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Application of Regional PMP Techniques to East Valley FRS Rehabilitation Program

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Purpose

The rehabilitation costs of many NRCS earthen flood control dams or flood retarding structures (FRS) located within Arizona have been impacted by the economics of cost dictated by the higher Probable Maximum Precipitation (PMP) values obtained for many locations using Hydro-Meteorological Report(HMR)-49. The cost considerations are balanced by needs to maintain public safety in areas downstream of the FRS. An alternative to using the HMR-49 PMP values is the application of Regional PMP (RPMP) or Site Specific PMP (SSPMP) techniques. The HMR PMP values are derived from application of general procedures outlined in the HMR. RPMP and SSPMP are storm-based with basin-specific calculations.

The five FRS considered for the East Valley RPMP study are Powerline, Vineyard Road, Rittenhouse, Magma and Florence FRS located about 35 miles southeast of Phoenix, Arizona. These structures were designed and constructed in the early 1960's. The FRS are in various stages of assessment or planning by NRCS. The five FRS being assessed are shown in **Figure1.** Note the braided network of streams that generally flow from the east-northeast to the west-southwest off slightly higher terrain to the east.

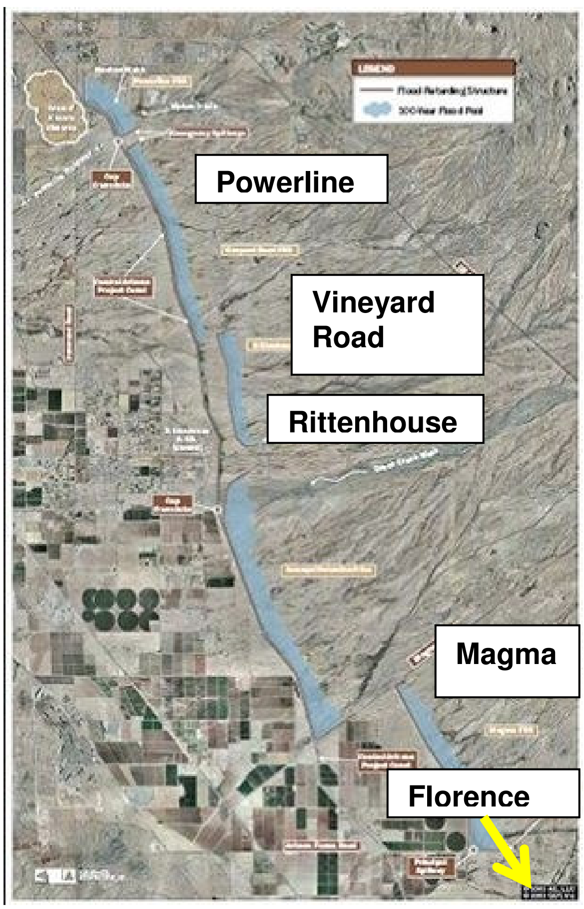


Figure 1 East Valley FRS

Public safety and Local Storm Flash Flooding

Arizona is noted as a state with a high frequency of flash flooding and floods despite its semi-arid to desert climate (Osterkamp and Friedman, 2000). However, individual basins experience flash floods on an infrequent basis. Most of the flooding events occur during the summer monsoon season. Thus it is quite likely that many FRS can go for months and even years without being impacted by a flash flooding event.

Immediately west of the five FRS is a steadily increasing population, fertile growing areas and important public transportation roads. Thus public safety issues caused by flooding or flash flooding are important considerations in the rehabilitation of the five FRS.

Three primary causes of flooding and flash flooding exist in Arizona according to Hales, 1974 and Maddox et al, 1995:

1. Short-duration, high intensity thunderstorms during the monsoon season from July to September.
2. Passage of decaying sub-tropical storms or hurricanes during August to November.
3. Passage of general storms from the Pacific Ocean from December to March.

The daily distribution of flash flooding events shown in HMR-49 and the NOAA publication, ***Storm Data***, is shown in **Figure 2**. This distribution follows closely the referenced articles on flash flood occurrence. The maximum number of extreme precipitation events occurs from June to September with a secondary general storm maximum from December to March. August 28 is the day with the highest occurrence of flash flood events. Extreme precipitation is identified as a precipitation event that has a 100-yr (once every 100 years) frequency or more (Osterkamp and Friedman, 2000). Review of the causes of these events includes both local thunderstorm produced flash floods and general storm flood events caused by the passage of sub-tropical disturbances and winter Pacific storm systems. HMR-50 defines a general-storm as “a storm that produces significant precipitation over at least several hundred square miles and lasts at least a day”.

Figure 2 Number of extreme precipitation events by day of year in Arizona from 1860 – 2005 as listed in HMR-49 and NOAA Storm Data.

