CHANNEL WIDTHS CHANGES ALONG THE MIDDLE RIO GRANDE, NM

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INTRODUCTION

This paper describes the temporal and spatial characteristics of the river channel width of the middle Rio Grande during the twentieth century. The Rio Grande is an alluvial river that originates in the San Juan Mountains in southwestern Colorado and runs through New Mexico and Texas and along the border between Texas and Mexico. Historically, it had a wide, sandy, braided planform with a high sediment load and was aggrading (Scurlock 1998 and Lagasse 1980).

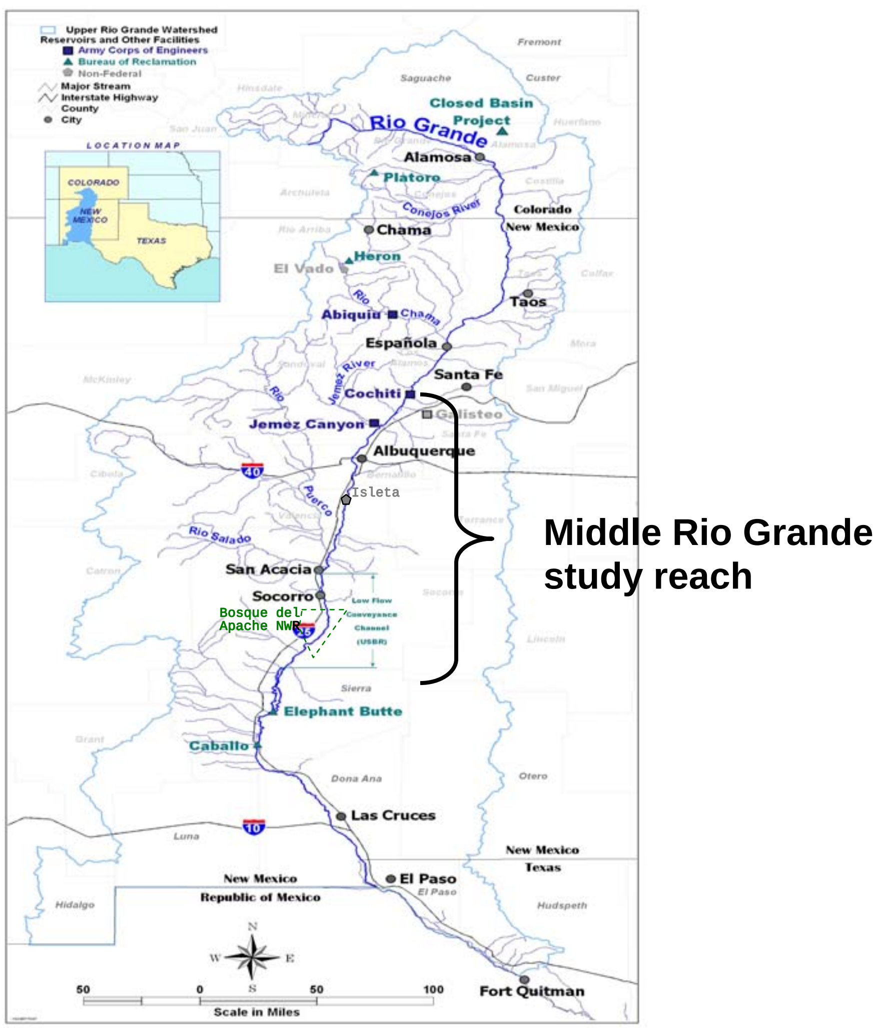

Figure 1 Middle Rio Grande study reach

The flow regime of the Rio Grande has varied over time. There are two primary sources of change: climate and water resource development. Periods of extended drought or wet hydrology have in particular influenced the magnitude, duration, and frequency of channel forming flows and the river morphology as have water delivery and flood control facilities. Figure 2 shows a timeline of these events. The general effect on the middle Rio Grande hydrology has been that peak flows have decreased in magnitude while the discharge has increased during winter base flow periods.

