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What Rainfall Return Frequency?

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ABSTRACT

In this paper, a comparison is made of available rainfall data in a localized study area of Los Angeles County, California. This particular area has also been studied by the State of California Department of Water Resources (DWR), the National Weather Service (NWS) National Oceanographic and Atmospheric Administration (NOAA), and the Los Angeles County (LAC) Department of Public Works. All three of these cited governmental agencies independently analyzed the rainfall data to identify rainfall trends for the study area, and then prepared statistical analyses in order to develop estimates of return frequencies for various peak durations of rainfall, among other items of interest to hydrologists. Additionally, these three agencies have available two different analyses of the available data, resulting in updates to their respective published works. Consequently, six different statistical analyses are available for comparison and assessment. In this paper, an examination is made of these six statistical studies and some of the differences between the various analyses are identified and explained.

Keywords: Rainfall Return Frequency; Comparison of Return Frequency Estimates; Rainfall; Rainfall Atlas

1. Introduction

Of interest are the hydrometeorological characteristics of rainfall and their statistical trends in a particular localized study area of Los Angeles County, California. This study area is shown in **Figure 1**. The study area is part of a regional extent shown in **Figure 2**.

Rainfall producing wind directions tend to move inwards from the Pacific Ocean towards the mountainous region that extends throughout the region, separating the valley area of Los Angeles from an arid region shown in the upper right portion of **Figure 2**. An analysis of the topography shows that the mountainous extent blocks inwards flowing moisture, causing orographic uplift, except for two topographic depressions, shown in **Figure 3**.

The easterly topographic depression is characterized by significantly lower rainfalls then the surrounding area (rainfall trough), a trend that is shown in both the National Weather Service (NWS) National Oceanographic and Atmospheric Administration (NOAA) and the Los Angeles County (LAC) publications; namely, the NOAA Atlas 2 (1973) and the LAC Hydrology Manual (2006) (see **Figures 4(a)** and **(b)**, respectively). A third readily available statistical analysis of rainfall is provided by the State of California Department of Water Resources (DWR). Because of the rainfall trough, statistical estimates of return frequencies of rainfall in the study area are complex, and consequently, the various considered three agency estimations of rainfall trends differ in the study area. In this paper, these various analyses are compared and difference is assessed, and possible explanations are suggested as to the underpinnings of these differences in statistical estimates of rainfall.

All three sources of rainfall return frequency estimates developed their respective results using the pool of rain gage information sets for the rain gages located within or in the vicinity of the study area. A summary of the rain gage characteristics available for the study area is provided in **Table 1**. **Figure 5** provides a display of the assembled rain gages relevant to the study area regardless of source or operating agency.

2. NOAA Publications

For the study region, two NOAA Atlas publications are available, dated 1973 [1] and 2011 [2]. These publications provide rainfall return frequency estimates for various peak durations throughout large regions of the southwest United States, including the study area. The NOAA statistical analysis is based upon the Generalized

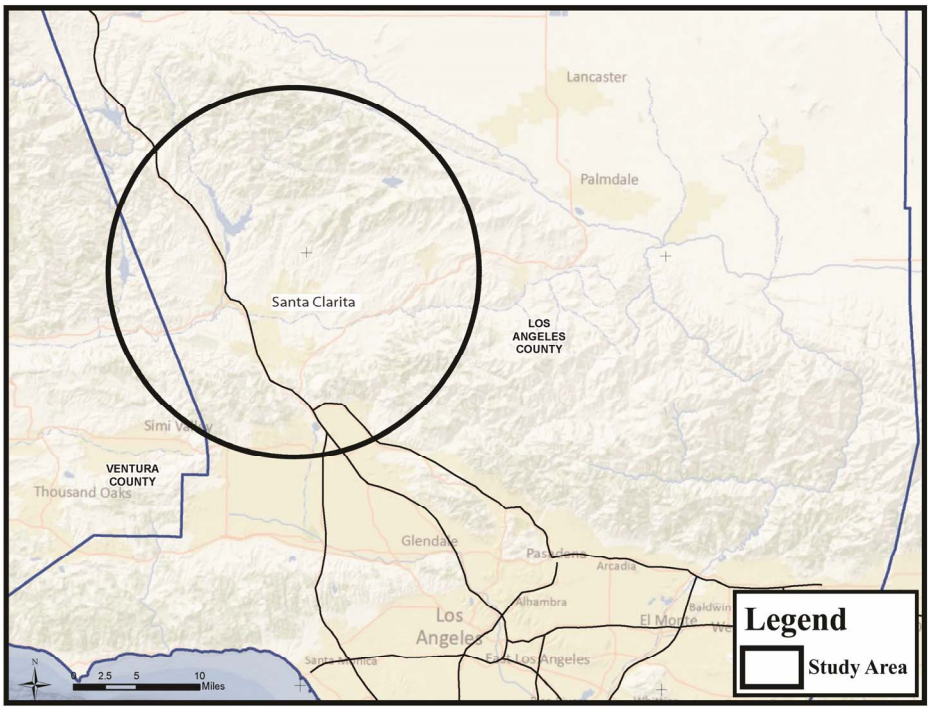


Figure 1. Study area (encircled).

Figure 2. Topographic relief map of study area and immediate vicinity.

Extreme Value (GEV) distribution, where statistical parameters are estimated regionally using rainfall gages located within the region shown in **Figure 5**. **Figures 6(a)** and **(b)** display the rainfall gages which were used in the most recent NOAA publication and are relevant to the study area. **Table 2** indicates which rain gages considered in this paper were also considered in the NOAA 2011 publication.

3. DWR Publications

The DWR rainfall statistical analysis is based upon the Pearson Type III distribution. Like the NOAA analysis, some of the statistical parameters are estimated on a regional basis by use of all rain gages located within a selected region. **Figures 7(a)** and **(b)** display the gages considered in the DWR analysis and the study area for

