

Human impacts on riparian ecosystems of the Middle Rio Grande Valley during historic times

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Abstract.-The development of irrigation agriculture in historic times has profoundly impacted riparian ecosystems in the Middle Rio Grande Valley of New Mexico. A vital relationship has existed between water resources and settlement in the semi-arid Southwest since prehistoric times. Levels of technology have influenced human generated changes in the riparian ecosystems of the Middle Rio Grande Valley.

The relationship of humans with the riparian ecosystems of the Middle Rio Grande Valley has been and is complex. The foundations for an understanding of historic human land uses are to be found in environmental, cultural, political and socio-economic factors and processes. The relationship of humans with the land is based on and regulated by resource availability, environmental conditions, levels of technological knowledge, political and socio-economic structures and cultural values regarding land and water and their uses.

During historic times, the riparian resources of the Middle Rio Grande Valley have been utilized by three groups: American Indian, Hispanic and Anglo-American. While some studies of cultural values regarding land and water do exist, these studies have tended to be simplistic. Studies of cultural values that do not romanticize certain groups and demonize others are a fundamental foundation of any understanding of the relationship between humans and riparian ecosystems.

The levels of technological knowledge available and utilized within the Middle Rio Grande Valley have profoundly influenced human impacts on riparian ecosystems. The outlines of these varying

levels of technology have been broadly defined but specifics have yet to be developed by researchers. These elements should include the introduction of intensive irrigation agriculture by the Spanish in the 17th century and building of railroads by the Anglo-Americans in the 19th century as well as the impacts of the introductions of plants and animals by the Euro-Americans throughout the last 450 years.

In this paper, we will look at the development of irrigation agriculture and its impacts on riparian ecosystems in the Middle Rio Grande Valley of New Mexico during historic times (e.g. after A.D. 1540). A vital relationship has existed between water resources and settlement in the semi-arid Southwest since prehistoric times (Wozniak 1987). Levels of technology have profoundly influenced human impacts on and human generated changes in riparian ecosystems of the Middle Rio Grande Valley. At the most simple level, the differences between stone tool and metal tool based subsistence systems are quite significant. This does not mean that stone tool technologies would not and did not enable humans to alter ecosystems. The stone tool technologies of prehistoric Indian populations in the Middle Rio Grande Valley did have significant impacts on ecosystems throughout New Mexico. Major transformations in Indian impacts did develop as a result of the introduction of metal tools by Euro-Americans in the late 16th

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century. With metal tool based technologies, Indian impacts on riparian ecosystems of the Middle Rio Grande Valley were intensified. The overall human impacts on these riparian ecosystems were expanded by direct Euro-American utilizations of the Middle Rio Grande Valley in the 17th and 18th centuries.

With the Spanish colonization of New Mexico in 1598 came the introduction of intensive irrigation agriculture into New Mexico. What is surprising about irrigation agriculture in the Rio Grande Valley is its relative rarity among the Pueblo Indians before Spanish settlement (Wozniak 1987). A common assumption exists about irrigation and the prehistoric Pueblo Indians in New Mexico which is found in virtually all popular discussions of and most scholarly studies on the Pueblo Indians, namely that all Pueblo groups in the Rio Grande Valley engaged in irrigation agriculture in prehistoric times and that the Coronado Expedition of 1540-1542 found the Pueblo Indians engaged in the extensive practice of irrigation agriculture. Neither of these assumptions is accurate and neither is founded on any scientific or documentary evidence. Recently, a few researchers (Cordell 1979; Earls 1985; Wozniak 1987) have expressed reservations with regard to the prevalent notion that the Pueblo Indians were ancient irrigators in the Rio Grande Valley.

The Anasazi, who were the prehistoric ancestors of the Pueblo Indians, invested considerable energy in soil and moisture conservation facilities such as check dams, terraces and grid gardens. In their subsistence strategies, the Anasazi engaged primarily in extensive agricultural systems based on ak-chin or floodwater farming. In looking at Anasazi agriculture, it is important to distinguish between water conservation systems and water diversion systems-only the latter are irrigation.