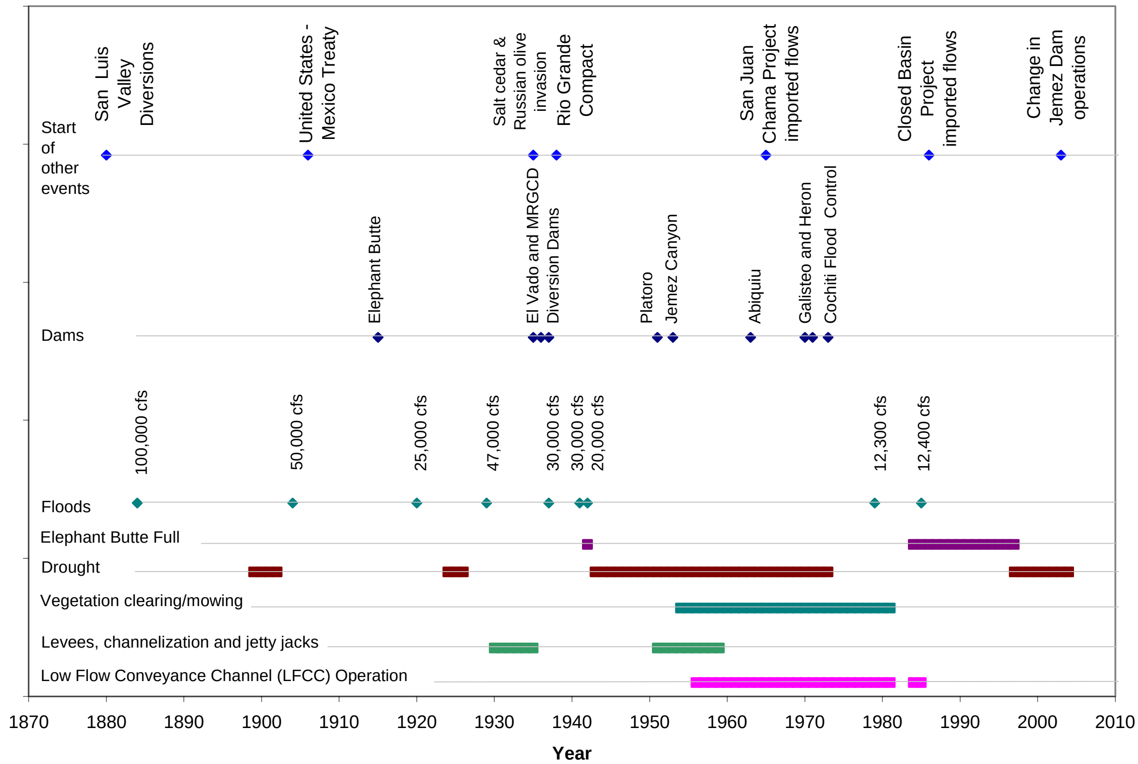

Figure 2 Timeline of significant events (adapted from Makar and Bauer 2004)

DATA AND METHODS

Planform data in the form of maps and aerial photographs are available in the Rio Grande GIS database (Oliver 2004) for nine data sets: 1908/18, 1935, 1949, 1962, 1972, 1984/85, 1992, 2001, and 2002. The earliest data are from hand-drafted linens while the rest are black and white aerial photography at various resolutions and were obtained from Reclamation's Albuquerque Area Office. Metadata that accompanies this database documents the categories of data and the limitations and sources of the data.

Active channel widths from Cochiti Dam to Elephant Butte Reservoir, at established cross sections with an approximate 500 foot spacing (cross section lines 19 through 1800 in Oliver 2004 and referenced by just the cross section number in this paper), are taken from digitized information in the GIS database. A few cross section lines are not perpendicular to the channel or the flow path, resulting in a small error in the channel widths. For this study, the active channel is the area of no or sparse vegetation cleared by the river which does not include vegetated islands or mechanically cleared areas. Figure 3 presents the widths for each set of data. Data in Figure 4 is normalized to an average annual change and illustrates the rate of change in width between dates of photography.

