# MONITORING AGGRADATIONAL AND DEGRADATIONAL TRENDS ON THE MIDDLE RIO GRANDE, NM

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**Abstract:** For nearly a century, topographic surveys of the river channel and floodplain associated with monitoring sedimentation trends have been conducted on the Middle Rio Grande valley extending from Cochiti Reservoir to the headwaters of Elephant Butte Reservoir. This 160-mile reach of alluvial river has some of the most problematic sedimentation issues in the United States. Reservoir sedimentation monitoring cross sections in Elephant Butte Reservoir have been resurveyed many times since they were established in 1916. The majority of sediment transported on the main stem Rio Grande is deposited in this reservoir. Analysis of the deposition along these cross sections shows over 600,000 acre-feet (23 percent) of storage were lost between 1916 and 1999 with the highest rate of reservoir sedimentation occurring prior to 1940. Additional cross sections in the upstream river have been established over time and field surveyed periodically by various federal and state agencies to monitor changes. The channel portion of many of these historical cross sections continues to be periodically field surveyed.

After an extensive period of construction of flood and sediment control facilities and channelization works, an aerial survey in 1962 established nearly 2000 photogrammetric aggradation/degradation (agg/deg) rangelines. These rangelines are spaced at about 500-foot intervals to monitor sedimentation and morphological changes of the river channel and floodplain for the entire Middle Rio Grande reach. Aerial surveys were conducted and data obtained for the same rangelines in 1972, 1992, and 2002. These cross section data have been analyzed to determine the rate and extent of sediment erosion and deposition. Trends are presented as average values for established sub-reaches and show significant differences in main channel volumetric changes over time among the sub-reaches. Conditions and responses vary along the study reach with the sediment deposition generally increasing downstream and decreasing over time. Historical main channel aggradational trends have in some cases reversed due to upstream dam construction and decreases in tributary sediment inflow.

Analysis of aggradational and degradational trends provides valuable evidence of the short- and long-term responses of the Middle Rio Grande to natural and anthropogenic influences. These trends are also used to evaluate river maintenance strategies, habitat recovery efforts, and estimate future processes and trends.

## INTRODUCTION

A historical record of the aggradational and degradational trends of the 160-mile reach of the Middle Rio Grande has been compiled by Bureau of Reclamation in cooperation with other federal and state agencies. (USBR 1967, 1974; Young et al., 2005 draft). Arid and semi-arid watersheds of easily erodible sediments and steep-gradient ephemeral tributaries contribute to the high geological rate of erosion of the basin drainage areas. Flash floods on these tributaries carry loads greater than the main stem channel can normally transport and form delta fans at their confluences. Irrigation diversions contribute to accumulation of sediments in the river channel by decreasing discharge, and diversion dams influence the river slope. Throughout the reach, the river is confined to a portion of its historical floodplain by levees associated with water delivery and drainage. About 90 miles of jetty fields are also present and previously encouraged sediment deposition in overbank areas and scour in the main channel. Excessive channel degradation disconnects the channel from the floodplain reducing the quality and quantity of in-stream and floodplain habitat and accelerating erosion of the bed and bank. Channel incision downstream of Cochiti Dam and corresponding increases in the potential for bank collapse are additional sources of sediments. Sediment deposition in the San Marcial area reduces channel capacity and water delivery efficiency, and it affects valley drainage, threatening the ability to effectively convey water through this reach. Historical losses involving sedimentation include the abandonment of productive lands, reduction in crop yields, increases in flood damages, and the inability of the State of New Mexico to deliver water required under the terms of the Rio Grande Compact while still providing sufficient water to meet normal irrigation demand (USBR 1967, 1974, and 2001).

Continued analysis and monitoring of the aggradational or degradational trends provides Middle Rio Grande river management agencies valuable quantifiable evidence of the short- and long-term responses of the Rio Grande to natural and anthropogenic influences. This additional understanding provides a useful basis for informed decision making regarding the effects of natural hydrologic variations, reservoir operations, habitat restoration, and channel maintenance activities on the river channel and floodplain.

## DATA COLLECTION AND ANALYSIS

A variety of data collection and analyses techniques are being utilized by Reclamation to support its Middle Rio Grande river maintenance program, improve the effectiveness of maintenance design practices, and reduce uncertainties related to river hydraulics, sediment transport, and geomorphic channel response.

