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Evaluation of the Streamflow-Gaging Network of Texas and a Proposed Core Network

Water-Resources Investigations Report 01–4155

U.S. Department of the Interior
U.S. Geological Survey

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By Raymond M. Slade, Jr., Teresa Howard, and Roberto Anaya

U.S. GEOLOGICAL SURVEY
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In cooperation with the Texas Water Development Board

Austin, Texas
2001

U.S. DEPARTMENT OF THE INTERIOR

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Abstract

The U.S. Geological Survey streamflow-gaging network in Texas is operated as part of the National Streamgaging Program and is jointly funded by the Geological Survey and Federal, State, and local agencies. This report documents an evaluation of the existing (as of October 1, 1999) network with regard to four major objectives of streamflow data; and on the basis of that evaluation, proposes a core network of streamflow-gaging stations that best meets those objectives. The objectives are (1) regionalization (estimate flows or flow characteristics at ungaged sites in 11 hydrologically similar regions), (2) major flow (obtain flow rates and volumes in large streams), (3) outflow from the State (account for streamflow leaving the State), and (4) streamflow conditions assessment (assess current conditions with regard to long-term data, and define temporal trends in flow). The network analysis resulted in a proposed core network of 263 stations. Of those 263 stations, 43 were discontinued as of October 1, 1999, and 15 were partial-record stations. Fifty-five of the proposed core-network stations meet two of the four major objectives, 16 stations meet three objectives, and 1 station meets all four. One-hundred eighty-five stations with a median record length of 33 years were selected to meet the regionalization objective. Ninety-two stations with a median record length of about 62 years were selected to meet the major-flow objective. Twenty-six stations with a median record length of 59 years were selected to meet the outflow from the State objective. Fifty stations with a median record length of 53 years were selected to meet the streamflow conditions assessment objective.

INTRODUCTION

Background

The Texas District of the U.S. Geological Survey (USGS), currently (1999) operates more than 300 streamflow-gaging stations in Texas. The stations, which fulfill multiple data needs, are operated with funding cooperation from Federal, State, and local governmental agencies and are part of the USGS National Streamgaging Program (described at http://water.usgs.gov/osw/programs/streamgaging.html). The Texas Water Development Board (TWDB) is the cooperating agency for the most stations. More than 25 years ago the USGS proposed a core streamflow-data network for Texas (Gilbert and Hawkinson, 1971). Data uses and funding were analyzed in 1985 (Massey, 1985). Since the original core network was proposed, the number of active streamflow-gaging stations has declined. As the State population and water use increase, the importance of a core streamflow-gaging network to provide surface-water information and to monitor water resources, especially during floods or droughts, increases.

The USGS operates two basic types of streamflow stations: continuous-record stations and partial-record stations. Continuous-record stations include daily flow stations for which instantaneous and daily mean streamflow are computed, and stage-only stations for which daily mean water levels are computed. Daily mean streamflows for the daily flow stations and daily mean water levels for the stage-only stations are published annually by the USGS.

Partial-record stations include flood-hydrograph stations for which daily mean streamflows that exceed a specific base discharge are computed; crest-stage stations for which annual peak streamflows are computed from peak stage data; and low-flow stations where streamflows are measured periodically. Daily mean and annual peak streamflows are published annually by the USGS; those data, along with recent instantaneous streamflows, are available at the USGS Texas home page at http://tx.usgs.gov/.

Purpose and Scope

The purpose of this report is to evaluate the existing[1] streamflow-gaging network of Texas with regard to four major objectives, and on the basis of that evaluation, propose changes to the existing network to better accomplish those objectives. Implementing the proposed changes to the streamflow-gaging network will result in a core network—a system of streamflow-gaging stations required to accomplish the four major objectives of the USGS and the TWDB. Streamflow-gaging stations on the Rio Grande and some of its larger tributaries that are operated by the International Boundary and Water Commission (IBWC) were not included in this analysis. Stations that gage springflow or flow in canals also were excluded; thus the gaging stations in this report represent streamflow from specific basins.

STREAMFLOW NETWORK ANALYSIS

History of Streamflow Gaging in Texas

The first streamflow-gaging station to record daily mean streamflow in Texas began operation in 1889. The station, located on the Rio Grande near El Paso, collected data in support of the design and operation of Elephant Butte Dam (Texas Board of Water Engineers, 1960). Several short-term stations collected streamflow data from major streams between 1895 and 1914 (Gilbert and Hawkinson, 1971). Systematic data collection commenced in 1897 with the establishment of four additional long-term stations (Massey, 1985). Daily flow stations still in operation today were installed on the Colorado River at Austin and on the Brazos River at Waco in 1898. By the beginning of the 20th century, the American Section of the IBWC began to collect streamflow data along the Rio Grande in Texas.

In 1915, the USGS and the State of Texas initiated formal cooperation in a statewide program to collect water-resources data, and the number of Texas stations more than doubled (fig. 1). Extensive flooding in 1921 created the impetus for rapid expansion of the gaging network. By 1925, more than 100 gaging stations were active, and 36 of the stations were equipped with data recorders. After 1925, however, network expansion ceased for about a decade because of a lack of cooperative funding. After Texas experienced catastrophic floods nearly every year from 1932 to1939, and with the passage of the Flood Control Act of 1936, the U.S. Army Corp of Engineers (USACE) funded 55 new stations. By 1939, the Texas streamflow-gaging network began to expand and remained stable during World War II.

From 1940 to 1951, most stations were installed as support for water-resources development (Gilbert and Hawkinson, 1971). In 1952, an investigation of the effect of U.S. Soil Conservation Service flood-prevention projects led to the installation of stations on streams with rural drainage areas of less than 250 square miles. The former Texas Board of Water Engineers (TBWE) (now Texas Water Development Board) reported that more than 220 continuous record streamflow-gaging stations were in operation in the State on September 30, 1957. During the decade from 1958 to 1968, the USGS established many more stations in Texas.

As data collection increased and quantitative methods were developed for engineering projects, the State Highway Department (now Texas Department of Transportation) identified the need for data pertinent to the magnitude and frequency of flood stage and discharge for use in bridge and culvert design (Massey, 1985). From 1964 to 1974, a statewide network of about 150 flood-hydrograph and crest-stage partial-record stations gathered considerable data that defined the characteristics of peak flows from small rural drainage areas. On the basis of these data, Schroeder and Massey (1977) developed equations to estimate peak-streamflow frequency for natural basins in Texas. Eighteen years later, Asquith and Slade (1995) analyzed the existing peak-streamflow database and reported on the maximum documented peak streamflow for stations and other sites throughout Texas. Two years later, the database was used to develop equations to estimate peak-streamflow frequency for natural basins in Texas (Asquith and Slade, 1997). The database also was used to define equations to estimate long-term mean streamflow for natural basins in Texas (Lanning-Rush, 2000).

The streamflow-gaging network peaked in 1972 with the operation of about 650 stations (fig. 1). From 1972 to 1996, the number of daily flow stations decreased from about 420 to less than 300. The gradual

[1] In this report, *existing* means as of October 1, 1999.

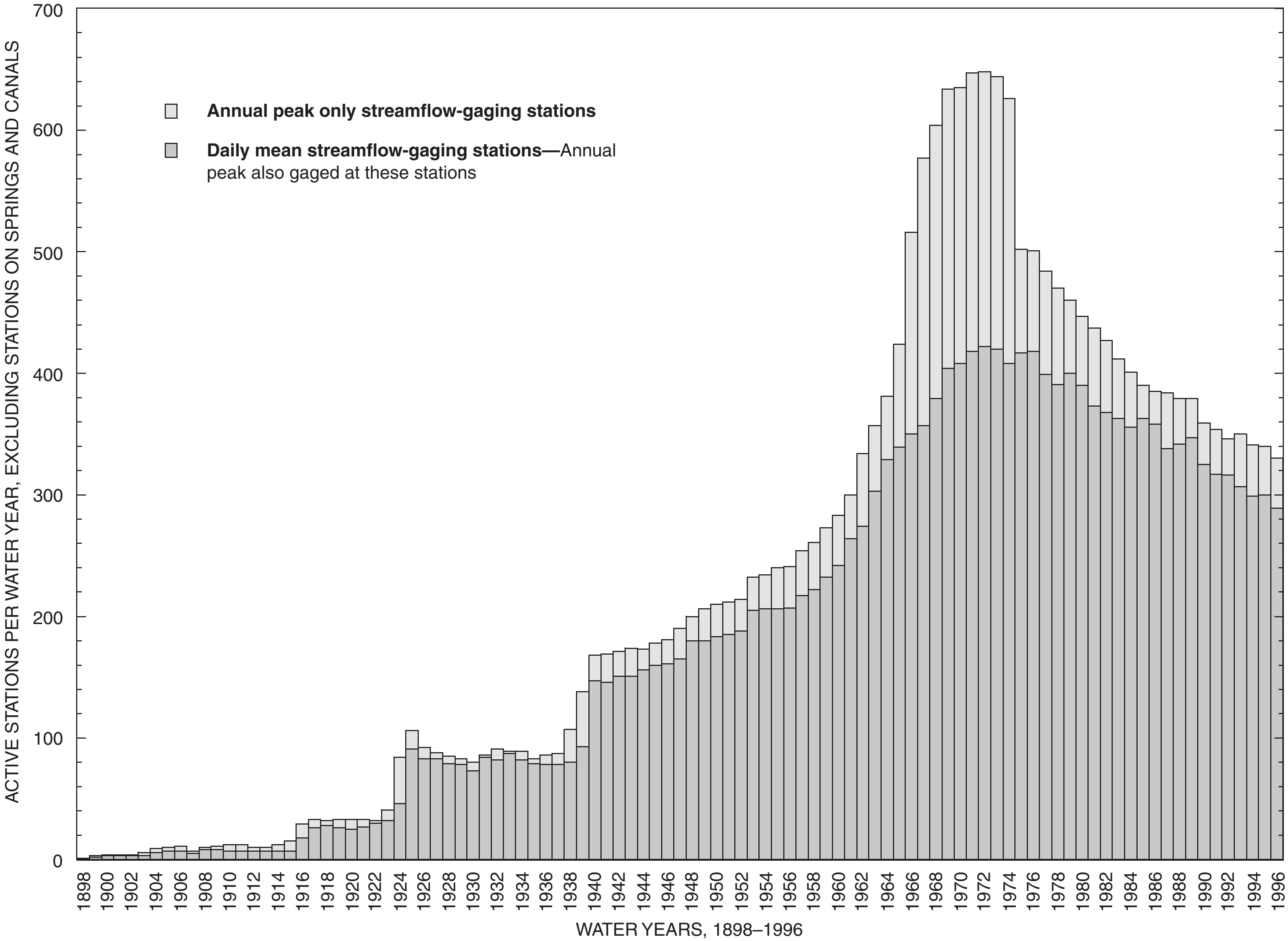


Figure 1. Number of daily mean and annual peak streamflow stations in Texas, 1898–1996.

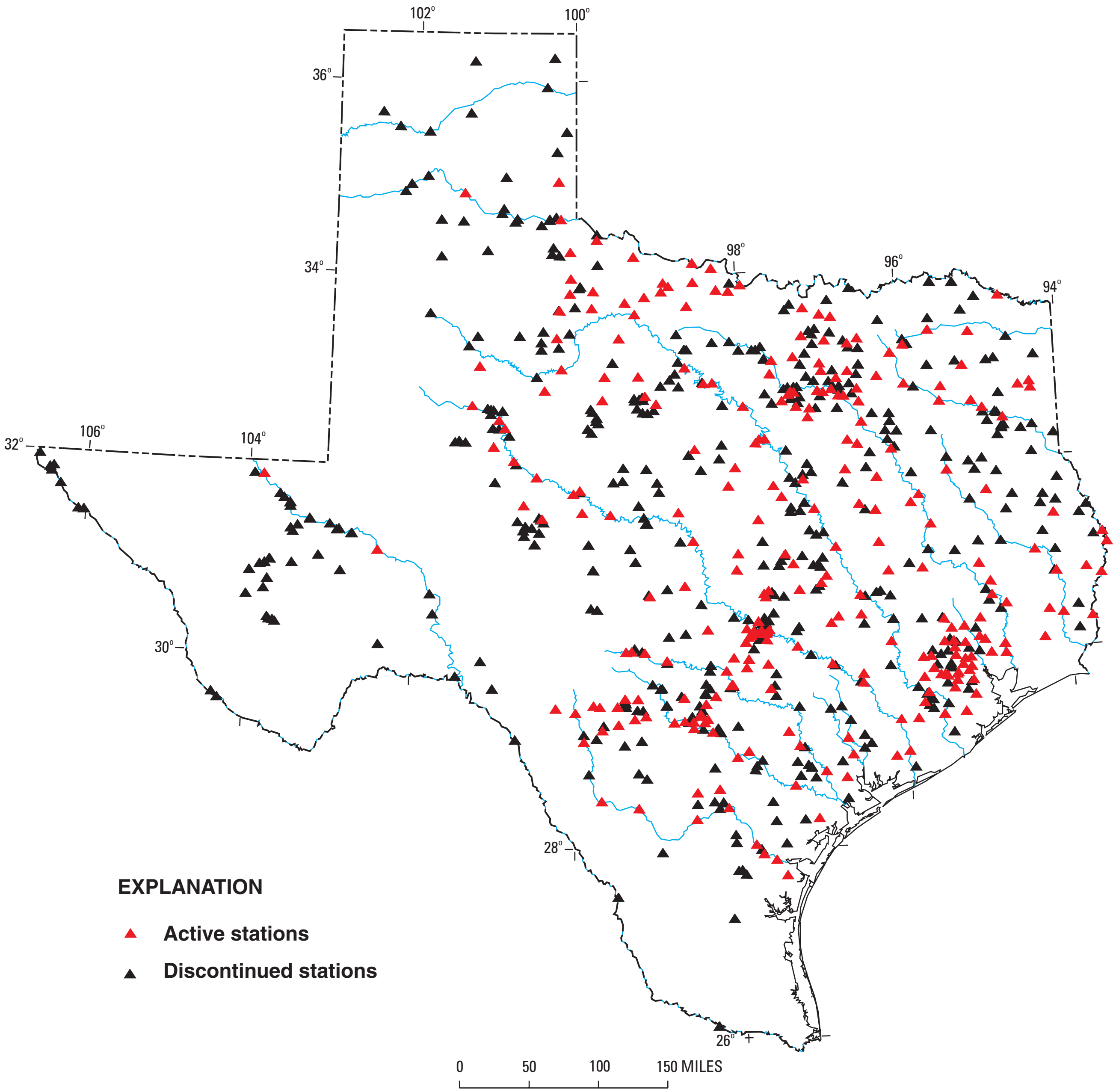


Figure 2. Locations of active and discontinued daily streamflow stations, October 1, 1998.

decline of the streamflow-gaging network has continued to the present time (1999). On October 1, 1998, the USGS streamflow-gaging network in Texas consisted of 312 daily flow stations (including springs and canals), 17 stage-only stations, 58 flood-hydrograph stations, 27 crest-stage stations, and 25 low-flow stations. The locations of all active and discontinued daily flow stations as of October 1, 1998, are shown in figure 2.

Network Evaluations in Texas

In Texas, three previous reports assess the State's streamflow-gaging network. In 1960, the TBWE published a report in cooperation with the USGS that evaluated the existing streamflow-gaging network and made recommendations for its expansion (Texas Board of Water Engineers, 1960). The report concluded that streamflow-gaging stations had been established in response to the data requirements of individual Federal and State agencies and local entities; and that a more systematic approach would improve understanding of hydrologic conditions in the State's widely variable watersheds. Citing the fact that physiographic and climatic diversity precluded the use of streamflow data from one basin to accurately predict streamflow in another, the TBWE proposed the establishment and maintenance of a network in accordance with USGS policy and philosophy. Specifically, two general classifications of streamflow-gaging stations were defined: hydrologic-network stations that provide data from natural, unregulated basins that could be used both for planning and design of future water-development projects and in research seeking scientific solutions to hydrologic problems; and water-management stations designed to meet specific data needs and to provide information about present and past streamflow conditions.

The TBWE analysis identified 88 stations from the 296 streamflow- and stage-recording stations in September 1958, as areal primary stations satisfying the conditions of regional representation and length of record necessary for hydrologic investigations; and proposed the reactivation or establishment of 58 additional areal stations for the primary network, for a total of 146 areal primary stations. Thirty-two stations were identified as areal secondary stations, and the study recommended the addition of 131 stations in the areal secondary category, for a total of 163 areal secondary stations. The goal of areal secondary stations was to collect sufficient data to correlate streamflow with that at areal primary sites. The TBWE report stated that 5 to 10 years of streamflow record collected at a secondary station usually would define an adequate correlation.