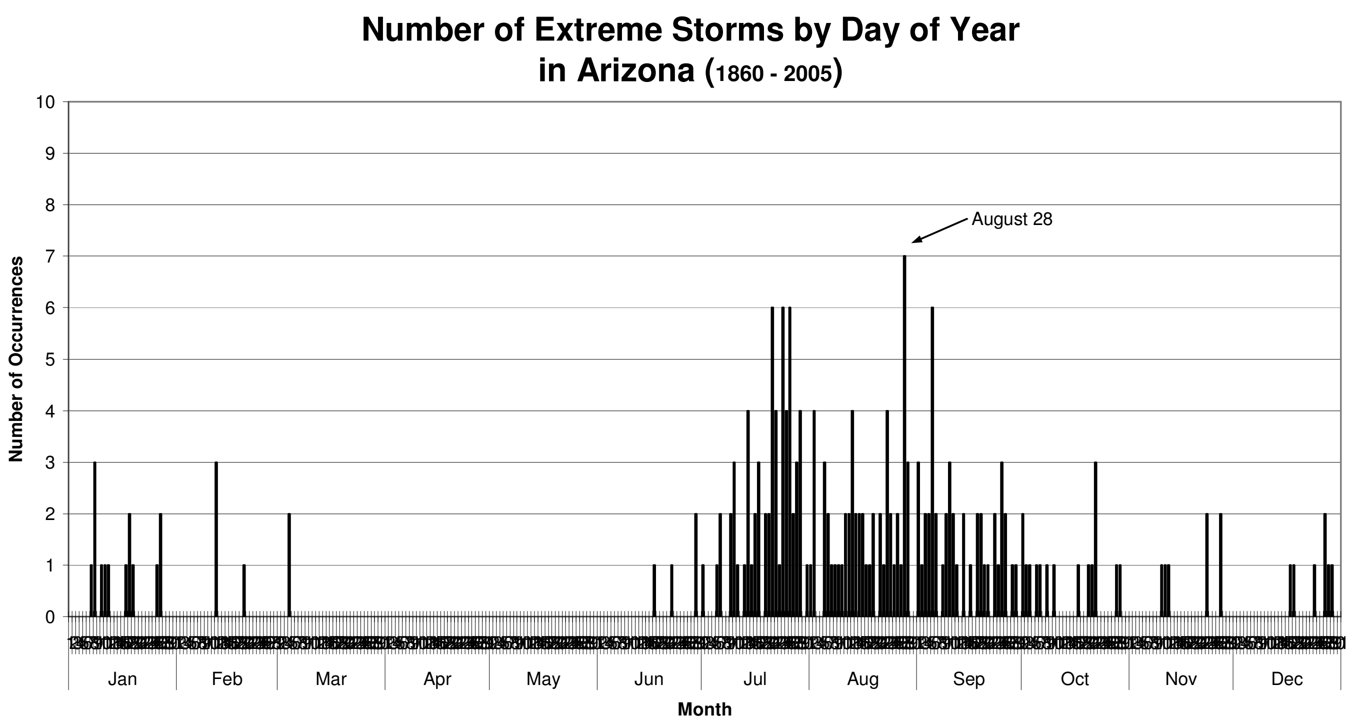


Figure 3 shows the location of 114 extreme precipitation events evaluated for the East Valley FRS using extreme precipitation data developed for the Safford, Graveyard and Frye FRS RPMP study (Henz, 2006).

Figure 3 Extreme precipitation events impacting the FRS watersheds extracted from the Safford, Graveyard, Frye FRS RPMP study (Henz, 2006).

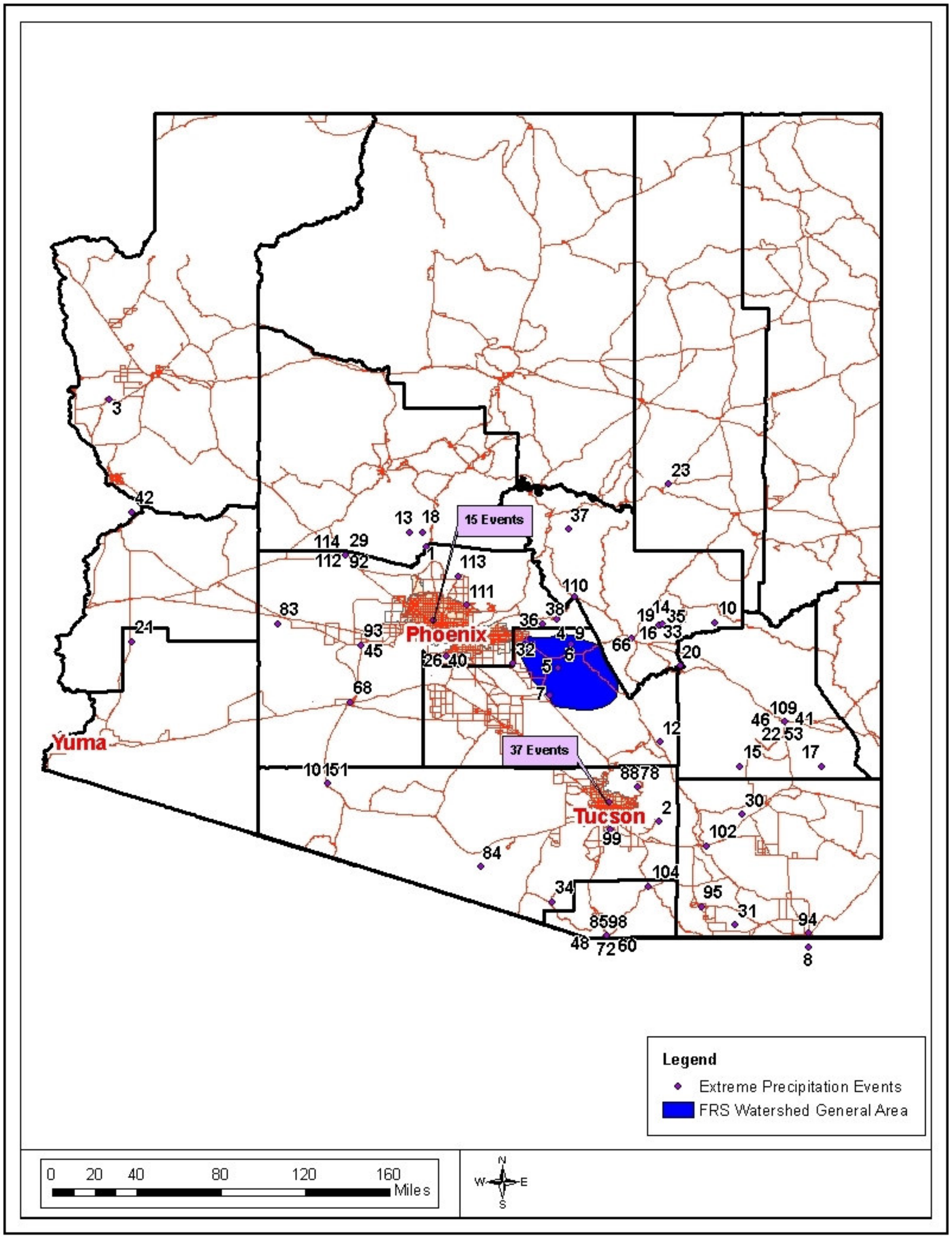
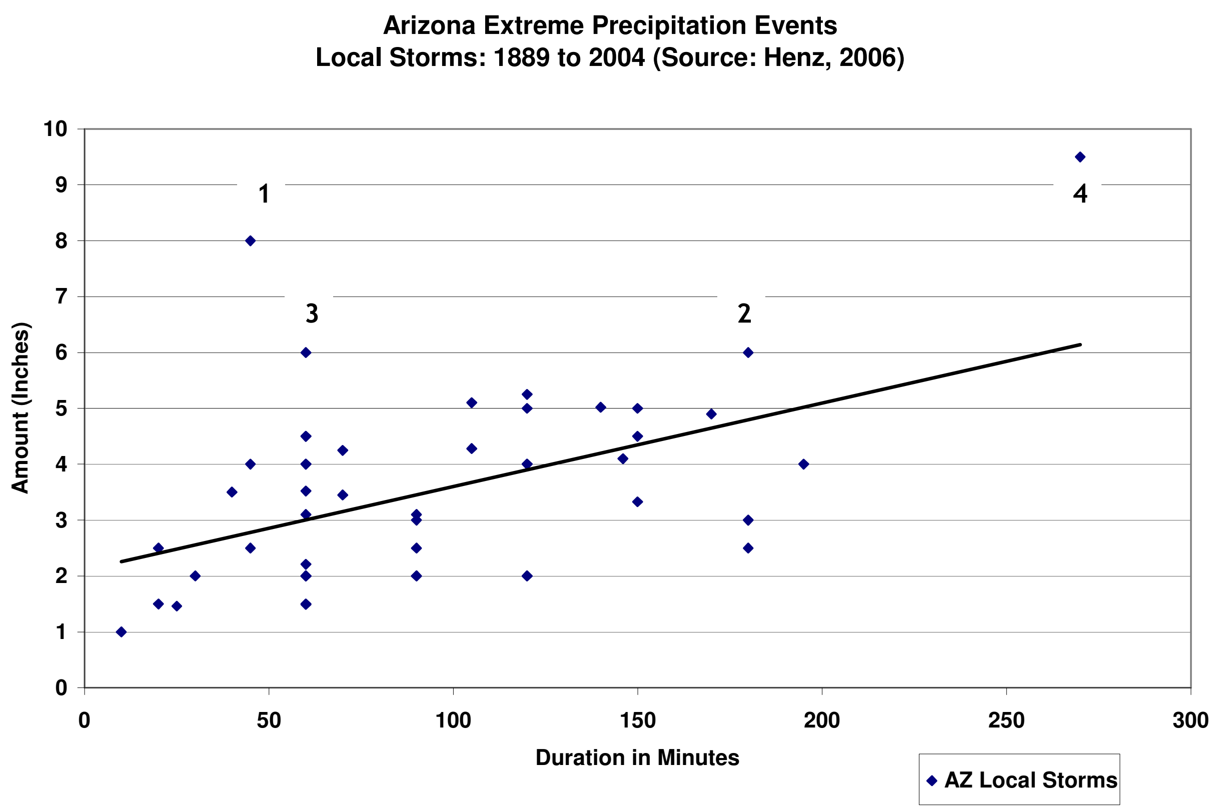