**Hydrographic Surveys:** This data collection includes river and reservoir cross section surveys, velocity and discharge measurements, sediment discharge measurements, and sediment sampling. The earliest comprehensive sedimentation survey of the entire Middle Rio Grande Valley was performed in 1936, corresponding to the completion of irrigation works constructed by the Middle Rio Grande Conservancy District. Subsequent sedimentation field surveys of limited cross sections were performed in 1940, 1941/42, 1944, and 1952/53. Data from these surveys have helped establish historical trends (USBR, 1967). Additional cross sections have been established and continue to be surveyed to support various river management goals by Reclamation and other agencies.

The Elephant Butte Reservoir rangelines are the oldest and most continuous cross section data sets available on the Middle Rio Grande. The original survey for Elephant Butte Reservoir was conducted between 1903 and 1908. A dozen resurveys have been conducted on the reservoir between 1916 and 1999. Resurveys are performed whenever there is an estimated 5 percent change in reservoir capacity based on historical trends. The 1999 resurvey estimated an average annual sediment accumulation rate for 84 years of record of about 7,200 acre-feet/year. The rates of reservoir capacity loss at Elephant Butte Reservoir provide reasonable estimates of the amount of sediment transported by the Rio Grande. Due to the length of the reservoir, virtually all sediment entering the reservoir is trapped. Figure 1 shows how reservoir capacity and cumulative water inflow have varied over time. Over 600,000 acre-feet (23 percent) of storage were lost between 1916 and 1999 with the highest rate of reservoir sedimentation occurring prior to 1940 (Collins and Ferrari, 2000).

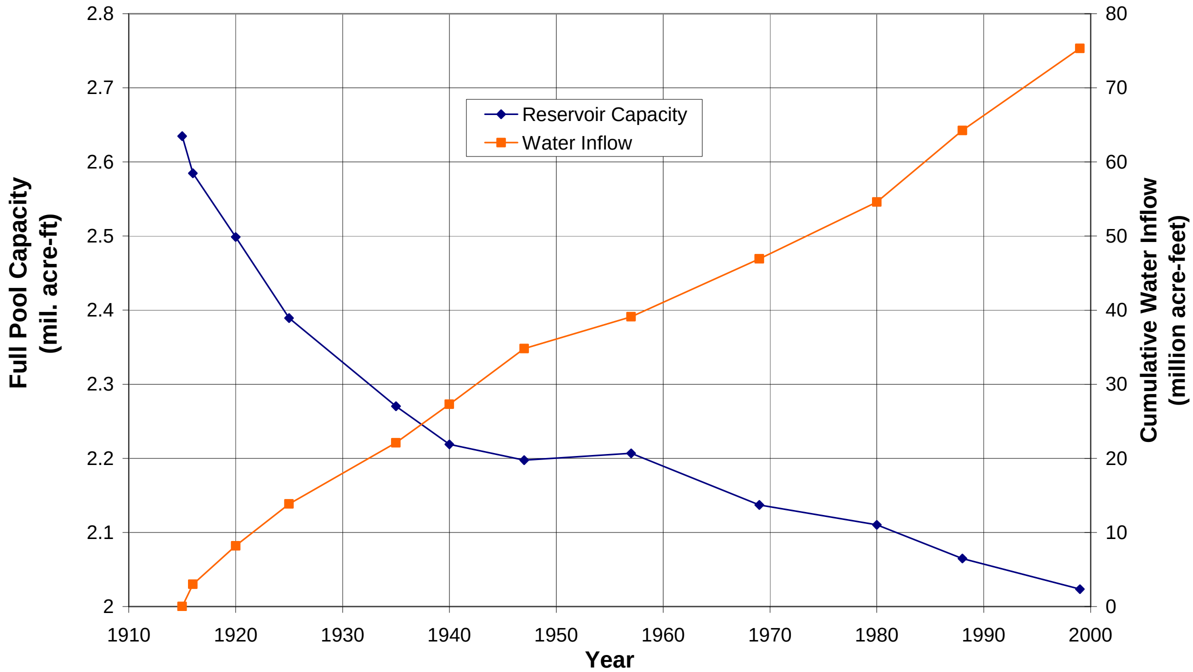



Figure 1 Elephant Butte Reservoir Capacity and Cumulative Water Inflow vs. Time

**Field observations:** These data include geomorphic observations such as mapping terrace and island formation, evaluating bank stability, classifying vegetation, and evaluating riverine and overbank habitat. The focus of this study is aggradational and degradation trends, more detailed analyses of the hydrologic and river process trends and documentation of planform changes including features such as terraces are available in other reports. (e.g., Bauer (1999); Makar and Strand (2002); Oliver (2004); Makar and Bauer (2004); Richard, Julien, and Baird (2005); Klawon and Makar (2002)) Generally over time, mean flows, channel and floodplain widths, and sediment transport rates have decreased, while channel depth, the number of islands and bars, and channel velocities have increased.

