RECENT CHANNEL INCISION AND FLOODPLAIN EVOLUTION WITHIN THE MIDDLE RIO GRANDE, NM

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INTRODUCTION

The Rio Grande was historically an aggrading river system with a wide, sandy, braided planform with an even more extensive floodplain/wetland system inundated during high flows (Scurlock 1998). Consecutive flooding of irrigated and inhabited lands prompted the Middle Rio Grande Project to create a series of large dams on the Rio Grande and its major tributaries (1950s-1970s) to control flooding and sedimentation (Lagasse 1980). Much of the Middle Rio Grande (MRG) today is no longer flooding and aggrading, but rather is evolving at a rapid rate in the opposite direction. For example, the active channel width, which has been decreasing since the 1930s, had a measurable decrease between the 2001-2002 data sets (Makar et al., 2006). The historical floodplain is in many places abandoned, with the formation of vegetated bars constituting the majority of flooded surfaces in these areas (Tashjian et al., 2006). As much of the floodplain became abandoned through degradation of the channel bed (a.k.a., incision), bank heights grew, but their growth has not appeared systematic as they change throughout the MRG (Klawon and Makar 2002, Massong et al. 2002, Ortiz 2004, and Massong 2005).

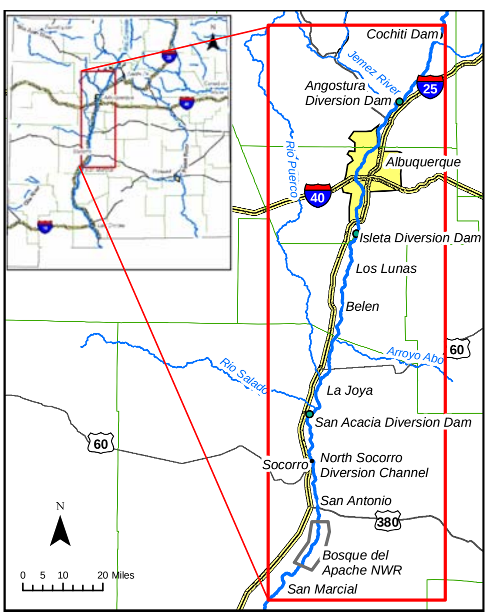

Figure 1: Location of the Middle Rio Grande (MRG) within the state of New Mexico.

The main purpose of this paper is to describe the current pattern of floodplain abandonment through examining bed incision data and terrace formation within the MRG and secondly to discuss possible governing processes that are influencing the channel bed elevations. The study extends from Cochiti dam at Cochiti, NM to the head of Elephant Butte Reservoir at the historic town of San Marcial, NM (Figure 1), a river reach of approximately 170 river miles (RM).

DATA AND METHODS

A variety of data were used to assess the degree of channel incision throughout the MRG. These data include: terrace maps in the high incision areas, field observations of bank heights where terrace maps do not currently exist, historical bed elevation data, current (2002) bed and bank elevation data, aerial photography, and existing GIS base layer/map data.

Data collected from field visits and plane flights determined location and degree of historical floodplain abandonment. Spring 2005 aerial photography, accomplished through a cooperative effort lead by the U.S. Fish and Wildlife Service, the New Mexico Interstate Stream Commission, and the U.S. Army Corps of Engineers, funded through the ESA Collaborative Program, the U.S. Army and the State of New Mexico, was also reviewed. Floodplains that remained dry throughout the runoff were confirmed abandoned. In the locations where the floodplain became inundated, an attempt was made to determine the river discharge at the time of flooding, as the 2005 runoff peak was greater than a 2-year event.

