd. Furthermore, the crest at Little Rock also occurred on June 3rd and came in just under flood stage which is 23.0 feet (Figure 3).

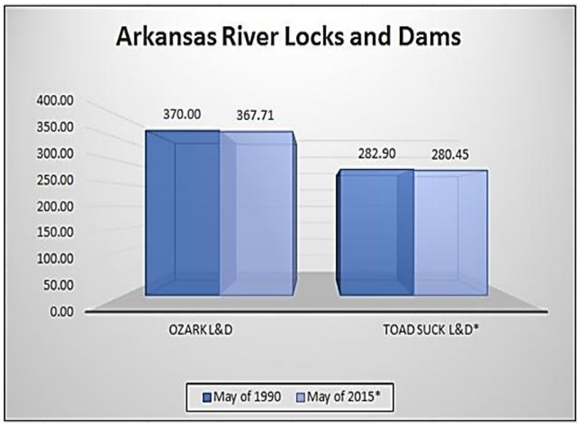

Figure 2. Crest heights of the Arkansas River

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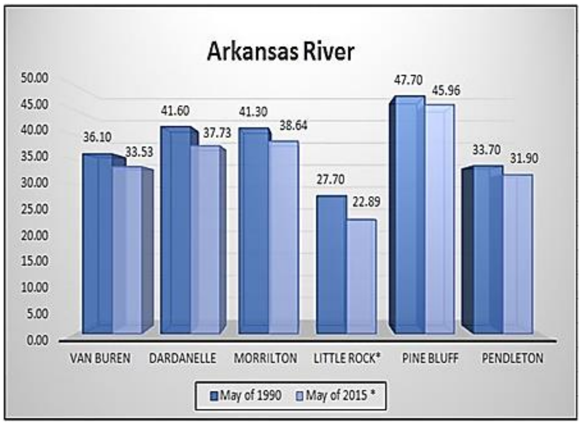


Figure 3. Crest heights of the Arkansas River at select locations

3. COMPARING THE METEROLOGY AND HYDROLOGIC ASPECTS

As mentioned in the previous section, the rainfall amounts and placement between the May of 1990 and May of 2015 events are very similar. Figures 4 and 5 show the rainfall totals for each of the respectively. Over 20 inches of rain fell across the west-central portions of Arkansas during the months of May. While they are indeed similar, there are still a few key differences. Differences were noted in the derivation of the precipitation analyses of the two events. Nearly four times the number of precipitation observations for May of 2015 exist than those of May 1990. There are more observations than ever before due to an increased number of automated reporting stations, such as CoCoRAHs (Community Collaborative Rain, Hail & Snow Network) sites. The increase in precipitation sites led to an increased effort and duration of data quality control.

Another difference between the two events is that more rain fell across portions of northwest Arkansas in May of 1990 versus May of 2015. The opposite is noted for May of 2015, where more rainfall is noted across southwest Arkansas. When we refer back to Figure 1, it can be argued that more rain fell in the Arkansas River hydrologic area in 1990 whereas higher totals were noted in the Red/Little River hydrologic areas (darker red section in Figure 1) in 2015. This could be one reason why the crests were higher in May of 1990.

Given the similarities of the rainfall distribution, it is possible to surmise that the atmospheric patterns would share common features.

