# EXTREME STORM EVENT ASSESSMENTS FOR NUCLEAR FACILITIES AND DAM SAFETY

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**Abstract**

Extreme storm events over the last 35 years are being assessed to evaluate flood estimates for safety assessments of dams, nuclear power plants, and other high-hazard structures in the U.S. The current storm rainfall design standard for evaluating the flood potential at dams and non-coastal nuclear power plants is the Probable Maximum Precipitation (PMP). PMP methods and estimates are published in the National Weather Service generalized hydrometeorological reports (HMRs). A new Federal Interagency cooperative effort is reviewing hydrometeorologic data from large storms which have occurred in the last 20 to 40 years and were not included in the database used in the development of many of the HMRs. Extreme storm data, such as the January 1996 storm in Pennsylvania, June 2008 Iowa storms, and Hurricanes Andrew (1992), Floyd (1999), Isabel (2003), Katrina (2005), need to be systematically assembled and analyzed for use in these regional extreme storm studies. Storm maximization, transposition, envelopment, and depth-area duration procedures will incorporate recent advances in hydrometeorology, including radar precipitation data and stochastic storm techniques. We describe new cooperative efforts to develop a database of extreme storms and to examine the potential impacts of recent extreme storms on PMP estimates. These efforts will be coordinated with Federal agencies, universities, and the private sector through an *Extreme Storm Events Work Group* under the *Federal Subcommittee on Hydrology*. This work group is chartered to coordinate studies and develop databases for reviewing and improving methodologies and data collection techniques used to estimate design precipitation up to and including the PMP. The initial effort focuses on: (1) collecting and reviewing extreme storm event data in the Southeastern U.S. that have occurred since Tropical Storm Agnes (1972); and (2) developing an electronic storm data catalog prototype. Uncertainties and exceedance probability estimates of PMP are being explored. Potential effects of climate variability and change on the PMP are also under investigation.

## INTRODUCTION

Storm-based precipitation is one of the major inputs to rainfall-runoff models, and is the dominant forcing variable that causes extreme floods. Data and methods for estimating extreme storms, up to and including the Probable Maximum Precipitation (PMP), are currently lacking. Currently, there is no mechanism in place within Federal Agencies to routinely collect, analyze, and archive extreme storm data that is useful for estimating extreme floods. In addition, there are no procedures in place to update storm data sets, methodology, and reports that are used to develop generalized PMP estimates. For example, the most recent PMP report was published in 1999 and used data up to February 1986. Thus, extreme storms that caused major floods such as January 1997 in California, February 1996 in Oregon, January 1995 in Pennsylvania and

rainfalls from Hurricanes Andrew (1992), Katrina (2005), Floyd (1999), and the 2008 Mid-West U.S. floods are not well-documented and not part of any storm catalog (e.g., USACE Storm Rainfall - 1945-1973) or data set useful for flood estimation. Improved extreme storm estimates, including exceedance probability estimates of storm properties, can be used for dam safety assessments, nuclear power plant designs and assessments, risk analysis, and understanding extreme flood processes.

The DAD data and PMP methods are used to provide "generalized" PMP estimates over large regions of the United States (Figure 1). The PMP estimates have been published in Hydrometeorological Reports (HMRs) (Table 1).