Figure 4 shows a plot of the duration of local storm extreme precipitation events compared to the observed duration of the event. The events plot in a relatively organized manner except for four events of six inches or more. The four events are:

1. Fort Mohave, August 28, 1891: 8.00 inches/45 minutes
2. Welton 15 WSW, August 23, 1955: 6.00 inches /3 hours
3. West Pima County, August 28, 1997: 6.00 inches/60 minutes
4. Roosevelt Lakes, September 9, 2003: 9.5 inches/4.5 hours

Figure 4 Arizona Extreme Local Storm Precipitation Events, 1889 - 2004



Three of these events demand a more detailed evaluation since they are based on estimated observations of rainfall. The amount of precipitation is especially suspect for the Fort Mohave observation where 8.00 inches in 45 minutes was estimated from a water trough. A review of the historical newspapers may shed more light on this event.

In the case of the West Pima County event (6.00 inches/60 min), the amount of precipitation is probably close to the observed value. However, the temporal distribution of the rain event should carefully be evaluated using radar and other weather observations. A more detailed analysis of this event should be done as part of any East Valley FRS RPMP study.

Finally, the recent Roosevelt Lakes rainfall and flooding event is an exceptional event. The rainfall was reported as 10.00 inches overnight. HDR accomplished a radar-rainfall reconstruction and estimated that 9.50 inches fell in a 4.5 hour period (Henz, 2006). The areal coverage of the heavy precipitation region of six inches or more was less than 50 square miles in three separate areas. This event warrants further evaluation and a detailed comparison with surface rainfall network observations and radar estimates of the rainfall. Over 200 homes were flooded downstream which underlines the public safety issues.

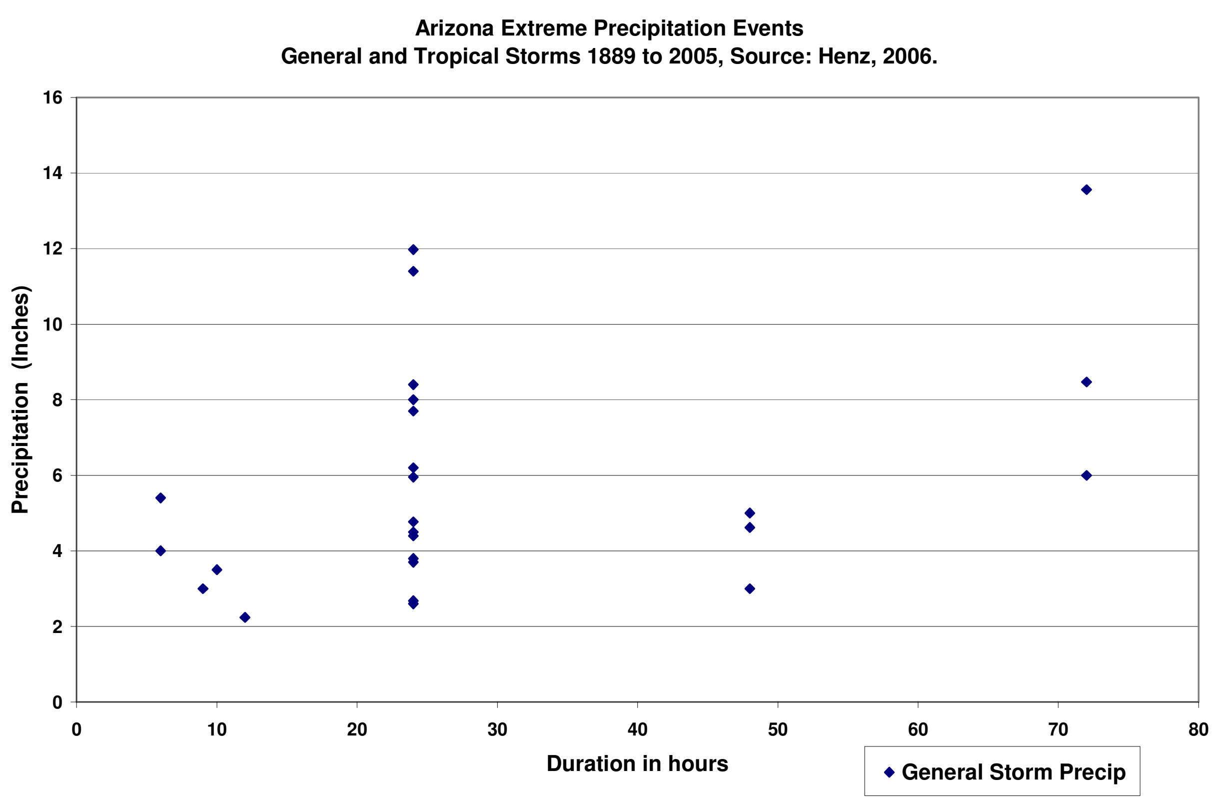
Public safety and General Storm Flooding

The impact on public safety by flooding caused by general storms has been quite significant in Arizona. As recently as January to March of 2005 a series of Pacific storm systems set up a conveyor belt of precipitation that brought flooding to major river systems in northern and central Arizona. Most of this flooding was confined to mountainous areas and downstream floodplains of the major rivers.

