Historical Changes in Streamflows, Channel Morphology, and Riparian Vegetation of the Rio Grande Downstream of Brownsville, Texas

The Rio Grande/Río Bravo drains an area of more than 440,300 square kilometers of Mexico and southwestern United States (Bartlett, 1984). The Rio Grande flows for 3,000 kilometers from its headwaters in the San Juan Mountains of southern Colorado to the Gulf of Mexico downstream of Brownsville, Texas. The "Rio," as it is often called, drains the southern Rocky Mountains of Colorado and northern New Mexico; the vast Chihuahuan Desert of southern New Mexico, northern Mexico, and southwestern Texas; and the subtropical lower valley of southern Texas (fig. 1).

Mean annual flow in the Rio Grande ranges from 6.0 million cubic meters in the snowmelt-dominated segments of

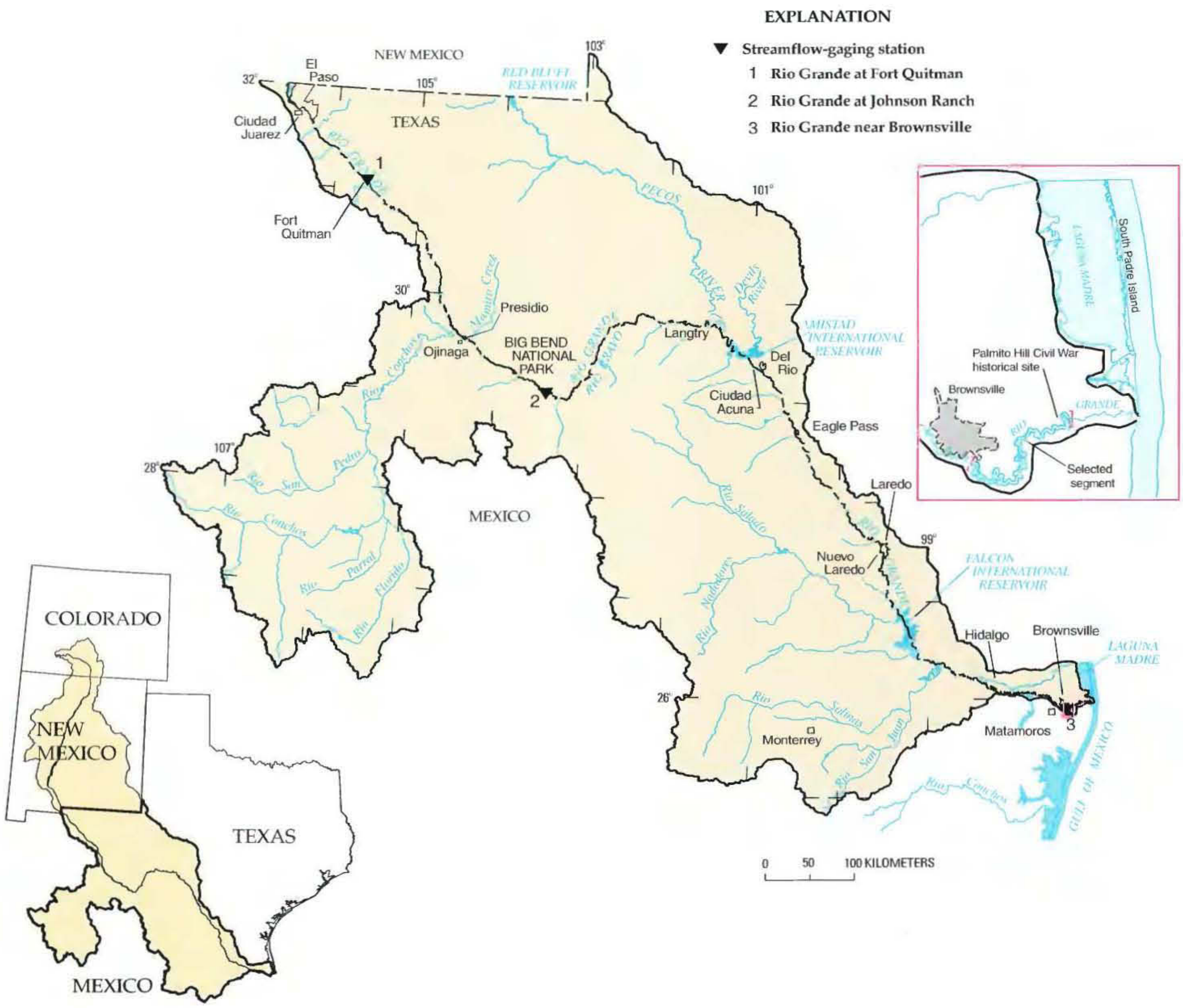

Figure 1. Rio Grande/Río Bravo Basin and location of selected streamflow-gaging stations and segment downstream of Brownsville, Texas.