A decade later, Gilbert and Hawkinson (1971) presented the results of their analysis of the 1970 Texas streamflow-gaging network of 464 stations as part of a national evaluation program. They concluded that the most serious deficiency in the collection of natural streamflow data was in the western one-third of the State, and accordingly, proposed the addition of nine stations in that region. They found the network in the eastern two-thirds of the State to be adequate. They further concluded that data collection from regulated streams was deficient and suggested additional gaging of inflow to and (or) outflow from 20 reservoirs.

Massey (1985) analyzed data uses and funding for the USGS streamflow-gaging stations in Texas, as part of a project to determine cost-effectiveness of the State's data program. The study presented a table of data use, station funding, and data availability for 391 continuous-record streamflow-gaging stations. The report concluded that all stations active in 1984 have sufficient uses to justify their continued operation. The three network-funding and nine data-use categories as defined in the report are presented in the following section.

NETWORK FUNDING AND DATA USES

The three sources of funding for the streamflow-data program are:

1. Federal program—funds directly allocated to the USGS for the purpose of collecting streamflow data.
2. Other Federal Agency (OFA) program—funds that have been transferred to the USGS by other Federal agencies for data collection by the USGS to meet the needs of those agencies.
3. Federal-State Cooperative programs—funds that combine USGS cooperative-designated Federal funding and funding from a non-Federal cooperating agency. Cooperating agency funds can be in the form of cash or direct services.

Each station in the streamflow-gaging network can be classified into one or more of the nine data-use categories defined by Massey (1985). The definitions of the nine primary data uses and the classification of stations active on October 1, 1999, are as follows:

Regional Hydrology: The relations between streamflow characteristics (measures of mean flows, peak flows, and low flows) and basin characteristics (geography and climate) form the basis of regional hydrology. The relation between streamflow and factors such as drainage area and precipitation characteristics can be used to estimate streamflow characteristics at ungaged sites. However, data must be gathered from streams largely unaffected by impoundments or diversions so that empirical relations are meaningful.

In the Texas network, six existing stations were in the regional hydrology data-use category. Two of the stations were designated as benchmark stations and four were index stations. Benchmark stations are part of the Hydrologic Benchmark Network of 50 sites nationwide in small drainage basins that are relatively free from human alterations. Data collected at benchmark stations provide information about the changing quantity and quality of streamflow and other conditions related to long-term trends. Index stations are long-term stations used to prepare a national monthly summary of water conditions.

Hydrologic Systems: Hydrologic-system stations provide data used to define current hydrologic conditions and to monitor changes and trends in the movement of water in both unregulated and regulated systems. Stations recording diversions and return flows and the passage of flows through regulated storage systems as well as stations defining the interaction of water systems are in this category.

Almost 95 percent of existing daily flow stations were hydrologic-systems stations. The Texas Natural Resource Conservation Commission (TNRCC) relies on data from many of these stations to administer water-use permits throughout the State. Various river authorities also use hydrologic-system stations to allocate water resources among users.

Legal Obligations: The USGS sometimes is obligated to operate stations to satisfy certain legal requirements, which include the verification or enforcement of existing treaties, compacts, and decrees. As of October 1, 1999, no stations in the Texas program were in this category.

Planning and Design: Certain projects require streamflow record for proper design and planning. Such projects include the construction or operation of dams, bridges, floodwalls, water-supply diversions, hydropower plants, and wastewater-treatment facilities. Stations in the planning and design data-use category were installed specifically for such projects and continue to serve in this capacity.

About 60 of the existing daily flow stations in Texas were in the planning and design data-use category. Among the cooperators for this type of station are the TNRCC, USACE, municipalities, and several river authorities.

Project Operation: These stations assist water managers in making operational decisions affecting reservoir releases, hydropower operations, or diversions for irrigation and other water consumption. To be useful for project operation, data must be available to operators on a real-time or near real-time basis. Routine data availability every few days might be sufficient for some projects on large streams.

About 100 of the existing daily flow stations were in the project-operation category. Data users include the TNRCC, TWDB, various river authorities, municipal water districts, flood control districts, USACE, and Bureau of Reclamation.

Hydrologic Forecasts: Accurate hydrologic forecasting relies on dependable and accurate near real-time data. Hydrologic-forecast gaging stations form the basis for flood forecasts in specific river reaches and for periodic flow-volume forecasts at specific locations or in regions at daily, weekly, monthly, or seasonal intervals. Another use of stations in this category is for the monitoring of low-flow conditions during times of drought. Stations in this category generally provide data on a real-time, or near real-time basis.

Stations designated by the National Weather Service as necessary for flood forecasting are in the hydrologic-forecast category. Other agencies including the TWDB, TNRCC, river authorities, municipal water districts, and USACE might use data during flood and drought conditions. Most streamflow data in Texas are available on a near real-time basis. Data are available to cooperators and the general public on the Internet. Because of rapid data transmission and data accessibility, nearly all existing streamflow-gaging stations were in the hydrologic-forecast data-use category.

Water-Quality Monitoring: Streamflow data at gaging stations where water-quality or sediment-transport data are collected are essential to the interpretation of chemical and biological constituents, sediment concentrations, and computation of daily and annual loads. About 180 streamflow-gaging stations operated by the USGS with funding from many cooperators were in this category. Stations in urban areas collect data related to the effects of urban runoff. Other stations monitor discharges from sewage-treatment facilities and industrial plants. Some stations provide data to help define eutrophication and turbidity problems in water supplies.

Stations operated as part of the National Stream-Quality Accounting Network (NASQAN) also are included in this category. NASQAN stations measure the amount of chemicals and sediment in flow at sites on the Nation's largest rivers to characterize sub-basins, identify regional source areas of chemicals and sediment, and assess human influences on observed concentrations and amounts of these materials. In the past, about 40 NASQAN stations were operated in Texas; as of October 1, 1999, only 8 NASQAN stations were active—7 on the Rio Grande and 1 on a tributary to the Rio Grande. The USGS monitors water quality at the

NASQAN stations, and the IBWC is responsible for streamflow-gaging operations at these stations.

Research: Gaging stations operated for research or water-investigations studies typically are in place for a limited time, often for only a few years. In the past, such stations have collected streamflow data to support model development.

About 80 existing stations were in the research category. About 30 of the stations are part of an urban hydrology project in Houston, and another 27 stations are part of a project to identify nonpoint discharge sources in urban areas. Eight investigations throughout the State used the remaining stations in the research data-use category.

Other: Streamflow-gaging stations in at least one of the eight categories also provide useful information for recreational planning. Canoeists, rafters, and fishermen who enjoy the streams of Texas benefit from the public availability of data from USGS gaging-stations. No stations, however, are operated or funded primarily for recreational purposes. The “other” category reflects the fact that streamflow data can be useful for purposes other than the original purpose of the station.

MAJOR OBJECTIVES OF A CORE NETWORK

The USGS and the TWDB defined four major objectives of a core network of streamflow-gaging stations for Texas. A gaging station must provide data that contribute to at least one of the four objectives to justify its inclusion in the core network. The four objectives are:

1. Regionalization (estimate flows or flow characteristics at ungaged sites in 11 hydrologically similar regions).
2. Major flow (obtain flow rates and volumes in large streams).
3. Outflow from the State (account for streamflow leaving the State).
4. Streamflow condition assessment (assess current conditions with regard to long-term data and define temporal trends).

The specific number of stations to be included in the network was not predetermined. All active and discontinued stations were considered for inclusion in the core network. New stations were not considered because the large network of active and discontinued stations was assumed to be a sufficient pool of stations from which to select the core network. Also, the historical data needed for each station in the core network are not available for new stations. Because of the expense involved in reactivating stations, a discontinued station was included in the core network only if it made a substantial contribution. Existing stations not included in the core network provide redundant data, data for specific studies, or data needed to meet other objectives. The USGS might continue to support and operate such stations but not as part of the core network. The remainder of this section describes the purpose for each objective and the defining factors used to select stations that meet the criteria of each objective.

Regionalization: It is not economically feasible to gage every stream site of interest. Thus other means are necessary to estimate flows or flow characteristics at ungaged sites. Regionalization stations must be located in natural, or mostly natural, basins and provide data important for defining flow characteristics in regions with similar hydrologic characteristics (fig. 3). Stations are distributed within each hydrologic region to characterize the range of basin characteristics (drainage area, main channel slope, and basin shape) of each region. Regionalization stations commonly are used to estimate low-, mean-, and high-flow characteristics at ungaged sites. Stations meeting the criteria for this objective provide data to develop regional regression equations for estimating flow characteristics and for simulation of flows or flow characteristics at specific ungaged sites. The USGS and other agencies maintain computer programs to estimate streamflow and streamflow characteristics for ungaged sites. Such computer programs and statistical procedures typically require data from gaged sites for model calibration.

Major Flow: The second objective of the core network is to monitor and define streamflow rates and volumes from major streams in the State. Stations monitoring major flows provide information crucial for water-resource management and thus are important to the TWDB, TNRCC, and other agencies. The major streams of Texas (pl. 1) provide the largest flow volumes and much of the State’s water supply. Decisions concerning water allocation for municipalities, agriculture, and industry (particularly in times of drought) depend on timely information about major flows.

For the purpose of this objective, a major flow is defined as the streamflow from a contributing drainage

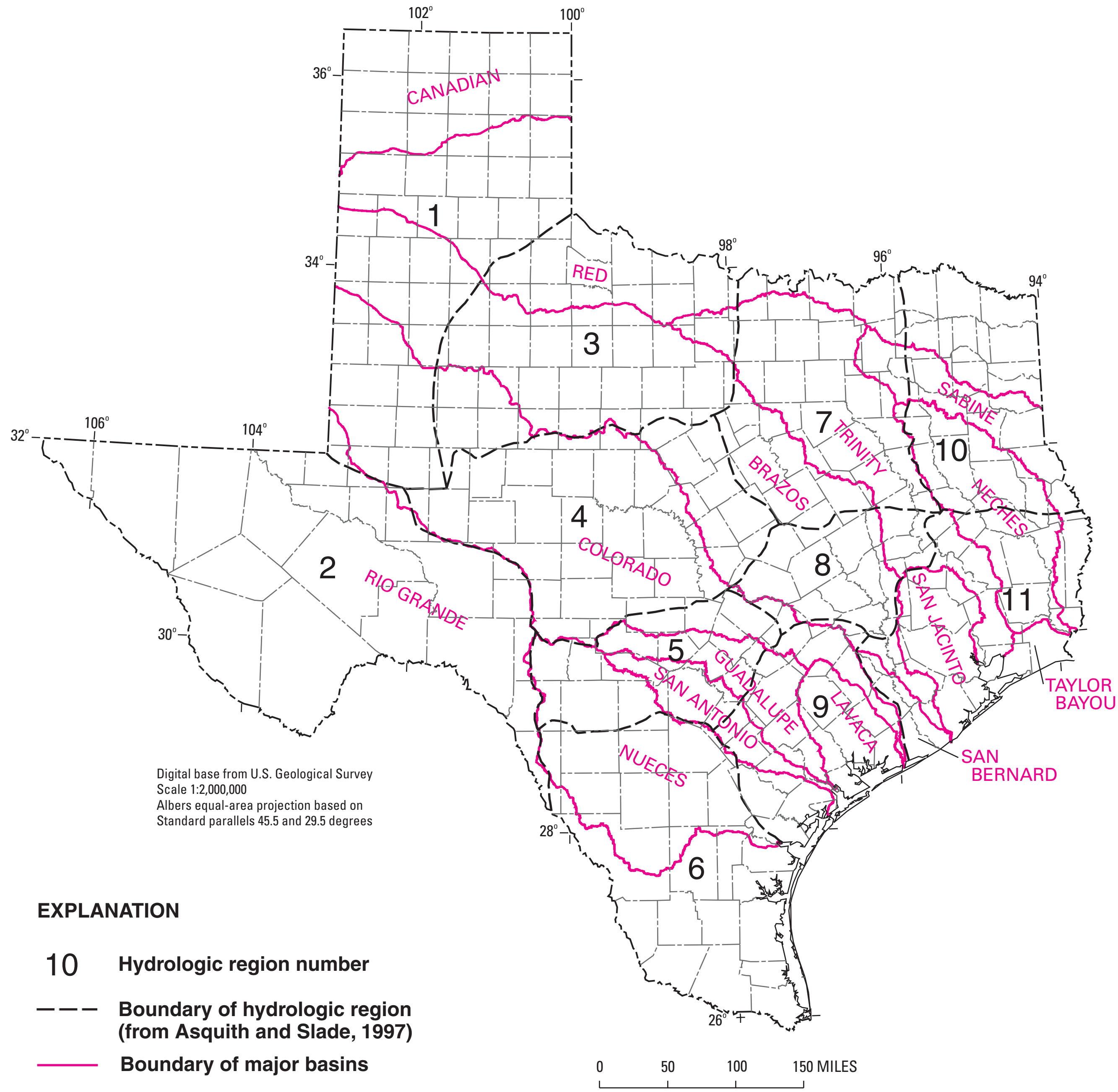


Figure 3. Hydrologic regions and major basins of Texas.

area of at least 1,000 square miles or as the streamflow of a river whose base flow is sustained by major springs. The Comal River (springflow from Comal Springs) and San Marcos River (springflow from San Marcos Springs) are the two streams in the State in the latter category. Most major flows in the State are regulated, so stations on these streams typically are not suitable for predicting flows or flow characteristics at other sites. However, data from these stations are needed for water-resource management. A sufficient number of stations on each major stream is required to define changes in streamflow over time and space. Many existing stations were excluded from the core network because their streamflow data are made redundant by nearby stations on the same stream. An analysis of the streamflow correlation between stations is presented later in this report.

Outflow from the State: The third major objective of the core network is to account for outflow from the State. Stations that provide data to meet this objective are at sites along the Gulf of Mexico or on the eastern border of the State and gage flow from basins greater than about 1,000 square miles. Their data define the quantity (and quality) of water leaving the State and can be used, along with data from stations gaging inflow to the State, to document statewide or basinwide water budgets of runoff. The effects of changes in land use, stream impoundment, and withdrawal rates are represented in the data collected at State outflow sites. Periodic water-quality and suspended-sediment data have been collected at most outflow stations. Such data, in combination with streamflow data, provide estimates of water-quality-constituent loads and trends in water-quality-constituent loads of flow into the Gulf of Mexico. Previous studies (Slade, 1992; Judd, 1995) have investigated streamflow to the Gulf of Mexico and include data from stations in Texas located near the Gulf of Mexico.

Most of the major basins in Texas originate within the State. Streamflow from the Canadian River, Pecos River, and Rio Grande, however, originates in New Mexico. A stream station on the Canadian River in New Mexico (Canadian River at Logan, N. Mex.) monitors inflow to Texas from that stream, a station on the Pecos River in Texas (Pecos River near Orla, Tex.) monitors inflow to Texas from that stream, and a station on the Rio Grande in Texas (Rio Grande at El Paso) monitors inflow to Texas from that stream.

Streamflow Conditions Assessment: Stations that provide data to meet the objective of streamflow conditions assessment must be long-term, geographically diverse stations with large natural, or mostly natural, basins. Data from these stations are used for assessment of flow conditions throughout the State and for analyses of temporal trends in streamflow. To be included in this category, a station must have at least 15 years of daily streamflow record; most of the stations have at least 30 years of record. Stations that provide data to meet the assessment objective must be distributed throughout the State so that the different hydrologic regions are represented. Streamflow-conditions-assessment stations provide information for both short-term and long-term planning. Stations that provide data to meet this objective also serve as indicators of both drought and flood conditions.

EVALUATION OF THE EXISTING NETWORK

Several tools were either developed or applied in the evaluation to determine whether stations should be included in the core network. Simple definition tests were sufficient to identify stations that met the criteria for three of the objectives: major flow, outflow from the State, and streamflow conditions assessment. Two tools were used to determine whether stations met the criteria for the regionalization objective: boundaries of hydrologic regions and a regional optimization model. A third tool, flow correlation analysis, was used to identify stations that provide redundant flow data, in order to minimize the number of stations needed to form the core network.

Hydrologic Regions

To conduct regional analysis of streamflow characteristics, the State was subdivided into regions that have relatively homogeneous hydrologic characteristics. The USGS has identified hydrologic regions (fig. 3) to define areas of similar climatology (precipitation and evaporation), physiography, surface geology, soils, and vegetation in previous studies (Asquith and Slade, 1995, 1997).

