Flood Frequency in Texas—Calculation of Peak-Streamflow Frequency at Gaging Stations

In cooperation with the Texas Department of Transportation

In 1991, the U.S. Geological Survey (USGS) began a 5-year study of floods in Texas. The study, which is being done in cooperation with the Texas Department of Transportation, uses streamflow data collected at streamflow-gaging stations to assess Texas flood characteristics. Two major objectives of the study are to determine for unregulated, rural basins (1) the most reliable method to calculate peak-streamflow frequency for Texas stations; and (2) a method to estimate peak-streamflow frequency at any Texas stream site (gaged or ungaged) using pertinent peak-streamflow information from nearby stations. This fact sheet pertains to the first objective of the study.

Peak-Streamflow Data and Frequency Calculation

For more than 100 years, the USGS has been monitoring streamflow and publishing streamflow data, including annual peak discharges, for stations throughout the United States. In Texas, peak-streamflow data are available for about 946 active and inactive stations on streams that drain rural (natural) or urban basins. About 23,000 values of peak streamflow are available. These data are referred to as systematic peak-streamflow data and include the date, discharge, and water-surface elevation (stage) for each event.

In addition to collecting peak-streamflow data in Texas, the USGS routinely collects, through newspaper accounts and interviews with local residents, information about historical peak streamflows. A historical peak streamflow is the highest peak streamflow since a known date preceding the installation date of the station; historical peak streamflow can occur either before or after the installation of a station. Historical data are critical for evaluating peak-streamflow frequency estimates for the larger recurrence intervals. Therefore, where available, historical data are included in peak-streamflow frequency investigations. Historical peak stage and streamflow data are available for approximately 50 percent of the stations in Texas.

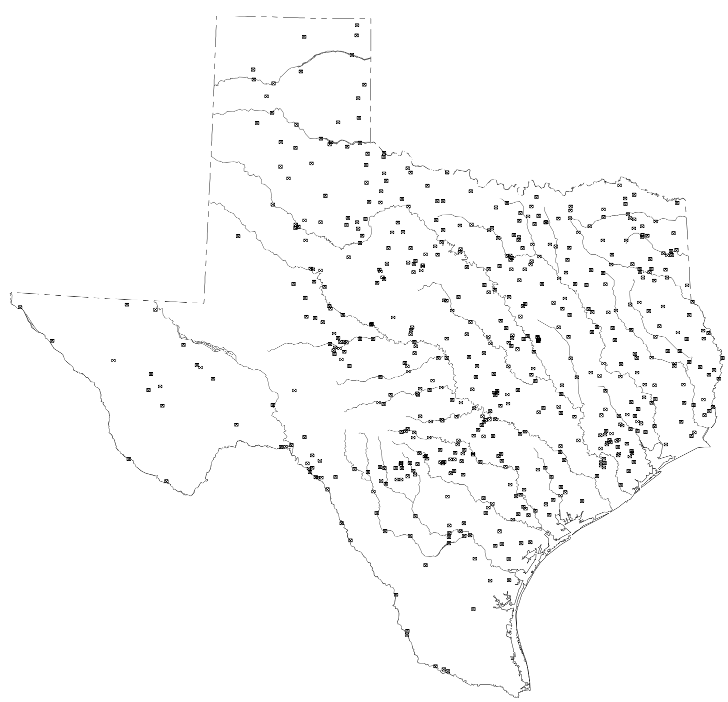
Typically, a minimum of about 8 years of peak-streamflow data is necessary to adequately define peak-streamflow frequency. The stations included in the 1991–96 study have at least 8 years of peak streamflow from unregulated, rural basins. An unregulated basin is defined as having less than 10 percent of its drainage area controlled by reservoirs or other human activities; a rural basin is defined as having less than 10-percent impervious cover. About 559 of the stations (see figure) meet the above criteria and thus are used in the study. The mean systematic record length for the stations is 23 years. Historical peak-streamflow values are available for about 33 percent of those stations, and the mean historical record length is 88 years.

The Interagency Advisory Committee on Water Data (IACWD) (1982) provides a standard procedure for peak-streamflow frequency calculation that involves a standard frequency distribution—the log-Pearson Type III (LPIII) distribution. The LPIII distribution uses systematic and historical peak-streamflow values to define its frequency distribution. The curvature in the distribution is defined by a skew coefficient used in the calculation procedure.

The LPIII distribution does not always adequately define the proper distribution of peak-streamflow values in Texas because of climatic and physiographic characteristics. An improper fit of the distribution to peak-streamflow values can produce erroneous values for peak-streamflow frequency.

Climatic and Physiographic Influences on Peak Streamflow

The climate and physiography of Texas vary considerably across the state. Accordingly, climatic and physiographic factors typically cause peak streamflows at a site to be nonuniformly distributed and to range by as much as 5 orders of



Locations of gaging stations in Texas with at least 8 years of peak-streamflow data from unregulated, rural basins.

magnitude. This nonuniformity and extreme range causes difficulty in determining reliable calculations of peak-streamflow frequency.