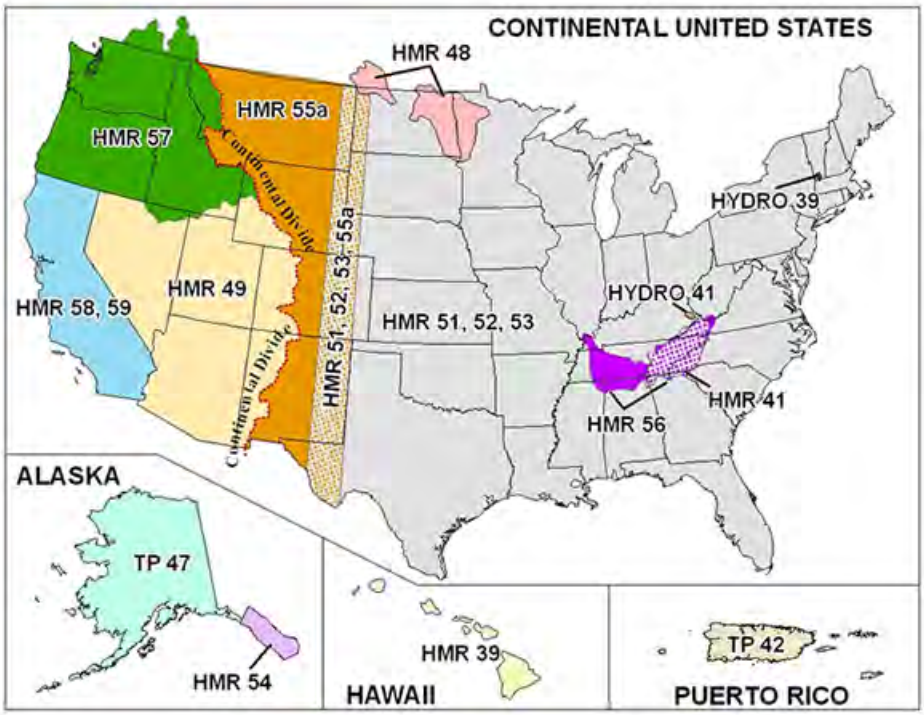


**Figure 1.** Regional coverages of generalized PMP reports in the United States (from NOAA/NWS Website: http://www.weather.gov/oh/hdsc/studies/pmp.html).

**Table 1:** Status summary of generalized Hydrometeorological Reports

| HMR No. | Publication Date | Latest Storm Used | Comments |
|---|---|---|---|
| 49 | 1977 | Sept. 3-7, 1970 | see HMR 50 for storm info; 1983 Prescott, AZ storm exceeds PMP |
| 51 | June 1978 | June 19-23, 1972 | Replaced HMR 33 (1956) |
| 55A | June 1988 | Aug. 1-4, 1978 | Replaced HMR 55 (1985) and TP 38 (1960) |
| 57 | October 1994 | Dec. 24-26, 1980 (general)<br>Aug. 16, 1990 (local) | Replaced HMR 43 (Nov. 1966) |
| 59 | February 1999 | Feb. 14-19, 1986 | Replaced HMR 36 (Oct. 1961) |

Other than the storms used in the HMRs, little to no storm data have been collected and analyzed for regional or generalized PMP estimates. Some limited extreme storm data have been collected and summarized for some states and by some consultants for site-specific or statewide PMP work. However, these data sets have not been analyzed for use in a larger region or for application to multiple structures. The data in Table 1 indicate that there is a definite need for storm data collection. There is also a lack of major storm data within an existing HMR. There are several limitations noted in the HMRs on providing space-time estimates of PMP, especially within orographic areas. Unlike the procedures in HMR 52, there are no methods for spatially and temporally distributing PMP over a watershed for locations other than the eastern United States.

## PROBLEM STATEMENT AND NEED

The Hydrometeorological Reports that form the basis for generalized probable maximum precipitation estimates rely on data that does not include the large storms that have occurred in the last 20 to 40 years. This creates a need to supplement these reports with site-specific analyses to incorporate the largest storms that have occurred in a particular region. Site-specific storm studies to date are done typically on an ad-hoc, individual dam or structure basis. The full benefits of these studies are not materialized, because there is no central archive for the documentation, storage, and sharing of extreme storms and related analyses. The extreme storm catalog should be expanded to include recent storms, and the HMRs should be updated to include the latest data.