Delineation of the hydrologic regions was based primarily on reports by Carr (1967) and Kier and others (1977). Delineation also was influenced by drainage-basin boundaries for the major streams and areal density of the existing streamflow-gaging stations. Major-stream drainage-basin boundaries in Texas generally are oriented from northwest to southeast, and many of the hydrologic boundaries are aligned with those drainage boundaries. Climatic-division boundaries, however, along with physiographic and geologic boundaries, generally are aligned perpendicular to the basin boundaries. The hydrologic boundaries that are oriented perpendicular to major-stream basin boundaries are closely aligned with climatic, physiographic, and geologic boundaries. Also, an effort was made to pass hydrologic boundaries through areas with few streamflow-gaging stations. Where feasible, the boundaries were located downstream from areas of relatively dense station distribution, so that stations would be in the same regions as their drainage basins. Eleven hydrologic regions formed the basis of the regional optimization model.

Regional Optimization Model

The objective of the regional optimization model (Tasker and Stedinger, 1989) is to develop an effective gaging strategy to indicate where gaging stations should be located and how long they should be operated to maximize hydrologic information that could be used for regional analyses. This model was used to identify the stations for the regionalization objective. To optimize regional hydrologic information subject to a set of budget constraints, a backward-step regression technique was used to identify the relative value of data for all active and discontinued gaging stations. On the basis of the relative value of a stations's data, along with the cost to operate existing stations and the cost to install and operate discontinued stations, the regionalization gaging network can be optimized on the basis of data value and expense. In addition to the budget constraints, stations that must remain active in the future were identified in the model. The model is based on regionalizing mean annual flows and 25-year peak discharges from basin characteristics such as drainage area, basin slope, basin shape, and mean annual precipitation (Tasker and Stedinger, 1989).

The regional regression method that relates mean annual flow or 25-year peak discharge at a station to drainage-basin characteristics is a multivariable regression model that can be written, after suitable transformations, in the form of the following linear equation:

$$Y = X\beta + \varepsilon, \tag{1}$$

where

- Y = logarithms of mean annual flows or 25-year peak discharges at all stations within a region,
- X = basin characteristics for the region,
- β = regression parameters to be estimated, and
- ε = random errors for the model.

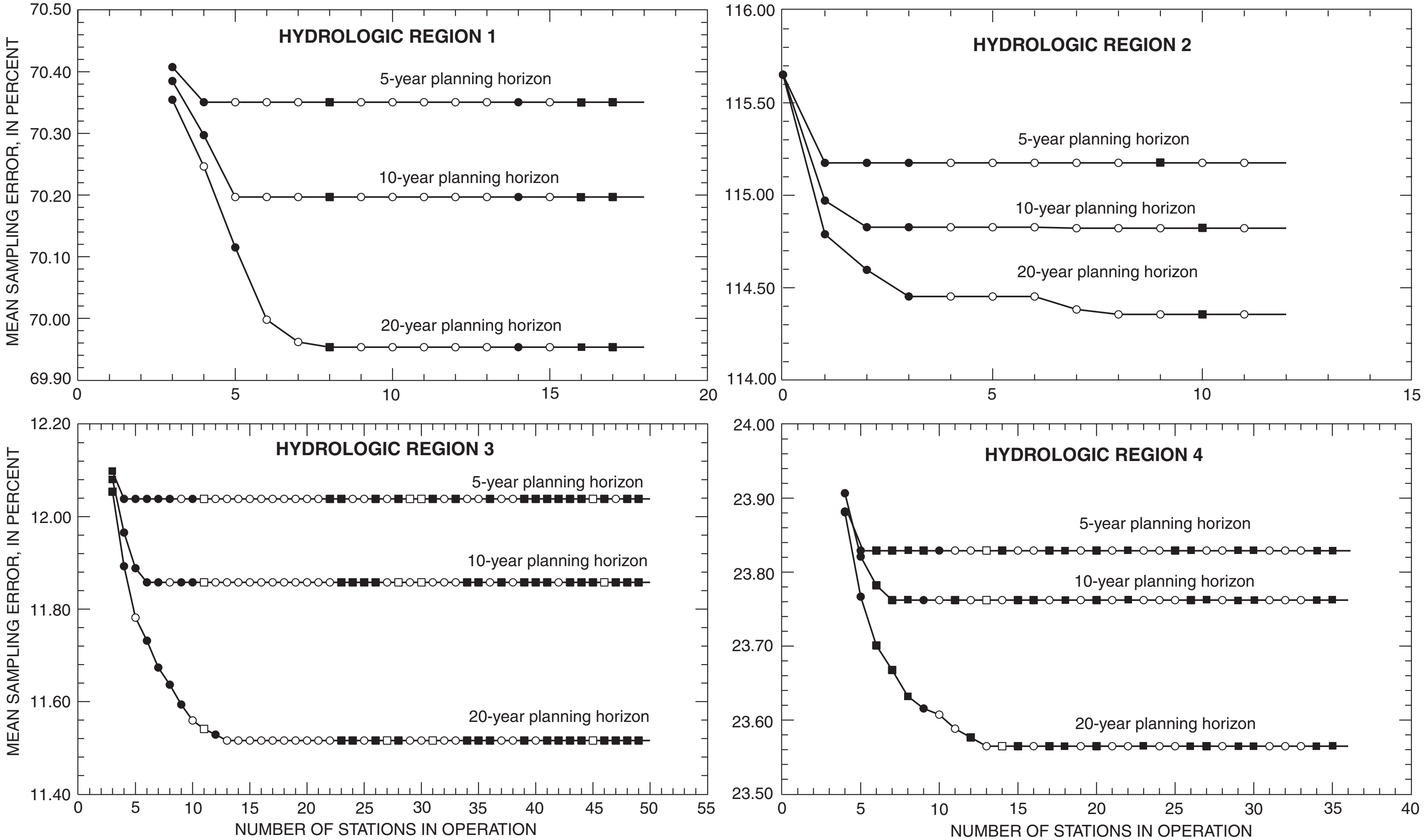
The mean annual flows and the 25-year peak discharges were log-transformed to achieve a more linear relation. Stedinger and Tasker (1985) and Tasker and Stedinger (1989) provide details for estimating β and ε using general least-squares (GLS) regression methods.

In general, GLS regression methods maximize regional hydrologic information by minimizing the average of the mean square error of prediction (MSEP) over a representative set of basin characteristics for all stations within a region. The MSEP, also known as the mean error variance, is a combination of the inherent model error variance (MEV) and the sampling error variance (SEV) for a station. The MEV remains constant for each region; therefore the average MSEP for each region is a function of the average sampling error variance (ASEV) constrained by a budget. The ASEV can be reduced by collecting new data, either by activating discontinued stations and adding them to the regression, by operating stations for longer periods, or by a combination of these two methods. This property of the ASEV allows an evaluation of the effects of collecting new data using different gaging strategies on the predictive ability of regional regression models and forms the basis for the network analysis that follows.

The ASEV can be computed from MSEP as a function of budget constraints such as the number of stations being operated and the length of the period of operation, referred to hereafter as a planning horizon. Fundamentally, the computation poses a very large nonlinear integer programming problem; however, an approximate solution can be obtained using a backward-step approach.

In summary, the backward-step approach begins with the computation of the ASEV for all possible gaging stations within a region being operated for a specified planning horizon. In an iterative process, a single gaging station then is dropped and the ASEV recomputed such as to maintain the minimum ASEV. This iterative process is continued until the minimum budget is achieved. The ASEV values are then transformed into mean sampling errors (in percent). This approach is applied separately for mean annual flows and 25-year peak discharges for each of 5-, 10-, and 20-year planning horizons and for each of the 11 hydrologic regions in Texas.

Figures 4–6 show the results from the model for the three planning horizons for the mean annual streamflows; every active and discontinued station with daily streamflow data in a natural basin was included in the model (352 stations). Figures 7–9 show the results for the same planning horizons for the 25-year peak discharges; 519 stations (all stations with annual peak data in a natural basin) were included in the model. The budget constraints are expressed in terms of the number of stations operated during the indicated planning horizons. The three curves in each figure show that, as the gaging stations are operated for longer periods of time, the mean sampling error is reduced. The shape of the curves indicates that, as more stations are kept active, the mean sampling error is reduced to a minimum, beyond which increasing the number of stations operated does not decrease mean sampling error.



EXPLANATION

- ● **Discontinued station selected for core network**
- ○ **Discontinued station not selected for core network**
- ■ **Active station selected for core network**
- □ **Active station not selected for core network**

Figure 4. Relation between mean sampling error, number of streamflow-gaging stations, and planning horizon for mean annual streamflow in hydrologic regions 1–4.

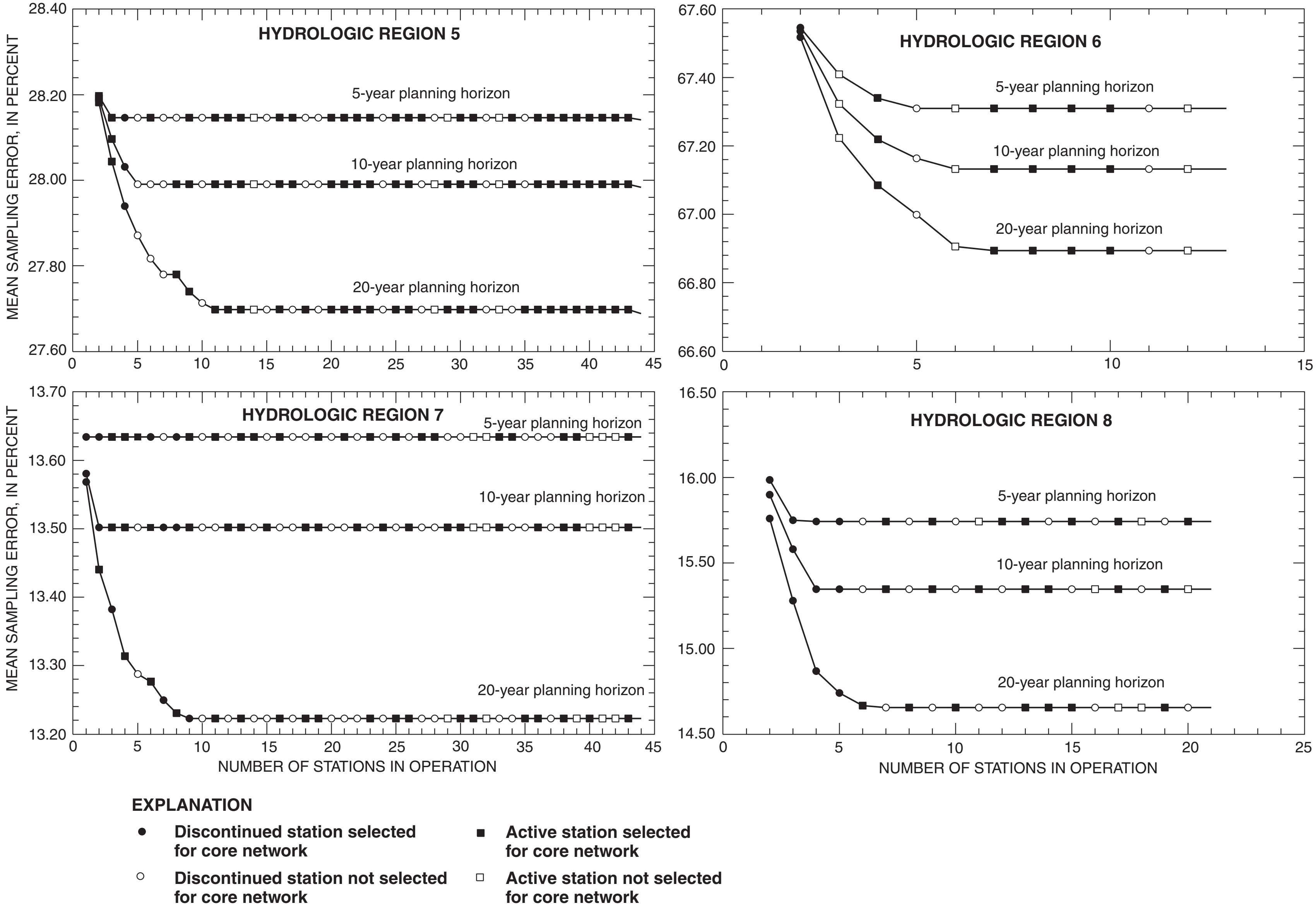


Figure 5. Relation between mean sampling error, number of streamflow-gaging stations, and planning horizon for mean annual streamflow in hydrologic regions 5–8.

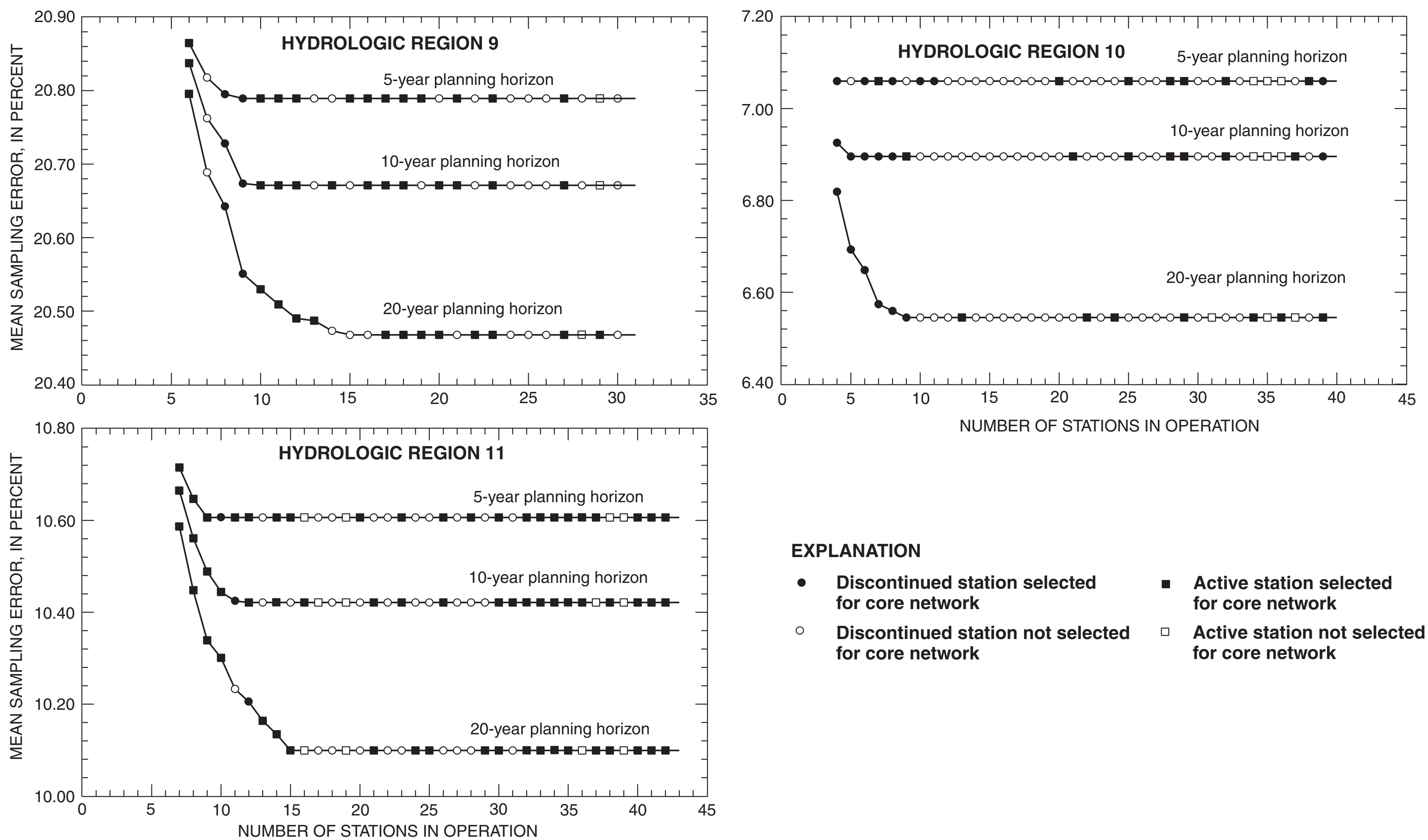


Figure 6. Relation between mean sampling error, number of streamflow-gaging stations, and planning horizon for mean annual streamflow in hydrologic regions 9–11.