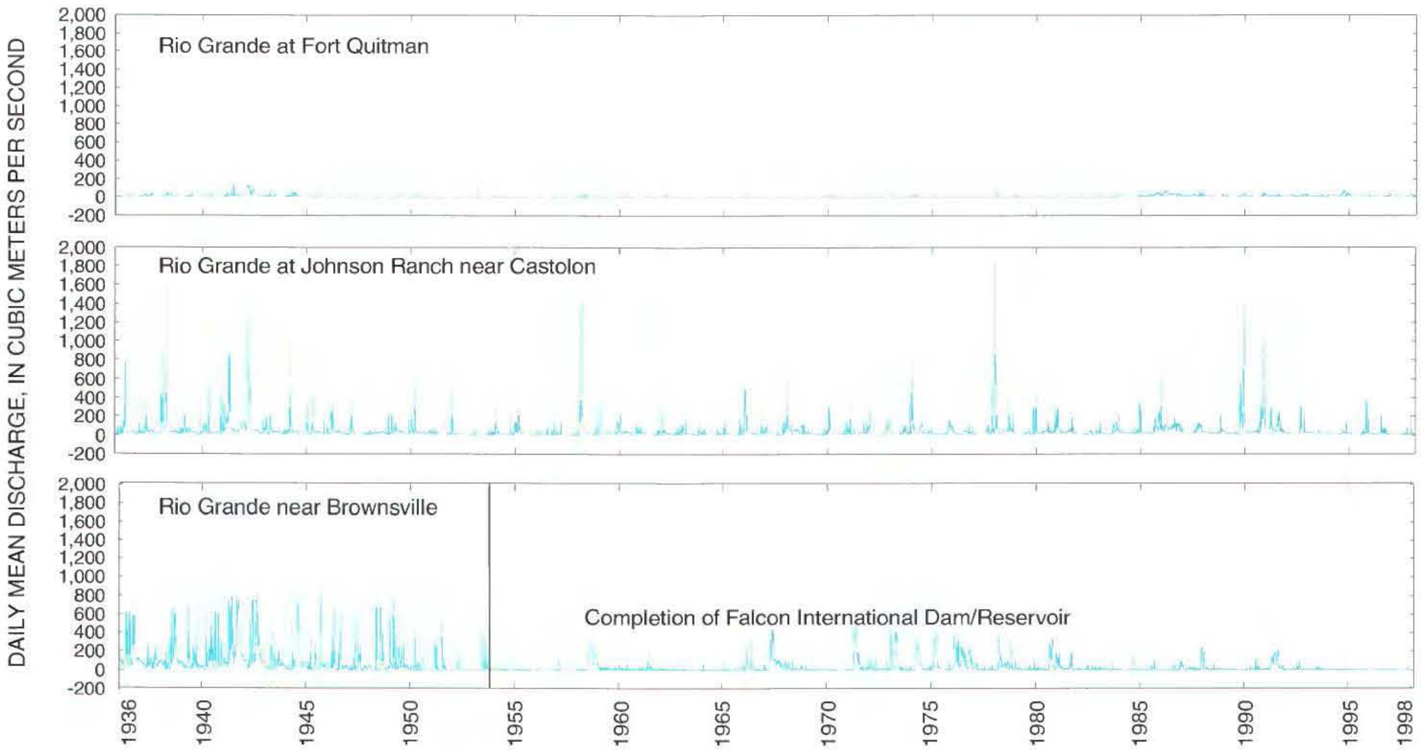

Figure 2. Hydrographs showing daily mean streamflow for three gaging stations on the Rio Grande.

the river in northern New Mexico to 22 million cubic meters near its mouth at the Gulf of Mexico. The Rio Grande is sometimes thought of as a river that has been disconnected in the middle. Downstream of El Paso, between Fort Quitman and Presidio, Texas, the river can be totally dry. Just upstream of Presidio, the Río Conchos, which drains 68,400 square kilometers of the Sierra Madre Occidental of Mexico, gives new life to the river. As much as 75 percent of the flow of the Rio Grande downstream of Presidio comes from the Río Conchos.