Serious flooding was most pronounced after the early 1993 storms caused by a strong El Nino storm track. General storms play a significant role in the evaluation of the flooding potential that could impact a FRS or floodplain.

General storm extreme precipitation events that should be evaluated for the East Valley FRS watersheds are shown in **Figure 5**. The "stacked" set of observations that appears over the over the 24-hour, 48-hour and 72-hour time periods are due to availability of observations noted for these time periods in the available storm reports.

Figure 5 Arizona Extreme General Storm Precipitation Events, 1889 - 2004



From the plot it appears that two classes of events exist that are based on the duration of the precipitation event:

1. General storms that produce 3-12 inches of precipitation in 24 hours or less, and

2. General storms that produce 3-14 inches of precipitation in 48-72 hours.

Given that the storm total precipitation amounts appear to be almost the same, it is likely that the rainfall from the events of less than or equal to 24-hours in duration produce the most stressing precipitation. These storms will be evaluated for this East Valley FRS PMP evaluation. These events were well observed by ground based rain gage networks.

The three general storm events that exceeded nine inches in 24 hours or more are listed below:

1. Casa Grande Ruins (1,400 ft), August 1-2, 1906, 9.10 inches/24 hours,
2. Workman Creek (7100 ft), September 4-5, 1970, 11.4 inches/24 hours
3. Harquahala Peak (5,681 ft), August 24-25, 1997, 11.97 inches/24 hours (state 24-hr record)

All three events were associated with decaying tropical storms or hurricanes that crossed Arizona. The measurement of these extreme events was reasonably well observed by surface rain gage networks. The Harquahala Peak and the Workman Creek locations do not appear to be transposable to the FRS watersheds because of topographic effects that could not be transferred to watershed. However, both events will be included in this evaluation for comparison purposes.

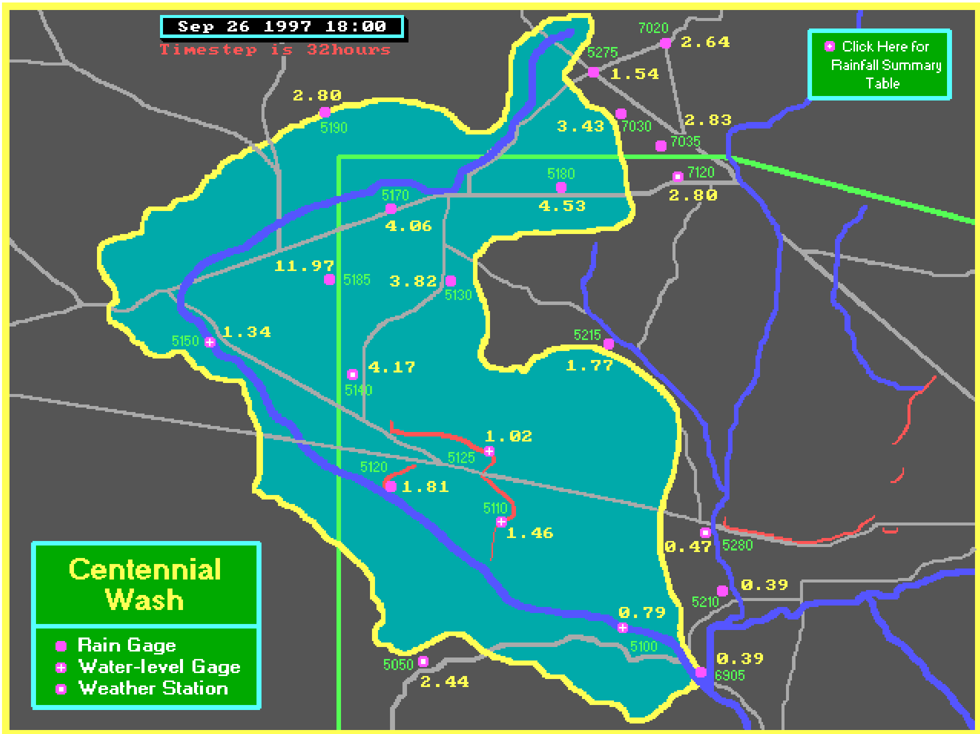
The highly localized aspect of the Harquahala Peak event is obvious in **Figure 6**. Note that this event was caused by the passage of rain bands associated with decaying Hurricane Nora as it crossed the state. The rain bands interacted with the terrain and strong low level winds of more than 25 mph to produce the heavy rains. A similar process created the Workman rain event in 1970 with the passage of decaying Hurricane Norma.

The precipitation data shown in **Figure 6** was obtained from the Flood Control District of Maricopa County (FCDMC) web site where a historical listing of county precipitation events is maintained. It is important to note that the precipitation measured at Harquahala Peak (11.97in) is almost three times as much as was observed at Gage #5140 (4.17 in) and Gage # 5170 (4.06 in). The impact of the terrain appears to be quite localized to the terrain feature within the basin.

A GIS estimation of the observed rainfall in Centennial Wash shows that 24-hour rainfall of 3.00 inches or more covered just less than 40 percent of the basin. The area of the basin estimated to be covered by 8.00 inches or more precipitation was about 7 percent and the area covered by 10 inches or more was about 2 percent. These values suggest that, in this case, the orographic effects of the rainfall affected only a very small part of the basin.

This point is brought up only to establish a benchmark that will be re-visited during the RPMP evaluation for the five FRS structures. Use of standard HMR-49 areal reduction techniques provides a very conservative over-estimate of the basin impacts of the peak point precipitation value.

Figure 6 **Harquahala Peak precipitation event rain as measured in the FCDMC rain gage network.**



What is HMR-49 Probable Maximum Precipitation (PMP)?