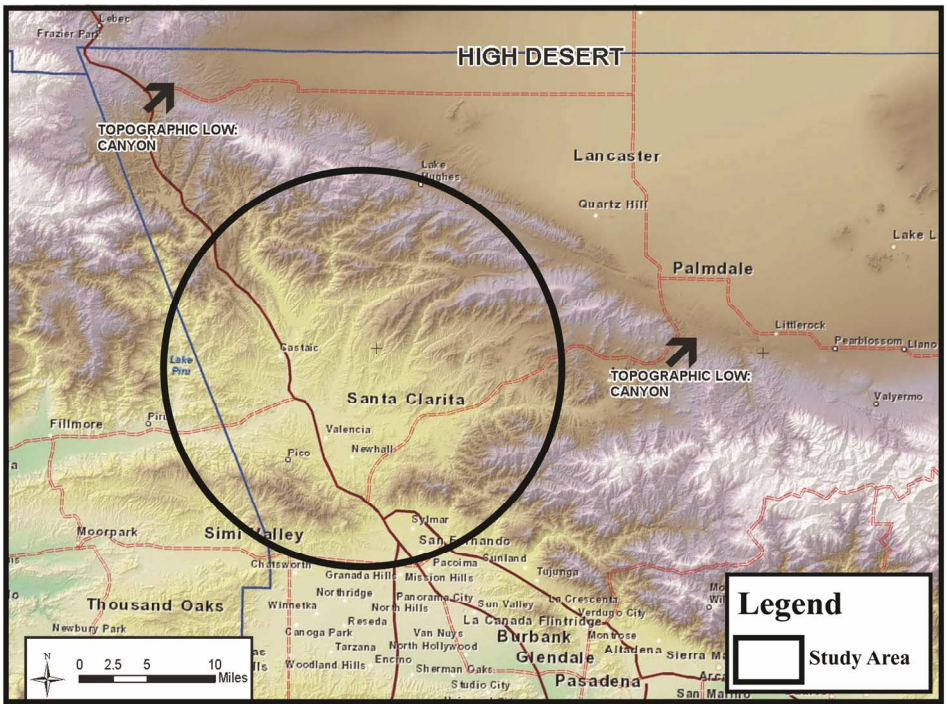


Figure 3. Topographic high regions and canyon relief locations.

Table 1. Rain gauge characteristics within the study area.

Gage ID	Type	Gage Name	Source	Data From	Data To	Data Years	Elevation (ft)
42516	D	Dry Canyon Reservoir	NOAA	1948	1990	42	1455
390	A	Bouquet Canyon	LADPW	1998	2010	12	1300
SAU	H	Saugus	CDEC	1995	2008	13	1450
372	A	San Francisquito Power House No. 2	LADPW	1940	2008	68	1580
1104C	D	Bouquet Canyon at Texas Canyon	LADPW	1950	2008	58	1760
1262	D	Saugus Reclamation Plant	LADPW	1986	2008	22	1150
451	D	Castaic Pat Sta	LADPW	1957	1969	12	1066
402	A	Mint Canyon	LADPW	1998	2010	12	1652
46159	H/D	Newhall AP	NOAA	1939	1949	10	1214
1012b	A	Castaic Junction	LADPW	1999	2008	9	1001
1012b	D	Castaic Junction	LADPW	1968	1999	31	1001
252	D	Castaic Lake	LADPW	1972	2008	36	1150
32	A	Newhall-Soledad Div. Hdqtrs	LADPW	1927	2008	81	1243
46162	15/H/D	Newhall S FC32CE	NOAA	1931	2008	77	1243
46161	D	Newhall 5 NW	NOAA	1996	2008	12	1765
46164	H/D	Newhall US RS	NOAA	1949	1968	19	1342
46165	D	Newhall	NOAA	1989	1996	7	1400
48014	D	Saugus Power Plant 1	NOAA	1947	2012	65	2089
CP9	H	Camp 9	CDEC	1997	2011	14	4000
125	D	San Francisquito Canyon Power House No.	LADPW	1950	2012	62	2105
1005	D	Mint Canyon Fire Station	LADPW	1965	2012	47	2300
WSG	H	Warm Springs	CDEC	1991	2012	21	4020
DVL	H	Del Valle	CDEC	1998	2008	10	1278

Continued

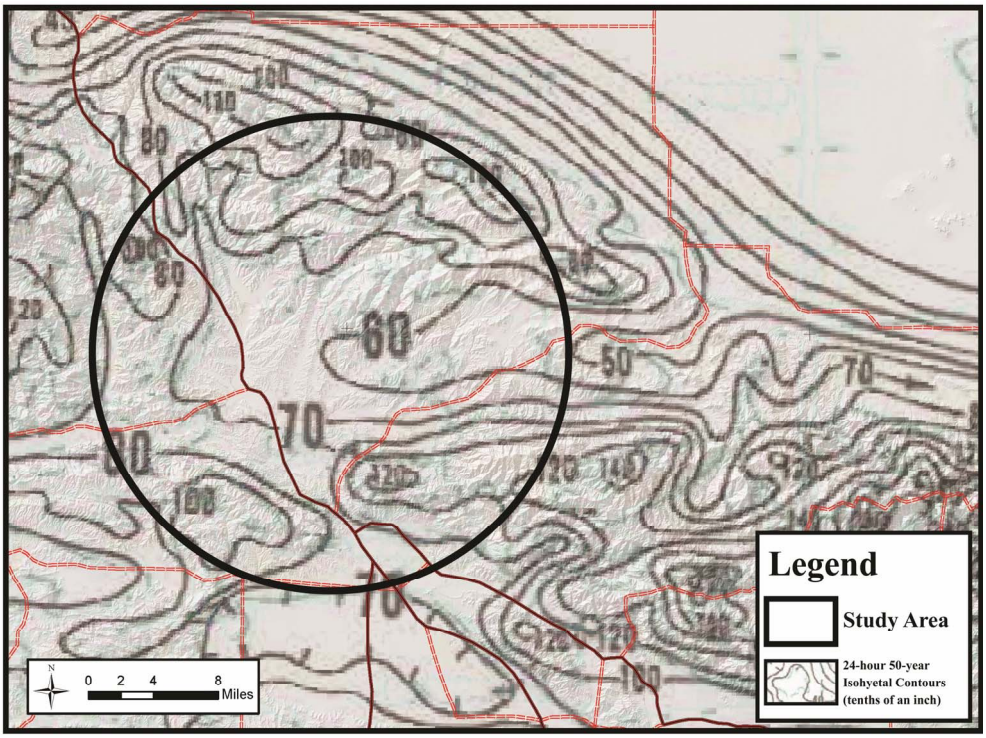
42735	D	Elizabeth Lake Cn FC12	NOAA	1955	1972	17	2080
47220	D	Radium Hot Springs	NOAA	1949	1955	6	2080
NHP	H	Newhall Pass	CDEC	2005	2012	7	2135
1263	D	Valencia Reclamation Plant	LADPW	1999	2008	9	1000
128	A	Elizabeth Lake-Warm Springs Camp	LADPW	1956	2012	56	2075
ALO	H	Aliso Canyon	CDEC	1997	2012	15	2780
1191	D	Bear Divide	LADPW	1971	2008	37	2700
47762	H	SAN FERNANDO PH 3	NOAA	1948	2012	64	1250
395	A	Olive View Sanitarium	LADPW	1981	2012	31	1425
40115	15/H/D	ALISO CANYON FC 446	NOAA	1939	1991	52	2367
446	A	Aliso Canyon—Oat Mountain	LADPW	1941	2012	71	2367
41013	D	Bouquet Canyon	NOAA	1940	1978	38	3061
46942	15/H/D	Piru Telematering	NOAA	1969	2008	39	244
33	D	Pacoima Dam	LADPW	1916	2012	96	1500
46602	D	PACOIMA DAM FC 33 A-E	NOAA	1931	2012	81	1559
301	A	Browns Canyon	LADPW	1995	2012	17	2400
801	D	Magic Mountain	LADPW	1966	2006	40	4720
293	D	Los Angeles Reservoir	LADPW	1978	2012	34	1150
GMTC1	A	Grass Mountain	MESO	2004	2012	8	4626
405	D	Soledad Canyon	LADPW	1962	2012	50	2150
SFD	H	SANTA FELICIA DAM	CDEC	1997	2012	15	1078
47759	D	SAN FERNANDO	NOAA	1931	1974	43	971
261	A	Acton- Escondido Canyon	LADPW	1970	2012	42	2960
40014	15/H/D	ACTN Escondido FC261	NOAA	1931	2012	81	2960
46940	D	Piru 2 ESE	NOAA	1959	2012	53	730
42734	D	Elizabeth Lake	NOAA	1931	1955	24	3281
47973	H	Santa Susana 4 NNE	NOAA	1956	1958	2	1520
45256	H	Magic Mountain	NOAA	1948	1966	18	4450
WTK	H	Whitaker	CDEC	1999	2012	13	4120
321	A	Pine Canyon Patrol Station	LADPW	1990	2012	22	3286
46891	D	Pine Canyon PS FC321E	NOAA	1955	1972	17	3291