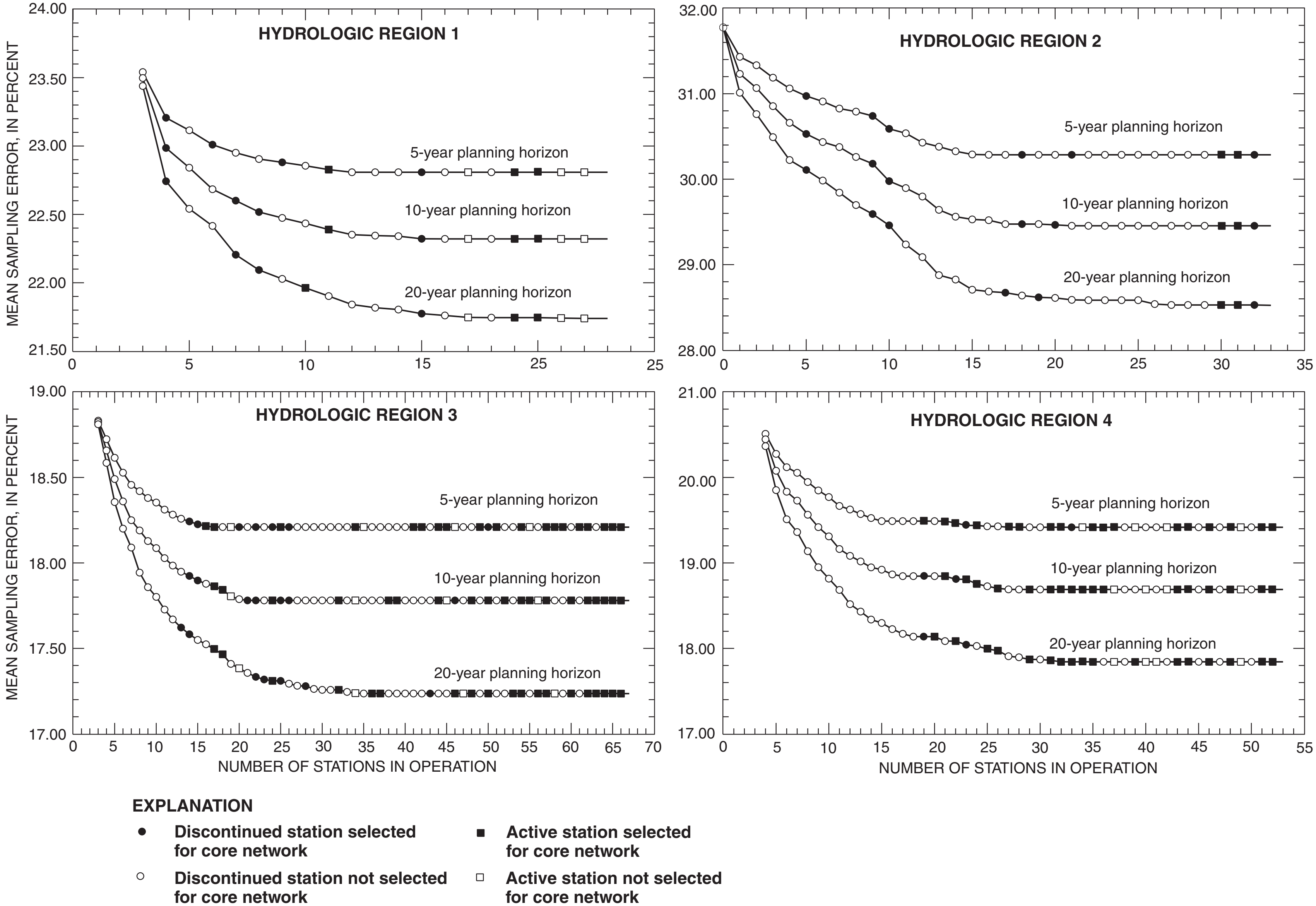


Figure 7. Relation between mean sampling error, number of streamflow-gaging stations, and planning horizon for 25-year peak streamflow in hydrologic regions 1–4.

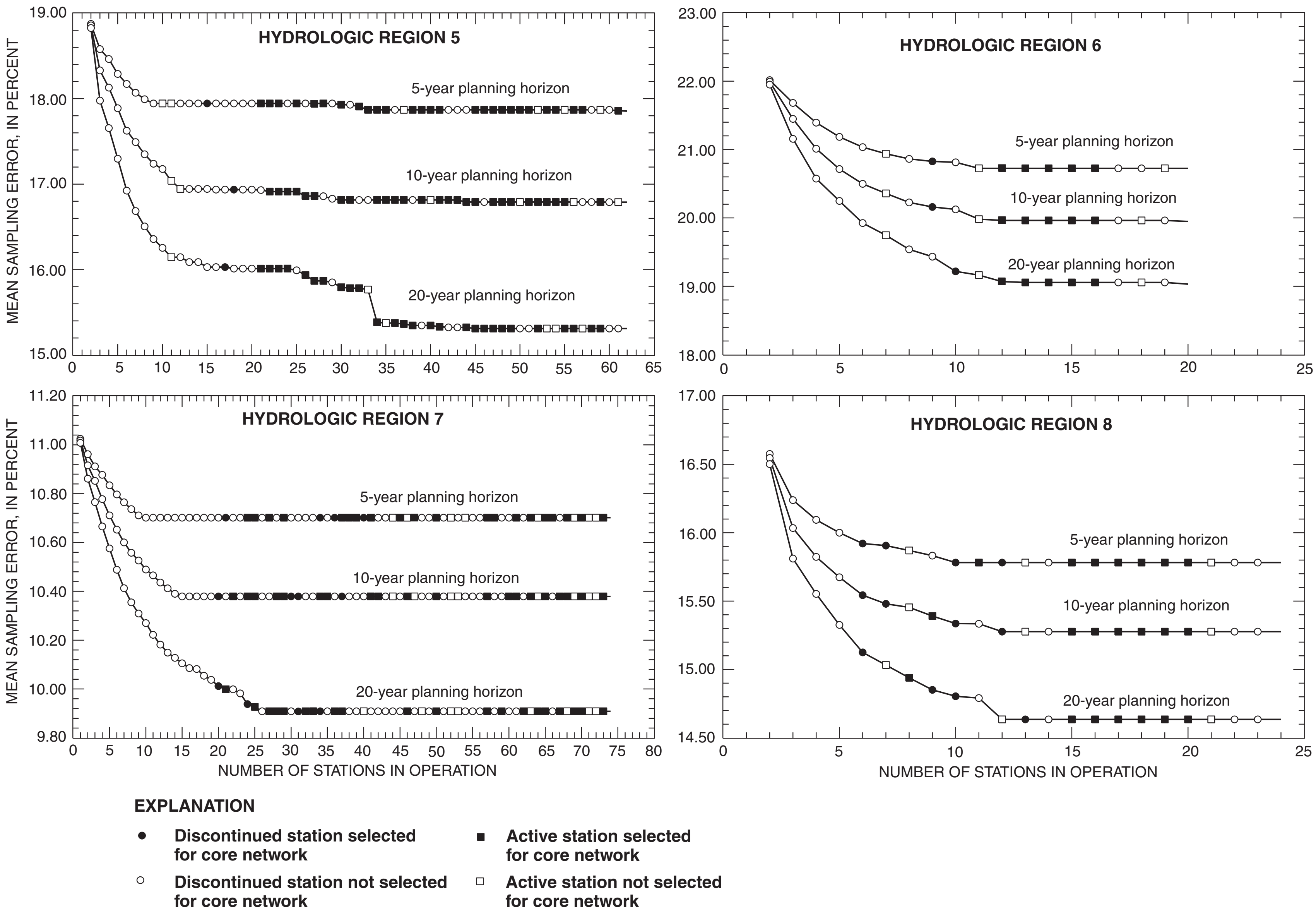


Figure 8. Relation between mean sampling error, number of streamflow-gaging stations, and planning horizon for 25-year peak streamflow in hydrologic regions 5–8.

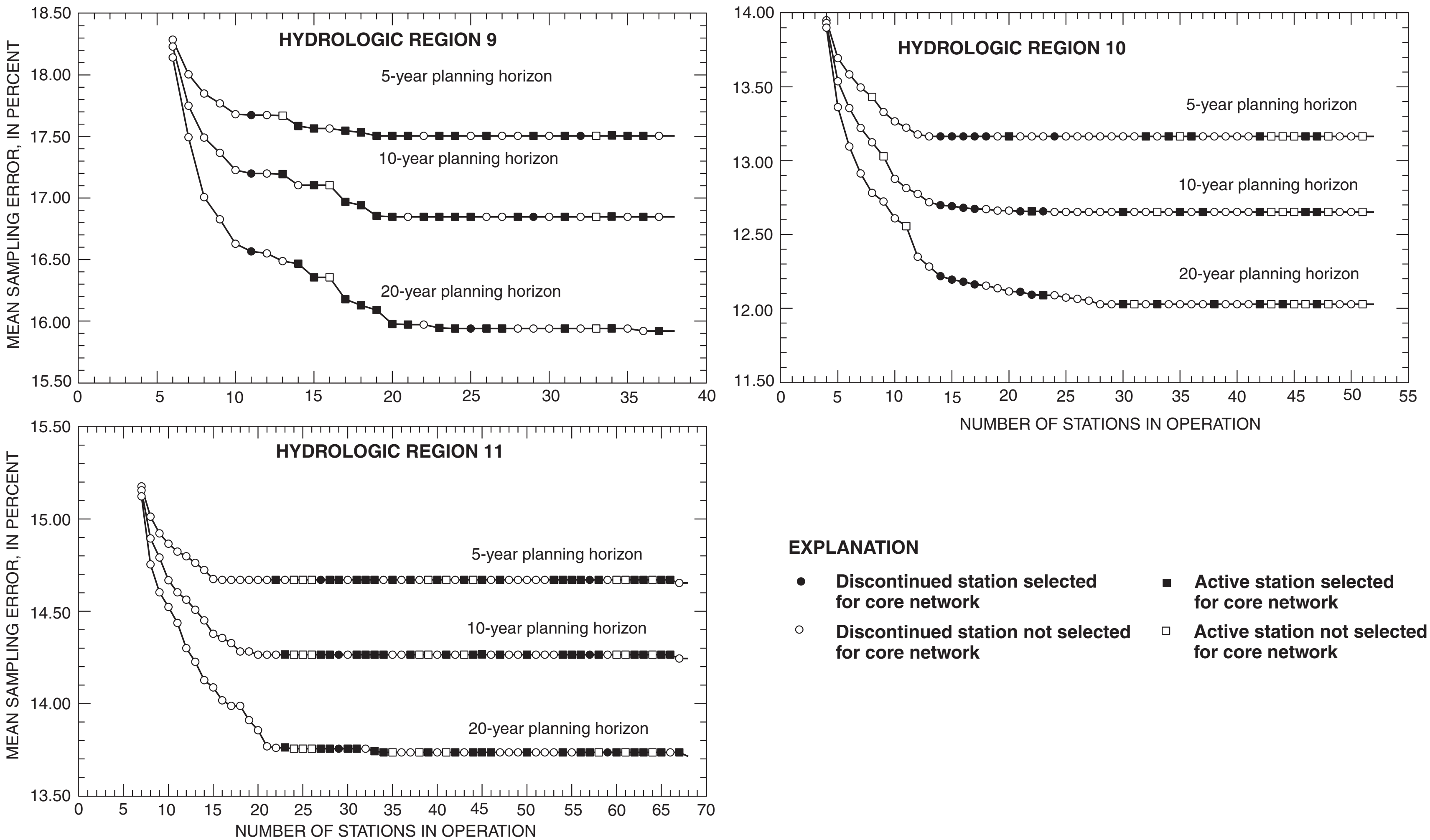


Figure 9. Relation between mean sampling error, number of streamflow-gaging stations, and planning horizon for 25-year peak streamflow in hydrologic regions 9–11.

The fact that mean sampling error does not decrease as the number of stations operated increases does not mean that nothing can be gained by operating those stations on the flat part of the curve—it means that the expected reduction in regional regression prediction error cannot be forecast accurately. Moreover, data collected at some specific stations on the flat part of the curve can be used for purposes other than regional hydrologic data analysis. What can be determined from the analysis is the rank ordering of stations in terms of their cost effectiveness for providing regional hydrologic information. Those stations on the steepest part of the curves offer the most valuable regional hydrologic information relative to basin characteristics. The ranking of the stations provides a means of deciding which stations should be continued for optimal regional hydrologic information if the budget will not allow all stations to be operated.

The shapes of the curves (figs. 4–9) reveal individual station needs for the planning horizons and indicate relative data needs for the regions. For example, for each region, increasing the duration of the planning horizon increases the number of stations on the steepest part of the curve. This indicates that longer planning horizons require more stations to effectively reduce the sampling error of the data. The scales in the figures for the sampling errors differ for the regions; thus the values of the errors together with the station positions on the error curve are used to determine the most effective stations for the regions and the State.

For the analyses regarding mean annual streamflows (figs. 4–6), regions 1 and 2 (fig. 3) have the largest sampling errors. This is attributed to the physiography and semiarid climate of the two regions. The mean annual precipitation for the regions ranges from about 8 to about 20 inches. Much of the annual precipitation is from a few thunderstorms that produce large areal variations in precipitation depth. Therefore, large variations in storm runoff and annual runoff can occur at the stations. The large variations in runoff cause large sampling errors in the data.

Specific stations in each hydrologic region (except region 2) were identified to be in the core network throughout each of the planning horizons. These were long-term stations that met the regionalization objective and were judged too important to discontinue. Such stations do not exist in region 2. In figures 4–9, the minimum number of gaging stations identified to be in the core network for each hydrologic region is indicated by the plotting position on the horizontal axis (number of stations in operation) of the left-most circle or square symbol. For example, for the 10-year planning horizon for region 1 (fig. 4), 18 stations were considered for the region. The points on the graph show the sampling error for the indicated number of stations included in the network. In the example, the first step of the model includes the full network of 18 stations as shown by the right end of the graph. The next step of the model identifies the station deemed the least important in maintaining a small sampling error, and that station is excluded from the model. The sampling error is then based on the 17 remaining stations, as indicated by the horizontal position of the right-most point on the graph. The right-most point on the graph represents the first “excluded” station. Three stations were too important to discontinue; thus the left-most circle, which represents the last of the 15 stations eligible to be excluded, is plotted at 3 on the horizontal axis. The three remaining stations in the optimization model provided the most hydrologic information on mean annual flow in terms of basin characteristics for region 1. If all 15 stations eligible to be excluded in the optimization process were discontinued, the three stations identified to remain active throughout the 10-year planning horizon would provide regional hydrologic information with a mean sampling error of 70.39 percent.

Some stations on the steep part of the curve (figs. 4–9) were not selected to be in the core network because the data are highly correlated with data from adjacent stations, as discussed in the next section. Likewise, some stations on the flat part of the curve are in the core network because they meet one or more objective other than regionalization.

If completely new stations (those without current or historical data) had been considered for the analysis, they probably would rank as most important because the value of data at a new station usually is greater than the value of data from an existing station. However, the location of a station and its basin characteristics also affect the value of the data for regional analysis—a new station located near an existing station might provide redundant data. An existing station that is unlike any other, in terms of basin characteristics, might be more important for regionalization than a new station with redundant basin characteristics.

Flow Correlation

A statistical test was done on streamflows for existing streamflow-gaging stations to identify the strength of association between gaged flows. The test is based on the correlation coefficient for annual mean and annual peak streamflows for proximate stations on the same stream. Candidate station pairs were processed if both stations had data for at least 10 corresponding years with similar basin conditions (regulated or unregulated). If both stations in a pair had corresponding years of unregulated and regulated data, data from both periods were processed. The station pairs were selected by visual inspection of the location of active stations.

For the analysis, 116 station pairs with annual mean flow data were chosen by inspection. Each station pair was located on the same stream or on a stream and its upstream tributary. Some of the stations were paired with more than one other station. Figure 10 shows the ranges of correlation coefficients for annual mean flows between paired stations in the Arkansas, Red, Brazos, Trinity, Neches, Sabine, and San Jacinto drainage basins. Figure 11 shows the ranges in the Colorado, Lavaca, Guadalupe, San Antonio, Nueces, and Rio Grande drainage basins. Figures 12 and 13 show the ranges of coefficients for annual peak flows between paired stations in the same two geographic areas. Tables 1–4 (at end of report) list the correlation coefficients for the paired stations.

Results from the correlation analysis for annual mean flows indicate that 81 station pairs have a coefficient of 0.90 or greater, and 61 of the 81 pairs have correlations of 0.95 or greater. Fewer station pairs exhibited such high correlations for annual peak streamflows. Of the 129 station pairs analyzed for correlation of annual peak flow, 43 pairs have a correlation of 0.90 or greater, and 17 of the 43 pairs have a correlation of 0.95 or greater.