An updated storm catalog is required to estimate the rainfall magnitude and spatial and temporal storm characteristics for various watersheds throughout the United States. Many agencies are using this information to develop extreme storm rainfall estimates for risk assessment and to determine the maximum flood potential at a particular location. Most of the storm information included in the extreme storm catalog was derived from published sources and supplemented with bucket survey information. Bucket surveys were used to get better definition of the rainfall magnitudes near the storm centers. Budget constraints have eliminated collection of bucket survey data in the past 20-30 years. Recent advances in use of radar reflectivity data should be examined as a source of information to supplement published rainfall data to expand the extreme storm catalog.

Many recent precipitation studies have used computer models to examine extreme storms. The HMRs use storm transposition and maximization techniques for determining generalized PMP estimates. These techniques should be compared against available computer modeling approaches that have been more recently developed. The advantages and disadvantages of each approach should be considered to determine the most appropriate approach for use in estimating extreme floods and to estimate the uncertainty in the estimates.

## WORK GROUP TASKS

1. Solicit Work Group membership from Federal and state agencies, universities (e.g. Bill Cotton, Colorado State University; Jim Smith, Princeton), professional organizations (e.g., AMS, ASME) and others with expertise in hydrometeorology, including consultants (e.g. Mel Schaefer,

MGS Engineering; Ed Tomlinson, AWA), and Federal and other labs (e.g. NOAA-NSSL, NOAA-ESRL, NCAR, etc.). Elect a chair and vice-chair.

2. Perform a literature review. Investigate improvements to methodologies (NRC, 1988; NRC, 1994; NRC, 2005; Cotton et al., 2003) and data collection techniques.

3. Develop a detailed scope of work/plan of study, and determine the necessary funding requirements to accomplish the work. Develop a long term plan to update the extreme storm catalog and HMRs for estimating PMP. Consider use of new technologies for storm analysis and data collection and dissemination. List possible approaches for acquiring funding to implement the plan.

4. Develop a list of individual Federal agency needs.

5. Inform the SOH and ACWI of the present state of Federal funding support, and the need to develop future budget support for long-term cooperative efforts to: maintain extreme storm databases; periodic review and updating of HMRs and the Catalog of Extreme Storms; development of site-specific studies of PMP and extreme storm event contributions to flooding, and support dam safety and nuclear facility installation evaluations.

6. Consider sponsoring an extreme storm workshop or specialty conference (e.g. at AMS, AGU, ASCE, etc.).

## PROTOTYPE EXTREME STORM DATABASE AND ARCHIVAL SYSTEM

An Extreme Storm Database will be developed to include pertinent data from storms contained in the Extreme Strom Catalog as well as from additional extreme storms that have occurred since 1973. The database will include historic storm information including the storm location and date, depth-area-duration relationships, temporal distribution, dew points, wind direction, elevation of the storm center, isohyetal maps, bucket survey data and radar images if available. The Extreme Storm Database will also include a "Data Archiving and Analysis System" which will include scanned images of original data collected from each storm event including the original ‘bucket survey’ forms, hand drawn isohyetal maps, and basic data collected from each storm event. This will allow the user to check the original data for each storm event. Also, the original isohyetal maps will be digitized into a GIS format for use in storm transposition studies and for computing depth area relationships. A schematic of the Data Archiving and Analysis System is shown in Figure 2.

