A CASE STUDY: CALCULATING A PRECIPITATION FREQUENCY CURVE USING L-MOMENT STATISTICS WITH EMAPHASIS ON THE UNCERTAINTIES IN THE ANALYSIS

Victoria L. Sankovich and John F. England, Jr.
Bureau of Reclamation, Technical Service Center, Denver, Colorado

1. INTRODUCTION

Regional frequency analyses, such as L-moments statistics developed by Hosking and Wallis (1997), assume that it is possible to augment a short record length of data at one location with data from a surrounding homogeneous region. Since precipitation observation records generally date back 100 years at best, and a greater record length is desirable, regional frequency statistics are appealing. For Dam Safety objectives at the Bureau of Reclamation, precipitation frequency curves up to the Probable Maximum Precipitation (PMP) are required as input into hydrologic models to create hydrographs. This paper assesses the application of L-moment statistics as a method to produce the precipitation frequency curve for East Park Dam, located in Northern California. The sources of uncertainty that were encountered during the statistical analysis are also identified and discussed.

2. BACKGROUND

Rainfall produced floods can overtop dams and result in dam failure if adequate releases through the spillways and outlets can not occur. South Fork (Johnstown), in the United States, Oros in Brazil, and Panset and Machhu II in India, are four such significant disasters resulting from inaccurate forecasting and estimation of flood conveyance requirements. In fact, 'overtopping has been the most common cause of failure of embankment dams' (Jansen 1983).

The mission of the Safety of Dams program at the Bureau of Reclamation is 'to ensure Reclamation dams do not present unacceptable risk to people, property, and the environment (USDOI 2011). To accomplish this mission, Reclamation has established risk-based procedures to quantify judgment and identify the conditions that impose risks to its structures (USDOI 2003).

Reclamation's Flood Hydrology Group evaluates a dam's overtopping potential by producing a Hydrologic Hazard Curve (HHC). An HHC is an estimation of flood magnitudes (or volumes) and their associated annual exceedance probabilities (AEPs) up to the Probable Maximum Flood (PMF). The PMF is the 'maximum runoff condition resulting from the most severe combination of hydrologic and meteorological conditions that are considered reasonably possible for a drainage basin' (Cudworth 1989). From the information provided by the HHC, flood hydrographs ('a graphical or tabular representation of the variation of discharge over time, at a particular point on a watercourse,' quoted from USDOI 1987) are created for the different hydrologic load conditions at specific AEPs. The

Address for correspondence:
Victoria Sankovich
E-mail: vsankovich@usbr.gov

hydrographs are routed to estimate reservoir levels and compared with discharge capacities to determine the risk of overtopping.

The methodology used to develop a HHC is dependent upon the level of study. The higher level studies (those that confirm a previously identified concern, those that evaluate risk reduction alternatives, and those where a conceptual design is transformed into a final design) utilize rainfall-based statistics (i.e. precipitation frequency) as input into rainfall-runoff models.

3. CASE STUDY: EAST PARK DAM, CA

Reclamation's Safety of Dams program has identified a need for hydrologic hazard information for East Park Dam, CA. East Park Dam is located in north-central California in the Sacramento Valley approximately 100 miles north of Sacramento (Figure 1). East Park Dam is part of the Orland Project which includes two storage reservoirs and a distribution system to provide water to irrigable land in Glenn County, CA. The dam was completed in 1910. It is a thick-arch concrete dam standing 139 ft. high and 266 ft. long. The reservoir has a capacity of 50,900 acre-ft.

Figure 1. Map depicting the location of East Park Dam, CA.

4. PRECIPITATION FREQUENCY CURVE

Regional annual maximum statistics calculated from the L-Moments method will be used to create the precipitation frequency curve. Since the L-Moments technique is a regional statistics method, this scheme allows space for time substitution (Hosking and Wallis 1997).