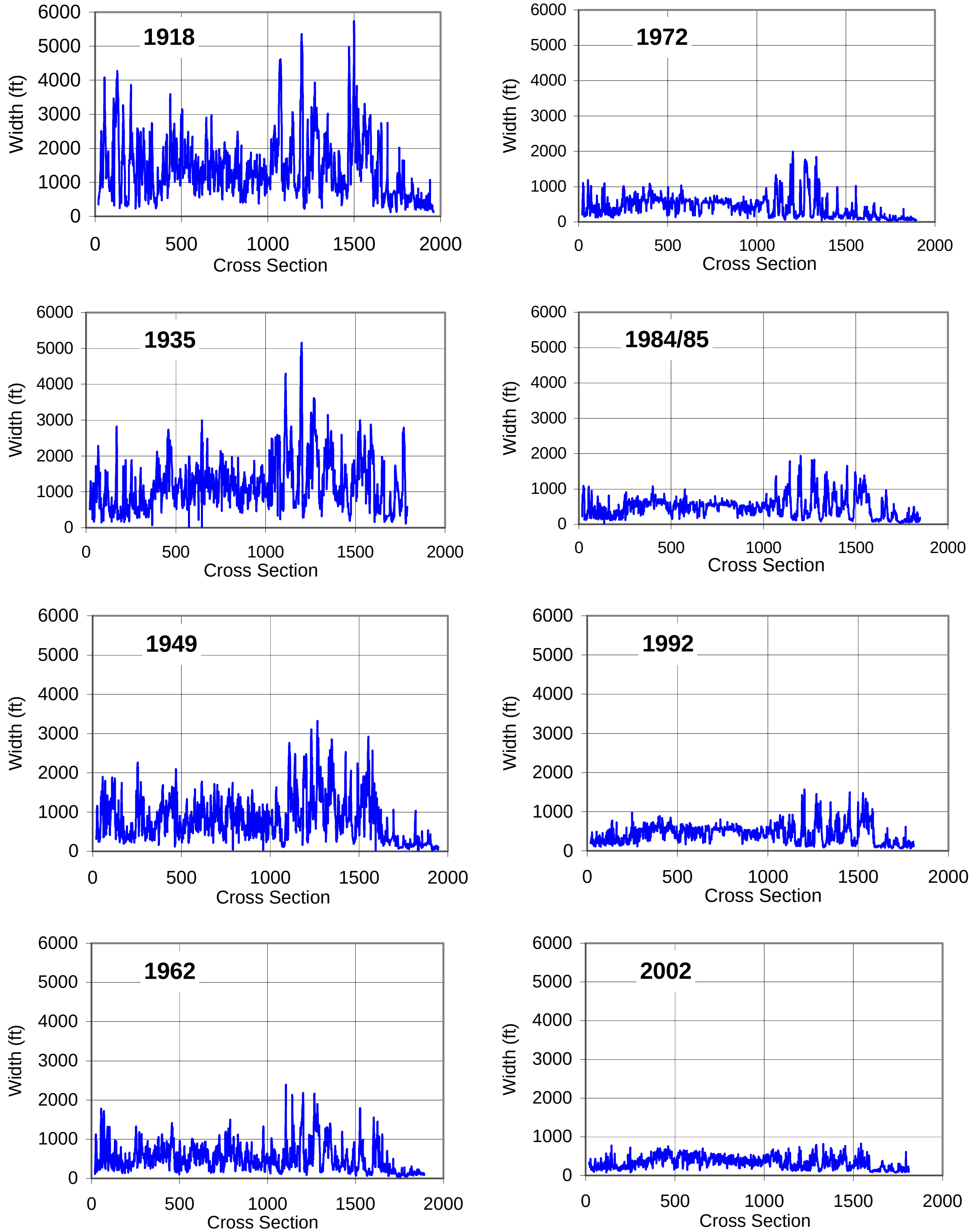

Figure 3 Active channel widths

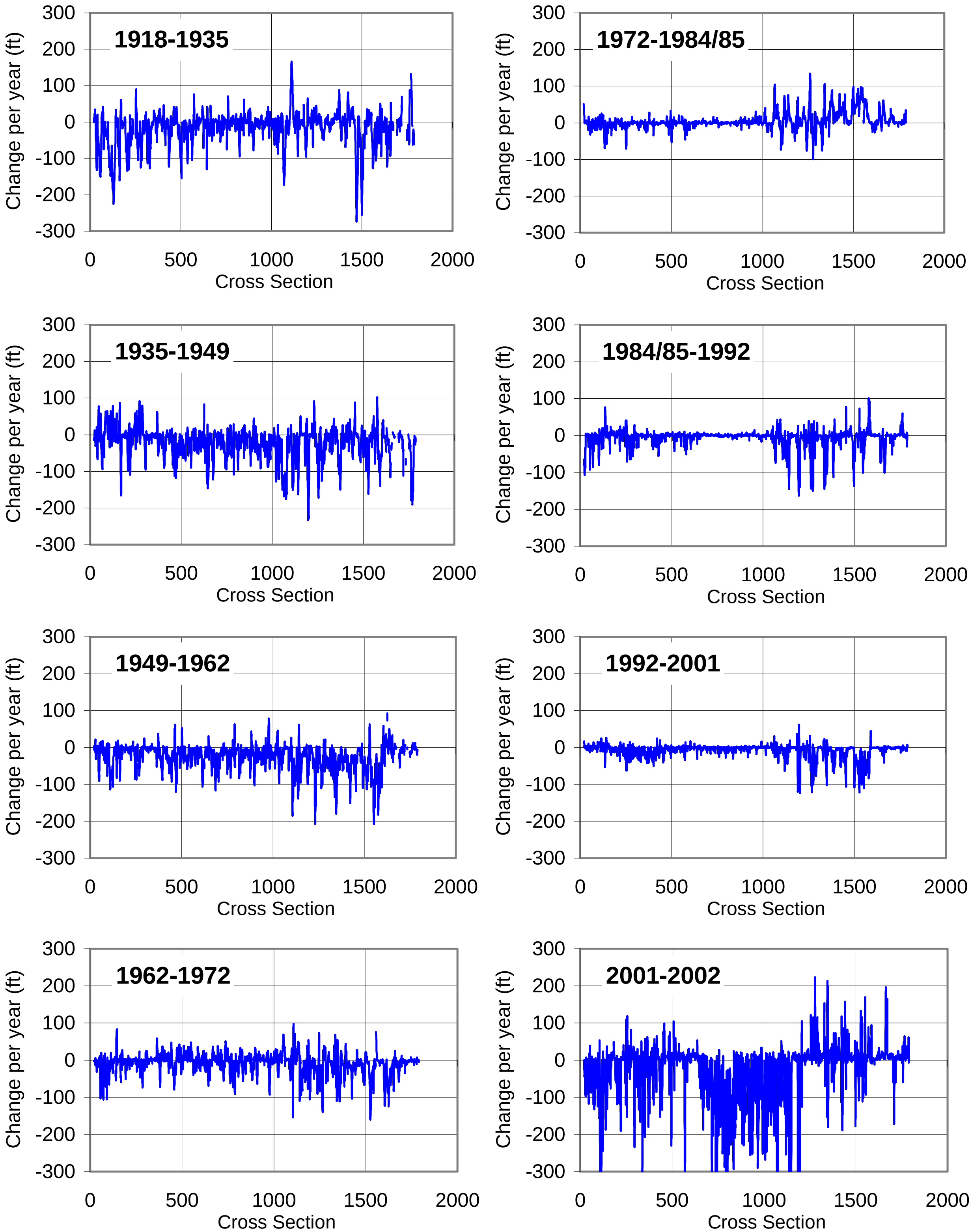

Figure 4 Average annual changes in active channel width

RESULTS AND DISCUSSION

Magnitude and rate of active channel width changes

On rivers like the Rio Grande, channel characteristics are often determined by major flood events (Knighton, 1998). These large events are followed by many years of adjustment, which may include narrowing, incision, and the formation of vegetated islands and bars. Previous studies (Richard et al. 2005, Makar and Bauer 2004, Makar and Strand 2003) have found a strong correlation between peak flows and active channel width. Some areas responded more strongly than others but decreased peak flows are associated with an overall decrease in the river channel width.