Most of the stations in this analysis are on regulated streams with large drainage areas, thus most meet the major flow objective. Paired stations with an annual mean streamflow correlation coefficient greater than 0.95 were reviewed to identify stations to be excluded from the core network. In some cases, streamflow at one station is highly correlated with streamflow at more than one other station, in which case a single station was selected for the core network. The stations selected for inclusion in the network were those with (1) the longer or longest period of record; (2) water-quality data; and (3) the closer or closest location to the mouth of the stream. Stations proximate to the stream mouth can represent outflow from the basin.

PROPOSED CORE NETWORK

The evaluation of the existing streamflow-gaging network was used to develop a core network that best meets the four major objectives previously discussed. The proposed core network comprises 263 stations. Table 5 (at end of report) lists the stations in the network and selected characteristics for each station, including the status (active or discontinued); the number of years of record; the contributing drainage area; the hydrologic region; and the objective or objectives for the station's data. Plate 1 shows the locations of the core network stations.

Also identified (see footnote 3, table 5) is a minimum core network, which is a smaller network designed to meet the objectives. The minimum core network comprises 243 stations and is considered the optimum network that could be operated if the cost of operating the entire core network is prohibitive.

Of the 263 stations in the core network, 43 are discontinued. Additionally, 15 of the 220 active stations are partial-record stations. Each of the major objectives requires streamflow volumes; thus each station in the network must be operated as a daily flow station in order to meet the objectives. Accordingly, to complete the core network, 43 stations would need to be reactivated, and 15 would need to be converted from partial-record status to continuous-record status. Of the 243 stations in the minimum core network, 25 are discontinued, and 14 are partial-record stations.

Many of the proposed core network stations meet more than one objective. Fifty-five of the stations meet two objectives, 16 stations meet three objectives, and 1 station meets all four objectives. A summary of the characteristics for the stations meeting each objective is presented below.

Regionalization: The regional optimization model previously discussed was used to identify the stations providing the most valuable data for each of the hydrologic regions. The stations selected as meeting the regionalization objective for the core network generally are those that contributed the most to reducing the regional regression prediction error—they are the stations on the steepest part of the mean sampling error curve (figs. 4–9). Many of the stations on the steepest part of the curve were not selected for the core network because their streamflows are highly correlated with those of stations that were selected. Of the 352 stations tested in the optimization model, 185 were selected

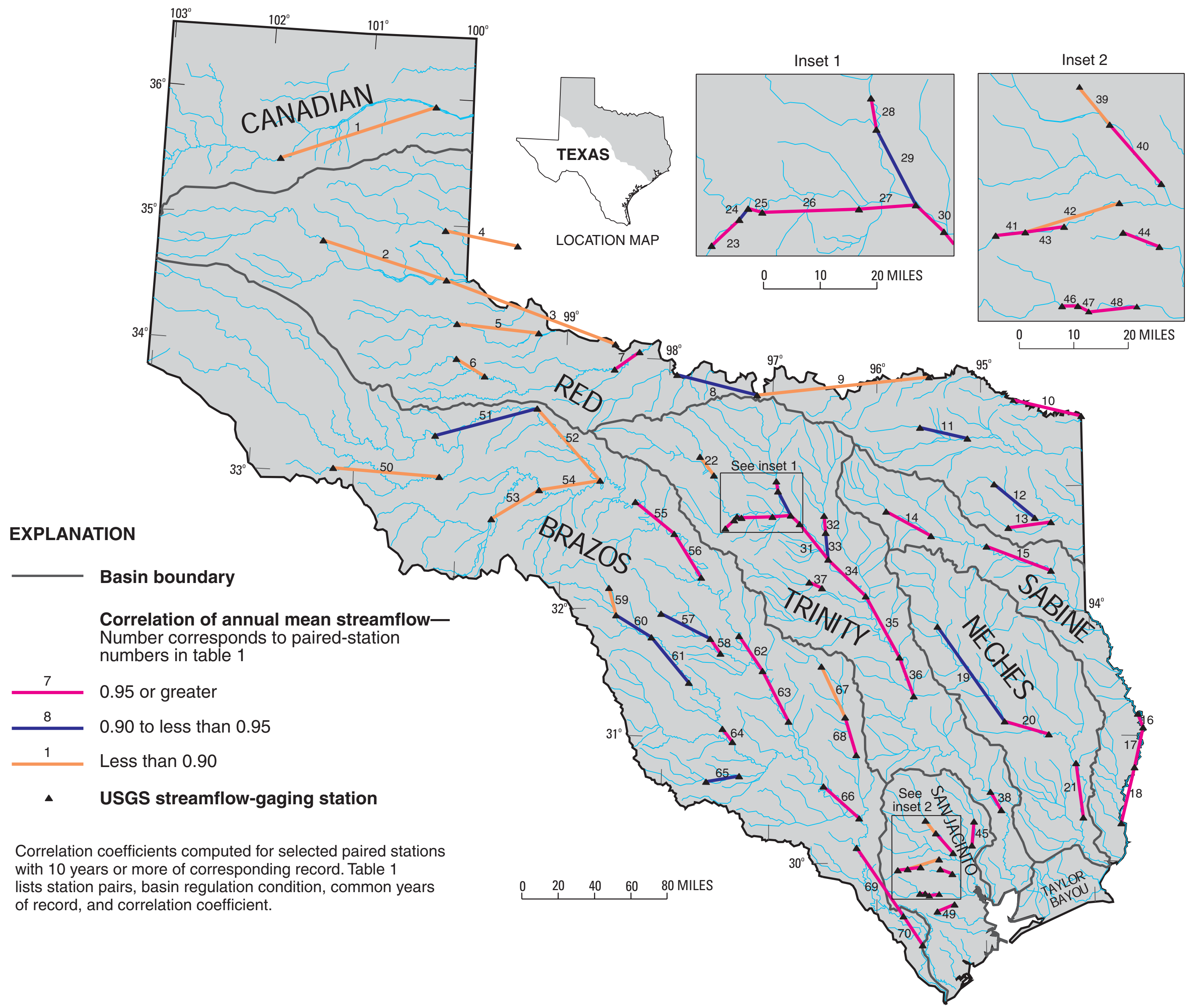


Figure 10. Correlation of annual mean streamflow between paired streamflow-gaging stations in north Texas.

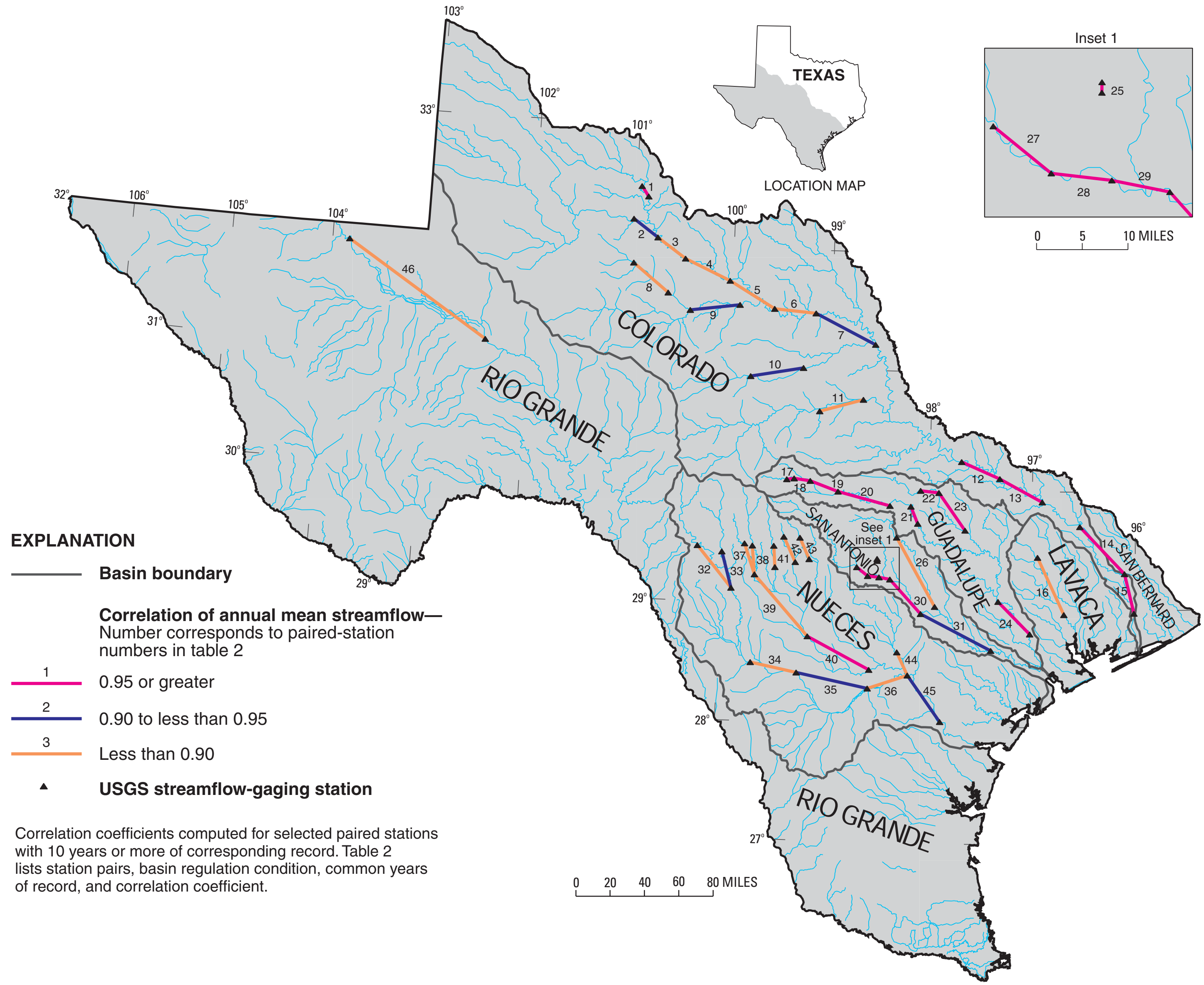


Figure 11. Correlation of annual mean streamflow between paired streamflow-gaging stations in south Texas.

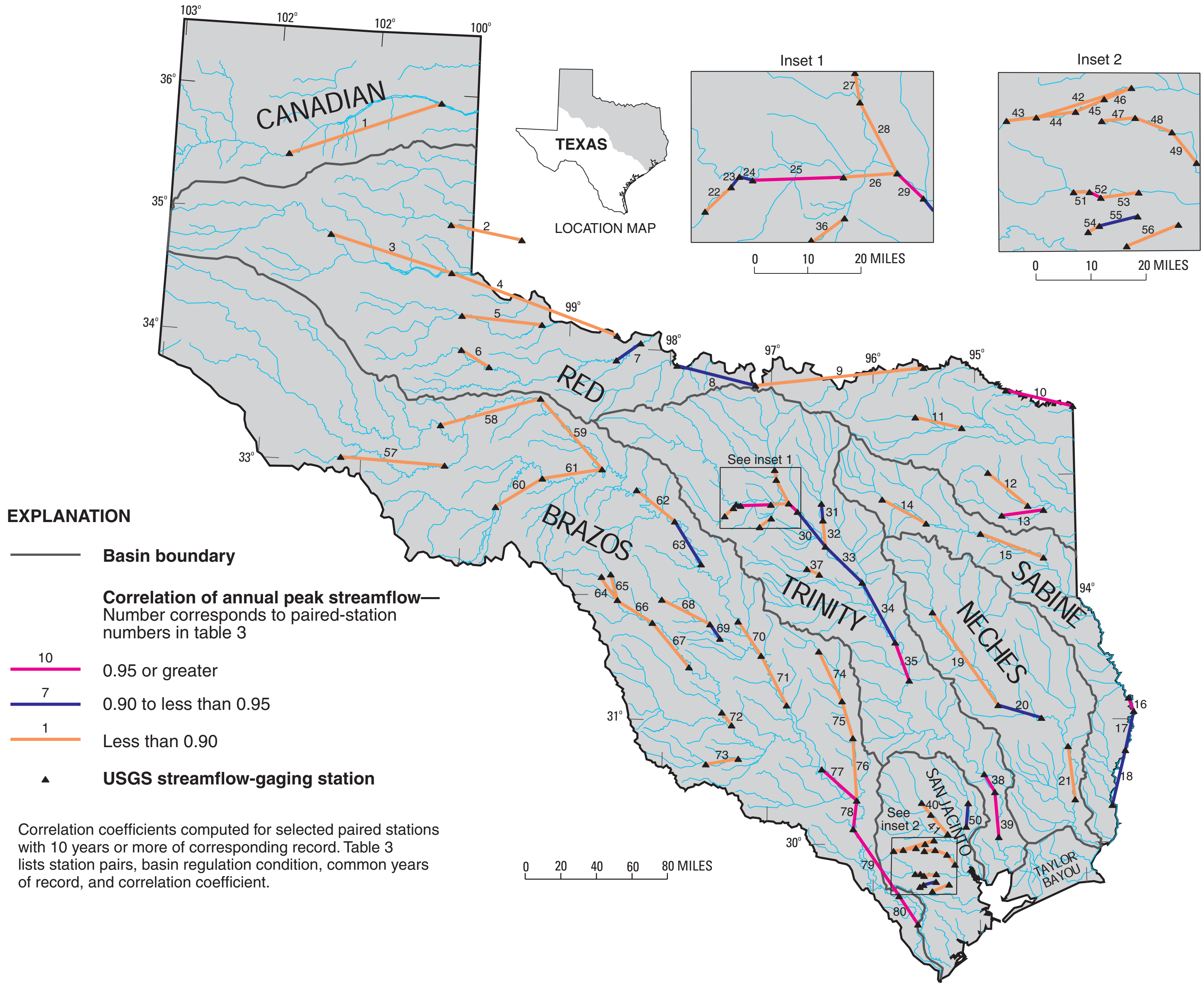


Figure 12. Correlation of annual peak streamflow between paired streamflow-gaging stations in north Texas.

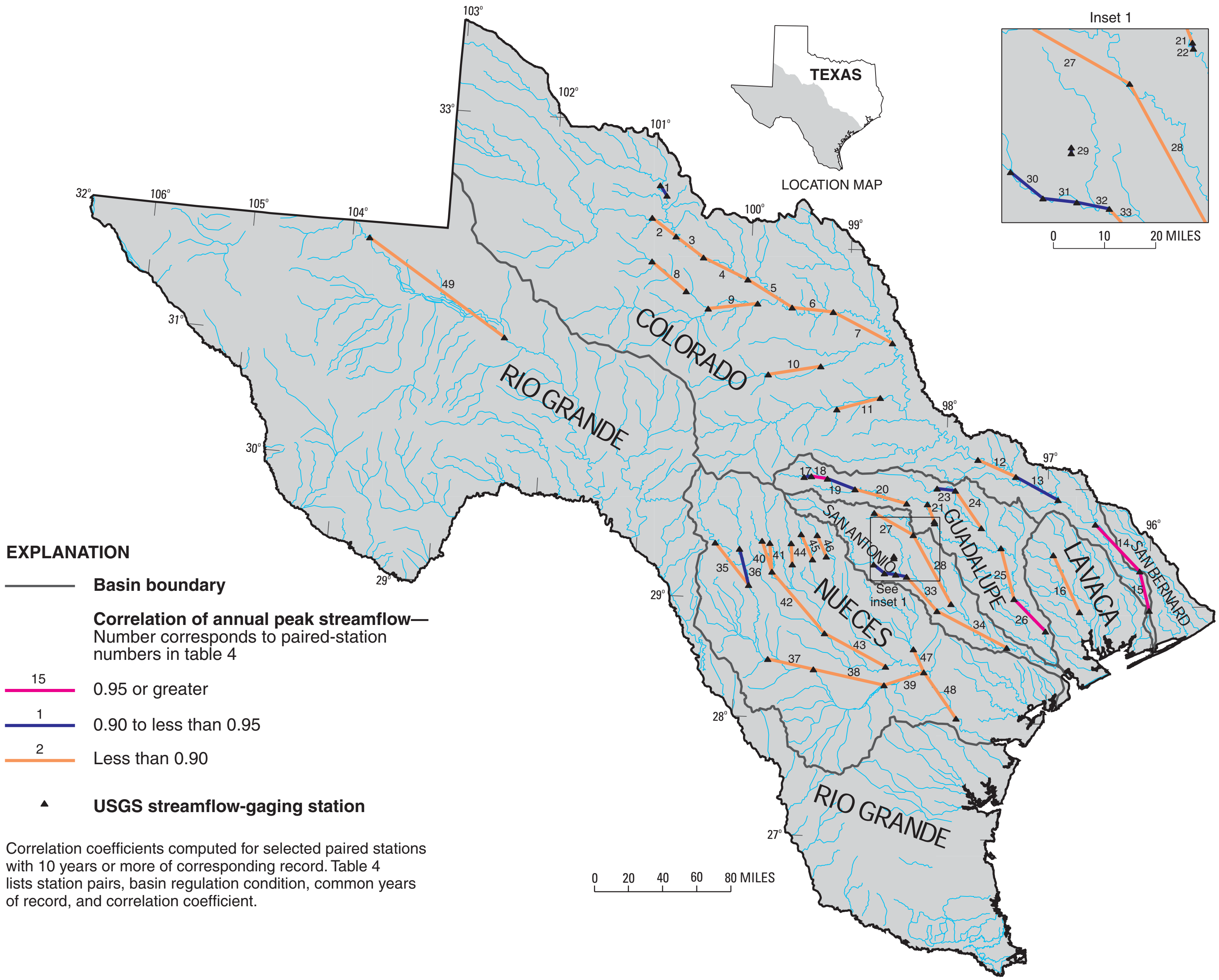


Figure 13. Correlation of annual peak streamflow between paired streamflow-gaging stations in south Texas.

for the core network—their median length of record is 33 years. Forty-one of the discontinued stations in the core network meet the regionalization objective. The number of regionalization stations in each hydrologic region ranges from 7 stations in region 6 to 28 stations in region 5.