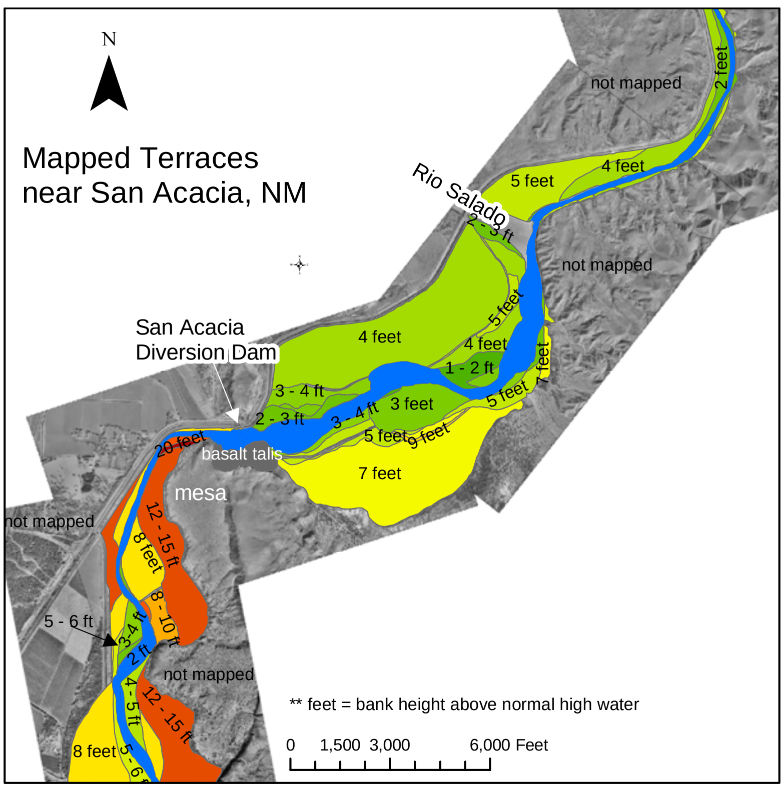

Figure 2: Sample of the abandoned floodplain data in the San Acacia, NM area that shows terrace height data associated with each polygon; partial data set from Massong 2005.

A series of historical terraces/abandoned floodplains exist throughout the MRG (Figure 2), some of which have been mapped; riverine terraces have recently been mapped near Bernalillo-Corrales, NM (Ortiz 2004) and from the Rio Puerco confluence to the head of Elephant Butte

(Massong 2005, Klawon and Makar 2002). For locations where data are not available, field visits have been made to observe bank heights and floodplain characteristics.

Historical and current cross section data (bed elevation data) were compiled by Chris Holmquist-Johnson (Reclamation-TSC, Sedimentation Group, Denver, CO) for: 1936-7, 1942-46, 1952-54, 1962, 1972, 1992, and 2002. Changes in bed elevation were used to initially define incision boundaries (Figure 3). Boundary refinements were made using the 2002 estimated bank height data (Figure 4) and field observations. Historical channel location data and channel outlines were digitized from Reclamation aerial photographs by Jan Oliver (Reclamation-TSC, Remote Sensing Group, Denver, CO). Spatial analyses were performed with ArcMap 9.0.

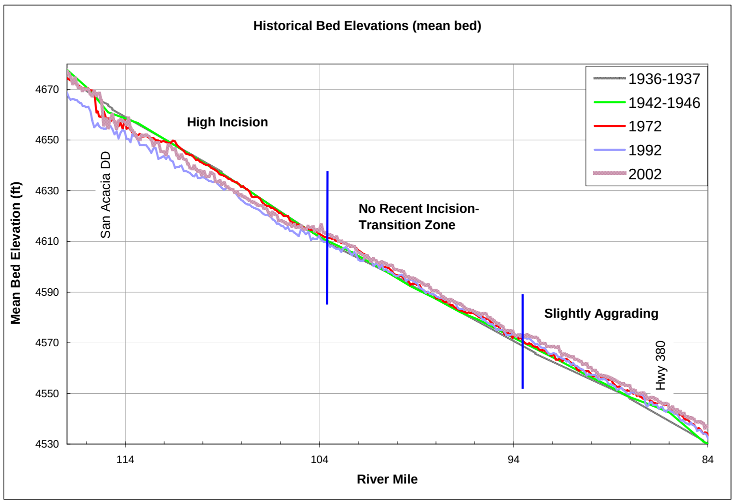

Figure 3: Sample of the Rio Grande bed elevation data available for the Middle Rio Grande; San Acacia Diversion Dam to the U.S. Highway 380 crossing near San Antonio, NM.