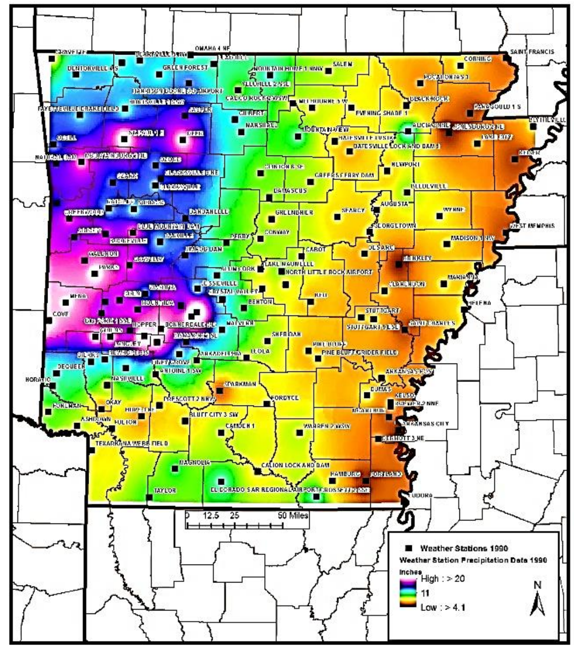


Figure 4. May 1990 Rainfall Totals

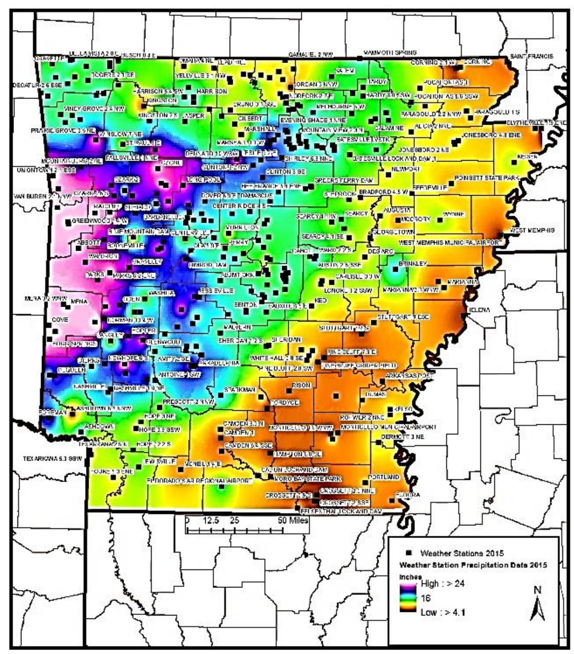


Figure 5. May 2015 Rainfall Totals

This can be done using composite data, and examining anomalies therein. The normalized anomalies for May of 1990 (Figure 6) and May of 2015 (Figure 7) were created by a series of dates on which the majority of the rain fell. As expected, the

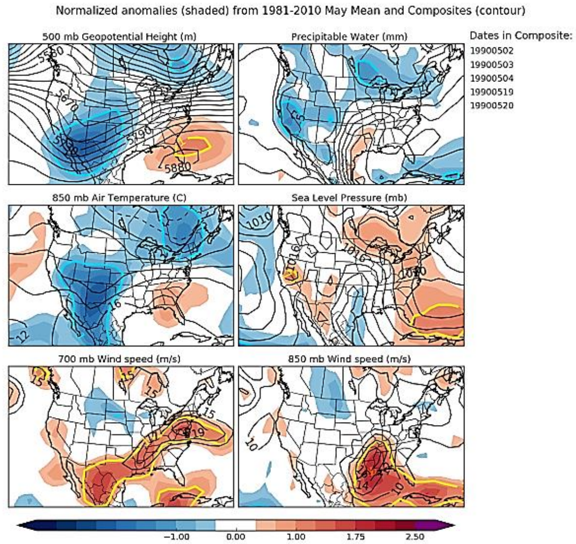


Figure 6. May 1990 Composite Charts

overall patterns have striking similarities especially with regard to the 500 hpa heights (top left corner). Here deep troughing can be seen over the Western CONUS with ascent supported over Arkansas. Also, the upper level flow would indicate that subtropical moisture was being advected from the Pacific Ocean. Another key feature is the 850 hpa low level winds (bottom right corner). For May of 1990, there is well above normal low level winds over the Arkansas which likely served to transport abundant moisture from the Gulf of Mexico. When comparing this to May of 2015, the low level winds are not as strong, however the precipitable water (top right) values are higher.