Data Type: A = ALERT (logger); M = Monthly; D = Daily Data; H = Hourly Data; 15 = 15 Minute; Agency Source: MESO = Mesowest; CDEC = California Data Exchange Center; LADPW = Los Angeles Department of Public Works; NOAA = National Oceanic and Atmospheric Administration.

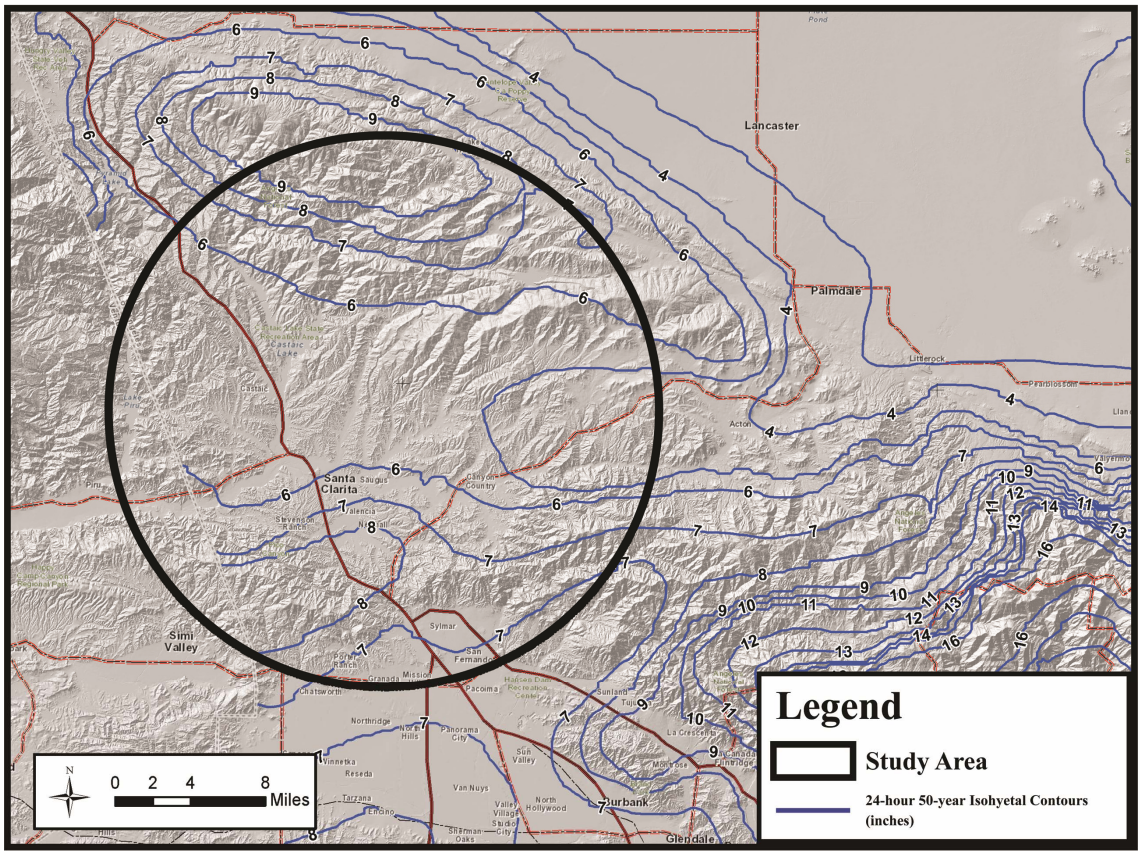
this paper. The DWR analysis results can be accessed at the web site *http://www.water.ca.gov/floodmgmt/hafoo/csc/climate_data* [3]. (DWR return frequencies are given for 1-day intervals whereas the other agencies considered herein use 24-hour intervals. For consistency, all data were compared as 24-hour values.) **Table 2** indicates which rain gages considered in this paper were also considered in the DWR rainfall analysis. The DWR updates their analysis frequently, with their most current information through 2010 available upon request [4].

4. LAC Hydrology Manual

The County of Los Angeles (LAC), California provides rainfall statistical estimates (in isohyetal map form) for the 50-year 24-hour peak duration throughout the 4083 square mile area of the County. The LAC also operates a network of rain gages and these gages are shown in the vicinity of this paper's study area in **Figures 8(a)** and **(b)**. Two versions of the Hydrology Manual are considered herein; namely, 1991 [5] and 2006 [6]. The County also published a report in 1997 [7], titled *Rainfall Frequency Analysis Report*, which gives additional estimates of return frequencies at selected gages, chosen by the County, rather than generalized isohyetals such as shown in the hydrology manuals. Six of the County's selected gages are located within the target study area.