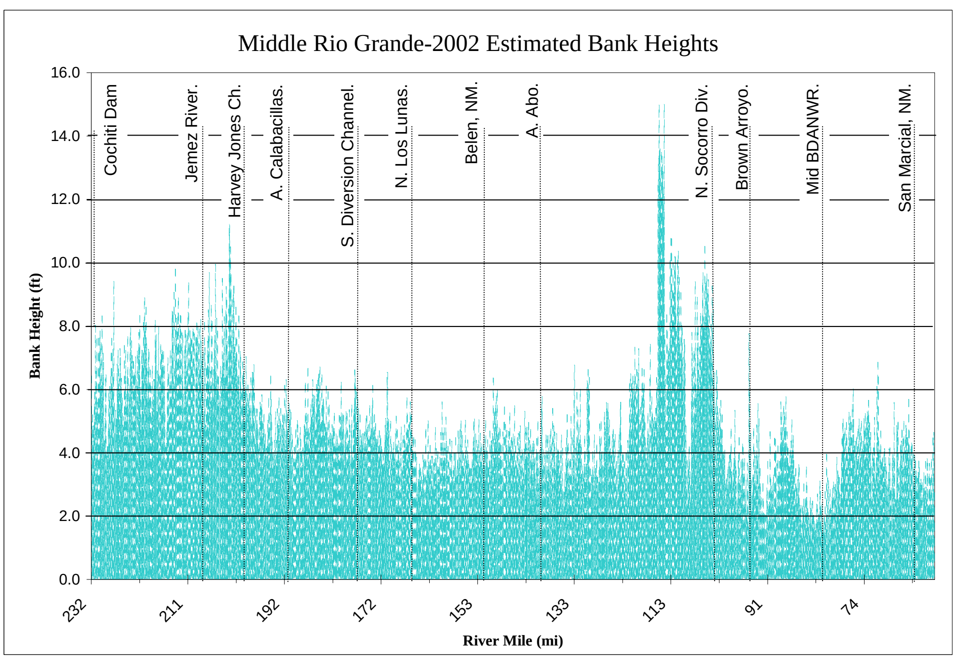

Figure 4: Estimated bank height for the MRG based on cross section data.

Incision was estimated first on whether the historic floodplain was currently active, which was assessed predominantly through field observations. Additional field inspections occurred in 2005, when the spring runoff flow exceeded the 2-year return period (peaking at almost 7,000 cfs in Albuquerque, NM). Bed and bank elevation data were used to better define boundaries between different amounts of incision (Figure 3).

RESULTS

Through comparisons of the bank heights and bed degradation data, the study area is divided into eleven reaches that either describes the amount of incision or aggradation present (Figures 4 & 5). The amount of incision ranged from no incision to high with bank heights greater than 6 ft.. In the active floodplain areas, the channel bed aggradation is described as either slightly (<10 ft. since 1935) or rapidly aggrading (>10 ft. since 1935). Reach descriptions follow.

1. Cochiti Dam to Jemez River (24 RM)-Moderate-High Incision: After operations began at Cochiti Dam in 1973, the channel bed immediately began to erode and coarsen (Lagasse 1980) which has continued to the present (Massong 2004). The large grain size that emerged quickly after 1973 is suspected in retarding incision (Lagasse, 1980), such that the floodplain although quickly abandoned, is not more than 6 ft. higher than the current channel elevation.

2. Jemez River to Harvey Jones Channel (10 RM)-High Incision: Bed degradation and coarsening have also been ongoing processes here since 1973, however the bank heights are higher than upstream. Unlike upstream, an extensive series of mid-channel bars emerged in the 1990s, and now act as floodplain surfaces.

3. Harvey Jones Channel to Arroyo Calabacillas (7 RM)-Moderate Incision: Bank height varies from 3-5 ft., decreasing in the downstream direction (Ortiz 2004). The channel planform is in transition from the wide, sand-bar-braided channel so characteristic of the Rio Grande prior to 1973 to a vegetated-island-braided channel with a gravel bed.

4. Arroyo Calabacillas to the South Diversion Channel (14 RM)-Low-Moderate Incision: Channel planform conversion is also ongoing in this section with islands becoming a dominant in-channel feature. However, the incision is less than upstream, with maximum 4 ft. bank height.

5. South Diversion Channel to Northern Los Lunas, NM (13 RM)-Low Incision: Although the historical floodplain is predominantly abandoned, relatively small sections flood at very high flows, as seen in 2005. Numerous mid-channel islands have also evolved in the last 5 years and now act as in-channel floodplains.

6. Northern Los Lunas, NM to Belen, NM (15 RM)-No Recent Incision: The recently formed, vegetated islands and bars as well as the historical floodplain areas became inundated at the highest 2005 flows. The bed elevation data indicates relative stability.

7. Belen, NM to Arroyo Abo (10 RM)-Low-Moderate Incision: Although bank heights are only slightly higher than found upstream, the historical floodplain is abandoned. Extensive vegetated island complexes now flood during the high flows.

8. Arroyo Abo to North Socorro Diversion Channel (36 RM)-High Incision: Unlike in the upstream reaches where one or maybe two historical floodplain surfaces existed, a series of floodplain surfaces are present. Review of historical photos, however, shows that many of the terraces formed prior to 1973 but within the last 100 years. The tallest terraces in this reach exist just downstream from San Acacia, NM (Massong 2005), with a distinct change in terrace heights at the San Acacia Diversion Dam (Figure 2).