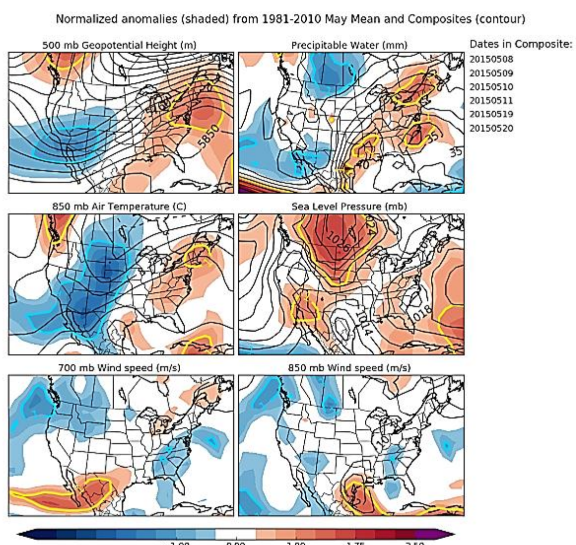


Figure 7. May 2015 Composite Charts

The Palmer Drought Severity Index (PDSI) is useful to analyze some of the soil conditions leading up to these flooding events. The PDSI uses temperature and precipitation data to calculate water supply and demand, and incorporates soil moisture (Palmer 1965). Figure 8 shows the Index's color scale values with white being near normal values to dark green being excessively moist. Starting with January of 1990 and 2015 (Figures 9a and 9b respectively), one can see that the soil moisture values already range from the positive side of near normal to moderately moist. Meanwhile, for 2015, PDSI values are generally in the mid-range category.

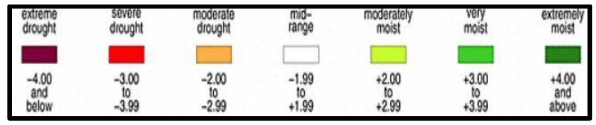


Figure 8. PDSI Color Scale

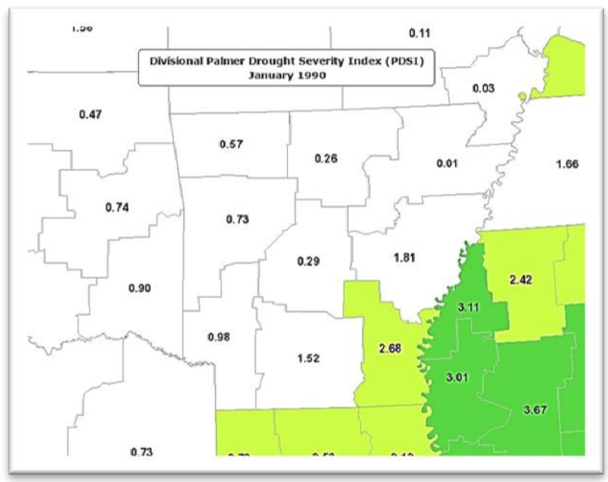


Figure 9a. January 1990 PDSI

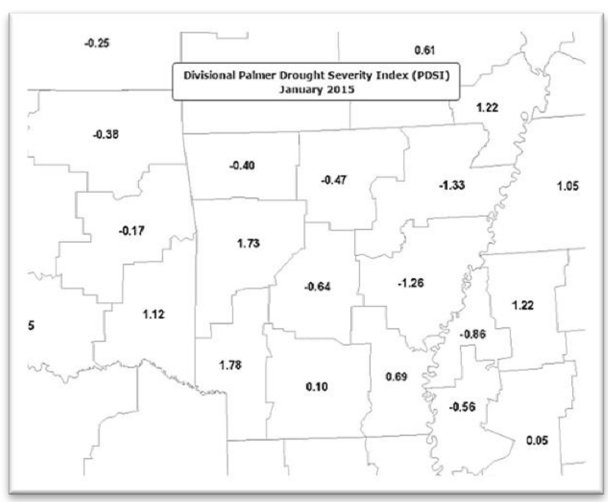


Figure 9b. January 2015 PDSI

By March of 1990, noticeable changes occur in the index values (Figure 10a). There are mostly positive numbers across the climate division zones that cover the western Arkansas River basins, but many are still considered to be in the normal range. However most, of Eastern Oklahoma is now in moderately moist range. For March 2015 (Figure 10b), there has been a shift to more positive values, but the majority of the state remains in the near normal range. The only exception is in southwestern Arkansas.