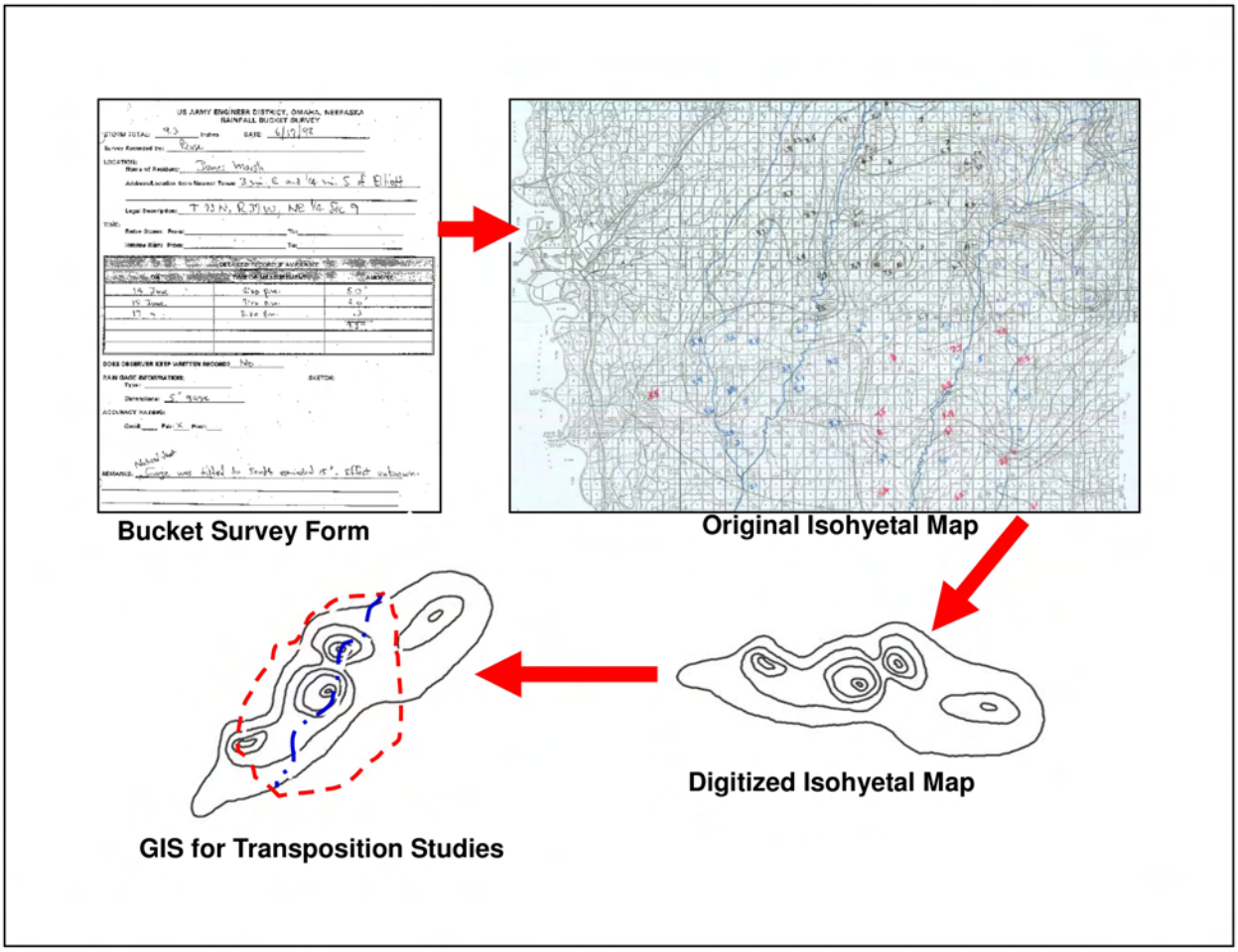


**Figure 2.** Extreme Storm Database Data Archiving and Analysis System Schematic.

Tasks to develop this system include compiling historic data for extreme storms from the NWS, USBR, USACE, state climatologists, and other agencies; updating the extreme storm catalog to include extreme storms that have occurred since 1973, scanning historical files and reports, and digitizing the isohyetal maps. In addition to the historical isohyetal maps, radar estimates of precipitation that are available beginning in about 1997 will be included in the database. A web site will be developed to create a centralized location for storing and sharing extreme storm information between all agencies as well as the public. The web site will also include electronic versions of the HMRs, site specific PMP studies, and other pertinent references for extreme storm studies that will be available for download. The layout, format and location of the web site will be developed by the Extreme Storm Events Work Group.