(a)



(b)

Figure 4. (a) NOAA Atlas 2 isohyetals corresponding to 50-year 24-hour peak duration; (b) LAC hydrology manual isohyetals corresponding to 50-year 24-hour peak duration.

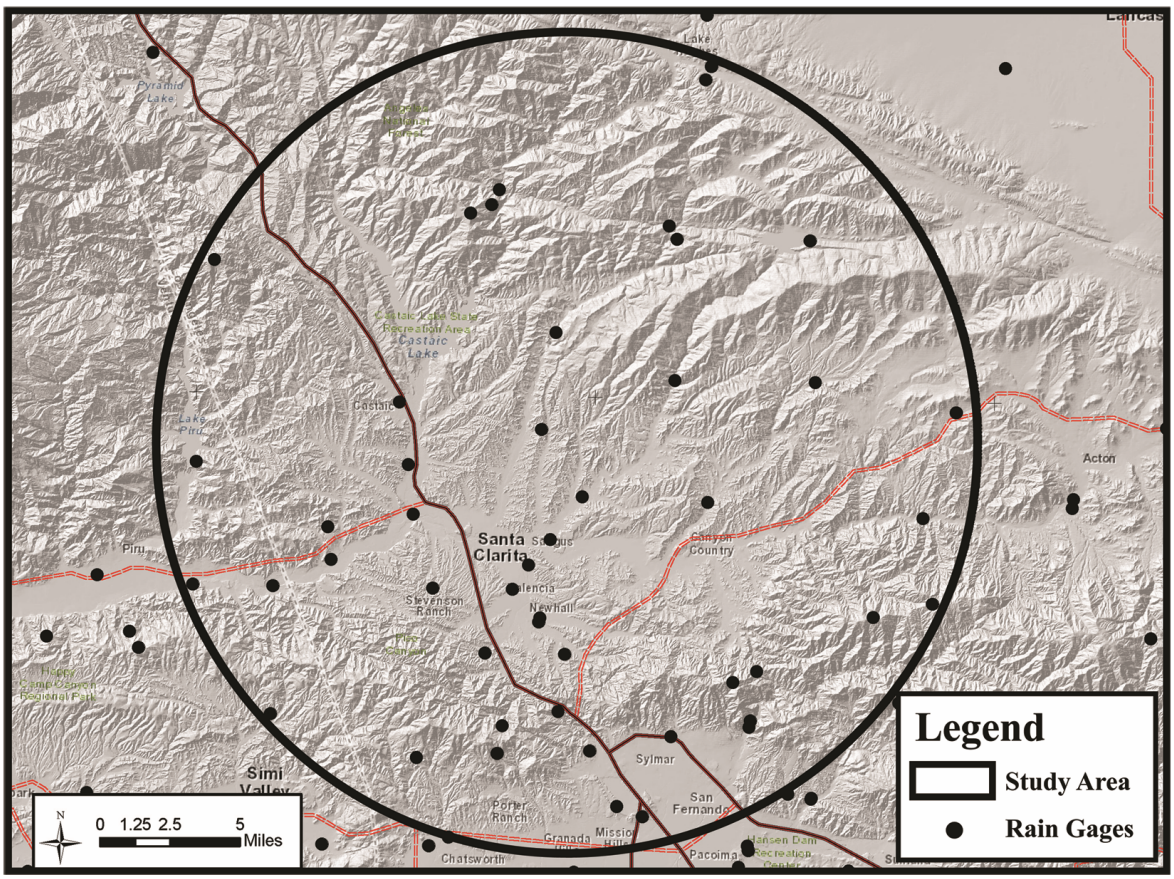


Figure 5. Rain gages within study area (all sources).

5. Comparison of Return Frequency Rainfalls for Various Peak Durations

Because the LAC Hydrology Manual only provides procedures for estimation of the peak 24-hour duration, and for the 50-year return frequency rainfall (the LAC Design Storm), this statistical estimate can be compared with the other publications considered. The LAC Hydrology Manual also provides an estimate for a four day 50-year return frequency rainfall as a fixed proportion of the peak 24-hour duration 50-year return frequency rainfall. **Table 2** shows which gages within the study area were used by each agency in their analysis. A comparison between procedures, different dates of publication, and different data sources, all for the same study area, is provided in **Tables 3** and **4**, including the LAC 1997 [7] publication titled *Rainfall Frequency Analysis Report*.

From **Tables 3** and **4**, several observations are made:

1) The NOAA Atlas estimates for the considered peak durations and return frequencies are generally similar, for the study area, even though there are approximately 38 years between rainfall data analysis;

2) The DWR estimates also indicate a close similarity between the two dates of available analysis, with approximately 7 years between analyses;

3) The LAC Hydrology Manual estimates show a considerable change in rainfall estimates with approximately 15 years between analyses.

4) The change observed in the LAC Hydrology Manual for the study area indicates a significant reduction in rainfall return frequency estimates. Such a change is not observed in either of the DWR or NOAA publications.