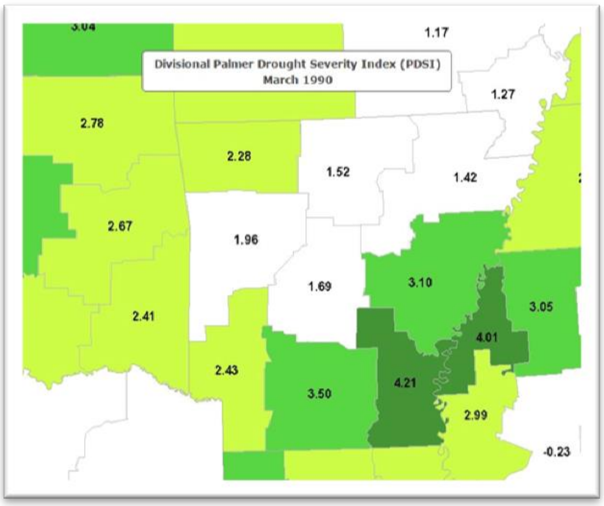


Figure 10a. March 1990 PDSI

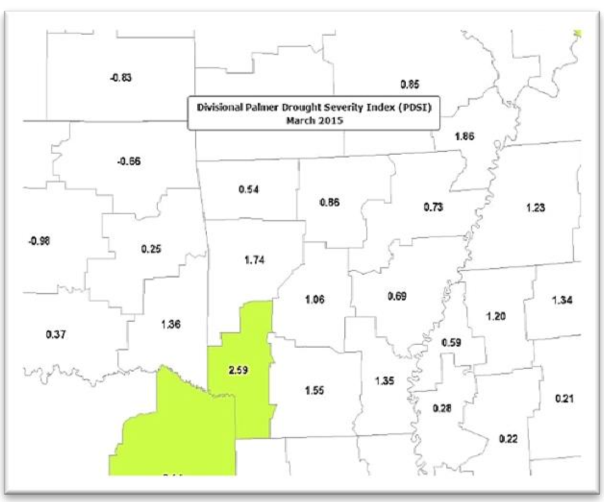


Figure 10b. March 2015 PDSI

Finally, by May of 1990 (Figure 11a), excessively moist conditions with values in excess of >4 have spread across portions of northwest and west-central Arkansas and back into eastern and southeastern Oklahoma. It is important to note that the climate divisions with the highest values correspond to the Arkansas River and tributaries basins. For May of 2015 (Figure 11a), there are near normal values across northeast Oklahoma and northwest Arkansas. Meanwhile, very moist soil conditions are noted across east-central Oklahoma and west-central Arkansas with excessively moist soils across southeast Oklahoma and southwest Arkansas and into the Arklatex region. The most moist climate regions are more centered toward the Red River basins (where significant record-breaking flooding occurred in 2015) and the values are not as high as in 1990. These soil moisture comparisons could help explain why higher crests were noted in 1990 versus 2015.

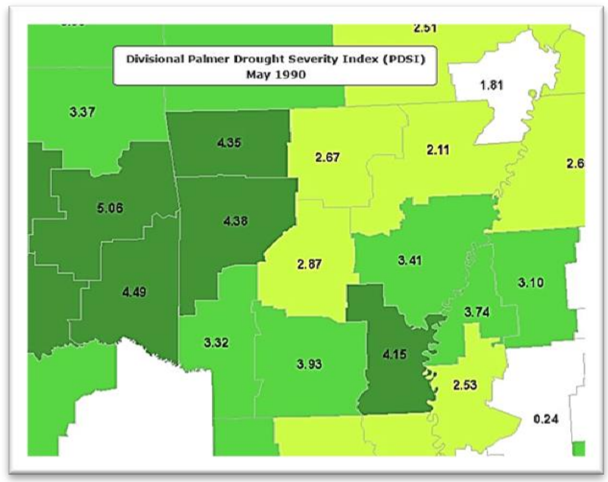


Figure 11a. May 1990 PDSI

Another factor that was examined was the El Niño Southern Oscillation (ENSO) phases for each event. Figure 12 shows a comparison plot of the consecutive overlapping seasons starting in the previous years' October and ending in May for both 1990 and 2015. There are both similarities and differences between the two events. For 1990, ENSO conditions started on the cool side of neutral before trending warm/neutral in the winter and spring. The index then steadied off remaining on the warm side. Conversely, for 2015, the index started on the warm side of ENSO neutral before trending cooler in the winter. Finally, the index trended warm again and eventually into an El Niño as indicated by the red numbering.