A review of the archeological record for the Rio Grande Valley of New Mexico shows considerable evidence of a variety of water and soil conservation features and of floodwater farming systems. However, there is no archeological evidence of any prehistoric irrigation features or irrigation systems in the Rio Grande Valley. As an aside, it should be noted that the Hohokam in central and southern Arizona did engage in substantial amounts of irrigation agriculture which is documented in the archeological record.

In the Middle Rio Grande Valley, the Anasazi developed a successful and diversified subsistence strategy that combined floodwater farming with hunting and gathering. As a result, they avoided the problems inherent in farming on the Rio Grande floodplain - floods, salinization, dense vegetation, disease and insects. Anasazi stone tool technology was adopted to sandy soils for floodwater farming not to irrigation agriculture in heavy bottomland soils.

In late 1540, the Coronado Expedition reached the Tiguex province that covered most of the present Middle Rio Grande Valley. The contemporary accounts of the Coronado Expedition (Hammond and Rey 1940) do not report any irrigation agriculture being practiced by any Pueblo Indians. The expedition narratives did report irrigation systems among the Indians of Sonora but none in New Mexico (Riley 1987). Records from late 16th century Spanish expeditions into New Mexico reported that irrigation agriculture was practiced by some Pueblo Indian communities in some parts of New Mexico (Hammond and Rey 1966). The Rodriguez - Chamuscado expedition of 1581 reported a Pueblo Indian irrigation system in the lower portion of Las Huertas Creek near its confluence with the Rio Grande; Las Huertas Creek was a perennial stream until developments in the early 20th century. The accounts of the Espejo expedition of 1582-1583 reported irrigation in the Piro provenience (near Socorro) on the sandy bottomlands with water being taken from side channels of the Rio Grande (Earls 1985). The Espejo expedition narratives also reported irrigation along the Rio San Jose near Acoma Pueblo and along Nutrias Creek at Zuni Pueblo. In the late 16th century, some Pueblos engaged in some irrigation agriculture but floodwater and other forms of dryland farming were the exclusive form of agriculture among most Puebloan groups and a major component among those few Pueblos who used some form of irrigation (Wozniak 1987). The agricultural commitment of the Pueblo Indians in the 16th century was to extensive floodwater farming systems and other strategies of water and soil conservation. The onset of Spanish settlement changed this. One of the first recorded activities of Spanish settlers in 1598 was the construction with Indian labor of an acequia (irrigation ditch) near San Juan Pueblo to provide

water for irrigation agriculture (Hammond and Rey 1953).

When the Spanish settled in New Mexico at the end of the 16th century, they brought with them new technologies and a variety of new domesticated plants and animals. These introduced species along with the new political, socio-economic and ideological structures which were imposed by the Spanish significantly altered Puebloan diets, economic structures and land use patterns.

Given the vital relationship between water and settlement in all semi-arid environments of the North American West, including New Mexico, it is not surprising that the Spanish of the 17th, 18th, and 19th centuries gravitated to the Rio Grande Valley and its tributaries. Spanish settlement depended upon irrigation agriculture for its economic base and, therefore, for its survival. Spanish missionaries and Spanish government officials imposed an irreversible reliance on irrigation agriculture upon the Pueblo Indians during the 17th century (Wozniak 1987). This combined socio-economic and technological change irretrievably undermined and altered traditional Puebloan subsistence systems, land use patterns and lifeways. In addition to a plethora of domestic livestock (sheep, goats, cattle, horses, mules, hogs, chickens, etc.) and new cultigens (wheat, barley, oats, onions, lettuce, watermelon, fruit trees, etc.) the Spanish also introduced native Mexican Indian crops such as tomatoes, *chiles*, cultivated tobacco and new varieties of corn and beans. These introduced species along with the introduction of metal tools such as axes, and metal tipped plows had a significant and sometimes adverse impact on native flora, fauna and soils. The role of metal tools and their impact on ecosystems before the 19th century should not be exaggerated since metal tools were generally in short, even critically short, supply throughout the 17th and 18th centuries in New Mexico.