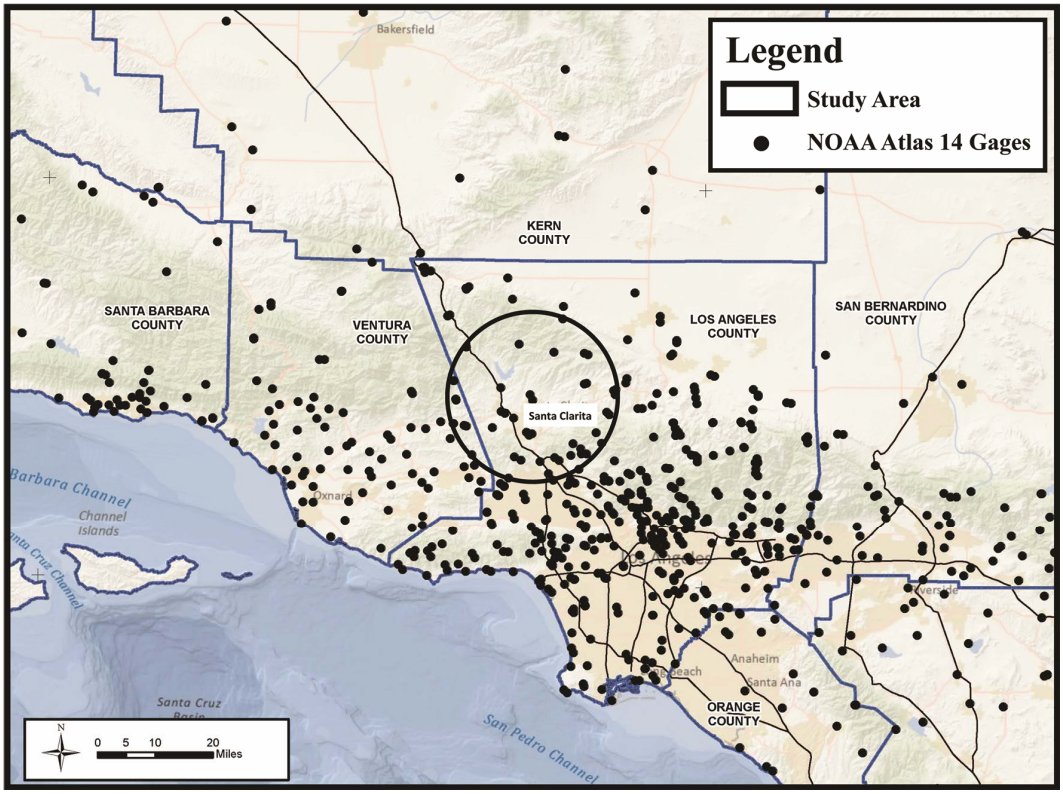
6. Discussion of Results

In this paper, a comparison is made of seven sources of information prepared during the last several decades that deals with the important topic of estimating rainfall quantities for various return frequencies. The study area under examination is the vicinity surrounding the City of Santa Clarita which is located near Los Angeles, California. The study area is exposed to coastal winds and moisture from the Pacific Ocean from the westerly and southwesterly directions, and is bordered to the north and northeast by a mountainous region that surrounds the entire northeasterly extent of the region, except for two canyon locations that are topographically low and connect the study region to the desert area located past the mountainous region. As a result of the topography, significant orographic effects are evident in the available

Table 2. Comparison of rain gages used in various agency studies.

Gage ID	Type	Gage Name	Source	Data From	Data To	Data Years	Elevation (ft)	LACHM (Ref. 1)	NOAA Atlas 14	DWR
42516	D	Dry Canyon Reservoir	NOAA	1948	1990	42	1455		Y	Y
SAU	H	Saugus	CDEC	1995	2008	13	1450			Y
372	A	San Francisquito Power House No. 2	LADPW	1940	2008	68	1580	Y		Y
1262	D	Saugus Reclamation Plant	LADPW	1986	2008	22	1150	Y		Y
451	D	Castaic Pat Sta	LADPW	1957	1969	12	1066			Y
46159	H/D	Newhall AP	NOAA	1939	1949	10	1214			Y
1012b	A	Castaic Junction	LADPW	1999	2008	9	1001		Y	
1012b	D	Castaic Junction	LADPW	1968	1999	31	1001		Y	Y
252	D	Castaic Lake	LADPW	1972	2008	36	1150		Y	Y
32	A	Newhall-Soledad Div. Hdqtrs	LADPW	1927	2008	81	1243		Y	Y
46162	15/H/D	Newhall S FC32CE	NOAA	1931	2008	77	1243		Y	Y
46161	D	Newhall 5 NW	NOAA	1996	2008	12	1765		Y	Y
48014	D	Saugus Power Plant 1	NOAA	1947	2012	65	2089			Y
CP9	H	Camp 9	CDEC	1997	2011	14	4000			Y
125	D	San Francisquito Canyon Power House No.	LADPW	1950	2012	62	2105	Y	Y	Y
1005	D	Mint Canyon Fire Station	LADPW	1965	2012	47	2300		Y	
WSG	H	Warm Springs	CDEC	1991	2012	21	4020			Y
DVL	H	Del Valle	CDEC	1998	2008	10	1278			Y
1263	D	Valencia Reclamation Plant	LADPW	1999	2008	9	1000	Y	Y	Y
128	A	Elizabeth Lake-Warm Springs Camp	LADPW	1956	2012	56	2075	Y		Y
1191	D	Bear Divide	LADPW	1971	2008	37	2700		Y	
47762	H	SAN FERNANDO PH 3	NOAA	1948	2012	64	1250		Y	Y
395	A	Olive View Sanitarium	LADPW	1981	2012	31	1425		Y	Y
40115	15/H/D	ALISO CANYON FC 446	NOAA	1939	1991	52	2367		Y	Y
446	A	Aliso Canyon—Oat Mountain	LADPW	1941	2012	71	2367	Y		Y
41013	D	Bouquet Canyon	NOAA	1940	1978	38	3061		Y	Y
46942	15/H/D	Piru Telematering	NOAA	1969	2008	39	244		Y	Y
33	D	Pacoima Dam	LADPW	1916	2012	96	1500		Y	Y
46602	D	PACOIMA DAM FC 33 A-E	NOAA	1931	2012	81	1559		Y	Y
801	D	Magic Mountain	LADPW	1966	2006	40	4720		Y	Y
293	D	Los Angeles Reservoir	LADPW	1978	2012	34	1150	Y		Y
405	D	Soledad Canyon	LADPW	1962	2012	50	2150	Y	Y	Y
SFD	H	SANTA FELICIA DAM	CDEC	1997	2012	15	1078		Y	
47759	D	SAN FERNANDO	NOAA	1931	1974	43	971		Y	
261	A	Acton- Escondido Canyon	LADPW	1970	2012	42	2960		Y	
40014	15/H/D	ACTN Escondido FC261	NOAA	1931	2012	81	2960		Y	Y
46940	D	Piru 2 ESE	NOAA	1959	2012	53	730		Y	Y
42734	D	Elizabeth Lake	NOAA	1931	1955	24	3281		Y	
45256	H	Magic Mountain	NOAA	1948	1966	18	4450			Y
WTK	H	Whitaker	CDEC	1999	2012	13	4120			Y
321	A	Pine Canyon Patrol Station	LADPW	1990	2012	22	3286			Y
46891	D	Pine Canyon PS FC321E	NOAA	1955	1972	17	3291			Y

Data Type: A = ALERT (logger); M = Monthly; D = Daily Data; H = Hourly Data; 15 = 15 Minute; Agency Source: MESO = Mesowest; CDEC = California Data Exchange Center; LADPW = Los Angeles Department of Public Works; NOAA = National Oceanic and Atmospheric Administration.