In order to understand the impacts of PMP on the project, a brief review of PMP is presented. The HMR-49 (1977) definition of PMP is:

> *"the **theoretically** greatest depth of precipitation for a given **duration** that is **physically possible** over a **particular drainage basin** at a particular time of year".*

This PMP definition has been superseded in subsequent HMR's. The most recent re-definition of Probable Maximum Precipitation (**PMP)** is given in HMR 55A (1988) as:

> *"**theoretically,*** the greatest depth of precipitation for a given **duration** that is ***physically possible*** over a ***given storm area*** at a *particular geographic* ***location*** at a *certain* ***time*** *of year".*

The estimation of PMP as described in HMR-49 identifies two primary types of storms: general-storms and local-storms. HMR-50, a companion document, provides examples and definitions of both the local and general storms of interest. HMR-50 defines a general-storm as "a storm that produces significant precipitation over at least several hundred square miles and lasts at least a day". Normally the general-storm takes either an extra-tropical or sub-tropical storm form.

HMR-50 defines a local-storm as "a period of unusually heavy rains exceeding 3.00" in 3 hours or less, that are reasonably isolated from surrounding rains and these rains are usually not associated with any organized meteorological system". Different methodologies are used to calculate PMP for general and local-storms in HMR-49.

The HMR-49 general-storm PMP considers two primary components:

1. **Non-orographic or convergence PMP** is due to atmospheric processes. It is based on moisture-maximized rainfalls of record that are adjusted for elevation changes and mountain barriers. Envelopment of regional maximized precipitation events can be used to establish an enveloped general-storm PMP curve.

2. **Orographic PMP** is precipitation produced by the forced ascent of moisture air over a topographic barrier and is considered when the moisture air encounters "*first upslopes".* The orographic component of an event is closely tied to the terrain impacts of the specific location.

3. The HMR **general-storm PMP** is the sum of the adjusted convergence PMP and orographic PMP.

The HMR-49 local-storm PMP considers three primary components:

1. The most intense local-storm values are moisture maximized and used to develop a maximized 1-hr, 1sq mi PMP.

2. Maps of the 1-hr, 1sq mi PMP were created that took into account *maximum 1-hr recorded rainfalls and broad-scale terrain features*.

3. The 1-hr PMP values are *modified for depth-duration and depth-area adjustments* based on historical record storms.

HMR-49 describes these PMP processes and modifications in considerable detail. After both the general-storm PMP and local-storm PMP are calculated, the PMP values are used to compute runoff impacts within the basin to determine the Probable Maximum Flood (PMF) that can be contained safely by the FRS.

The design values of PMP for the Magma FRS were calculated by the SCS and determined to be 10.4 inches for the 6-hr local storm and 17.9 inches for the 72-hr general storm in August. However, it is estimated that the HMR PMP values for the other four FRS are likely within 10 percent of these values and will be used as the baseline in this study due to its limited scope.

NOAA Atlas II was recently updated by NOAA Atlas 14 (2004) using an updated set of precipitation observations from the past 25 years. HMR 49 was originally written in 1977 and re-printed in 1984. A companion document, HMR-50, was published in 1981 and describes the meteorology of the important precipitation events that have occurred in the Colorado River and Great Basin drainages. These documents have provided the primary methodology for the estimation of PMP within Arizona, including the five FRS referenced in this paper.

The HMR PMP calculations are based on a general "broad-brush" approach to estimating the PMP values over areas the size of states. HMR-49 provides PMP-plates and calculation sheets to provide estimates of the PMP values for any basin in Arizona. Both the initial temporal distribution and areal reduction of HMR PMP's were based heavily on values used in NOAA II, Volume VIII. Both of these distributions were based almost exclusively on storm data gathered east of the Mississippi River.

Some modification of the temporal distributions of the PMP was offered by Arkell and Richards (1989) and recently by NOAA Atlas 14, Volume 2 which used data observed in the Western United States. The areal reduction factors used in HMR-49 and NOAA Atlas II are based on storm data from the eastern United States. The NOAA 14 areal reduction factor study has not been released for use.

Regional and Site-Specific PMP studies offer an alternative

An alternative to the HMR-based PMP values used for design are either site-specific PMP (SSPMP) or regional PMP (RPMP) studies. In contrast to HMR-derived PMP calculations, SSPMP and RPMP are both storm-based and basin-specific in their calculation of PMP. A SSPMP study focuses on calculating PMP for a specific basin. A RPMP focuses on calculating PMP for a series of smaller basins with similar terrain and climate characteristics.
Both SSPMP and RPMP studies have been successfully implemented in FRS rehabilitation projects in New England, Upper Mid-West, Montana, Wyoming, Colorado, Utah, New Mexico, Arizona and California for the past twenty years. Application of SSPMP and RPMP has been minimal in Arizona to date with only two studies sent to the Arizona Department of Water Resources (ADWR) for review.

A site-specific PMP (SSPMP) was accomplished for the evaluation of the Lynx Lake FRS and its basin in the mountains southeast of Prescott for George Sabol Consulting Engineers in 1994 (Henz, 1994). This SSPMP reduced HMR values by 15-20 percent for the local storm PMP and 20-25 percent for the general storm PMP below the HMR values. The SSPMP was accepted by ADWR in 1995. Since this study was completed, ADWR added a requirement for a peer review of SSPMP and RPMP studies before acceptance will be considered.

In 2005 a draft Regional PMP (RPMP) was completed for three basins near Safford, Arizona (HDR, 2006): the Stockton, Frye Creek and Graveyard basins (referred to as SGF RPMP). These basins are located along the eastern slopes of the Coronado National Forest and Pinaleno Mountains with Mt. Graham towering 10,542 ft as the prominent peak. The SGF RPMP study calculated a 16-24 percent drop in the local storm PMP values and a 28-33 percent drop in the general storm PMP values. This study is currently undergoing peer review but indicates the opportunity for PMP reductions from HMR values, especially for basins with significant elevation changes.

Can a RPMP benefit the FRS watershed PMP calculations?

This white paper will provide a preliminary evaluation of the application of RPMP techniques to the five East Valley FRS basins identified earlier in this paper. Since this is only a white paper evaluation as opposed to a detailed RPMP study, the results should be considered preliminary in nature. It can only provide an estimate of possible changes in the HMR-49 PMP values that could develop by completing a RPMP study on the five FRS watersheds. An overview of the five basins' characteristics and a preliminary estimate of possible changes in the HMR PMP compared to the RPMP will be presented.

In general, six RPMP calculation steps are followed in RPMP studies after the historical storm search is completed and the storms identified for direct analyses. The steps are listed along with an estimated range of change in the HMR PMP values:

1. **Seasonal adjustment**: typically the date of the extreme precipitation event is moved 15 days towards the warmer time of year to make adjustments for a possible related increase in moisture available to the event. This adjustment adds 5 to 10 percent to the observed precipitation.