With the colonization of New Mexico by the Spaniards, irrigation and irrigation development entered into a new era in the Rio Grande Valley (Wozniak 1987). The introduction of new crops, such as wheat, that required irrigation in order to produce harvests in semiarid New Mexico encouraged the development and/or expansion of Pueblo Indian irrigation. The Spaniards insisted that the Indians grow these crops, particularly wheat, so

that the Spaniards could obtain their customary foodstuffs even in New Mexico. At least part of the tribute that the Spanish regime required from the Puebloans was exacted in the form of wheat, so the Indians had to irrigate in order to meet these demands. Other tribute demands for foodstuffs would also push the Puebloans toward intensive (i.e., irrigation) agriculture during the seventeenth century, with considerable disruptive consequences for Puebloan society in New Mexico. Irrigation agriculture produced ever expanding impacts on riparian ecosystems as the bosques were cut down to expand the field systems.

During the seventeenth century, the Spanish settlers in New Mexico survived on tribute in food and labor collected from the Puebloans under the *encomienda* and *repartimiento* systems (Scholes 1937, 1940). The Spanish missions or *reducciones* concentrated Puebloan populations into a much smaller number of pueblos than had been occupied before the arrival of the Spaniards. The *reducciones* were established for religious, political, economic, and military reasons and served to enhance Spanish control and supervision over the native Indian populations (John 1975; Scholes 1937, 1940). Concentration of the heretofore scattered Puebloan settlements also enabled both ecclesiastical and secular authorities to exploit the Indian labor force more effectively and to levy tribute. Tribute demands and the *reducciones* themselves often drove the Puebloans to escape Spanish control by withdrawing into the mountains or joining the nomadic Indian tribes (Hammond and Rey 1953).

Throughout the seventeenth century, the Spaniards steadily increased their demands for native labor and goods while the labor force was being progressively reduced by disease and warfare (Earls 1985). Missionization appears to have produced the first of the major population declines that then continued as a result of epidemics and drought (Earls 1985). Demands for native labor by both the *encomenderos* and the friars along with the increasing European population placed strong pressures on the Puebloans to improve their productivity in order to supply food for both groups. These pressures led to an increased and in some cases a virtually exclusive reliance on irrigation agriculture (Earls 1985). The Spaniards encouraged the development of Puebloan irrigation farming not only to ensure the increased produc-

tivity that would supply them with food and to obtain introduced European crops but also because irrigation agriculture made possible the concentration of Puebloan populations in the *reducciones*. The friars thus intended both to increase Puebloan productivity and to maintain a newly imposed sedentism among the New Mexico Pueblos. Dry farming was replaced by more intensive agricultural strategies involving fields irrigated by diversions of water through ditches. At the same time hunting virtually disappeared, to be replaced by livestock herding (Earls 1985). The gathering of wild plants and plant products declined as the Puebloans were tied to their irrigated field in their efforts to meet the demands of the colonists and missionaries (Earls 1985).

Agricultural intensification through irrigation was a demanding system with regard to labor, and the requirements of the system were difficult to meet owing to the decline in Indian populations. Such intensification was necessary, however, if the alimentary demands of the friars and encomenderos and the simultaneous demands for other goods and services were to be met (Earls 1985). Contrary to Ellis's (1970) contention that the Spaniards found irrigation widespread and flourishing in the Rio Grande Valley, it was the institution of the *reducciones* that produced a rapid change in the Puebloan subsistence system from expansive to intensive agriculture. This increased and heretofore unnecessary dependence on agriculture led to a decrease in hunting, gathering, and trade in subsistence goods with the nomadic tribes. Mineral deposits, although present in several areas of New Mexico, were insignificant and unexploited in the 17th century. Apart from an erratic pinyon crop, and the relatively unimportant collection of wild animal skins and cotton textiles, there were virtually no exploitable natural resources which were not already available in quantity in the mining districts of Chihuahua - New Mexico's only potential market.