Major Flow: With the exception of Taylor Bayou and the San Bernard and Lavaca River Basins, major flow stations are in each of the 15 major river basins identified on plate 1. The flow characteristics and water use vary along many of the major streams in Texas, especially the Red, Sabine, Trinity, Brazos, and Colorado Rivers. Therefore, streamflow-gaging stations are needed at many sites along the rivers. Ninety-two major flow stations are identified in the core network. The median length of record for these stations is about 62 years, and only four of the stations are discontinued. The number of stations with upstream basins greater than 1,000 square miles that were active as of October 1, 1999, is about 140; therefore 50 of these existing stations are not included in the core network. Most of the stations were excluded from the network as a result of the flow-correlation analysis.

Outflow from the State: Twenty-one streams that flow out of the State were identified. Only one of those streams, the Sulphur River, is not gaged for outflow. The Sulphur River crosses the State border just downstream from Lake Texarkana (pl. 1). The stream reach downstream from the reservoir frequently is in backwater from another river, thus cannot be gaged for streamflow without great expense. However, as of 1999, the USACE determines outflow from Lake Texarkana. Those data can be used to represent State outflow from the Sulphur River Basin.

Because of backwater from the Gulf of Mexico or other water bodies, some stations are located upstream from the mouths of streams. In some cases these stations also are upstream from large tributaries to the outflow streams. Therefore, the sum of gaged flows on the main channel and the tributary or tributaries can be used to compute basin outflow. Such is the case for Cypress Creek (three stations) and the Neches River (three stations). Two stations gage outflow from the Sabine and Guadalupe Rivers. One station on the Sabine is just upstream from where the river becomes a state border with Louisiana, and the other station is near the mouth of the river at the Gulf of Mexico. For the Guadalupe River, one station is near the mouth where streamflow gaging sometimes is complicated by backwater from the Gulf of Mexico, and the other station is farther upstream. For the other outflow streams, one station is used to gage each outflow from the State. Twenty-six stations, with a median record length of 59 years, were selected as meeting this objective. All these stations were active as of October 1, 1999, and included in the core network.

Streamflow Condition Assessment: Fifty stations were selected as meeting this objective in the core network, each of which was active as of October 1, 1999. Each of these stations also meets the regionalization objective. The median length of record for these stations is 53 years. The number of stations within each hydrologic region ranges from two stations in region 8 to seven stations in regions 9 and 11.

The USGS presents an on-line assessment of streamflow conditions based on data from stations that have at least 30 years of data. The assessment presents, for each station, near real-time flow conditions as a percentile of its historical data. The assessment is at http://water.usgs.gov/tx/nwis/rt.

SUMMARY

The USGS streamflow-gaging network in Texas is operated as part of the National Streamgaging Program and is jointly funded by the USGS and Federal, State, and local agencies. The streamflow-gaging network has changed substantially during the more than 100 years since its inception. The network began with a few stations in the 1890s, peaked at about 650 stations in the 1970s, and currently (1999) is about one-half that size.

This report documents an evaluation of the existing (as of October 1, 1999) network with regard to four major objectives of streamflow data; and on the basis of that evaluation, proposes a core network of streamflow-gaging stations that best meets those objectives. The objectives are (1) regionalization (estimate flows or flow characteristics at ungaged sites in 11 hydrologically similar regions), (2) major flow (obtain flow rates and volumes in major streams), (3) outflow from the State (account for streamflow leaving the State), and (4) streamflow conditions assessment (assess current conditions with regard to long-term data, and define temporal trends). Simple definition tests were sufficient to identify stations that met the criteria for major flow, outflow from the State, and streamflow conditions assessment. A regional optimization model (in addition to hydrologic region boundaries) was used to determine whether stations met the regionalization objective. The optimization model maximizes the value of the gaging-station data and minimizes the cost of obtaining the data, thus optimizing the network on the basis of value and expense. Among the stations that met at least one of the four network objectives, flow correlation analysis was used to identify stations that provide redundant flow data. Paired stations that were highly correlated (annual mean streamflow correlation coefficient greater than 0.95) were reviewed. A single station was selected for the core network from groups of two or more highly correlated stations.

The network analysis resulted in a proposed core network of 263 stations. Of those 263 stations, 43 were discontinued as of October 1, 1999, and 15 were partial-record stations. Thus, implementation of the core network would require reactivation of 43 stations and conversion of 15 stations from partial record to continuous record. Fifty-five of the proposed core-network stations meet two of the four major objectives, 16 stations meet three objectives, and 1 station meets all four.

One-hundred eighty-five stations with a median record length of 33 years were selected to meet the regionalization objective. The number of regionalization stations in each hydrologic region ranges from 7 to 28. Ninety-two stations with a median record length of about 62 years were selected to meet the major-flow objective. Major-flow stations are in 12 of the State's 15 major river basins. Twenty-six stations with a median record length of 59 years were selected to meet the outflow from the State objective. Although only 21 streams that flow out of the State were identified, gaging stations on large tributaries are needed in basins where main-stem gages are upstream of the tributary-main stem confluence. Fifty stations with a median record length of 53 years were selected to meet the streamflow-conditions-assessment objective. The number of streamflow-conditions-assessment stations in each hydrologic region ranges from two to seven.

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Table 1. Correlation coefficients of annual mean streamflows for paired stations in north Texas basins

[USGS, U.S. Geological Survey; R, regulated; U, unregulated]

Station pair no. (fig. 10)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
1	07227500	07228000	R	33	0.382
2	07297910	07299540	U	11	.768
3	07299540	07308500	R	13	.687
4	07300000	07300500	R	44	.697
5	07307800	07308200	U	21	.822
6	07311600	07311700	R	23	.753
7	07312500	07312700	R	29	.983
8	07315500	07316000	R	58	.939
9	07316000	07335500	R	60	.811
10	07336820	07337000	R	26	.978
11	07343000	07343200	R	35	.902
12	07344500	07346000	R	29	.934
13	07346050	07346070	R	33	.981
14	08017410	08018500	R	26	.966
15	08020000	08022040	R	18	.978
16	08025360	08026000	R	22	.999
17	08026000	08028500	R	41	.992
18	08028500	08030500	R	71	.993
19	08032000	08033000	R	46	.909
20	08033000	08033500	R	48	.986
21	08040600	08041000	R	7	.999
22	08044000	08044500	R	40	.801
23	08047000	08047500	R	49	.963
24	08047500	08048000	R	51	.901
25	08048000	08048543	R	16	.996
26	08048543	08049500	R	16	.989
27	08049500	08057000	R	69	.965
28	08053000	08055500	R	45	.981
29	08055500	08057000	R	56	.934
30	08057000	08057410	R	39	.995
31	08057410	08062500	R	39	.986
32	08061750	08062000	R	22	.996
33	08062000	08062500	R	46	.922
34	08062500	08062700	R	32	.989
35	08062700	08065000	R	32	.980

Table 1. Correlation coefficients of annual mean streamflows for paired stations in north Texas basins—Continued

Station pair no. (fig. 10)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
36	08065000	08065350	R	33	0.996
37	08063800	08064100	R	13	.964
38	08066250	08066500	R	30	.998
39	08067650	08068000	R	14	.870
40	08068000	08068090	R	12	.994
41	08068720	08068740	R	19	.986
42	08068740	08069000	R	21	.892
43	08068740	08068800	R	13	.974
44	08075900	08076000	U	28	.969
45	08070000	08070200	R	12	.986
46	08073500	08073600	R	18	.997
47	08073600	08073700	R	16	.999
48	08073700	08074000	R	11	.996
49	08075400	08075500	U	26	.975
50	08079600	08080500	U	34	.719
51	08082000	08082500	R	47	.904
52	08082500	08088000	R	46	.883
53	08084000	08085500	R	72	.866
54	08085500	08088000	R	36	.839
55	08089000	08090800	R	28	.976
56	08090800	08091000	R	28	.989
57	08094800	08095000	R	29	.918
58	08095000	08095200	R	37	.991
59	08099100	08099500	R	26	.805
60	08099500	08100000	R	30	.930
61	08100000	08100500	R	33	.915
62	08093100	08096500	R	21	.980
63	08096500	08098290	R	30	.990
64	08102500	08104500	R	39	.951
65	08105300	08105700	R	11	.928
66	08109000	08110200	R	17	.985
67	08110325	08110500	R	17	.776
68	08110500	08111000	R	43	.982
69	08111500	08114000	R	58	.997
70	08114000	08116650	R	25	.997

Table 2. Correlation coefficients of annual mean streamflows for paired stations in south Texas basins

[USGS, U.S. Geological Survey; R, regulated; U, unregulated]

Station pair no. (fig. 11)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
1	08120700	08121000	R	30	0.952
2	08123800	08123850	R	29	.914
3	08123850	08124000	R	28	.259
4	08124000	08126380	R	17	.616
5	08126380	08136700	R	17	.794
6	08136700	08138000	R	25	.887
7	08138000	08147000	R	64	.911
8	08133500	08134000	R	46	.786
9	08136000	08136500	R	81	.922
10	08144500	08144600	R	14	.938
11	08150800	08151500	R	33	.803
12	08158000	08159200	R	36	.985
13	08159200	08160400	R	8	.993
14	08161000	08162000	R	58	.992
15	08162000	08162500	R	48	.992
16	08163500	08164000	U	53	.895
17	08165300	08165500	U	29	.961
18	08165500	08166200	U	10	.987
19	08166200	08167000	U	10	.981
20	08167000	08167500	U	57	.967
21	08167800	08168500	R	36	.993
22	08171000	08171300	R	40	.990
23	08171300	08172000	R	27	.966
24	08175800	08176500	R	32	.999
25	08178000	08178050	R	4	.998
26	08185000	08186000	R	34	.712
27	08180700	08180800	R	14	.988
28	08180800	08181500	R	25	.988
29	08181500	08181800	R	34	.979
30	08181800	08183500	R	34	.982
31	08183500	08188500	R	60	.923
32	08190500	08192000	U	51	.722
33	08190000	08192000	U	57	.923
34	08193000	08194000	R	57	.874
35	08194000	08194500	R	53	.915
36	08194500	08210000	R	15	.839
37	08196000	08197500	R	43	.777
38	08195000	08197500	R	43	.780
39	08197500	08205500	R	43	.685
40	08205500	08206600	R	18	.964
41	08198000	08198500	R	44	.827
42	08201500	08202700	R	35	.532
43	08200000	08200700	R	36	.787
44	08208000	08210000	R	53	.708
45	08210000	08211000	R	10	.935
46	08412500	08446500	R	54	.775

Table 3. Correlation coefficients of annual peak streamflows for paired stations in north Texas basins

[USGS, U.S. Geological Survey; R, regulated; U, unregulated]

Station pair no. (fig. 12)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
1	07227500	07228000	R	34	0.181
2	07300000	07300500	R	15	.847
3	07297910	07299540	U	11	.438
4	07299540	07308500	R	14	.367
5	07307800	07308200	U	30	.523
6	07311600	07311700	R	23	.685
7	07312500	07312700	R	29	.939
8	07315500	07316000	R	48	.945
9	07316000	07335500	R	10	.726
10	07336820	07337000	R	25	.967
11	07343000	07343200	R	35	.823
12	07344500	07346000	R	32	.606
13	07346050	07346070	R	34	.958
14	08017410	08018500	R	26	.835
15	08020000	08022040	R	18	.836
16	08025360	08026000	R	22	.983
17	08026000	08028500	R	41	.934
18	08028500	08030500	R	72	.910
19	08032000	08033000	R	57	.700
20	08033000	08033500	R	60	.941
21	08040600	08041000	R	7	.870
22	08047000	08047500	R	49	.703
23	08047500	08048000	R	53	.920
24	08048000	08048543	R	16	.938
25	08048543	08049500	R	16	.961
26	08049500	08057000	R	70	.874
27	08053000	08055500	R	45	.870
28	08055500	08057000	R	56	.745
29	08057000	08057410	R	40	.973
30	08057410	08062500	R	40	.943
31	08061750	08062000	R	22	.917
32	08062000	08062500	R	46	.874
33	08062500	08062700	R	32	.920
34	08062700	08065000	R	32	.943
35	08065000	08065350	R	33	.985
36	08049580	08049700	R	11	.875
37	08063800	08064100	R	13	.783
38	08066250	08066500	R	31	.993
39	08066500	08067000	R	52	.985
40	08067650	08068000	R	21	.637

Table 3. Correlation coefficients of annual peak streamflows for paired stations in north Texas basins—Continued

Station pair no. (fig. 12)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
41	08068000	08068090	R	12	0.864
42	08068740	08069000	R	22	.493
43	08068720	08068740	R	21	.879
44	08068740	08068800	R	14	.899
45	08068800	08069000	R	14	.764
46	08068900	08069000	R	10	.868
47	08075780	08075900	R	31	.686
48	08075900	08076000	R	31	.833
49	08076000	08076700	R	23	.833
50	08070000	08070200	R	12	.943
51	08073500	08073600	R	18	.882
52	08073600	08073700	R	13	.972
53	08073700	08074000	R	26	.869
54	08074800	08074810	R	19	.873
55	08074810	08075000	R	20	.935
56	08075400	08075500	R	32	.747
57	08079600	08080500	U	35	.655
58	08082000	08082500	R	50	.692
59	08082500	08088000	R	46	.730
60	08084000	08085500	R	73	.697
61	08085500	08088000	R	36	.713
62	08089000	08090800	R	28	.874
63	08090800	08091000	R	28	.919
64	08099300	08099500	R	12	.670
65	08099100	08099500	R	31	.539
66	08099500	08100000	R	30	.658
67	08100000	08100500	R	33	.721
68	08094800	08095000	R	30	.666
69	08095000	08095200	R	37	.940
70	08093100	08096500	R	21	.780
71	08096500	08098290	R	30	.713
72	08102500	08104500	R	39	.623
73	08105300	08105700	R	11	.376
74	08110325	08110500	R	17	.813
75	08110500	08111000	R	46	.834
76	08111000	08110200	R	18	.831
77	08109000	08110200	R	18	.967
78	08110200	08111500	R	18	.973
79	08111500	08114000	R	58	.968
80	08114000	08116650	R	27	.975

Table 4. Correlation coefficients of annual peak streamflows for paired stations in south Texas basins

[USGS, U.S. Geological Survey; R, regulated; U, unregulated]