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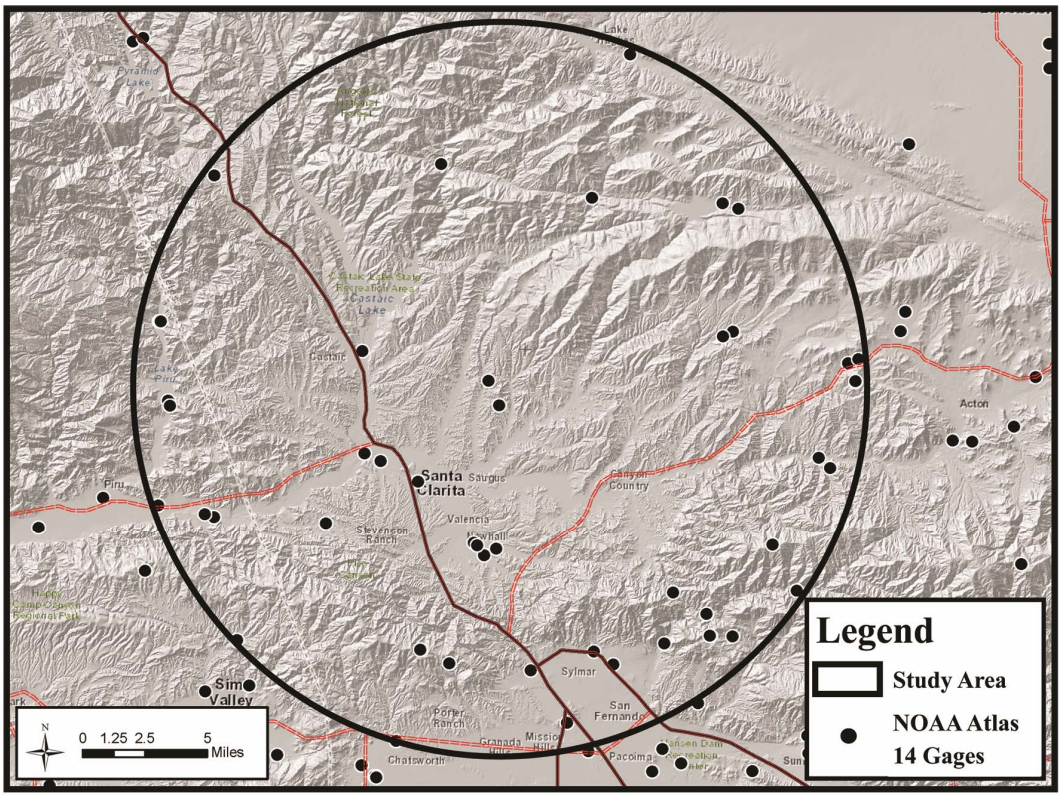
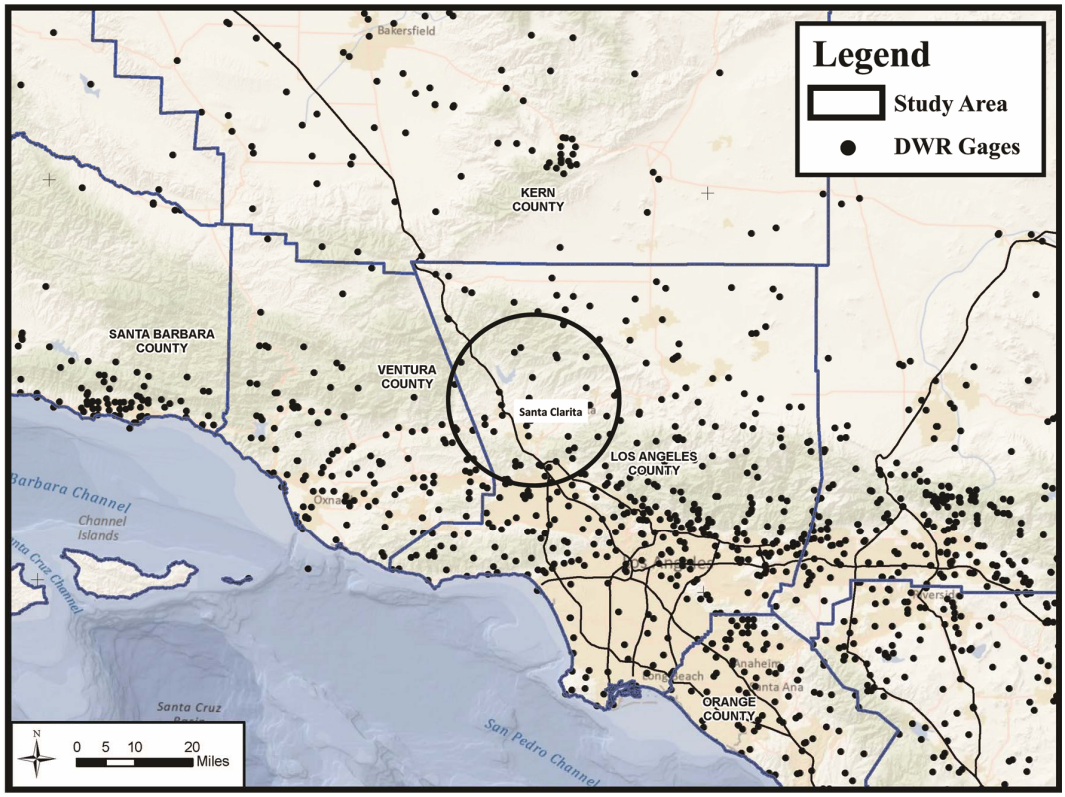


(b)

Figure 6. (a) Rain gages used in NOAA Atlas 14 (interior and exterior of study area); (b) NOAA Atlas rain gages within study area.