The climatic variability in Texas contributes substantially to the nonuniformity and extreme range in peak streamflow. Many world-record precipitation events have occurred in Texas. For example, near Thrall (about 30 miles northeast of Austin) during September 9–10, 1921, an unofficial total of 38.2 inches of rain fell in 24 hours; and a 1935 storm near D'Hanis (about 40 miles west of San Antonio) produced 22 inches of rain in 2 hours, 45 minutes. Destructive floods occur somewhere in the State nearly every year. Recently, catastrophic flooding occurred in southeast Texas (October 1994) and in north-central Texas (December 1991). Long-term droughts that frequently cause periods of no flow or extreme low flow also occur throughout the State. At least one drought has occurred in some part of Texas in every decade of the 20th century.

The physiography of Texas contributes to the extreme range in peak streamflow at sites. Much of the western half of the State contains alluvial basins in which large evapotranspiration rates cause substantial reduction of the smaller (more frequent) peak streamflows; thus, the peak-streamflow range at many stations is increased. Conversely, many streams in the eastern half of the State have sustained flow from shallow water tables. Additionally, the peak-streamflow range at stations on streams in central Texas is increased by substantial peak-streamflow loss into fractured limestones during droughts and by extraordinarily large streamflows, enhanced by thin soils and steep slopes, during periods of abundant rainfall.

Recent USGS Work on Calculation of Peak-Streamflow Frequency

The USGS has aggregated the systematic and historical peak-streamflow data in Texas and has summarized and computerized the IACWD procedure for estimating peak-streamflow frequency. In addition, the USGS has: (1) devised a method to estimate generalized skew coefficients in Texas; (2) devised a method to estimate low-outlier thresholds; and, (3) investigated the most extreme peak streamflows in Texas, and their statistical relation to the probable maximum flood.

Estimation of Generalized Skew Coefficients

The skew coefficient is difficult to estimate reliably for stations with short records. Therefore, the IACWD recommends using a weighted skew coefficient with the LPIII distribution. This skew coefficient is calculated by weighting the skew coefficient computed from the peak-streamflow data at a station, and a generalized skew coefficient representative of the surrounding area. The weighted skew coefficient is based on the inverse of the respective mean square errors for the two coefficients.

Stations with at least 20 years of peak-streamflow data from unregulated, rural basins—about 255 stations—were used to estimate generalized skew coefficients, and a map depicting lines of equal values for generalized skew coefficients for Texas was developed. A nationwide map for estimating generalized skew coefficients is included in the IACWD procedure. The mean square error for the IACWD generalized skew coefficients is 0.30. The mean square error for the coefficients from the current (1991–96) study is 0.12. The lower mean square error associated with the current study indicates that it might provide more reliable estimates of generalized skew coefficients. Additionally, the IACWD map of generalized skew coefficients was developed with data through 1973, and much data have been collected since then.

Estimation of Low-Outlier Thresholds

The climatic and physiographic characteristics of Texas occasionally cause extremely small peak-streamflow values (low outliers). Typically, low outliers are identified by visually fitting the LPIII distribution curve to the peak-streamflow values. The presence of low outliers in the data can substantially affect the distribution curve; therefore, low outliers should be excluded by the specification of a low-outlier threshold. All peak-streamflow values (including zero) below the threshold are excluded from the fitting of the LPIII distribution. For example, one calculation of the 100-year peak-streamflow for a station on the Nueces River in south-central Texas is 1,480,000 ft^3/s (cubic feet per second); however, many low outliers are present in the data. Using the proper low-outlier threshold reduces that value to 308,000 ft^3/s—a more reasonable value considering the fact that 550,000 ft^3/s is the highest documented peak streamflow at this station in at least 158 years. About 60 percent of the stations in the study have one or more peak streamflows less than their respective low-outlier threshold. As part of the 5-year study, a statistical procedure was developed to estimate low-outlier thresholds.

Estimation of Probable Maximum Floods

Knowledge of extreme peak streamflow potential for a stream site often is useful to define an upper limit for peak-streamflow values. About 832 extreme peak streamflows for stations and other sites are documented in Texas. The study investigated an "envelope" curve for each of 11 regions in the State, based on the relation between basin drainage area and the documented extreme peak streamflows. Peak streamflows from these curves are highly correlated to probable maximum floods, and the study investigated a statistical procedure from which probable maximum floods can be estimated.

—William H. Asquith and Raymond M. Slade, Jr.

Reference

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: Reston, Va., U.S. Geological Survey, Office of Water Data Coordination, Hydrology Subcommittee Bulletin 17B [variously paged].

Information on technical reports and hydrologic data related to flood frequency in Texas can be obtained from:

Project Chief, Flood Frequency
U.S. Geological Survey
8011 Cameron Road
Austin, TX 78754–3898
(512) 873–3000