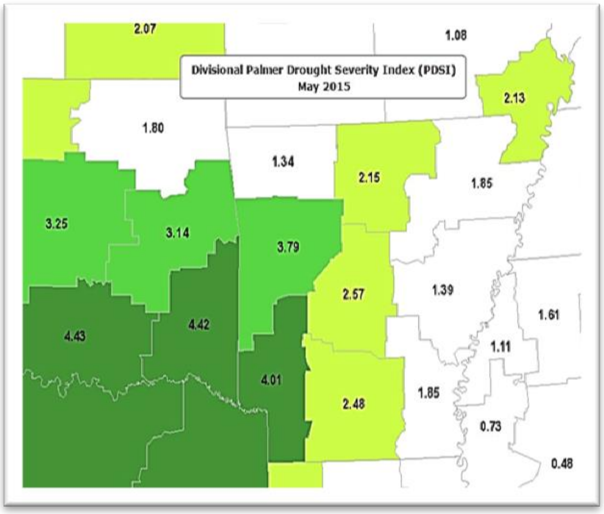


Figure 11b. May 2015 PDSI

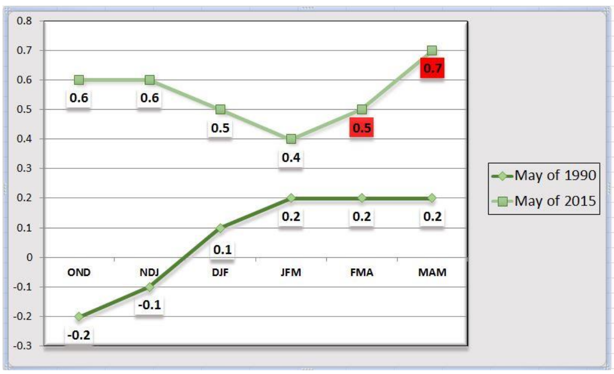


Figure 12. Oceanic Niño Index

Lastly, the overall yearly ENSO patterns were examined. Both 1990 and 2015 had several periods of La Niña followed by ENSO neutral conditions leading up to the flooding events in May. However, 1990 stayed neutral (but on the warm side) until mid-1991 when an El Niño began. Meanwhile, 2015 warmed into an El Niño much faster and is now one the strongest episodes on record.

4. SEVERITY OF IMPACTS

The Arkansas River flooding events of 1990 and 2015 the events produced detrimental impacts to the state. Arkansas is a highly agricultural state with its numerous rivers providing water for irrigation. However, the extreme flooding along the Arkansas River brought devastation to thousands of acres of farmland and to the cities' infrastructures. In 1991, the U. S. Army Corps of Engineers (USACE) conducted a study of the May 1990 flooding. Table 2 shows the estimated dollar amounts of the agricultural losses. In Table 3, data collected by the USDA Risk Management Agency was used to compare estimated

TABLE 2
AGRICULTURAL LOSSES BY RIVER BASIN
(in thousands of Dollars)

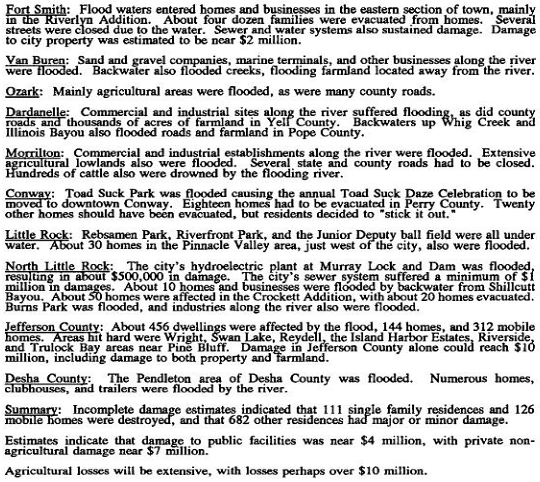
Item	White	Arkansas	Red	Total
Farm Facilities	19	9,029	12,785	21,833
Livestock and Poultry	1	240	1,500	1,741
Crop Losses				
Cotton	125			125
Corn		150	500	650
Hay		245		245
Milo		152		152
Pecans			500	500
Rice	1,548	1,090		2,638
Sorgum	189		500	689
Soybeans	445	125		570
Wheat	5,785	4,159	3,000	12,944
Other	534	1,520		2,054
	8,646	16,710	18,785	44,141

Table 2. May 1990 Agricultural Losses

loss amounts strictly from crops that were lost due to flooding, moist soils/heavy rainfall, and wet and cool conditions. The data includes values from both May and June of each year as the Arkansas River did not finish cresting at a few locations until early in June of 2015. It is important to note that an exact comparison is not possible as several counties that had damages did not distinguish any criteria as to what caused the losses. As such, it is possible that the crop losses could have been greater in 1990 versus 2015. Also, an adjustment has not been made to account for inflation at this time. Finally, in Figure 13, an excerpt from the NWS Storm Data reports for May of 1990 provides a summary of the impacts and monetary losses due to the flooding. It was approximated that total amount of public infrastructural damage was around 4 million dollars or near 7.2 million dollars when adjusting for 2015's inflations rates. In May of 2015, total damages in Jefferson County (Pine Bluff) alone was estimated to be around 5 million dollars. More research is needed to account for total losses in 2015.