The area of study was limited to a region of similar climatological characteristics as the East Park watershed. The geography of the East Park watershed is rather complex, as it is located on the eastern slope of the Coastal Range. Consequently, a region that is climatologically similar must also exhibit highly orographic characteristics. To aid in the delineation of this region, PRISM mean annual precipitation maps (Oregon Climate Service 2011) NOAA Atlas 2 regions (Miller et al. 1973), and the National Weather Service (NWS) Climatological Divisions were consulted (NWS 2011). A map of this region may be found in Figure 2.

The precipitation data for this region was obtained from the NWS Cooperative Network (COOP). The National Climatic Data Center (NCDC) distributes the daily precipitation totals from this network via the Summary of the Day TD-3200 precipitation product. A dataset consisting of the annual maximum daily (approximately 24-hour) precipitation for all of the gauges within the region was compiled. Discordancy tests were performed to remove the rain gauges with data that were inconsistent in comparison to the dataset as a whole. The ultimate list of 92 rain gauges defined the homogenous region (Figure 3). This translates to approximately 3,000 station-years of data.

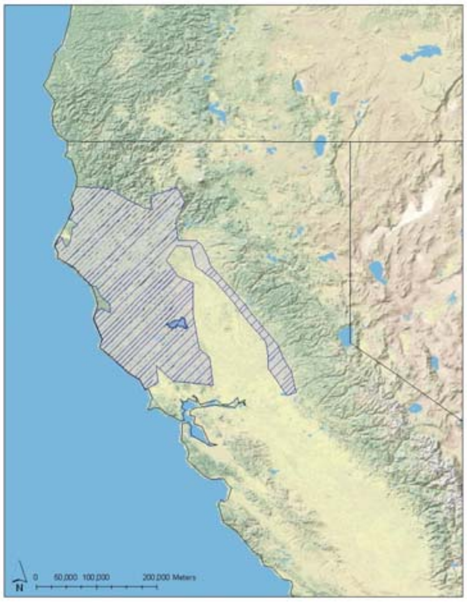

Figure 2. Map displaying the region of similar climatological characteristics as the East Park watershed, shown as the hatched area. The East Park watershed is shown in blue.

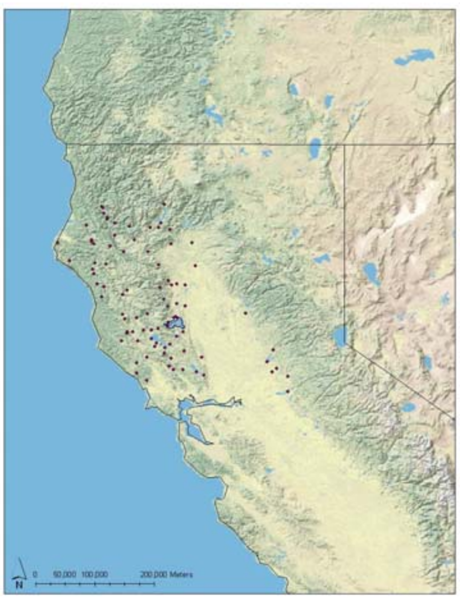

Figure 3. Rain gauges comprising the homogeneous dataset are shown as red dots. The East Park watershed is shown in blue.

L-moment ratios were computed from the rain gauges' data. From these ratios, a common set of distribution parameters was calculated and used to define a single probability distribution function (i.e. the regional growth curve) for the homogeneous region. The three distribution parameters are listed in Table 1 and suggest that the Generalized Logistic (GL) distribution best represents the one-day annual maximum precipitation data for the region.

ξ	α	k	h
0.951	0.186	-0.156	-1

Table 1. Generalized Logistic distribution parameters.

This distribution was next applied to East Park Dam, considered a 10 mi^2 (approximate point) feature. To accomplish this, the regional growth curve was scaled by a point precipitation value representative of East Park Dam. Specifically, the regional growth curve was scaled by the average of the mean annual maximum precipitation values of rain gauges located closely in the vicinity of the East Park watershed (scale factor is 2.80 in). The result is a daily (approximately 24-hour) frequency curve for the 10 mi^2 East Park Dam.