Station pair no. (fig. 13)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
1	08120700	08121000	R	31	0.923
2	08123800	08123850	R	29	.621
3	08123850	08124000	R	28	.382
4	08124000	08126380	R	17	.439
5	08126380	08136700	R	17	.794
6	08136700	08138000	R	27	.682
7	08138000	08147000	R	68	.755
8	08133500	08134000	R	56	.737
9	08136000	08136500	R	82	.828
10	08144500	08144600	R	16	.764
11	08150800	08151500	R	33	.269
12	08158000	08159200	R	36	.853
13	08159200	08160400	R	8	.940
14	08161000	08162000	R	66	.977
15	08162000	08162500	R	49	.964
16	08163500	08164000	U	57	.700
17	08165300	08165500	U	30	.932
18	08165500	08166200	U	12	.976
19	08166200	08167000	U	12	.928
20	08167000	08167500	U	67	.854
21	08167800	08168500	R	37	.724
22	08168500	08169500	R	19	.943
23	08171000	08171300	R	42	.904
24	08171300	08172000	R	28	.721
25	08173900	08175800	R	12	.880
26	08175800	08176500	R	33	.970
27	08183900	08185000	R	30	.440
28	08185000	08186000	R	35	.519
29	08178000	08178050	R	4	.941
30	08180700	08180800	R	14	.928
31	08180800	08181500	R	25	.944

Table 4. Correlation coefficients of annual peak streamflows for paired stations in south Texas basins—Continued

Station pair no. (fig. 13)	USGS upstream station no.	USGS downstream station no.	Basin regulation condition	Common years of record	Correlation coefficient
32	08181500	08181800	R	34	0.903
33	08181800	08183500	R	34	.879
34	08183500	08188500	R	63	.743
35	08190500	08192000	U	52	.696
36	08190000	08192000	U	69	.906
37	08193000	08194000	R	57	.754
38	08194000	08194500	R	55	.747
39	08194500	08210000	R	17	.899
40	08196000	08197500	R	44	.793
41	08195000	08197500	R	45	.860
42	08197500	08205500	R	45	.509
43	08205500	08206600	R	18	.816
44	08198000	08198500	R	44	.863
45	08201500	08202700	R	35	.361
46	08200000	08200700	R	36	.782
47	08208000	08210000	R	56	.751
48	08210000	08211000	R	13	.851
49	08412500	08446500	R	56	.497

Table 5. Core network of streamflow-gaging stations in Texas

[USGS, U.S. Geological Survey; major objective 1, regionalization; major objective 2, major flow; major objective 3, outflow from State; major objective 4, streamflow condition assessment; D, discontinued; CR, continuous-record station; R, regulated; --, objective not met; A, active; U, unregulated; PR partial-record station]

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
07227448	Punta de Agua Creek near Channing, Tex.	D	CR	6	R	3,570	1	✓	✓	--	--
07227500	Canadian River near Amarillo, Tex.	A	CR	65	R	15,400	1	--	✓	--	✓
[2]07228000	Canadian River near Canadian, Tex.	A	CR	63	R	18,200	1	--	✓	✓	--
07233500	Palo Duro Creek near Spearman, Tex.	A	CR	37	U	440	1	✓	--	--	--
07235000	Wolf Creek at Lipscomb, Tex.	A	CR	44	R	475	1	--	--	--	✓
[2]07297910	Prairie Dog Town Fork Red River near Wayside, Tex.	A	CR	33	U	930	1	✓	--	--	✓
07298000	North Tule Draw at reservoir near Tulia, Tex.	D	CR	31	U	65.0	1	✓	--	--	--
07298500	Prairie Dog Town Fork Red River near Brice, Tex.	D	CR	11	U	1,580	1	✓	✓	--	--
[3]07299512	Jonah Creek at Weir near Estelline, Tex.	D	CR	8	U	65.5	1	✓	--	--	--
07299540	Prairie Dog Town Fork Red River near Childress, Tex.	A	CR	36	R	2,960	1	✓	✓	--	--
07299670	Groesbeck Creek at State Hwy. 6 near Quanah, Tex.	A	CR	39	U	303	3	✓	--	--	--
07299890	Lelia Lake Creek below Bell Creek near Hedley, Tex.	A	CR	3	U	74.0	1	✓	--	--	--
[2]07300000	Salt Fork Red River near Wellington, Tex.	A	CR	48	U	1,010	1	✓	✓	✓	✓
07301410	Sweetwater Creek near Kelton, Tex.	A	CR	38	U	267	1	✓	--	--	--
[2]07308200	Pease River near Vernon, Tex.	A	CR	39	U	2,930	3	✓	✓	--	✓
07308500	Red River near Burkburnett, Tex.	A	CR	41	U	14,600	3	✓	✓	--	--
07311630	Middle Wichita River near Guthrie, Tex.	A	CR	4	U	50.3	3	✓	--	--	--
07311700	North Wichita River near Truscott, Tex.	A	CR	40	U	937	3	✓	--	--	--
07311800	South Wichita River near Benjamin, Tex.	A	CR	40	U	584	3	✓	--	--	--
07311900	Wichita River near Seymour, Tex.	A	CR	21	U	1,870	3	✓	✓	--	--
07312500	Wichita River at Wichita Falls, Tex.	A	CR	63	R	3,140	3	--	✓	--	--
07314500	Little Wichita River near Archer City, Tex.	A	CR	59	R	481	3	--	--	--	✓
07314900	Little Wichita River above Henrietta, Tex.	A	CR	47	R	1,040	3	--	✓	--	--
07315200	East Fork Little Wichita River near Henrietta, Tex.	A	CR	37	U	178	3	✓	--	--	--
[3]07316000	Red River near Gainesville, Tex.	A	CR	65	R	24,800	7	--	✓	--	--
07316200	Mineral Creek near Sadler, Tex.	D	CR	8	U	26.0	7	✓	--	--	--
[3]07336750	Little Pine Creek near Kanawha, Tex.	D	CR	12	U	75.4	10	✓	--	--	--
07337000	Red River at Index, Ark.	A	CR	64	R	42,094	10	--	✓	✓	--

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
07342465	South Sulphur River at Commerce, Tex.	A	CR	9	U	150	7	✓	--	--	--
07342480	Middle Sulphur River at Commerce, Tex.	A	CR	9	U	44.1	7	✓	--	--	--
[2]07343000	North Sulphur River near Cooper, Tex.	A	CR	51	U	276	10	✓	--	--	✓
07343200	Sulphur River near Talco, Tex.	D	CR	41	R	1,370	10	--	✓	--	--
[2]07343500	White Oak Creek near Talco, Tex.	A	CR	51	R	494	10	--	--	--	✓
07344486	Brushy Creek at Scroggins, Tex.	A	CR	22	U	23.4	10	✓	--	--	--
07346000	Big Cypress Creek near Jefferson, Tex.	A	CR	56	R	850	10	--	--	✓	--
07346045	Black Cypress Bayou at Jefferson, Tex.	A	CR	32	U	365	10	✓	--	✓	--
[2]07346070	Little Cypress Creek near Jefferson, Tex.	A	CR	55	U	675	10	✓	--	✓	✓
08017200	Cowleech Fork Sabine River at Greenville, Tex.	A	CR	42	U	77.7	7	✓	--	--	--
[2]08017300	South Fork Sabine River near Quinlan, Tex.	A	CR	42	U	78.7	7	✓	--	--	--
08018500	Sabine River near Mineola, Tex.	A	CR	55	R	1,360	10	--	✓	--	--
08018730	Burke Creek near Yantis, Tex.	D	CR	10	U	33.1	10	✓	--	--	--
08020000	Sabine River near Gladewater, Tex.	A	CR	69	R	2,790	10	--	✓	--	--
08020200	Prairie Creek near Gladewater, Tex.	D	CR	9	U	48.9	10	✓	--	--	--
[3]08021000	Cherokee Bayou near Elderville, Tex.	D	CR	9	U	120	10	✓	--	--	--
08022040	Sabine River near Beckville, Tex.	A	CR	62	R	3,590	10	--	✓	✓	✓
[3]08022400	Socagee Creek near Carthage, Tex.	D	CR	12	U	82.6	10	✓	--	--	--
08026000	Sabine River near Burkeville, Tex.	A	CR	45	R	7,480	11	✓	✓	--	--
08029500	Big Cow Creek near Newton, Tex.	A	CR	49	U	128	11	✓	--	--	✓
[2]08030500	Sabine River near Ruliff, Tex.	A	CR	76	R	9,330	11	--	✓	✓	--
08032000	Neches River near Neches, Tex.	A	CR	62	R	1,150	10	--	✓	--	--
08033500	Neches River near Rockland, Tex.	A	CR	95	R	3,640	11	--	✓	--	✓
[3]08033700	Striker Creek near Summerfield, Tex.	D	CR	9	U	146	10	✓	--	--	--
08036500	Angelina River near Alto, Tex.	A	CR	43	R	1,280	10	--	✓	--	✓
[2]08041000	Neches River at Evadale, Tex.	A	CR	82	R	7,950	11	--	✓	✓	--
[2]08041500	Village Creek near Kountze, Tex.	A	CR	65	U	860	11	✓	--	✓	✓
08041700	Pine Island Bayou near Sour Lake, Tex.	A	CR	33	U	336	11	✓	--	✓	--
08044500	West Fork Trinity River near Boyd, Tex.	A	CR	53	U	1,730	7	✓	✓	--	--
08044800	Walnut Creek at Reno, Tex.	A	CR	8	U	75.6	7	✓	--	--	--

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
[3]08046000	Clear Fork Trinity River near Aledo, Tex.	D	CR	28	R	251	7	✓	--	--	--
08048000	West Fork Trinity River at Fort Worth, Tex.	A	CR	80	R	2,620	7	--	✓	--	--
08048970	Village Creek at Everman, Tex.	A	CR	11	U	84.5	7	✓	--	--	--
08049500	West Fork Trinity River at Grand Prairie, Tex.	A	CR	76	R	3,070	7	--	✓	--	--
[3]08049550	Big Bear Creek near Grapevine, Tex.	D	CR	13	U	29.6	7	✓	--	--	--
08049580	Mountain Creek near Venus, Tex.	A	PR	14	U	25.5	7	✓	--	--	--
08049700	Walnut Creek near Mansfield, Tex.	A	CR	40	U	62.8	7	✓	--	--	--
08050400	Elm Fork Trinity River at Gainesville, Tex.	A	CR	15	U	174	7	✓	--	--	--
08050800	Timber Creek near Collinsville, Tex.	A	CR	15	U	38.8	7	✓	--	--	--
08050840	Range Creek near Collinsville, Tex.	A	CR	8	U	29.2	7	✓	--	--	--
08052700	Little Elm Creek near Aubrey, Tex.	A	CR	41	R	75.5	7	✓	--	--	--
[2]08053500	Denton Creek near Justin, Tex.	A	CR	51	R	400	7	--	--	--	✓
08055500	Elm Fork Trinity River near Carrollton, Tex.	A	CR	77	R	2,460	7	--	✓	--	--
[3]08056500	Turtle Creek at Dallas, Tex.	D	CR	41	R	7.98	7	✓	--	--	--
08057410	Trinity River below Dallas, Tex.	A	CR	44	R	6,280	7	--	✓	--	--
08061540	Rowlett Creek near Sachse, Tex.	A	CR	31	U	120	7	✓	--	--	--
08062000	East Fork Trinity River near Crandall, Tex.	A	CR	50	R	1,260	7	--	✓	--	--
08062500	Trinity River near Rosser, Tex.	A	CR	63	R	8146	7	--	✓	--	--
[3]08062900	Kings Creek near Kaufman, Tex.	D	CR	25	R	233	7	✓	--	--	--
08064100	Chambers Creek near Rice, Tex.	A	CR	17	R	807	7	--	--	--	✓
08064700	Tehuacana Creek near Streetman, Tex.	A	CR	32	U	142	7	✓	--	--	--
08065000	Trinity River near Oakwood, Tex.	A	CR	77	R	12,800	7	--	✓	--	--
08065200	Upper Keechi Creek near Oakwood, Tex.	A	CR	39	U	150	7	✓	--	--	--
08065700	Caney Creek near Madisonville, Tex.	D	CR	13	U	112	8	✓	--	--	--
[2]08065800	Bedias Creek near Madisonville, Tex.	A	CR	33	U	321	8	✓	--	--	✓
08066170	Kickapoo Creek near Onalaska, Tex.	A	CR	35	U	57.0	11	✓	--	--	--
08066200	Long King Creek at Livingston, Tex.	A	CR	38	U	141	11	✓	--	--	--
08066300	Menard Creek near Rye, Tex.	A	CR	35	U	152	11	✓	--	--	✓
[2]08066500	Trinity River at Romayer, Tex.	A	CR	77	R	17,200	11	--	✓	✓	--
08067500	Cedar Bayou near Crosby, Tex.	A	PR	29	U	64.9	11	✓	--	--	--

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
08068450	Panther Branch near Spring, Tex.	D	CR	6	U	34.5	11	√	--	--	--
[2]08068500	Spring Creek near Spring, Tex.	A	CR	62	U	409	11	√	--	--	√
08068780	Little Cypress Creek near Cypress, Tex.	A	PR	18	U	41.0	11	√	--	--	--
08069000	Cypress Creek near Westfield, Tex.	A	CR	56	U	285	11	√	--	--	--
[2]08070000	East Fork San Jacinto River near Cleveland, Tex.	A	CR	61	U	325	11	√	--	--	√
08070500	Caney Creek near Splendora, Tex.	A	CR	57	U	105	11	√	--	--	--
[4]08071000	Peach Creek at Splendora, Tex.	A	CR	36	U	117	11	√	--	--	--
08071280	Luce Bayou above Lake Houston, near Huffman, Tex.	A	CR	16	U	218	11	√	--	--	--
[4]08072050	San Jacinto River near Sheldon, Tex.	A	PR	31	U	2,880	11	--	√	√	--
08072300	Buffalo Bayou near Katy, Tex.	A	CR	23	U	63.3	11	√	--	--	--
08072730	Bear Creek near Barker, Tex.	A	CR	23	U	21.5	11	√	--	--	--
[3]08072760	Langham Creek at West Little York Rd. near Addicks, Tex.	A	PR	23	U	24.6	11	√	--	--	--
08076180	Garners Bayou near Humble, Tex.	A	PR	14	U	31.0	11	√	--	--	--
08078000	Chocolate Bayou near Alvin, Tex.	A	CR	54	U	87.7	11	√	--	--	--
[3]08079500	North Fork Double Mountain Fork Brazos River at Lubbock, Tex.	D	CR	12	U	200	1	√	--	--	--
08079600	Double Mountain Fork Brazos River at Justiceburg, Tex.	A	CR	39	U	244	3	√	--	--	--
[2]08080500	Double Mountain Fork Brazos River near Aspermont, Tex.	A	CR	72	U	1,860	3	√	√	--	√
[3]08080540	McDonald Creek near Post, Tex.	D	CR	13	U	79.2	3	√	--	--	--
08082000	Salt Fork Brazos River near Aspermont, Tex.	A	CR	64	R	2,500	3	--	√	--	--
08082500	Brazos River at Seymour, Tex.	A	CR	77	R	5,970	3	--	√	--	--
08082700	Millers Creek near Munday, Tex.	A	CR	37	U	104	3	√	--	--	--
08083100	Clear Fork Brazos River near Roby, Tex.	A	CR	38	U	228	3	√	--	--	--
[3]08083400	Little Elm Creek near Abilene, Tex.	D	CR	16	U	39.1	3	√	--	--	--
08083420	Cat Claw Creek at Abilene, Tex.	A	PR	11	U	13.0	3	√	--	--	--
08083480	Cedar Creek at I–20 at Abilene, Tex.	A	PR	7	U	136	3	√	--	--	--
08084000	Clear Fork Brazos River at Nugent, Tex.	A	CR	77	R	2,200	3	--	√	--	--
08084800	California Creek near Stamford, Tex.	A	CR	38	U	478	3	√	--	--	--
08085500	Clear Fork Brazos River at Fort Griffin, Tex.	A	CR	77	R	3,990	3	--	√	--	--
[3]08086050	Deep Creek at Moran, Tex.	D	CR	15	U	228	3	√	--	--	--
[2]08086212	Hubbard Creek below Albany, Tex.	A	CR	34	U	613	3	√	--	--	√