**Aerial photography:** This data collection includes mosaics of aerial photography and digital ratio-rectified or digital orthophotos that are the basis for deriving photogrammetric cross sectional data and developing digital terrain models and maps. Aerial photography data are typically collected for the river corridor between the levees in the months of January or February when foliage and river flows are at a minimum. Two to three ground control stations are located within every river mile using GPS survey equipment. Mapping, digital imagery, and cross sectional data are collected at the scale of 1:4800 or 1 inch equals 400 feet. Ground position accuracy for planimetric features are within ± 8 to 10 feet and within ± 0.5 feet for ground surface elevations.

The main focus of this study was the analysis of the current aggradation/degradation (agg/deg) photogrammetric cross sections between Cochiti Dam and Elephant Butte Reservoir. The cross sections were established at roughly 500-foot intervals in 1962 to record the condition of the channel improvement works and serve as a basis for future evaluation of sedimentation and morphologic changes in the river channel and floodplain. The frequency of aerial surveys has been about every 10 years; photogrammetric data sets were collected in 1962 (Abram Aerial Survey Corporation), 1972 (Limbaugh Engineers, Inc.), 1992 (Koogle & Pouls Engineering, Inc.), and 2002 (Pacific Western Technologies, Ltd.).

A consequence of using conventional aerial photography to develop cross section data is that the underwater portion must be estimated. The elevation data obtained from the aerial photography for inundated portions represent the water surface, not the channel bottom. The underwater prism for each cross section is solved iteratively using backwater analysis with actual stream gage discharge data, photograph interpretation, and a rectangular prism assumption for the channel's underwater geometry.

For the data analysis, the river was divided into five sub-reaches based on historical geographic boundaries as described in the 1967 and 1974 Summary Reports. The most downstream San Marcial reach boundary was set to avoid any duplication of data obtained from the previously described reservoir sedimentation surveys. Table 1 below relates the divisions and the corresponding agg/deg cross sections that bound the reach divisions. Young et al. (2005) also provide similar data delineated by utilizing geomorphic reaches defined for water operation studies and further subdivision of the San Marcial reach into two sub-reaches.

Table 1 Middle Rio Grande Sub-Reach Divisions

| Sub-Reach Name | Cross section number | |
|---|---|---|
| | Upstream Boundary | Downstream Boundary |
| Cochiti | 17 | 236 |
| Albuquerque | 236 | 656 |
| Belen | 656 | 1207 |
| Socorro | 1207 | 1505 |
| San Marcial | 1505 | 1584 |