Counties Bordering the Arkansas River	Crop Losses reported for May and June 1990	Crop Losses reported for May and June 2015
Crawford	$61,904.00	$341,134.00
Sebastian*	$0.00	$296,259.00
Franklin*	$0.00	$38,255.00
Johnson*	$0.00	$160,149.00
Logan*	$0.00	$110,138.00
Conway	$38,239.00	$559,017.00
Perry*	$0.00	$448,924.00
Faulkner	$158,904.00	$1,178,940.00
Pulaski	$66,777.00	$271,152.00
Jefferson	$382,511.00	$1,279,888.00
Arkansas	$36,360.00	$741,176.00
Lincoln	$89,687.00	$239,572.00
Desha	$240,273.00	$1,008,969.00
Total Losses	$1,074,655.00	$6,673,573.00

Table 3. Crop Loss Comparison



Fort Smith: Flood waters entered homes and businesses in the eastern section of town, mainly in the Riverlyn Addition. About four dozen families were evacuated from homes. Several streets were closed due to the water. Sewer and water systems also sustained damage. Damage to city property was estimated to be near $2 million.

Van Buren: Sand and gravel companies, marine terminals, and other businesses along the river were flooded. Backwater also flooded creeks, flooding farmland located away from the river.

Ozark: Mainly agricultural areas were flooded, as were many county roads.

Dardanelle: Commercial and industrial sites along the river suffered flooding, as did county roads and thousands of acres of farmland in Yell County. Backwaters up Whig Creek and Illinois Bayou also flooded roads and farmland in Pope County.

Morrilton: Commercial and industrial establishments along the river were flooded. Extensive agricultural lowlands also were flooded. Several state and county roads had to be closed. Hundreds of cattle also were drowned by the flooding river.

Conway: Toad Suck Park was flooded causing the annual Toad Suck Daze Celebration to be moved to downtown Conway. Eighteen homes had to be evacuated in Perry County. Twenty other homes should have been evacuated, but residents decided to "stick it out."

Little Rock: Rebsamen Park, Riverfront Park, and the Junior Deputy ball field were all under water. About 30 homes in the Pinnacle Valley area, just west of the city, also were flooded.

North Little Rock: The city's hydroelectric plant at Murray Lock and Dam was flooded, resulting in about $500,000 in damage. The city's sewer system suffered a minimum of $1 million in damages. About 10 homes and businesses were flooded by backwater from Shillcutt Bayou. About 50 homes were affected in the Crockett Addition, with about 20 homes evacuated. Burns Park was flooded, and industries along the river also were flooded.

Jefferson County: About 456 dwellings were affected by the flood, 144 homes, and 312 mobile homes. Areas hit hard were Wright, Swan Lake, Reydell, the Island Harbor Estates, Riverside, and Trulock Bay areas near Pine Bluff. Damage in Jefferson County alone could reach $10 million, including damage to both property and farmland.

Desha County: The Pendleton area of Desha County was flooded. Numerous homes, clubhouses, and trailers were flooded by the river.

Summary: Incomplete damage estimates indicated that 111 single family residences and 126 mobile homes were destroyed, and that 682 other residences had major or minor damage.

Estimates indicate that damage to public facilities was near $4 million, with private non-agricultural damage near $7 million.

Agricultural losses will be extensive, with losses perhaps over $10 million.

Figure 13. National Climatic Data Center Storm Data entry from May 1990

5. IMPACT-BASED DECISION SUPPORT SERVICES: MAY OF 2015 EVENT

Another key difference between the two events comes in the form of Impact-Based Decision Support Services or IDSS. In the spring of 1990, a significant portion of the technology to support operational meteorology, and associated decision support that is used today did not exist. Even routine email briefings to emergency managers and other partners were unheard of. However, over the last decade, email briefings, webinars, and in-person briefings have become a standard practice. During the May 2015 flood event, NWS Little Rock (LZK) staff members provided daily webinar briefings at the office Arkansas Department of Emergency Management (ADEM). Coordinated collaboration calls were organized by WFO LZK between county-level emergency managers, the River Forecast Centers, USACE, and the U.S. Geological Service (USGS) to discuss contingency forecasts and possible impacts. Figure 14 show a briefing slide of the forecasted crest at Pine Bluff along with the potential impacts and historic crests for context.