2. **In-place moisture maximization**: The in-place maximization takes into account the lowering of the event to 1000mb and a re-calculation of this impact on the 1000mb 12-hr persisting dew point. Normally, in-place maximization produces an increase of 5 to 25 percent in the observed event.

3. **Transposition adjustment**: a comparison is made of the maximum 1000mb dew point for the season at both the location of the extreme precipitation event and the location of the basin to which the event will be transposed. Typically, this adjustment can produce from a 5 percent decrease to a 15 percent increase in the precipitation value.

4. **Elevation-Adjusted Maximized Precipitation:** The average elevation of the five basins is less than 2,500 feet. Elevation adjustment of local storm events for basin elevations less than 6,000 feet is not recommended. General storm PMP could be reduced/**increased** by 9 percent per 1,000ft of increased/**lowered** elevation based on event transposition.

5. **Areal Reduction of Local and General-storm Precipitation:** HMR 49's Figure 4.9 (p. 123) is used to determine the areal reduction factor of local storm events. General-storm precipitation is areal reduced using Figure 3.20 (p 89) in HMR-49. These reductions will be on the order of a 5-30 percent decrease in the HMR-49 PMP for local storms and 2-10 percent decrease for the general storm based on FRS basin size.

6. **Orographic adjustments to the maximized precipitation pattern**: The impacts of barrier depletion of the transposed and maximized precipitation patterns will be minimal. However, the lack of topography will eliminate the transposition of some storms into the basin because of meteorological considerations such as event inflow winds and storm-steering winds.

This white paper will rely on the storm event evaluations that were prepared as part of the SGF RPMP study though some original calculations were prepared to assist in the evaluation. This white paper will use each of these six steps to provide a coherent evaluation of the potential impacts of RPMP on the East Valley basins.

HDR identified five local and three general storms form the SGF RPMP that provide a very representative sample of the extreme precipitation events that hazard the East Valley FRS. The storms are identified in **Tables 1 and 2** with in-place moisture maximization values determined in the SGF RPMP study after its review by NRCS and Kimley-Horn & Asscoiates (K-H). A detailed RPMP study may identify other storms as the controlling events but that is beyond the scope of this paper.

The local storms and their seasonally adjusted, in-place moisture maximizations, as calculated in the peer reviewed SGF RPMP study update are listed in **Table 1**.

Table 1 In-place moisture maximization for key local-storm events

LOCAL-STORMS								
Event Number, Name Date	**Event Inches/ minute**	**Event Persisting Td (F)**	**Elevation**	**12-hr Persisting 1000mb Td (F)**	**Event Season Max Td (F)**	**PWI in inches Max/Event**	**Max Factor**	**P-max Inches**
#2 Ft. Mohave 8/28/1891	8.00/45min	71	540	72	77	314/247	1.27	10.16/45min
#7 Welton 8/23/1955	6.00/180min	70	2800	76	78	329/290	1.13	6.78/180min
#8 Phoenix 6/22/1972	5.25/120min	65	1120	67	75	285/195	1.46	7.67/120min
#9 Sabino Canyon 7/15/1999	7.50/360min	57	6500	72	79	344/247	1.39	10.43/360min
#10 Roosevelt Lakes 9/09/2003	9.50/270min	60	4500	70	76	299/225	1.33	12.64/270min

The general storms and their in-place, seasonally adjusted moisture maximization, as calculated in the SGF RPMP study, are listed in **Table 2**. These values represent the ones determined as part of the SGF peer review process. These values appear in the final report of the SGF RPMP study.

Table 2 In-place moisture maximization for key general-storm events

GENERAL-STORMS								
Date	**Event Inches**	**Event Persisting Td (F)**	**Elevation Feet**	**12-hr 1000mb - Td (F)**	**Event Season Max Td (F)**	**PWI Max /Event**	**Max Factor**	**P Max Inches**
#11 Casa Grande Ruins 8/1-2/1906	9.10/ 24 hr	68	1400	71	74.5	273/236	1.16	10.56
#16 Workman Creek 9/4-5/1970	11.4/ 24hr	51	7100	68	73	260/205	1.27	14.48
#17 Harquahala Peak 9/24-25/1997	11.97/ 24 hr	55	5681	69	71.0	236/214	1.10	13.17

All storms will be transposed along with the most likely transposition candidates into the five FRS basins. The non-highlighted storms are included only to provide a comparison to other key storms that occurred in the region. The Workman Creek (Case # 16) and the Harquahala Peak (Case #17) events are the products of strong topographic influence with an accompanying set of atmospheric structure variables that may preclude the transposition of the event into the FRS watersheds in a RPMP. However, for comparison purposes in this paper, they will be transposed along with the other events.

Table 3 shows the transposition factor calculation for each event that relies on a comparison of the maximum seasonal 1000mb event dew point and the maximum seasonal 1000mb dew point for the East Valley FRS location using the monthly dew point maps in HMR-49 and HMR-50.

Table 3 Seasonal transposition factors for key local and general-storm events

Events	a	b	c	d		e
Local storms	Event Season Max 1000 mb Td (F)	PWI in inches Event Max	Seasonal Max 1000mb Td (F)	PWI in inches Seasonal Max	d/b = e	Transposition Factor
#2 Ft. Mohave	77	3.14	78.5	3.38	3.38/3.14	1.08
#7 Welton	78	3.29	78.5	3.38	3.38/3.29	1.03
#8 Phoenix	75	2.85	75.5	2.93	2.93/2.85	1.03
#9 Sabino Canyon	79	3.44	78.5	3.38	3.38/3.44	0.98
#10 Roosevelt Lakes	76	2.99	76.5	3.05	3.05/2.99	1.02
General storms						
#11 Casa Grande Ruins	74.5	2.73	76.5	3.05	3.05/2.73	1.12
#16 Workman Creek	73	2.60	74.5	2.80	2.80/2.60	1.08
#17 Harquahala Peak	71.0	2.36	73.0	2.60	2.60/2.36	1.10

Table 4 shows the calculation for the in-place event maximization for each event and the application of the transposition factor from **Table 3** to create an event precipitation value that is explicitly in-place maximized and seasonally and transposition adjusted for location. **Table 5** applies an areal adjustment to each of the event P-Max values in **Table 4** for the different East Valley basins using Figure 4.9 (local storms) and Figure 3.20 (general storms) in HMR-49. It should be noted that each of the areal adjustments depends on both basin size and event duration as used in Figure 4.9 to determine the appropriate areal reduction.