The Rio Grande downstream of Albuquerque, New Mexico, is a regulated river. Four major reservoirs impound the Rio Grande: Elephant Butte and Caballo Reservoirs in southern New Mexico and Amistad and Falcon International Reservoirs along the Texas border with Mexico. These reservoirs, which were constructed for water storage and flood control, have provided a continuous source of water for irrigation, allowing year-round farming in the Rio Grande Valley of Mexico and the United States. Irrigation water for agriculture accounts for 80 percent of surface-water use in the U.S. part of the river basin (Texas Natural Resource Conservation Commission, 1996). The 1906 Allocation Treaty ensures that the United States will deliver 74 cubic hectometers of irrigation water annually to Mexico by way of International Dam between El Paso and Ciudad Juarez (Meuller, 1975). The International Dam is the major flow-diversion structure on the Rio Grande. However, many smaller diversion dams carry water to crops in the floodplain of the river, and numerous drainage ditches return this water, often more saline, to the main channel of the river. The International Boundary and Water Commission (IBWC) has undertaken channel modification of the Rio Grande over much of its length between Elephant Butte Reservoir and Fort Quitman. Between El Paso and Fort Quitman, the river has been straightened from 249 to 142 kilometers in length.

About 10 million people live in the Rio Grande Basin; the fastest growing areas are the El Paso and Ciudad Juarez metropolitan area and the McAllen to Brownsville corridor in the lower Rio Grande Valley of South Texas (Texas Natural Resource Conservation Commission, 1996). In 1956, Mexico initiated the Border Industrialization Program, often referred to as the *maquiladora* program. This program, which provides incentives for foreign companies to construct factories in Mexico, has fostered the establishment of over 900 *maquiladoras* along the international border between Texas, New Mexico, and Mexico.

Population growth and agricultural and industrial development along the main stem of the Rio Grande, particularly the segment of the river that forms the international boundary between Texas and Mexico, has caused changes in water-quality conditions and in historical flows of the river. Changes to a river's flow patterns, and more specifically, changes in the timing and magnitude of a river's peak or higher flows have important consequences for channel