With the advent of the social media era, such as Facebook, Twitter (Figure 15), and Instagram, the National Weather Service in Little Rock was able to quickly post or tweet messages and graphicasts concerning the flooding dangers. This near-constant form of communication allowed for hundreds of individuals to receive the most current information and to "share" the posts with others. By doing so, thousands more individuals were reached and made aware of the high-impact event.

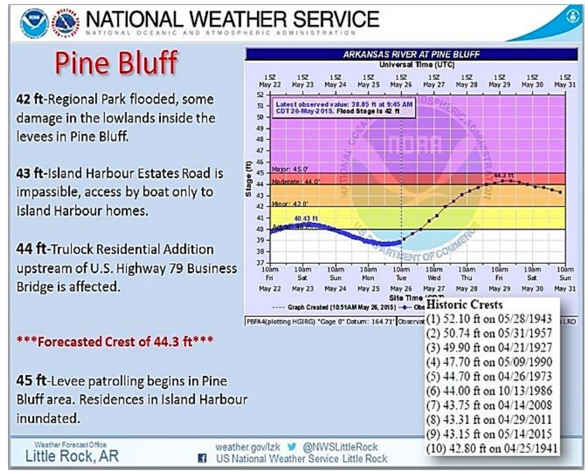


Figure 14. Briefing slide used by WFO LZK briefing to ADEM

6. SUMMARY AND CONCLUSIONS

The flooding events of May of 1990 and May of 2015 included several commonalties. Both years experienced excessive rainfall over portions of the Arkansas River basins in Western Arkansas on the of more than 20 inches and record-breaking flooding as a result. It can be concluded that the amounts and placement of the rainfall mostly had the greatest influence during the events

Normalized anomalies created from composite data have shown the similarities and differences between the two events with regard to the overall synoptic pattern and moisture advection. May of 1990 had greater low level moisture advection across the region and a lower value of standard deviation for the 500 hpa trough. This may indicate that the storm systems in May of 1990 were more robust or possibly generated higher rainfall rates leading to more runoff. This theory could be supported in part by the examination of soil moisture. Analysis of the 1990s' PDSI shows that the soils became saturated more quickly leading up the actual flooding in May. The antecedent saturated soil conditions would allow for greater runoff and, therefore, higher crests. However, it should be noted that the greatest values of the PDSI for May of 1990 are located across northwest and west-central Arkansas versus May of 2015 where west-central and southwest Arkansas had the highest values of the PDSI. This slight difference in placement could also explain why the crests in 2015 were lower. Lastly, there were some similarities and differences between the ENSO phases, however no significant conclusion can be drawn until more of a pattern can be determined.

It was also shown that significant progress has been made in the areas of Impact Decision Support Services (IDSS). Compared to 1990, there are many more communication tools at the disposal of the Nation Weather Service to support their partners.

7. FUTURE WORK

Additional research on the May 1990 and 2015 flooding events will include a closer examination of the effects of ENSO as well as determine if there is an North Atlantic Oscillation (NAO) or Pacific Decadal Oscillation (PDO) teleconnection. Given that the head waters of the Arkansas River originate in The Rocky Mountains and that rainfall amounts over Eastern Oklahoma highly influence river levels downstream, it is possible that a closer examination of these factors could yield assistance in forecasting river crests for future events. Furthermore, so called "atmospheric rivers" or corridors of upper level moisture have been known to aid the creation of efficient rainfall producing storm systems. Early detection of these atmospheric features could provide better precipitation forecasts and increase lead time for river flood warnings.

Since the research on these two flooding events began, another record-breaking rainfall and Arkansas River flooding event occurred. In December of 2015, water levels along the Arkansas River rose to higher levels than those that occurred in May of 2015. A similar event took place in December and early January of 1982. Perhaps by comparing these two December events with one another and with the May events a better understanding of the meteorological and hydrological characteristics can be attained.

8. ACKNOWLEDGEMENTS

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