Table 4 Seasonally adjusted, in-place maximized and transposed key local and general storm events to the East Valley FRS location

Events	a	b	c	d	e
Local storms	Event Inches/ minute	Max Factor	P-max Inches	Transposition Factor	Transposed P-Max inches
#2 Ft. Mohave	8.00/45min	1.27	10.16/45min	1.08	10.97
#7 Welton	6.00/180min	1.13	6.78/180min	1.03	6.98
#8 Phoenix	5.25/120min	1.46	7.67/120min	1.03	7.90
#9 Sabino Canyon	7.50/360min	1.39	10.43/360min	0.98	10.22
#10 Roosevelt Lakes	9.50/270min	1.33	12.64/270min	1.02	12.89
General storms	Inches/hour				
#11 Casa Grande Ruins	9.10/ 24 hr	1.16	10.56	1.12	11.83
#16 Workman Creek	11.4/ 24hr	1.27	14.48	1.08	15.64
#17 Harquahala Peak	11.97/ 24 hr	1.10	13.17	1.10	14.50

Table 5 Areal precipitation adjustment from Figure 4.9 in HMR-49 (local storms) and Figure 3.20 in HMR-49 (general storms) for the East Valley basins for key local and general-storm events

Events	a	P	V	R	M	F
Local storms	**Transposed P-Max inches**	**Areal adjustment factor (a x P)**	**Areal adjustment factor (a x V)**	**Areal adjustment factor (a x R)**	**Areal adjustment factor (a x M)**	**Areal adjustment factor (a x F)**
#2 Ft. Mohave	10.97	0.58 (6.36)	0.55 (6.03)	0.55 (6.03)	0.52 (5.70)	0.56 (6.14)
#7 Welton	6.98	0.69 (4.82)	0.66 (4.61)	0.66 (4.61)	0.63 (4.40)	0.67 (4.68)
#8 Phoenix	7.90	0.66 (5.21)	0.63 (4.98)	0.63 (4.98)	0.60 (4.74)	0.64 (5.06)
#9 Sabino Canyon	10.22	0.75 (7.67)	0.72 (7.36)	0.72 (7.36)	0.69 (7.05)	0.73 (7.46)
#10 Roosevelt Lakes	12.89	0.71 (9.15)	0.68 (8.76)	0.68 (8.76)	0.65 (8.38)	0.69 (8.89)
General storms						
#11 Casa Grande Ruins	11.83	0.95 (11.24)	0.93 (11.00)	0.93 (11.00)	0.92 (10.88)	0.94 (11.12)
#16 Workman Creek	15.64	0.95 (14.86)	0.93 (14.55)	0.93 (14.55)	0.92 (14.39)	0.94 (14.70)
#17 Harquahala Peak	14.50	0.95 (13.78)	0.93 (13.49)	0.93 (13.49)	0.92 (13.34)	0.94 (13.63)

P = Powerline, V = Vineyard Road, R = Rittenhouse, M = Magma, F = Florence

Note the abbreviations used to denote each of the basins and the application of the appropriate areal adjustment factor to the value of the event transposed P-Max value from column a. The resulting areal-adjusted event precipitation value is contained within the parentheses. **Table 6** shows the application of the elevation change factors for each event and each of the East Valley basins. HMR-59 calls for no change in local storms occurring at or below 6,000 ft and +/- 9 percent change each 1,000 ft decrease/increase in elevation.

Table 6 Elevation precipitation adjustment from HMR-59 (local storms) = Zero for elevations below 6,000 feet and from HMR-57 (general storms) +/- 9 percent per 1,000 ft decrease/increase in elevation for the East Valley basins for key local and general-storm events

Events	a	P	V	R	M	F
Local storms	**Event(Row)/ Basin (Column) (elevation factor)**	**2591 ft**	**1835 ft**	**1924 ft**	**1865 ft**	**2037 ft**
#2 Ft. Mohave	540	1	1	1	1	1
#7 Welton	2800	1	1	1	1	1
#8 Phoenix	1120	1	1	1	1	1
#9 Sabino Canyon	6500 (1.045)	(1.045)	(1.045)	(1.045)	(1.045)	(1.045)
#10 Roosevelt Lakes	4500	1	1	1	1	1
General storms		Elevation change, ft (factor)				
#11 Casa Grande Ruins	1400	-1191 (0.89)	-435 (0.96)	-524 (0.95)	-465 (0.96)	-637 (0.94)
#16 Workman Creek	7100	4509 (1.41)	5265 (1.47)	5176 (1.47)	5235 (1.47)	5063 (1.46)
#17 Harquahala Peak	5681	3090 (1.28)	3846 (1.35)	3757 (1.34)	3816 (1.35)	3644 (1.33)

P = Powerline, V = Vineyard Road, R = Rittenhouse, M = Magma, F = Florence

Note that the Sabino Canyon event is the only localized storm that required an elevation adjustment since it occurred at 6500 feet. It requires an increase of 4.5 percent for the 500 ft decrease in elevation that occurs in transposition. Each of the general storm events requires an elevation adjustment for either an increase or decrease in elevation. Unlike the local storm “elevation cap” of 6,000 ft, general storms apply the elevation adjustment factor for any elevation changes. The elevation adjustment factor for each basin and event is the value in the parentheses.

Table 7 shows the application of the elevation adjustment to the event precipitation values obtained in **Table 5** that were adjusted for in-place event maximization, seasonal and transposition factors and areal basin adjustments. These precipitation values are the final event values that are used to provide an estimate of the RPMP value for each basin. The bolded values in **Table 7** represent the maximum event values for the local and general storms. HDR has bolded both the Casa Grande Ruins and Harquahala Peak general storm values.

If the local storms were plotted in an envelopment curve by the event duration a final RPMP value could be computed. However, the Roosevelt Lakes event dominates the distribution and will be used to compare to the HMR-49 local storm PMP value of 10.4 inches in 6 hours. The HMR-49 72-hr PMP value is 17.9 inches. The HMR-49 PMP values were obtained from a PMP study conducted on the Florence FRS (Dribble and Associates, 2003). These values are reasonable for comparison purposes for the other FRS. HMR-49 specifies that the 24-hr general storm PMP can be estimated by taking 0.80 times the 72-hr PMP value. This procedure results in a general storm 24-hr HMR PMP of 14.32 inches.