Based on the historical record of storms in the vicinity of the East Park watershed, the storm that would be most devastating to the area would be a 72-hour storm. Thus, the 24-hour frequency curve was scaled to a 72-hour duration. This was accomplished by applying a scale factor of 1.75, provided in Hydrometeorological Report (HMR) No. 59: Probable Maximum Precipitation for California (Corrigan et al. 1999).

For the frequency curve to be representative of the East Park watershed, another scale factor is applied to transform the curve from 10 mi^2 to approximately 100 mi^2, in accordance with the size of the watershed. This value (0.9025) was also derived from HMR 59 (Corrigan et al. 1999).

The 100 mi^2 basin 72-hour frequency curve was extrapolated from ~3,000 years to the Probable Maximum Precipitation (PMP) (Figure 3). PMP is 'theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of year' (Hansen et al. 1988). The PMP for East Park Dam is 31.23 in (calculated via Corrigan et al. 1999), which corresponds to an AEP of ~ 9.09 x 10^{-6} (110,000-year return period).

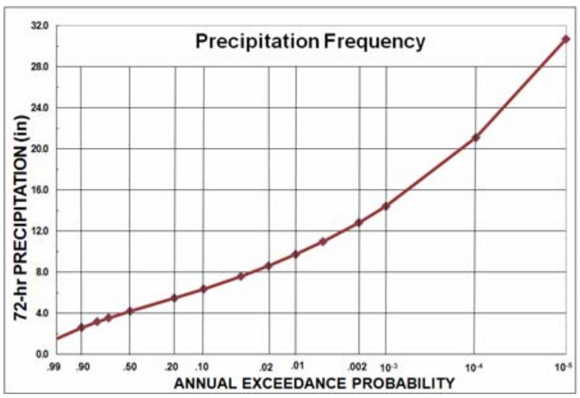

Figure 3. Precipitation Frequency curve for East Park Dam, CA, extrapolated to the PMP.

5. UNCERTAINTIES IN THE ANALYSIS

The shape of the precipitation curve (Figure 3) shows a tail that is more flat that was expected. As such, the PMP is associated with a smaller AEP than anticipated. This could be a result of the assumptions made to complete the analysis. From other coastal California basins, AEP estimates of PMP have been on the order of 1/50,000 years.

The following assumptions were made to compute the precipitation frequency curve: 1) It was assumed that the annual maximum precipitation observations from each rain gauge captured all significant rain events (i.e. that only one significant event occurred at each gauge within a calendar year), and the network was sufficient to capture extreme precipitation events. 2) It was assumed that the rain gauge data within the statistically homogeneous region represented significant precipitation for the watershed, and that the Generalized Logistic distribution was appropriate for this region. However, those gauges with discordant data (i.e. those gauges with high precipitation outliers) had to be eliminated from the dataset in order to achieve homogeneity. 3) It was assumed that it was appropriate to use the 24-hour to 72-hour ratio published in HMR 59 (Corrigan et al. 1999) to scale the precipitation frequency curve to 72-hours. 4) It was assumed that the PMP value calculated from HMR 59 and the 24-hour to 72-hour ratio from HMR 59 remains accurate, even though HMR 59 was produced using individual storm data from 1905-1986, rather than fixed-area relationships from point data. 5) It was assumed that the annual maximum daily precipitation data used in the analysis were approximately stationary, such that the past precipitation is representative of future extreme precipitation estimates. We are in the process of examining this assumption at several other sites in Californa where hydrologic hazard information is needed for dam safety.

6. CONCLUSION

Due to a need for hydrologic hazard information at East Park Dam, CA, it was necessary to estimate a precipitation frequency curve for the East Park watershed. The precipitation curve was created using regional L-Moments statistics. The result is shown in Figure 3.

This curve will subsequently be used as input into a rainfall-runoff model to create a Hydrologic Hazard Curve. Flood peaks may then be compared with spillway discharge capacities to determine the risk of overtopping at the dam.

The precipitation frequency curve for the East Park watershed has a tail that is much more flat than expected, and therefore, the PMP is associated with an AEP that is smaller than anticipated. This may be the result of the assumptions made to complete the analysis.

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