Economic exploitation, religious persecution, and the failure of the Spaniards to protect the Puebloans from nomadic raiders culminated in the Pueblo Revolt of 1680 (Hackett 1942; John 1975). After decimating the Spanish settlements and driving the remaining settlers from the northern Rio Grande Valley, the Puebloans shed Spanish religion and culture but retained Spanish crops

and technology, both civilian and military (Hackett 1942). The continuing legacy of Spanish colonization could be seen in the residual importance of irrigation agriculture. Despite the directions and wishes of the religious leaders of the Pueblo Revolt, the Pueblo Indians continued to utilize Spanish crops and technology.

Puebloan factionalism and calculated economic warfare ultimately enabled Diego de Vargas to reduce the Pueblos once again to Spanish rule between 1692 and 1694 (Espinosa 1942). Only Vargas himself was authorized to have an *encomienda* after the Reconquest; all other Spanish settlers were to support themselves by their own labors. Economic conditions, however, forced the newly returned Spaniards to rely upon a system of tribute in food and labor from the exhausted pueblos that, in its operations and efforts, resembled the discredited *encomienda* and *repartimiento* system. These exactions drove most of the Puebloans into a second revolt in 1696 (Espinosa 1942). The Spaniards crushed the new revolt with the assistance of those pueblos that did not join the rebellion (Espinosa 1942). After 1697, a new economic regime was established in New Mexico, one that centered on community land grants rather than *encomiendas*. Internecine warfare among the Puebloans during the Revolt and Reconquest led to the abandonment of many 17th century pueblos, particularly in the Middle Rio Grande Basin. These abandonments had a profound effect on 18th century resettlement and land use patterns (Wozniak 1987).

The century following the reconquest is crucial to an understanding of the cultural diversity of the Middle Rio Grande Basin. Throughout most of the 18th century, New Mexico was not an active participant in the developing colonial world system of which it was an almost forgotten part. More significant were raids by and warfare with New Mexico's nomadic neighbors: the Navajos, the Apaches, the Utes and the Comanches. The alternating periods of war and peace had a major impact on settlement patterns and resulted in periods of expansion followed by periods of settlement contractions and abandonments (Wozniak 1987). Warfare between the nomadic Indians, and the Spanish and the Puebloans affected land uses in the Middle Rio Grande Basin until after the American Civil War.

The 18th century also witnessed the gradual compartmentalization of Puebloan culture and society. On the one hand, Puebloan communities needed to co-exist with the dominant Hispanic culture; on the other hand, there was the equally obvious desire to maintain individual Puebloan traditions and identity. Out of the 18th century, there developed the Puebloan and Spanish Colonial cultural traditions which are still evident on the landscapes of the Middle Rio Grande Basin. Both traditions had to cooperate and interact in order to survive in the semi-arid environment of New Mexico and to defend themselves against attacks by the semi-nomadic Indian tribes that surrounded New Mexico.

With the reconquest of New Mexico in the mid 1690s, the Spaniards instituted a new settlement system that transformed the way they utilized the resources of New Mexico (Wozniak 1987). Before the Pueblo Revolt the Spaniards had occupied New Mexico with a small number of settlers who held large tracts of land. These seventeenth century settlers grazed livestock and depended upon the Pueblos to produce surpluses of food as well as products such as woven goods, salt, and piñon nuts. After the Reconquest, because a secure hold on New Mexico had a higher value than the extraction of economic wealth, the Spanish government made grants of land (*mercedes*) to ensure the effective occupation of New Mexico by means of self-sufficient farming and herding communities (Westphall 1983).