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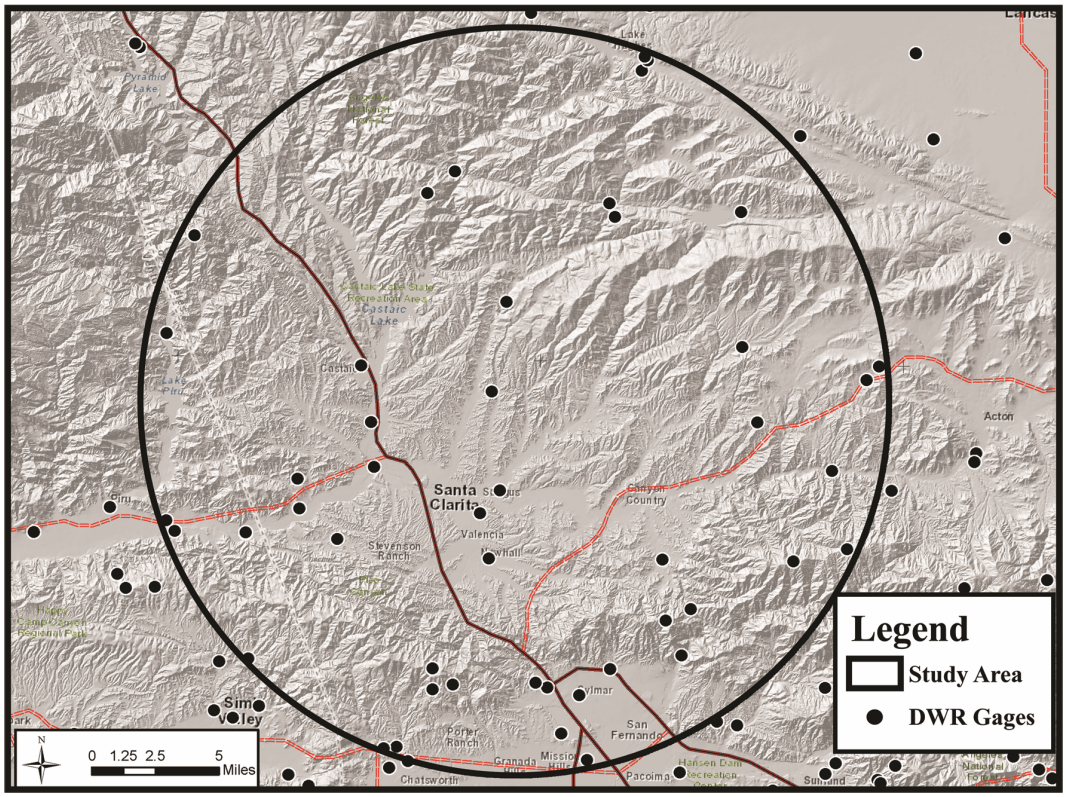
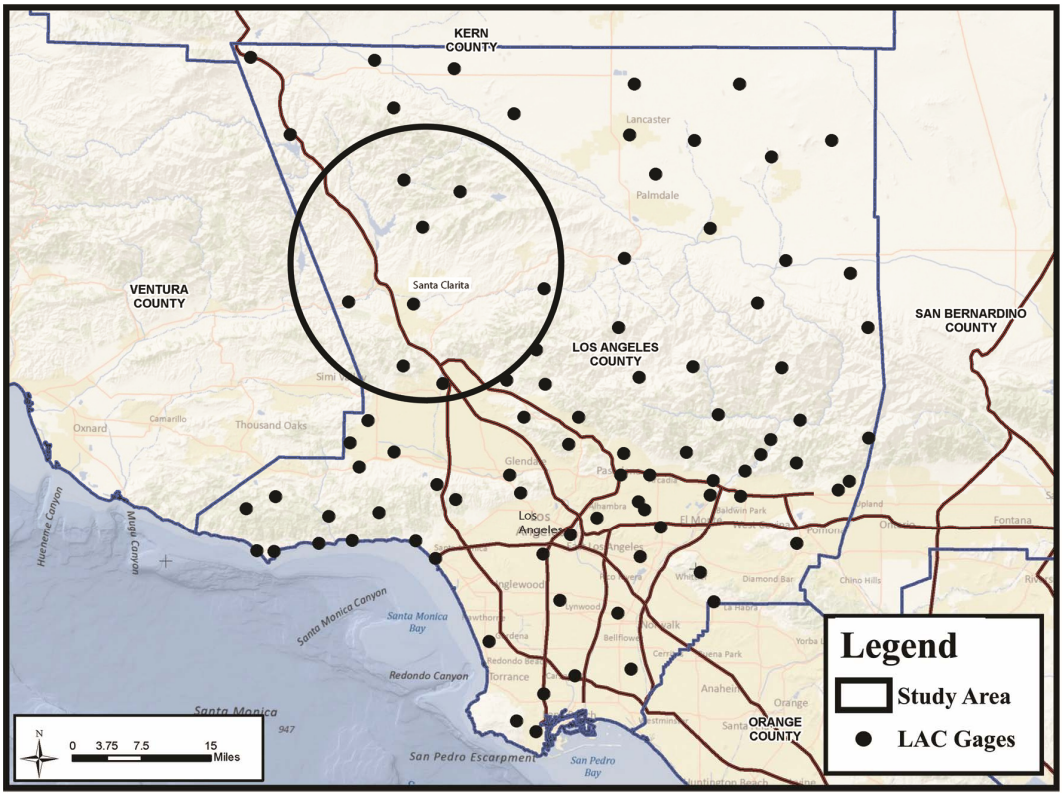


(b)

Figure 7. (a) Rain gages used by State of California Department of Water Resources (interior and exterior of study area); (b) State of California Department of Water Resources rain gages within study area.



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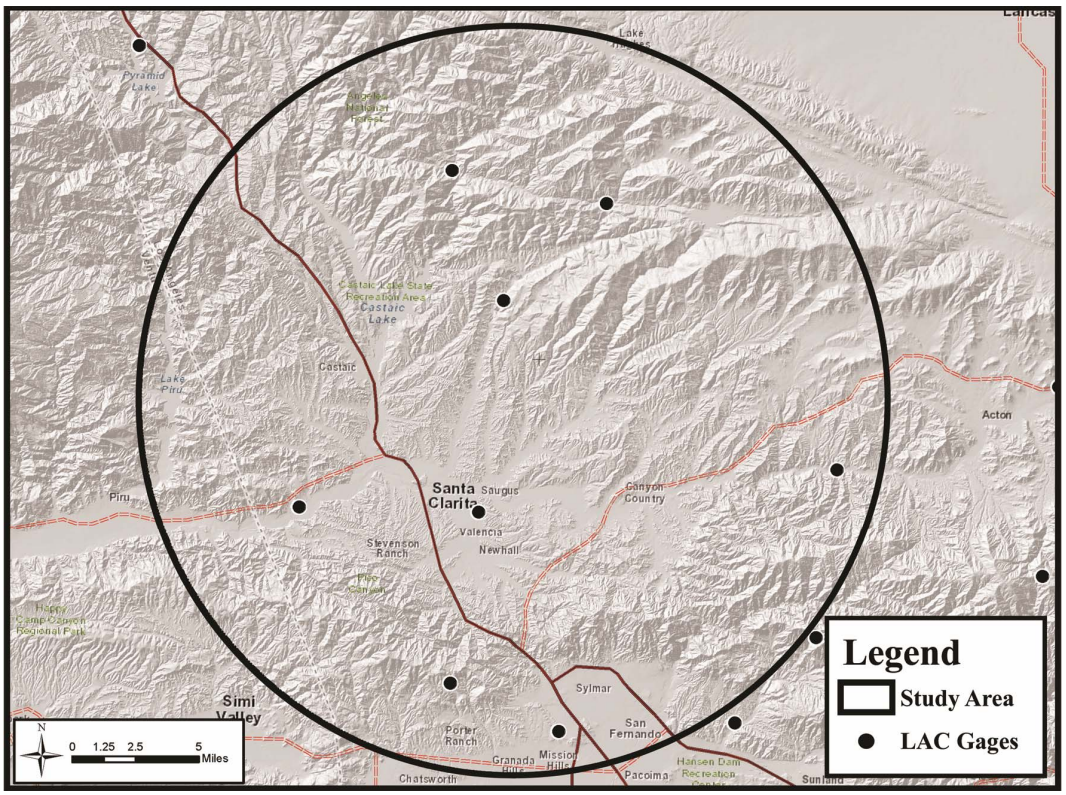

(b)

Figure 8. (a) Rain gages used by Los Angeles County (interior and exterior of study area); (b) Los Angeles County rain gauges within study area.