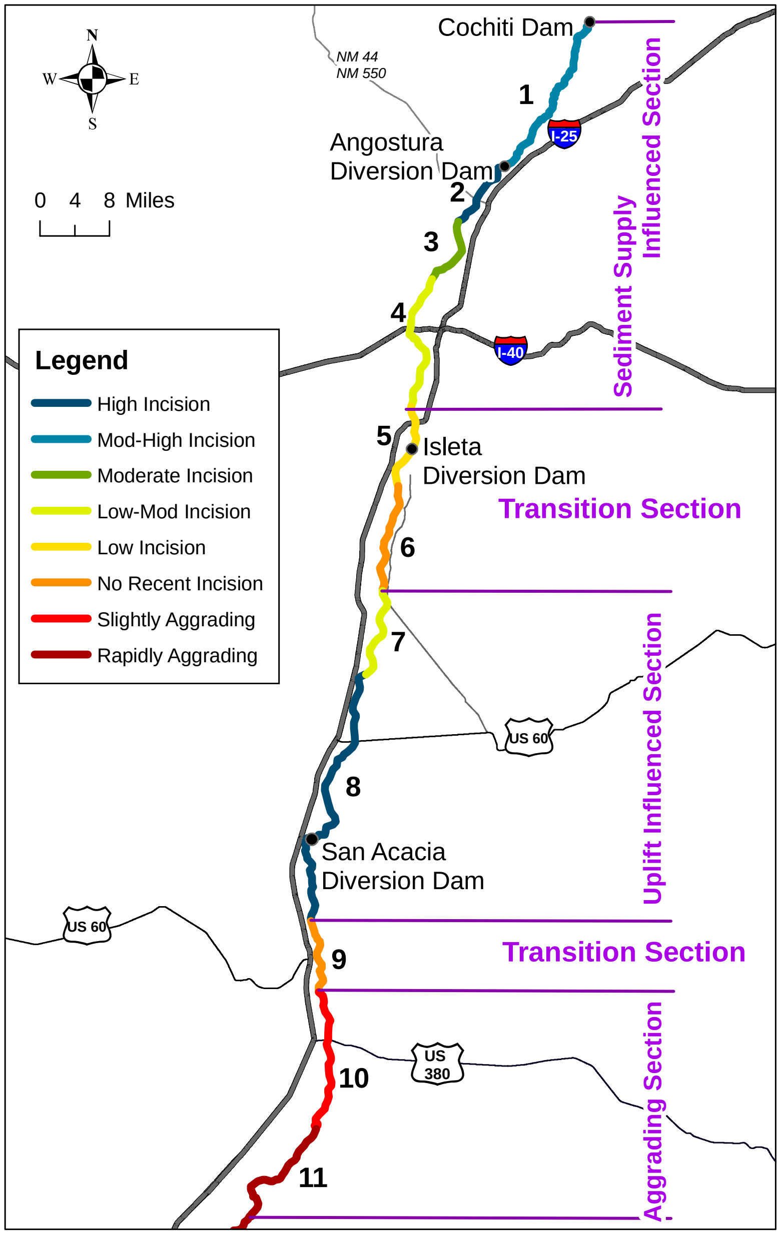

Figure 5: Summary figure showing incision trends from Cochiti Dam to Elephant Butte Reservoir, NM; numbers correspond to reach descriptions in the text. Channel descriptions are as follows: **high incision** has bank heights >6 ft.; **moderate incision** has bank heights 3-5 ft.; **low incision** has bank heights <3 ft.; **slightly aggrading** channels have <10 ft. of aggradation since 1935, while the **rapidly aggrading** is >10 ft. of aggradation; combination descriptions (i.e., Mod-High) indicates a mixture of bank heights.

9. North Socorro Diversion Channel to Brown Arroyo (9 RM)-No Recent Incision: Within a very short distance, the high upstream incision ends (Klawon and Makar 2002), and the channel bed elevation becomes somewhat stable (Figure 3). This transition reach separates the degradation upstream and aggradation downstream in a very short distance that acts almost as a 'pivot point'.

10. Brown Arroyo to the middle of Bosque Del Apache National Wildlife Refuge (13 RM)-Slightly Aggrading: This section is and has been gradually aggrading since the 1930s; bank heights are low and the floodplain along with newly formed islands are flood prone.

11. Middle of Bosque Del Apache National Wildlife Refuge to San Marcial, NM (15 RM)-Rapidly Aggrading: Although the Rio Grande has a long-term history of aggradation (Lagasse 1980), this reach is aggrading excessively. Bed accretion is about 15 ft. in the last 65 years. The historical floodplain located within the levee system is active and noticeably aggrading along with the channel bed; islands and bars are uncommon.