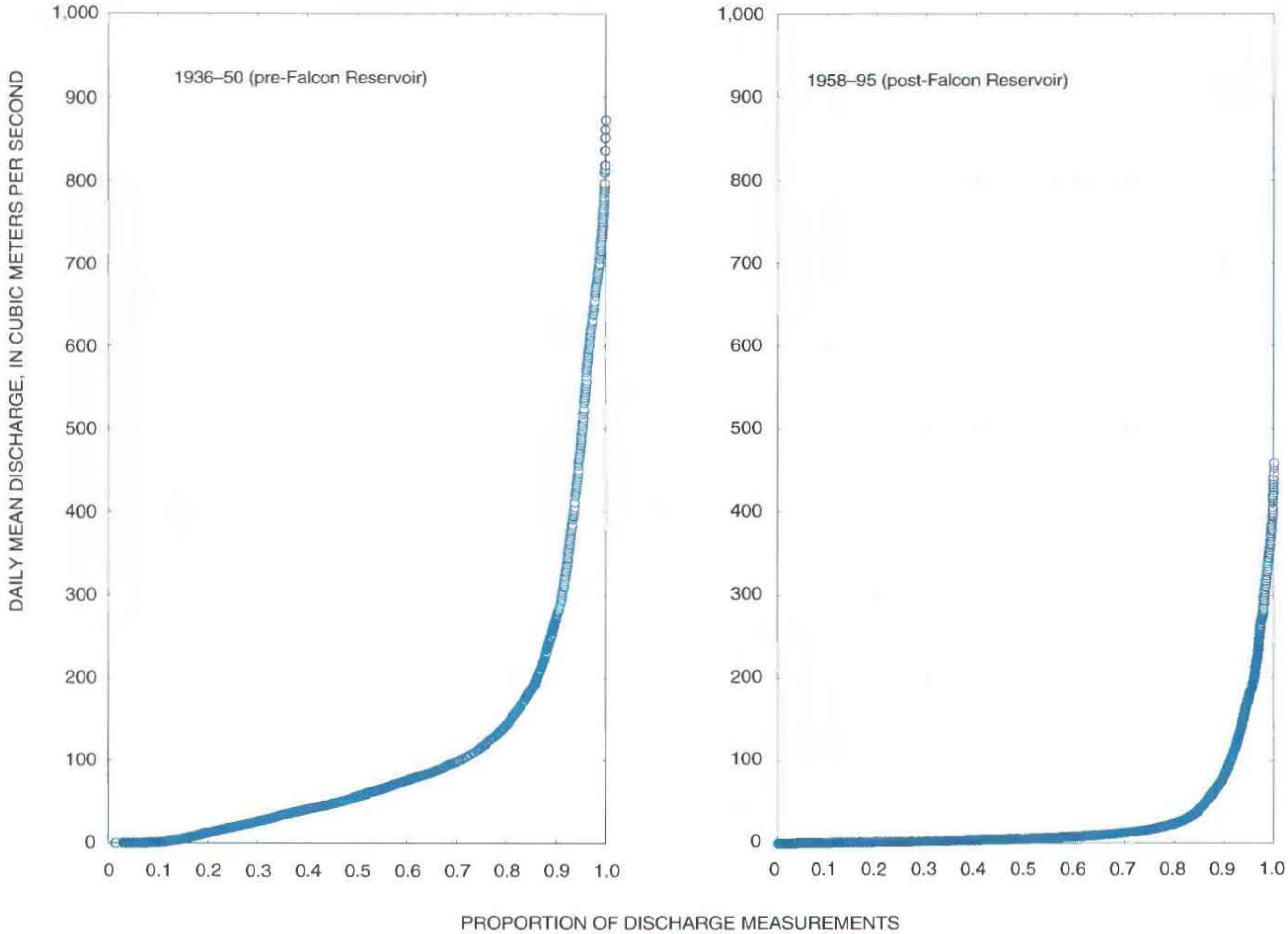

Figure 3. Distribution of daily mean discharge at the Rio Grande near Brownsville before and after construction of Falcon International Reservoir.

features and riparian zone vegetation (Leopold, 1994). These changes in channel and riparian zone features will in turn influence the makeup and status of riparian and aquatic biological communities. This report presents the results of an assessment of changes in general streamflow patterns at selected locations on the Rio Grande between El Paso and Brownsville and of changes in channel and riparian features downstream of Brownsville that are thought to have been caused by changes in streamflows.

Historical Changes in Streamflows in the Rio Grande

Three locations (fig. 1) on the Rio Grande between El Paso and Brownsville were selected to investigate changes in historical streamflows. The streamflow-gaging stations operated by the IBWC at each of these locations have been monitoring daily mean flows since the early 1920s or 1930s. These stations are Rio Grande at Fort Quitman, 2.4 river kilometers downstream of old Fort Quitman; Rio Grande at Johnson Ranch near Castolon, 2.2 river kilometers upstream of the old Johnson Ranch headquarters in Big Bend National Park; and Rio Grande near Brownsville, 10.9 river kilometers downstream of the International Bridge between Brownsville and Matamoros, Mexico. An equivalent period of streamflow record, 1936–98, was selected to characterize streamflow at each station.

Daily mean streamflow at the Fort Quitman station did not exceed 200 cubic meters per second during 1936–98 (fig. 2). This is partially a result of upstream reservoirs in New Mexico regulating flows. In contrast, daily mean streamflow is as great as 1,800 cubic meters per second at the Johnson Ranch station, which is downstream of the confluence with the Río Conchos (fig. 1). Flows at the Johnson Ranch station are more seasonal than flows at the Fort Quitman station, with increased flows in late summer corresponding to the onset of monsoonal rains in the Chihuahuan Desert. These seasonal flows reflect the flow of the Río Conchos, which is less regulated than the Rio Grande above El Paso. The streamflow record for the station just downstream from Brownsville (fig. 2) shows that the variability in flows decreased substantially after the completion of Falcon International Reservoir in 1958. In particular, the proportion of flows greater than 100 cubic meters per second decreased

Figure 4. 1950 and 1995 aerial photographs of part of segment of the Rio Grande downstream of Brownsville, Texas.

from a proportion of 0.3 or 30 percent during 1936–50 to a proportion of 0.1 or 10 percent during 1958–95 (fig. 3).

The segment of the Rio Grande from downstream of Falcon Reservoir to the mouth of the Rio Grande at the Gulf of Mexico is bordered by tracts of undeveloped riparian and floodplain lands that are part of the U.S. Fish and Wildlife Service (USFW) complex of wildlife refuges and the National Audubon Society Sabal Palm Preserve. These lands contain some of the last stands of native riverside vegetation such as the sabal palm. However, these native stands are being displaced in many areas by more aggressive exotic species such as African bermuda and salt cedar (Larry Ditto, U.S. Fish and Wildlife Service, oral commun., 1999). Changes in streamflows in the Rio Grande, specifically the lack of higher out-of-bank flows, can be an important cause of the encroachment of these exotic species.