Figure 3 illustrates the general narrowing trend over time; such that channel widths in 1918 are the widest and 2002 the narrowest. Channel width data in 1918 shows that the reach was generally wider than 1,500 feet, with many areas in excess of 2,500 feet. By 1949, most of the reach was still wider than 1,000 feet, but few areas were greater than 2,000 feet and the extensive variability found in the 1918 channel width data is gone. The 1972 data set continues the decreasing width trend, such that nearly all the cross sections are less than 1,000 feet wide. The most recent data set from 2002 shows that at present, all of the cross sections have channel widths less than 1,000 feet, and that the majority are also less than 750 feet.

Decreases in width between 1918 and 1935 can be partially attributed to construction of riverside irrigation facilities such as drains and canals that are protected by levees. After 1941, there was an extended period of below average stream flows and peak flows. The river channel narrowed through vegetation encroachment on bars and islands that were no longer cleared by flooding. Drought conditions were still prevalent in 1962, but narrowing was also due to channelization. Beginning in the 1950s, large sections of the river were narrowed with jetty jacks to more efficiently transport water and sediment downstream. The jacks also trapped sediment and protected the banks. The Low Flow Conveyance Channel (LFCC) between San Acacia Diversion Dam and Elephant Butte Reservoir reduced flows by diverting up to 2,000 ft^3/s from the floodway from the late 1950s through the early 1980s. Widths continued to narrow through 1972, with vegetation encroachment during drought and channelization largely responsible for the narrowing.

Beginning in 1979 through the late 1980s, there were higher flows in the river. With minor exceptions, the LFCC has not been operated since the early 1980s, also increasing the flows in the river. In the 1960s through the 1980s, large sections of the river were mechanically cleared of vegetation to maintain flood capacity. By 1985, the active channel width widened to near the edge of the cleared floodway along much of the river. Low water levels were seen in the years around 1990 and after 1995 and mean channel width decreased more in the 1992, 2001, and 2002 photos.

Vegetation plays an important role in width adjustment on the Rio Grande. The majority of the widening that has occurred was where floodway clearing had taken place before periods of higher peaks. Vegetation continues to encroach when not scoured or cleared away. Once established, vegetation anchors deposited sediments and makes lateral adjustment difficult unless certain thresholds such as critical shear stress or root strength are exceeded. Rowntree and

Dollar (1999) report riparian vegetation locally increases bank stability as a function of root mass and depth and tends to reduce channel capacity through narrowing. Their evidence indicates that narrow stable reaches are associated with relatively thick vegetation and wider, unstable channels have more sparse riparian vegetation. In aggrading reaches, they postulate the reduced channel capacity results in increased overbank flooding which may lead to avulsion. This is similar to conditions seen on the Rio Grande just upstream of Elephant Butte Reservoir.

The trend of general narrowing is also evident in Figure 4 in that the majority of changes are negative. Note that the 2001-2001 data only represents one year of change, while the other figures are yearly averages of multiple years. The narrowing between 2001 and 2002 is still striking and generally a consequence of the drought and significant vegetation encroachment. The persistence of the new vegetation was tested during the high peaks of the 2005 runoff and field observations show that while some areas widened many did not, as the runoff flows did not completely scour the vegetation from islands and bars. The next set of aerial photography is likely to be very important in estimates of future width changes. Close examination of Figure 4 shows that cross sections with significant narrowing in one photo stabilize or even widen in the next. Also of note is the appearance of a downstream progression in narrowing in some areas. Narrowing is likely related to the downstream progression of incision and bed material coarsening documented in Bauer (1999), Leon (1998), Makar and Strand (2002) and Massong et al. (2006). More detailed examination of this phenomenon is planned in the future.