Table 7 Seasonally adjusted, in-place maximized, transposed, areal and elevation adjusted key local and general storm events to the East Valley FRS location

Events		P	V	R	M	F
Local storms	**Elevation adjustment from Table 6**	**Table 6 Elevation adjustment factor x Table 5 (precip)**	**Elevation adjustment factor (a x V)**	**Elevation adjustment factor (a x R)**	**Elevation adjustment factor (a x M)**	**Elevation adjustment factor (a x F)**
#2 Ft. Mohave	1	6.96	6.03	6.03	5.70	6.14
#7 Welton	1	4.82	4.61	4.61	4.40	4.68
#8 Phoenix	1	5.21	4.98	4.98	4.74	5.06
#9 Sabino Canyon	(1.045)	8.01	7.69	7.69	7.37	7.80
#10 Roosevelt Lakes	1	**9.15**	**8.76**	**8.76**	**8.38**	**8.89**
General storms	**See the P, V, R, M, F values in Table 6**	Inches	Inches	Inches	Inches	Inches
#11 Casa Grande Ruins	**See the P, V, R, M, F values in Table 6**	**10.00**	**10.56**	**10.45**	**10.44**	**10.45**
#16 Workman Creek	**See the P, V, R, M, F values in Table 6**	20.89	21.44	21.33	21.17	21.40
#17 Harquahala Peak	**See the P, V, R, M, F values in Table 6**	**17.62**	**18.21**	**18.08**	**18.01**	**18.13**

P = Powerline, V = Vineyard Road, R = Rittenhouse, M = Magma, F = Florence

Table 8 compares the HMR-49 local and general PMP values to the Roosevelt Lakes, Casa Grande Ruins and Harquahala Peaks events as a per cent of the HMR PMP. Again this comparison is meant to provide a means of comparison and falls short of a complete RPMP calculation. However, the comparison provides a valid evaluation of the potential changes in HMR-49 computed PMP's by applying the RPMP technique.

Table 8 Potential changes in East Valley basin PMP by application of RPMP techniques to each basin. Note that Harquahala Peak event is included only for comparison purposes as elevation considerations would eliminate it from transposition.

Event	Duration	Powerline	Vineyard Road	Rittenhouse	Magma	Florence
Local	storms					
#10 Roosevelt Lakes	270 min	9.15	8.76	8.76	8.38	8.89
HMR-49	360 min	10.4	10.4	10.4	10.4	10.4
% Change		-12%	-16%	-16%	-19%	-15%
General	storms					
HMR-49	24 hours	14.32	14.32	14.32	14.32	14.32
#11 Casa Grande Ruins	24 hours	10.00	10.56	10.45	10.44	10.45
% Change		-30%	-26%	-27%	-27%	-27%
#17 Harquahala Peak	24 hours	17.62	18.21	18.08	18.01	18.13
% Change		+23%	+27%	+26%	+26%	+27%

The two primary events for the comparison are the Roosevelt Lakes storm event for the local storm RPMP and the Casa Grande Ruins storm event for the general storm RPMP. Please note that a review of the other events in **Table 7,** if plotted in an envelopment curve as part of a complete RPMP, would have resulted in approximately the same values used for comparison in **Table 8.** Thus the reductions presented in **Table 8** are very representative of RPMP reductions expected in the East Valley FRS.

Please note that the comparison provided for the Harquahala Peak event was included **only to show** the impact of including an orographic event to the East Valley FRS basins that **does not** meet transposition criteria. The Harquahala event occurred during the passage of decaying Hurricane Nora and as described earlier resulted in a localized terrain enhancement of the rainfall. The nearly 5,700 foot elevation of the Harquahala rainfall measurement exceeds the relatively flat terrain of the East Valley FRS basins by several thousand feet. The red column color denotes the orographic nature of the event.

Summing the estimated impacts of doing a RPMP using the six steps outlined above resulted in **the reduction of the HMR-49 PMP by 12-19 percent for the local storm and 25-30 percent for the general storm**. Please note that these numbers are of a very preliminary nature and simply are used to illustrate the potential that exists for completing a thorough RPMP study. Again the PMP reductions were estimated by comparing the preliminary event values to the

Florence FRS HMR-49 values for local and general storm PMP. Actual HMR-49 PMP values could vary slightly (+/- 5 percent) with the other FRS watersheds. However, the comparison is appropriate for use in a white paper.

It is possible that calculation of an actual RPMP could result in another 5-10 percent reduction in the East Valley FRS RPMP values. The additional reductions would be a factor of the areal reduction impacts that could occur with detailed evaluation of observed areal coverage of recent and historical events as compared to the HMR-49, Figure 4.9 values. Additionally, temporal distributions of observed extreme precipitation events may display a different temporal distribution than the one suggested by HMR-49. Finally, the orientation of event precipitation fields in the basin based on inflow winds and cloud layer winds associated with each event could impact the options for placement of the precipitation field in the basin.

Use of a RPMP or SSPMP study could reduce PMP's by 15-25 percent or more

This white paper briefly outlined the problems inherent in using HMR-49 PMP procedures for FRS rehabilitation work in the East Valley FRS watersheds. Increasing population needs have exacerbated the safety concerns.

Regional and site-specific PMP studies have been used successfully in many states to reduce the HMR computed PMP values for FRS rehabilitation projects. Many of these projects have resulted in reductions of 10 to 30 percent in the PMP values used for design. In Arizona a prior SSPMP and a draft RPMP has estimated reductions of 12 to 32 percent in the PMP values.

Recent studies of radar-observed areal coverage of local storm precipitation fields in the Western United States indicate that the current areal reduction procedures of HMR-49 may produce ***a 10 to 50 percent over-estimate*** of the observed precipitation fields.

Summing the estimated impacts of doing a RPMP in the East Valley FRS watersheds, using the six steps outlined above, may result in **the reduction of the HMR-49 PMP by 12-20 percent for the local storm and 25-30 percent for the general storm**. Please note that these numbers are of a preliminary nature but illustrate the potential PMP reductions that exist for completing a thorough RPMP study. This white paper supports the utilization of RPMP techniques to support FRS rehabilitation efforts in the East Valley of Maricopa County, Arizona.

Glossary

General storm: "a storm that produces significant precipitation over at least several hundred square miles and lasts at least a day".

Local storm: "a period of unusually heavy rains exceeding 3.00" in 3 hours or less, that are reasonably isolated from surrounding rains and these rains are usually not associated with any organized meteorological system".

Mid-latitude synoptic storm systems: refers to large scale storm systems or migratory low pressure areas that bring extensive areas of cloudiness and long duration precipitation events that cross North America or Europe.

Probable Maximum Precipitation (PMP): *"theoretically,* the greatest depth of precipitation for a given duration that is *physically possible* over a *given storm area* at a *particular geographic location* at a *certain time of year".* HMR 55A (1988)

Sub-tropical storm systems: storm systems that occur between 20 degrees North and 35 degrees North that usually take the form of decaying hurricanes, low pressure areas or easterly waves. These storm systems bring clouds, locally heavy rainfall and moderately strong winds.

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