Historical Changes in Channel and Riparian Features Downstream of Brownsville, Texas

A segment of the Rio Grande downstream of Brownsville (fig. 1) was selected to characterize historical changes in channel and riparian features that might have been caused by changes in streamflows. The segment extends about 38 kilometers from just upstream of the IBWC gaging station near Brownsville to just downstream of the Palmito Hill Civil War historical site (inset, fig. 1). Aerial photographs (scale 1:20,000) taken in 1950 by the Soil Conservation Service (now the Natural Resources Conservation Service) and U.S. Geological Survey digital orthophoto quadrangles (DOQs) derived from 1995 National Aerial Photography Program aerial photographs (scale 1:40,000) were used to compare channel and riparian features (fig. 4). The 1950 aerial photographs were rectified to match the scale of the 1995 DOQs for comparison. The difference between daily mean discharge when the 1950 and 1995 aerial photographs were taken was only 0.5 cubic meter per second; the effect of this difference on channel features in the photographs, at this scale, is thought to be negligible.

Various channel and vegetative-cover measurements were made to assess changes along the Rio Grande during 1950–95 (table 1). The vegetation score for point bars was based on assigning values from 1.0 to 5.0 according to the area of the bar covered by vegetation. For example, a vegetation score of 1.0 indicates vegetation coverage of 0 to 25 percent of the bar, and a score of 5.0 indicates coverage of 75 to 100 percent. These measures were determined using geographic information system (GIS) software.

The largest changes in channel and riparian features in the segment are in riparian vegetation, point-bar area and vegetation, and wetted channel width (fig. 5, table 1). Between 1950 and 1995, the frequency of breaks in riparian vegetation increased by an average of 35 percent; however, the length of these breaks increased by an average of more than 300 percent. The average width of riparian vegetation decreased by about 57 percent on the U.S. bank and about 47 percent on the Mexican bank. An increase in the number and extent of breaks in riparian vegetation might have been caused by land-use practices including the clearing of vegetation to increase land available for cultivation. However, a decrease in the intensity and frequency of higher flows might have caused a reduction in recharge to the alluvial aquifer, thus lowering the alluvial water table, and similarly reducing the density and extent of riparian vegetation.

The average point-bar area increased by 111 percent, and the average score of vegetation coverage of the same point bars increased by 230 percent. The average wetted channel width decreased by 32 percent. A decrease in the frequency of higher river flows (such as out-of-bank flows) and the resulting increase in rooted vegetation are probably the cause of channel narrowing and the stabilization of point bars.

These changes in channel and riparian features in this segment of the Rio Grande downstream of Brownsville are further illustrated by comparing the 1950 aerial photograph to the 1995 aerial photograph for a part of the segment studied (fig. 4). Point bars in the 1950 photograph are primarily unvegetated sand. The same point bars in the 1995 photograph have little or no sand visible and are largely covered with vegetation. The channel in the 1995 photograph is visibly narrower and is more simplified than the channel in the 1950 photograph.

Many native species of riparian vegetation require seasonal flooding to germinate, and the periodic flooding of the riparian zone affects soil chemistry through the import and removal of organic matter, in the replenishment of mineral resources, and in maintaining a large flux of energy and nutrients in the riparian zone (Mitsch and Gosselink, 1993). Riparian zone vegetation provides important nesting and feeding habitat for resident and migratory birds and often provides the only substantial cover for other wildlife, particularly in more arid regions. This report provides evidence of a decreasing trend in higher flow events (which might have caused the narrowing of the channel) and increased vegetative coverage leading to more stable channel bars and a less continuous riparian buffer zone paralleling the river in this segment of the Rio Grande downstream of Brownsville, Texas.

Table 1. Channel and riparian features for the segment of the Rio Grande downstream of Brownsville, Texas

[m, meters, m^2, square meters]

Feature	1950	1995	Percent change
Linear segment length (m)	19,193	19,181	–0.063
Curvilinear segment length (m)	59,323	60,847	2.57
Sinuosity of segment	3.09	3.17	2.59
Left bank [U.S.] length (m)	57,770	57,922	.263
Right bank [Mexico] length (m)	57,625	58,615	1.72
Length of breaks in riparian vegetation, left bank [U.S.] (m)	6,536	26,701	309
Length of breaks in riparian vegetation, right bank [Mexico] (m)	4,340	17,834	311
Frequency of breaks in riparian vegetation, left bank [U.S.]	43	56	30.2
Frequency of breaks in riparian vegetation, right bank [Mexico]	62	87	40.3
Average width of riparian vegetation, left bank [U.S.] (m)	32.4	13.9	–57.1
Average width of riparian vegetation, right bank [Mexico] (m)	22.5	12.0	–46.7
Average wetted channel width (m)	55.9	38.0	–32.0
Average area of point bars (m^2)	10,153	21,441	111
Average score of vegetation coverage of point bars	1.0	3.3	230