Table 3. Comparison of 50-year 24-hour rainfalls for rain gages located within the study area (and common to all sources of return frequency estimates).

Gage	DWR (2003)	DWR (2010)	*Percent Change*	NOAA Atlas 2 (1973)	NOAA Atlas 14 (2011)	*Percent Change*	LACHM (1991)	LACHM (2006)	*Percent Change*	LACHM (1991)	LAC (1997)*	*Percent Change*
32	7.19	7.24	**0.7**	7.5	7.59	**1.2**	11.1	8.2	**−26.1**	11.1	7.20	**−35.1**
125	5.87	5.90	**0.5**	7.2	7.13	**−1.0**	8.6	7.0	**−18.6**	8.6	5.69	**−33.8**
128	7.36	7.42	**0.8**	8.4	7.04	**−16.2**	10.5	7.1	**−32.4**	10.5	7.77	**−26.0**
372	5.72	5.82	**1.7**	6.8	6.79	**−0.1**	7.2	5.75	**−20.1**	7.2	5.79	**−19.6**
1005	4.26	4.44	**4.2**	5.8	5.48	**−5.5**	5.9	4.9	**−16.9**	5.9	4.06	**−31.2**
1012	4.90	4.88	**−0.4**	6.8	5.91	**−13.1**	9.2	5.75	**−37.5**	9.2	4.87	**−47.1**
Average			**1.3**			**−5.8**			**−25.3**			**−32.1**

*Rainfall Frequency Analysis Report, Los Angeles County Public Works, Water Conservation Division, April 1997.

Table 4. Comparison of 50-year 24-hour rainfalls for between NOAA, LAC, and DWR.

Gage	DWR (2010)	NOAA Atlas 14 (2011)	*Percent Change*	DWR (2010)	LACHM (2006)	*Percent Change*	NOAA Atlas 14 (2011)	LACHM (2006)	*Percent Change*	LACHM (2006)	LACHM (1997)	*Percent Change*
32	7.24	7.59	**4.8**	7.24	8.2	**13.3**	7.59	8.2	**8.0**	8.2	7.20	**−12.2**
125	5.90	7.13	**20.8**	5.90	7.0	**18.6**	7.13	7.0	**−1.8**	7.0	5.69	**−18.7**
128	7.42	7.04	**−5.1**	7.42	7.1	**−4.3**	7.04	7.1	**0.9**	7.1	7.77	**9.4**
372	5.82	6.79	**16.7**	5.82	5.75	**−1.2**	6.79	5.75	**−15.3**	5.75	5.79	**0.7**
1005	4.44	5.48	**23.4**	4.44	4.9	**10.4**	5.48	4.9	**−10.6**	4.9	4.06	**−17.1**
1012	4.88	5.91	**21.1**	4.88	5.75	**17.8**	5.91	5.75	**−2.7**	5.75	4.87	**−15.3**
Average			**13.6**			**9.1**			**−3.6**			**−8.9**

rain gage data. However, within the local vicinity of the two topographic lows, rainfall data demonstrate significantly less orographic effects than observed in the other rain gages within the study area. Because of the significant orographic effects and variations in topography within the study area, significant variations in rainfall quantities are observed, resulting in a challenging situation in the analysis and estimation of peak duration rainfall quantities and their respective return frequency estimates. Comparison of the said seven sources of estimates for rainfall return frequency, developed by three climatology agencies (NOAA, State of California DWR, LAC), show significant differences between agency estimates and also differences in updated reports by the individual agencies. Particularly, information from the NOAA 1973 and more recent 2011 Rainfall Atlases show minor variation in return frequency rainfall estimates, as also is the case with the State of California DWR estimates, but significant decrease in rainfall estimates is seen in the LAC publications. Furthermore, similarity is observed between the NOAA and DWR publication results, but significant difference is seen between the LAC and the said other two agencies. Finally, significant difference is seen between the LAC rainfall isohyetal mapping and the associated LAC report for the same region under study.

In the tabulations of **Tables 3** and **4**, and in the rain gage location plots of rain gages located within the Study Area (seen in **Figures 6(b)**, **7(b)** and **8(b)**), it is seen that the LAC analysis utilizes far fewer rain gages within the Study Area than either the DWR or NOAA analysis. Similarly, on a regional scale, the LAC analysis uses far fewer rain gages throughout the region than do the DWR or NOAA analyses. Within the Study Area, there are located only eight gages common to all sources of statistical estimates (the eight gages being the subset of available gages used by the LACHMs). In the LAC 1997 publication, six gages within the Study Area give site specific return frequencies. At each of these six gage locations, values were read from the various isohyetal maps and are compared in **Tables 3** and **4**. Consequently, the DWR and NOAA analyses are based upon much larger populations of data than is the LAC analysis. As a result, not only is the LAC analysis based upon a much smaller sample size than the DWR or NOAA analyses, but the detail provided in estimating rainfall return frequency values is less spatially defined by the smaller data set used in the LAC analysis. Consequently, there may be good reason to consider all three analyses when assessing rainfall quantities and associated return frequencies throughout not only the Study Area focused upon in this

paper, but also throughout the LAC region.

7. Conclusion

An analysis of available rainfall data in a localized study area of Los Angeles, California, is presented. This particular study area is also studied by the State of California Department of Water Resources (DWR), the National Weather Service NOAA, and also the Los Angeles County (LAC) Department of Public Works. All three of these governmental agencies independently analyzed rainfall data and prepared statistical analyses to develop estimates of return frequencies for various peak durations of rainfall. Additionally, these three agencies have prior statistical analyses of the available rainfall data, resulting in updates to their respective published works. Consequently, six different statistical analyses are available for comparison and assessment. In this paper, an examination is made of these six statistical studies and some of the differences between the various analyses are identified. Possible explanations as to the underpinnings of the observed differences between these rainfall statistical results are suggested.

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