In place of a small number of exploitive *encomiendas*, which had proved to be a political, military, and economic disaster, the Spanish authorities established an ever-expanding number of land grants on which the Hispanic settlers supported themselves through agriculture and stock-raising (Carlson 1971). In the early days after the Spanish reconquered New Mexico, a number of individual land grants were given to people who had been prominent in the Reconquest. Though given to individuals, these were not *encomiendas*; the recipients were expected, to support themselves by their own endeavors and those of their extended families and servants (Carlson 1975; Van Ness 1979). Indian labor was virtually unavailable owing to the catastrophic population decline of the late 17th century. This decline continued at a reduced level in the 18th

century, while the non-Indian population steadily expanded. At the same time, the Spaniards were prohibited from exploiting what little Indian labor might have been available (Simmons 1969). The Indian pueblos settled into a system of local self-sufficiency under the religious, but not economic, supervision of the mission friars (Adams and Chavez 1956). Most land grants in the eighteenth century were given to groups rather than individuals, in an effort to settle as many people as possible on the land and in order to provide for defensible settlements (Simmons 1969; Westphall 1983). New Mexico became a region of small, self-sufficient Puebloan and Hispanic communities, held together by fear of nomadic raids and by the necessities of mutual defense.

In order for a settlement to succeed, irrigable land was necessary (Carlson 1971; Ressler 1968; Van Ness 1979). The accessibility of water to cultivate bottomlands was a primary consideration in the grants of land by the Spanish government. Subsistence agriculture employing irrigation farming and livestock herding was the economic basis for these settlements. Consequently land grants were made primarily along the Rio Grande and the Rio Chama and their perennial tributaries. The irrigable lands on each grant were divided among the settlers, while the rest of the land was held in common for pasture and woodland (Van Ness 1979; Westphall 1983). While Spanish colonial ordinances required, and the times in which the grants were made frequently dictated, that settlements be compactly organized for defense, most New Mexico land grant settlements were straggly communities of dispersed *ranchos* (Simmons 1969). Formal plazas were rare, despite the threat of Indian raids. Even the villas of Santa Fe, Santa Cruz, and Albuquerque were scattered over large areas in order for farmers to live near their irrigable fields (Simmons 1969). The expanding number of land grant settlements in the 18th and 19th century had far reaching impacts on riparian ecosystems throughout the Rio Grande Valley; these included alterations in stream flows and impacts on native vegetation, especially the *bosques*. The *bosques* suffered particularly significant reductions in the first half of the 19th century.

The long-lot system which prevailed on most land grants was developed to accommodate community land grants and as a response to local

conditions in the Rio Grande Valley of northern New Mexico. However, this system of property division did not resemble the Puebloan field systems of the 17th or 18th centuries. Long-lot farms developed as a means of growing introduced crops that required irrigation in a semiarid environment where both land and water resources were limited (Carlson 1975; Van Ness 1979). The system assured settlers maximum access to limited water resources and proved to be a practical and equitable method of partitioning irrigable lands among the large numbers of settlers required by military necessities. The resulting small subsistence farms never produced significant agricultural surpluses nor were they intended to do so (Carlson 1975). Colonial policy was not directed toward economic prosperity but toward the successful occupation of New Mexico, which the defense of New Spain was deemed to require (Carlson 1975; John 1975).

In the Rio Abajo, where Puebloan populations south of the confluence of the Rio Grande and Rio Jemez had virtually disappeared, arable land was more plentiful, particularly along the Rio Grande; extensive grazing lands were also available in the Middle Rio Grande Basin (Wozniak 1987). Water, also, was more securely available and more manageable for irrigation purposes in the Rio Abajo than in the Rio Arriba, especially south of San Felipe Pueblo. The continual threat and often devastating impact of raids by nomadic Indians limited expansion, however, except in the Bernalillo and Albuquerque areas.