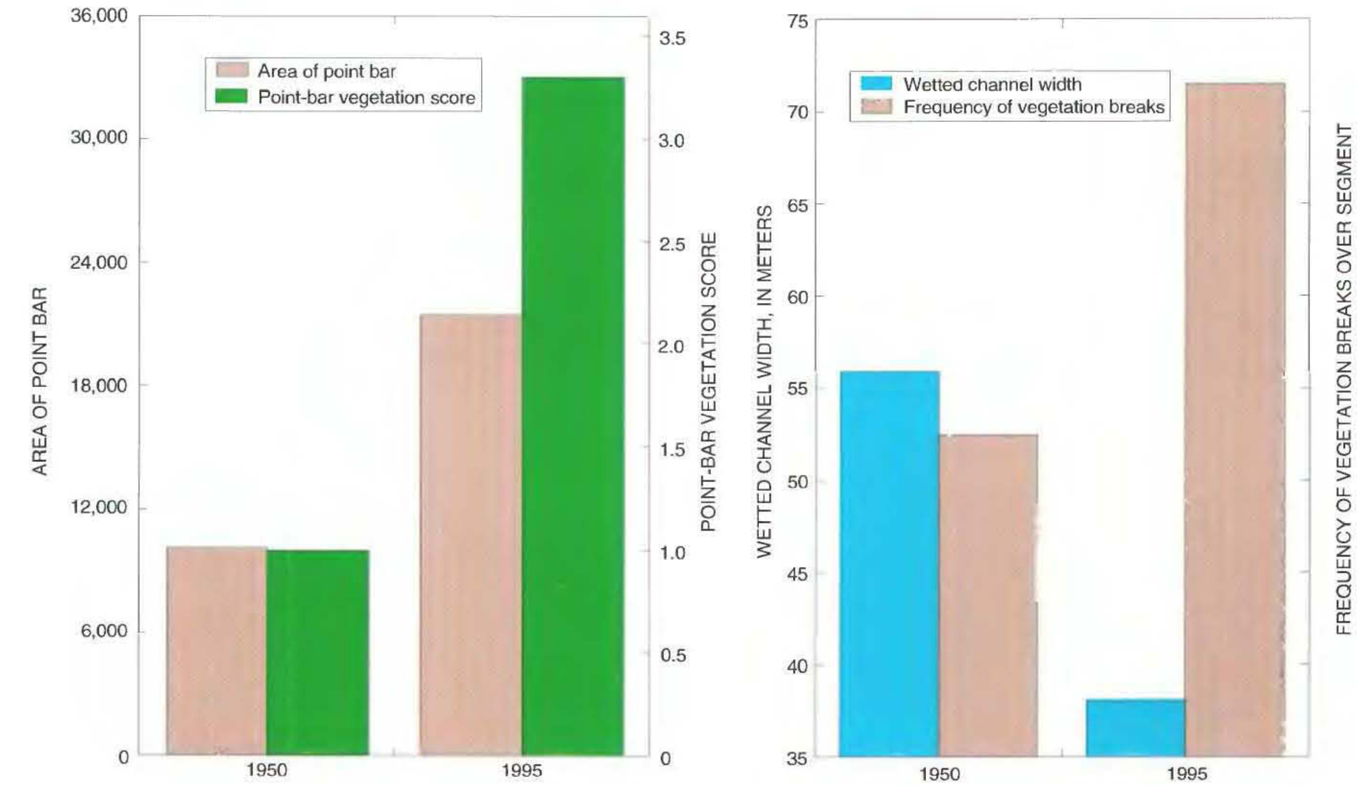

Figure 5. Channel and riparian zone features for segment of the Rio Grande downstream of Brownsville, Texas.

—J. Bruce Moring and Rita Setser

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For more information, please contact:

District Chief
U.S. Geological Survey
8027 Exchange Dr.
Austin, TX 78754–4733
E-mail: dc_tx@usgs.gov

Phone: (512) 927–3500
FAX: (512) 927–3590
World Wide Web: http://tx.usgs.gov/

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