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
08086260	Pecan Creek near Eolian, Tex.	D	CR	9	U	26.4	3	√	--	--	--
08086290	Big Sandy Creek above Breckenridge, Tex.	A	CR	39	U	280	3	√	--	--	--
08088000	Brazos River near South Bend, Tex.	A	CR	62	R	13,100	3	--	√	--	--
08088100	Salt Creek at Olney, Tex.	D	CR	20	U	11.8	3	√	--	--	--
08088610	Brazos River near Graford, Tex.	A	CR	11	R	14,000	3	--	√	--	--
08089000	Brazos River near Palo Pinto, Tex.	A	CR	77	R	14,200	3	--	√	--	--
08090800	Brazos River near Dennis, Tex.	A	CR	32	R	15,700	7	--	√	--	--
08091000	Brazos River near Glen Rose, Tex.	A	CR	77	R	16,300	7	--	√	--	--
08091500	Paluxy River at Glen Rose, Tex.	A	CR	53	R	410	7	--	--	--	√
08093100	Brazos River near Aquilla, Tex.	A	CR	62	R	17,700	7	--	√	--	--
[3]08093250	Hackberry Creek at Hillsboro, Tex.	D	CR	13	U	57.9	7	√	--	--	--
08095200	North Bosque River at Valley Mills, Tex.	A	CR	41	R	1,150	7	√	√	--	--
08096500	Brazos River at Waco, Tex.	A	CR	102	R	20,000	7	--	√	--	--
08098300	Little Pond Creek near Burlington, Tex.	D	CR	20	U	22.2	8	√	--	--	--
08099300	Sabana River near De Leon, Tex.	A	PR	40	U	264	4	√	--	--	--
08100500	Leon River at Gatesville, Tex.	A	CR	50	R	2,340	4	--	√	--	--
[2]08101000	Cowhouse Creek at Pidcoke, Tex.	A	CR	50	U	455	4	√	--	--	√
08102500	Leon River near Belton, Tex.	A	CR	77	R	3,540	8	--	√	--	--
08103800	Lampasas River near Kempner, Tex.	A	CR	38	R	818	4	√	--	--	--
08103900	South Fork Rocky Creek near Briggs, Tex.	A	CR	38	U	33.3	4	√	--	--	--
08104100	Lampasas River near Belton, Tex.	A	CR	29	R	1,320	8	--	√	--	--
08104500	Little River near Little River, Tex.	A	CR	43	R	5,230	8	--	√	--	--
08104700	North Fork San Gabriel River near Georgetown, Tex.	A	CR	32	R	248	8	√	--	--	--
08104900	South Fork San Gabriel River at Georgetown, Tex.	A	CR	33	U	133	8	√	--	--	--
08105100	Berry Creek near Georgetown, Tex.	A	CR	33	U	83.1	8	√	--	--	--
08106500	Little River at Cameron, Tex.	A	CR	83	R	7,070	8	--	√	--	--
08108200	North Elm Creek near Cameron, Tex.	D	CR	11	U	44.8	8	√	--	--	--
08108700	Brazos River at State Hwy. 21 near Bryan, Tex.	A	CR	7	R	29,500	8	--	√	--	--
[2]08109700	Middle Yegua Creek near Dime Box, Tex.	A	CR	38	U	236	8	√	--	--	√
08109800	East Yegua Creek near Dime Box, Tex.	A	CR	38	U	244	8	√	--	--	--

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
08110100	Davidson Creek near Lyons, Tex.	A	CR	38	U	195	8	√	--	--	--
08110430	Big Creek near Freestone, Tex.	A	CR	22	U	97.2	7	√	--	--	√
08110800	Navasota River at Old San Antonio Road near Bryan, Tex.	A	CR	3	R	1,290	8	--	√	--	--
08111700	Mill Creek near Bellville, Tex.	D	CR	30	U	376	11	√	--	--	--
08114000	Brazos River at Richmond, Tex.	A	CR	82	R	35,400	11	--	√	√	--
08115000	Big Creek near Needville, Tex.	A	CR	53	U	42.8	11	√	--	--	--
08116400	Dry Creek near Rosenburg, Tex.	D	CR	21	U	8.65	11	√	--	--	--
[2]08117500	San Bernard River near Boling, Tex.	A	CR	46	U	727	11	√	--	√	√
08117995	Colorado River near Gail, Tex.	A	CR	12	U	498	3	√	--	--	--
08121000	Colorado River at Colorado City, Tex.	A	CR	56	R	1,590	3	--	√	--	--
[3]08121500	Morgan Creek near Westbrook, Tex.	D	CR	9	U	230	3	√	--	--	--
08123800	Beals Creek near Westbrook, Tex.	A	CR	42	U	1,990	3	√	√	--	--
08123850	Colorado River above Silver, Tex.	A	CR	33	R	4,650	4	--	√	--	--
08124000	Colorado River at Robert Lee, Tex.	A	CR	54	R	5,050	4	√	√	--	--
08126380	Colorado River near Ballinger, Tex.	A	CR	93	R	6,110	4	--	√	--	--
[2]08127000	Elm Creek at Ballinger, Tex.	A	CR	68	R	450	4	--	--	--	√
08128000	South Concho River at Christoval, Tex.	A	PR	70	U	413	4	√	--	--	--
08128400	Middle Concho River above Tankersley, Tex.	A	PR	39	U	1,610	4	√	√	--	--
08131400	Pecan Creek near San Angelo, Tex.	D	CR	25	U	81.1	4	√	--	--	--
[2]08134000	North Concho River near Carlsbad, Tex.	A	CR	76	U	1,190	4	√	√	--	√
08136500	Concho River at Paint Rock, Tex.	A	CR	85	R	5,440	4	--	√	--	--
08136700	Colorado River near Stacy, Tex.	A	CR	32	R	12,800	4	--	√	--	--
08137500	Mukewater Creek at Trickham, Tex.	D	CR	23	R	70.0	4	√	--	--	--
08138000	Colorado River at Winchell, Tex.	A	CR	67	R	13,800	4	--	√	--	--
08143600	Pecan Bayou near Mullin, Tex.	A	CR	33	R	2,070	4	--	√	--	--
08144500	San Saba River at Menard, Tex.	A	CR	84	U	1,130	4	√	√	--	--
08145000	Brady Creek at Brady, Tex.	D	CR	47	R	588	4	√	--	--	--
08146000	San Saba River at San Saba, Tex.	A	CR	81	R	3,040	4	--	√	--	--
08147000	Colorado River near San Saba, Tex.	A	CR	84	R	19,800	4	--	√	--	--
08150000	Llano River near Junction, Tex.	A	CR	84	U	1,850	4	√	√	--	--

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
08150800	Beaver Creek near Mason, Tex.	A	CR	37	U	215	4	✓	--	--	--
[2]08151500	Llano River at Llano, Tex.	A	CR	61	U	4,190	4	✓	✓	--	✓
08152000	Sandy Creek near Kingsland, Tex.	A	CR	33	U	346	4	✓	--	--	--
08152900	Pedernales River near Fredericksburg, Tex.	A	CR	20	U	369	5	✓	--	--	--
08153500	Pedernales River near Johnson City, Tex.	A	CR	61	U	901	5	✓	--	--	--
08154700	Bull Creek at Loop 360 near Austin, Tex.	A	CR	22	U	22.3	5	✓	--	--	--
08155200	Barton Creek at State Hwy. 71 near Oak Hill, Tex.	A	CR	19	U	89.7	5	✓	--	--	--
08158000	Colorado River at Austin, Tex.	A	CR	102	R	27,600	5	--	✓	--	--
08158700	Onion Creek near Driftwood, Tex.	A	CR	21	U	124	5	✓	--	--	--
08158810	Bear Creek below FM 1826 near Driftwood, Tex.	A	CR	22	U	12.2	5	✓	--	--	--
08158840	Slaughter Creek at FM 1826 near Austin, Tex.	A	CR	23	U	8.24	5	✓	--	--	--
08159000	Onion Creek at U.S. Hwy. 183, Austin, Tex.	A	CR	31	U	321	5	--	--	--	✓
[3]08159150	Wilbarger Creek near Pflugerville, Tex.	D	CR	17	U	4.61	8	✓	--	--	--
08159200	Colorado River at Bastrop, Tex.	A	CR	40	R	28,600	9	--	✓	--	--
08160000	Dry Creek at Buescher Lake near Smithville, Tex.	D	CR	26	U	1.48	9	✓	--	--	--
08160800	Redgate Creek near Columbus, Tex.	A	CR	39	U	17.3	9	✓	--	--	✓
08161000	Colorado River at Columbus, Tex.	A	CR	85	R	30,200	9	--	✓	✓	--
08162600	Tres Palacios River near Midfield, Tex.	A	CR	29	U	145	9	✓	--	--	--
[2]08164000	Lavaca River near Edna, Tex.	A	CR	62	U	817	9	✓	--	✓	✓
[2]08164300	Navidad River near Hallettsville, Tex.	A	CR	39	U	332	9	✓	--	--	✓
08164390	Navidad River at Strane Park near Edna, Tex.	A	CR	4	U	579	9	✓	--	✓	--
08164450	Sandy Creek near Ganado, Tex.	A	CR	23	U	289	9	✓	--	--	--
08164503	West Mustang Creek near Ganado, Tex.	A	CR	23	U	178	9	✓	--	--	--
08164504	East Mustang Creek at FM 647 near Louise, Tex.	A	CR	4	U	90.8	9	✓	--	--	--
08164600	Garcitas Creek near Inez, Tex.	A	CR	30	U	91.7	9	✓	--	--	--
08164800	Placedo Creek near Placedo, Tex.	A	CR	30	U	68.3	9	✓	--	--	--
08165300	North Fork Guadalupe River near Hunt, Tex.	A	CR	33	U	168	5	✓	--	--	--
08165500	Guadalupe River at Hunt, Tex.	A	CR	35	U	288	5	✓	--	--	--
08166200	Guadalupe River at Kerrville, Tex.	A	CR	15	U	510	5	✓	--	--	--
[2]08167000	Guadalupe River at Comfort, Tex.	A	CR	62	U	839	5	✓	--	--	✓

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
08167500	Guadalupe River near Spring Branch, Tex.	A	CR	78	U	1,320	5	✓	✓	--	--
08167600	Rebecca Creek near Spring Branch, Tex.	D	CR	19	R	10.9	5	✓	--	--	--
08168500	Guadalupe River above Comal River at New Braunfels, Tex.	A	CR	73	R	1,520	5	--	✓	--	--
08169000	Comal River at New Braunfels, Tex.	A	CR	63	R	130	5	--	✓	--	--
08171000	Blanco River at Wimberley, Tex.	A	CR	74	U	355	5	✓	--	--	--
08172000	San Marcos River at Luling, Tex.	A	CR	61	R	838	9	--	--	--	✓
08175000	Sandies Creek near Westhoff, Tex.	A	CR	45	U	549	9	✓	--	--	--
[2]08176500	Guadalupe River at Victoria, Tex.	A	CR	66	R	5,200	9	--	✓	✓	--
08176900	Coleto Creek at Arnold Rd. near Schroeder, Tex.	A	CR	22	U	357	9	✓	--	--	✓
08177300	Perdido Creek at FM 622 near Fannin, Tex.	A	PR	22	U	28.0	9	✓	--	--	--
08177500	Coleto Creek near Victoria, Tex.	A	CR	38	R	514	9	✓	--	--	--
08178880	Medina River at Bandera, Tex.	A	CR	18	U	427	5	✓	--	--	--
08181400	Helotes Creek at Helotes, Tex.	A	CR	32	U	15.0	5	✓	--	--	--
08181500	Medina River at San Antonio, Tex.	A	CR	61	R	1,320	5	--	✓	--	--
08183500	San Antonio River near Falls City, Tex.	A	CR	75	R	2,110	9	--	✓	--	--
[2]08186000	Cibilo Creek near Falls City, Tex.	A	CR	70	U	827	9	✓	--	--	✓
08188500	San Antonio River at Goliad, Tex.	A	CR	67	R	3,920	9	--	✓	✓	--
[5]08188800	Guadalupe River near Tivoli, Tex.	A	CR	34	R	10,100	9	--	✓	✓	--
08189200	Copano Creek near Refugio, Tex.	A	CR	30	U	87.8	9	✓	--	--	--
[3]08189300	Medio Creek near Beeville, Tex.	D	CR	16	U	204	9	✓	--	--	--
[2]08189500	Misson River at Refugio, Tex.	A	CR	61	U	690	9	✓	--	✓	✓
[2]08189700	Aransas River near Skidmore, Tex.	A	CR	37	U	247	9	✓	--	✓	--
08190000	Nueces River at Laguna, Tex.	A	CR	78	U	737	5	✓	--	--	--
[2]08190500	West Nueces River near Brackettville, Tex.	A	CR	55	U	694	5	✓	--	--	✓
08192000	Nueces River below Uvalde, Tex.	A	CR	73	U	1,860	5	✓	✓	--	--
08194000	Nueces River at Cotulla, Tex.	A	CR	77	R	5,170	6	--	✓	--	--
08194200	San Casimiro Creek near Freer, Tex.	A	CR	39	U	469	6	✓	--	--	--
08194500	Nueces River near Tilden, Tex.	A	CR	59	R	8,090	6	--	✓	--	✓
08195000	Frio River at Concan, Tex.	A	CR	75	U	389	5	✓	--	--	--
08196000	Dry Frio River near Reagan Wells, Tex.	A	CR	48	U	126	5	✓	--	--	--

Footnotes at end of table.

Table 5. Core network of streamflow-gaging stations in Texas—Continued

USGS station no. (pl. 1)	Name	Status as of 10/01/99	Type of data	Record length (water years[1])	Regulation condition through 1997	Drainage area (square miles)	Hydrologic region (fig. 3)	Major objective of core network met			
								1	2	3	4
08197500	Frio River below Dry Frio River near Uvalde, Tex.	A	CR	49	U	631	5	✓	--	--	--
08198000	Sabinal River near Sabinal, Tex.	A	CR	58	U	206	5	✓	--	--	--
08198500	Sabinal River at Sabinal, Tex.	A	CR	48	U	241	5	✓	--	--	--
08200000	Hondo Creek near Tarpley, Tex.	A	CR	48	U	95.6	5	✓	--	--	--
08200700	Hondo Creek at King Waterhole near Hondo, Tex.	A	CR	39	U	149	5	✓	--	--	--
08201500	Seco Creek at Miller Ranch near Utopia, Tex.	A	CR	39	U	45.0	5	✓	--	--	--
08202700	Seco Creek at Rowe Ranch near D'Hanis, Tex.	A	CR	39	U	168	5	✓	--	--	--
[2]08205500	Frio River near Derby, Tex.	A	CR	85	U	3,430	6	✓	✓	--	✓
08206700	San Miguel Creek near Tilden, Tex.	A	CR	37	U	783	6	✓	--	--	--
[2]08208000	Atascosa River at Whitsett, Tex.	A	CR	70	U	1,170	6	✓	✓	--	✓
08210400	Lagarto Creek near George West, Tex.	D	CR	17	U	155	6	✓	--	--	--
08211000	Nueces River near Mathis, Tex.	A	CR	61	R	16,700	6	--	✓	✓	--
08211520	Oso Creek at Corpus Christi, Tex.	A	CR	28	U	90.3	6	✓	--	--	--
08211900	San Fernando Creek at Alice, Tex.	A	CR	25	R	507	6	--	--	✓	✓
08212400	Los Olmos Creek near Falfurrias, Tex.	A	CR	19	U	476	6	✓	--	✓	✓
[6]08374000	Alamito Creek near Presidio, Tex.	A	PR	68	U	1,500	2	✓	✓	--	✓
[6]08374500	Terlingua Creek near Terlingua, Tex.	A	PR	68	U	1,070	2	✓	✓	--	✓
08376300	Sanderson Canyon at Sanderson, Tex.	D	CR	12	U	195	2	✓	--	--	--
08408500	Delaware River near Red Bluff, NM	A	CR	62	U	689	2	✓	--	--	✓
[3]08412500	Pecos River near Orla, Tex.	D	CR	60	R	21,200	2	--	✓	--	--
08431700	Limpia Creek above Fort Davis, Tex.	D	CR	21	U	52.4	2	✓	--	--	--
08433000	Barrilla Draw near Saragosa, Tex.	D	CR	8	U	612	2	✓	--	--	--
08435700	Sunny Glen Canyon near Alpine, Tex.	D	CR	9	U	29.7	2	✓	--	--	--
08446500	Pecos River near Girvin, Tex.	A	CR	61	R	29,600	2	--	✓	--	✓
[6]08449400	Devils River at Pafford Crossing near Comstock, Tex.	A	PR	41	U	3,960	2	✓	✓	--	✓

[1] October 1–September 30, designated by calendar year in which it ends; for example, the year ending September 30, 1999, is water year 1999.

[2] Station identified as too important to exclude from regional optimization model.

[3] Station excluded from minimum core network.

[4] Station 08072050 San Jacinto River near Sheldon gages outflow from San Jacinto River. It is likely that daily streamflow cannot be gaged at this station because of effects from tides. In that case, station 08071000, Peach Creek at Splendora, can be used to estimate total flow into Lake Houston, which could represent outflow from the basin.

[5] Maximum gage heights upstream and downstream from saltwater barrier.

[6] Station currently operated by International Boundary and Water Commission, thus not used in optimization model.

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