DISCUSSION

In 117 miles of the 170 river miles of the Middle Rio Grande, the channel bed is incising and has largely abandoned its historical floodplain. Although recently developed islands and bars flood during high flows, the loss of the large floodplain system indicates a change in governing processes. Based on the bed elevation/bank height information, the eleven reaches have been combined into sections that attempt to link processes to the channel patterns (Figure 5). Section 1, Sediment Supply Influenced Section, extends from Cochiti Dam to South Diversion Channel, joining Reaches 1-4, about 57 RM. Section 2, Uplift Influenced Section, extends from the Arroyo Abo confluence to North Socorro Diversion Channel, combining Reaches 7 and 8, about 48 RM. Section 3, Aggrading Section, groups Reaches 10 & 11, about 30 RM.

The influence of dams on river systems is a well discussed and documented topic throughout the world. Most Rio Grande studies (Lagasse 1980, Richard, 2001, Ortiz 2004, Massong and Porter 2004, Massong and Porter 2005) document a dramatic reduction in sand-sized sediments which is resulting in an increasing grain size and localized bed degradation. Section 1 shows a degrading river system downstream from Cochiti Dam, in which the highest incision is near the dam. The incision systematically decreases downstream such that about 60 miles downstream from the dam near the Isleta Diversion Dam the floodplain is at least in part active. The floodplain inundation increases downstream to the Los Lunas, NM area, about 70 miles downstream of Cochiti Dam. Section 1 incision is distinct from Section 2; only one historical floodplain appears to have been abandoned in Section 1, creating only one terraced surface. Only one terrace supports the concept of a single event, such as a permanently reduced supply of sediment changing the governing process. Lagasse (1980) found that the reduction in sediment supply quickly reversed the historically aggrading Rio Grande to a degrading system directly downstream of Cochiti Dam; this process/mechanism now appears to be influencing almost 60 miles downstream from the dam outlet. As a significant increase in sediment supply is unlikely, channel bed degradation will likely continue to increase bank heights and migrate downstream.

A series of riverine terraces centered near San Acacia, NM is an obvious signature of the Socorro Magma Body crustal uplift. Ouchi (1983) discussed the influence of this uplift through a review of bed elevation data (1930s-1970s) which showed a persistent ‘bulge’ in the river’s longitudinal profile located over the magma body. Recent investigations by Klawon and Makar (2002) and Massong (2005) focused on mapping the variations in bank heights in the Socorro, NM area; they found that a series of terraces extend from approximately Arroyo Abo to the North Socorro Diversion Channel. These terraces peak in height near San Acacia, NM (Figure 2 and Massong 2005), which is also the approximate center of uplift (Larsen and Relinger 1983). Since the outline of terraces in Section 2 closely mirrors the estimated uplift associated with the magma body, geology appears to be dominating floodplain abandonment in this Section. However, Massong (2005) also clearly shows that several terraces have formed since the early 1970s, some are already as high as 6 feet. These data likely indicate additional processes (i.e., reduced supply of sediment) are influencing the recently abandoned floodplains in this Section.

Downstream from the transition zone (Reach 9), aggradation is ongoing and increases in a downstream direction. Reclamation archive data/studies (Scurlock 1998, and Makar and Strand 2002) show that this section of the MRG has been subject to aggradation dating back to the earliest records (pre-1900). USGS Rio Grande gage data clearly show that all gages in the Middle Rio Grande, even the gage at San Marcial (Massong et al., 2002), have a reduced suspended sediment supply since Cochiti Dam began operating; however, the bed elevation data shows a steadily aggrading channel in Section 3, a system obviously laden with sediment. The lack of channel response in this Section to the change in sediment supply is not well understood. For the continued aggradation, one thought is that the aggradation may be geologic; Larsen and Relinger (1983) suggest that just south of the Socorro Magma Body, the crust could be sinking. The theorized subsidence is a secondary effect of the uplifting ‘bulge’ of the Socorro Magma Body which could account for the continued and constant aggradation in this Section. Interestingly, bank height increases with the aggradation (Figure 4), such that the higher bank heights occur with the high aggradation; unfortunately, the process controlling this channel response is also not well understood.

This incision study is a clear example illustrating the effects of two processes that influence the Rio Grande. One of the most noticeable changes over the last 10 years is the emergence of stable, vegetated bars and islands throughout the MRG. As the historical floodplain is predominantly abandoned in the upper MRG, these features now act as floodplains, even though they are within the active channel. Interestingly, bar/island formation is independent of changes in the bed elevation, as they form in both the degrading and aggrading channel sections. Along with the curious channel features at San Marcial, NM, a variety of processes are obviously influencing the MRG, creating the complicated riverine system found today.

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