Reach based changes

The reach boundaries of similar width and magnitude of change shift depending on the period and location examined but some large scale trends are evident. For example, the channel near the Bosque del Apache National Wildlife Refuge (BDANWR) area has always been the widest and immediately upstream of Elephant Butte Reservoir the narrowest. Four reaches are discussed below:

Cochiti Dam to Isleta Dam (63 river miles, cross sections 19 to 655)

This reach was wide with a high amount of variability in 1918 and shows a fairly high level of channel width change through 1962. After 1962, the amount of narrowing decreases and the widths stabilized. The channelization and bank stabilization effort in the 1950s is a component of the uniformity. There was not a large change between the 1972 and later data, indicating Cochiti Dam (which closed in 1973) may not yet have had a large impact on width adjustment. It appears that major width adjustment in this reach had occurred by 1962 until the recent drought fostered significant vegetation growth and channel narrowing between 2001 and 2002. Richard et al. (2005) suggests the width of the Rio Grande in the upper portion of the reach may have been in equilibrium by 2001. When data become available, it will be interesting to compare widths after the high flows of 2005 to see whether they approach the previous condition.

Isleta Dam to Rio Puerco Confluence (42 river miles, cross sections 655 to 1099)

There is less variability in widths in this reach, i.e. fewer very wide or very narrow cross sections. The amount of width change within a time period is also quite consistent in the reach; however, the channelization and bank stabilization effort in the 1950s resulted in the large reduction in width between 1949 and 1962. The narrowing continues at reduced rate through 1972, with very little change until 2002 when the largest amount of narrowing occurs between

2001 and 2002 throughout the reach. Field observations indicate that the channel is shifting towards a single-thread planform. The uniformity of both widths and width changes over time and the suddenness of the large change in 2002 indicate there has been a planform shift from braided to single thread. This reach has also shown little to no incision (Massong et al. 2006). It will bear watching for incision if the large reduction in width and the transition from braided to a single-thread channel are maintained.

Rio Puerco Confluence to mid-BDANWR (49 river miles, cross sections 1099 to 1580)
This reach has generally had the most variability in width and the widest widths in the time periods examined. It also shows the highest widening rates (except in between 1935 and 1949). Despite the generalized narrowing in 2001 to 2002, this reach had the largest magnitude of widening while width reductions were smaller than that those upstream. Immediately downstream from San Acacia, NM, a section with the highest amounts of incision (Massong et al. 2006) rapidly widened in 2005 (Massong 2005), suggesting that discharge is still a major influence in determining channel width in this reach, especially in locations where the planform is single thread and the bank height is taller than root depth.

Mid-BDANWR to Elephant Butte Reservoir (18 river miles, cross sections 1099 to 1800)
Always the narrowest and least variable, this reach generally shows lower amounts of width change. The historical pattern has included channel avulsions, consistent aggradation, and a perched riverbed (Makar and Strand 2002). Much of this reach was relocated when the river channel was moved to the east side of the valley during Low Flow Conveyance Channel construction. The cut channel with thickly vegetated banks has been generally stable, except for periodic avulsions that impinge on and sometimes breach the levees. The levee breaches have been repaired and the channel returned to the constructed alignment. This maintenance is certainly a factor in the stability of the widths in this reach.

CONCLUSIONS

Width changes of the Rio Grande have resulted from natural processes such as the response to large floods and drought but also have been influenced by anthropogenic modifications. The long dry periods with low peak flows facilitated vegetation encroachment and narrowing. Flood control dams that changed the timing and decreased the magnitude of upstream peaks plus channelization and bank stabilization activities have resulted in a narrower active channel. Photography from 2001, 2002, and 2004 shows that the development of well-established vegetated islands has increased in recent years. With uninterrupted and continued development of islands, the wetted channel width will continue to decrease. Eventually, the islands may become attached to the river bankline. The resulting river is likely to be single thread, narrow, high velocity, and incised with increased meandering tendencies. In aggrading reaches, thick vegetation locally stabilizes the channel at lower flows but channel avulsions may still occur during high peaks.

Planned future analysis on the Rio Grande includes integrating the width changes documented herein with the channel incision discussed in Massong et al. (2006), lateral mobility concepts in Richard et al. (2005) and the changing relationships between water and sediment loads documented in Bauer (1999), Leon (1998), Makar and Strand (2002), and MEI (2002).

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