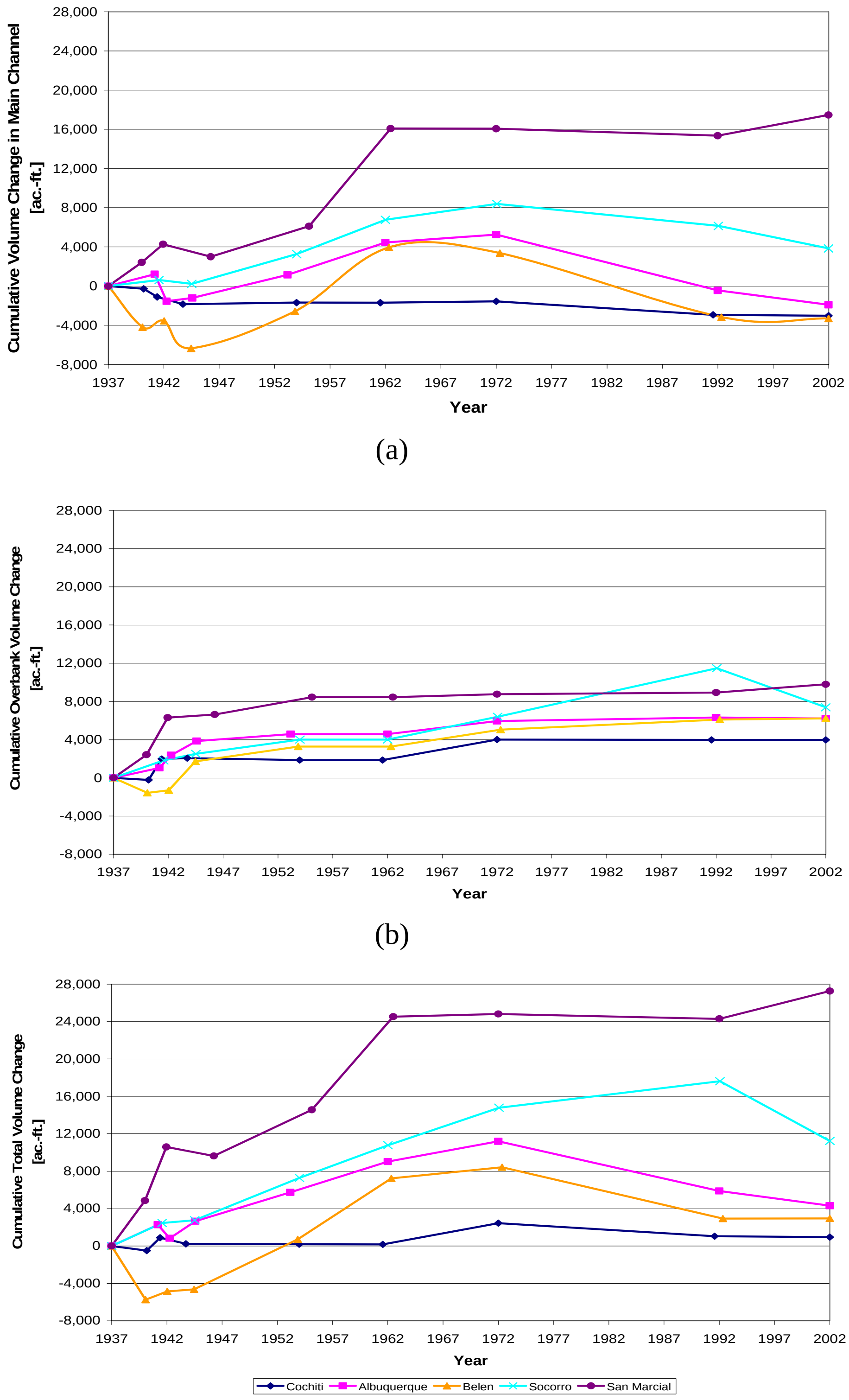
Computer programs and spreadsheets were applied in the analysis of cross section data for the 1962, 1972, 1992, and 2002 data sets. The accuracy of the river and floodplain volumetric changes and mean bed elevation comparisons was improved (when compared to the pre-1962 data sets) through the use of mathematical solutions based on a greater number of cross sections and a greater number of points representing each cross section. Other indicators used in this data analysis to evaluate the agg/deg trends include sub-reach slope, average bed elevation, and river and floodplain agg/deg volumetric changes. The sedimentation volumetric changes are reported for the main channel, flood plain, and total section, as shown in Figures 2a, 2b, and 2c, respectively. The main channel definition used in this study is the active channel, or the portion of the floodway the river has maintained clear of vegetation. The boundary for computing the volumetric change between the main channel and the overbanks for each cross section is determined according to the widest main channel definition combination obtained for the left and right main channel limits from both data sets for the period analyzed.

Comparison of the figures shows that the downstream-most San Marcial reach has experienced the most sediment accumulation, whereas the main channel of the upstream-most Cochiti reach has consistently lost sediment. The three middle reaches have varied between aggradation and degradation trends over the study period. The floodplains for all reaches experience most of the recorded accumulation prior to 1972 and have remained relatively steady since then.

## CONCLUSION

The Middle Rio Grande is a complex, dynamic system that experiences a myriad of resource management issues related to its aggradational and degradational trends. The efforts Reclamation and other agencies have made to the long-term collection of the agg/deg data on the Middle Rio Grande have provided significant benefits in supporting informed decisions related to reservoir operations, habitat restoration, and channel maintenance. The data are used to assess the response of the river channel to current and historical river management activities. Under the Middle Rio Grande Project activities of note include construction of flood and sediment control facilities such as Jemez Dam in 1953, Abiquiu Dam in 1963, Galisteo Dam in 1970, Cochiti Dam in 1973 and river channelization works from San Acacia Diversion Dam to Elephant Butte Dam and from Cochiti Dam to the Rio Puerco Confluence. The data provide substantial river morphological information such as channel width, floodplain width, river migration rates, river bed profile and changes over time in aggradation and degradation of the river and the floodplain. These trends are used to assess channel capacity, available aquatic and riparian habitats, channel stability, and the channel's response to flow releases from upstream dams. Most recently, the 2002 agg/deg cross section data and mapping were also utilized to analyze width trends by Makar et al. (2006), in geologic interpretation of channel incision and terrace formation in Massong et al. (2006); and as base geometry data for sediment transport modeling by Holmquist-Johnson (2006).

The need for ongoing data collection efforts and river and channel floodplain analysis related to the aggradation and degradation trends described will continue in the future to support informed maintenance decisions.




(c)

Figure 2 Cumulative Sediment Volumetric Change from 1937 – 2002
(a) Main Channel, (b) Overbank, and (c) Total

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