Little changed in the formalities of obtaining land grants under the Mexican regime, and the vicissitudes of settlement remained much the same as well. The total area given in land grants between 1821 and 1846, however, probably exceeded that granted during the preceding 125 years (Westphall 1983). Most of these grants were outside the Rio Grande Valley and placed large areas of grazing land under the control of individuals in what can only be termed an orgy of deliberate fraud and rapacity by prominent New Mexicans, aided and abetted by Mexican government officials in New Mexico. This raid on the public domain had precedents in the grazing grants west of the Rio Puerco in the 1760s. The Mexican period grants set the patterns for land use that would prevail in the Middle Rio Grande Basin throughout the 19th

and into the 20th century. Trade with the Anglo-Americans, the incipient development of a live-stock industry and some mining began the gradual transformation of the economy and land use patterns of the Middle Rio Grande Basin. These changes included both more extensive and intensive utilization of resources outside of the main valley.

Throughout the eighteenth century and first half of the nineteenth century the Indian pueblos suffered from declining populations and had to compete with Hispanic settlers for arable land and to a lesser extent for water. Unfortunately information regarding Puebloan irrigation systems is scarce and spotty, but enough can be derived from ecclesiastical reports to provide an adequate picture of Puebloan irrigation during the Spanish and Mexican periods. The best and most extensive report on the Pueblo Indians was that of Fray Dominguez from the latter part of the eighteenth century, but other, less comprehensive reports also exist (Adams 1954; Adams and Chavez 1956; Morfi 1932).

When the Americans occupied New Mexico in 1846, they found a largely agrarian society that was concentrated in the Rio Grande Valley and depended for its survival upon irrigation agriculture and raising livestock. Both Hispanic and Puebloan communities controlled and managed the irrigation systems that covered most of the irrigable lands along the mainstream of the Rio Grande and its tributaries.

Just prior to the annexation of New Mexico by the United States, Josiah Gregg visited the territory on several occasions during the 1830s. Gregg (1954) noted the fertility of the bottomlands and the barrenness of the unirrigated uplands. New Mexican agriculture was primitive by American standards. The crude plows were used only on loose soils; most land was cultivated with the hoe alone (Gregg 1954). Nearly all of the farms and settlements in New Mexico were located in valleys with perennial streams. In some valleys, crops were regularly stunted by the seasonal depletion of stream flows. One acequia madre was generally sufficient to convey water for the irrigation of an entire valley or the fields of one town or settlement (Gregg 1954). Community ditches were most common; private ditches were relatively rare (Gregg 1954). New Mexicans in the late Mexican

period grew mostly corn and wheat under a system of subsistence agriculture (Gregg 1954). While the scope and extent of irrigation activities in the Rio Grande Valley had steadily expanded in the Spanish and Mexican periods, the nature of irrigation agriculture had remained very much the same. Expansion of irrigation systems in the Rio Grande Valley was strictly a response to population growth. The primary focus on subsistence agriculture and livestock herding persisted in the Rio Grande Valley for some time after the American annexation of New Mexico under the Treaty of Guadalupe Hidalgo.

After the arrival of the railroads in the late 1870s and early 1880s, irrigated acreage in the Middle Rio Grande Basin expanded substantially until the 1890s when drought, upstream development, salinization, and defective drainage brought expansion virtually to a halt (Wozniak 1987). Although irrigated acreage had expanded, the actual irrigation systems and their organizations had changed very little between 1846 and 1910. In the Middle Rio Grande Valley, most expansion after 1846 took place in areas where raids by nomadic Indians had caused earlier attempts at settlement to fail.

The vast majority of farmers in 1910 were still Puebloan or Hispanic New Mexicans. Increasing numbers of Anglo-Americans had begun to engage in irrigation agriculture, but most were too poor to introduce modern irrigation technology (Wozniak 1987). The real impact of Anglo-Americans on the New Mexican economy during the Territorial period (1846-1912) was in the development of a livestock industry with its accompanying infrastructure of railroads and market towns. Most of the essential developments in the livestock industry in the Territorial Period took place away from the Rio Grande on the uplands and plains that surrounded the valley. The emergence of large scale sheep and cattle herding had significant impacts on ecosystems of the Middle Rio Grande Basin, particularly on soils, native vegetation and water resources.

With the American acquisition of New Mexico came the beginning of the end of the economic stability that New Mexican subsistence farmers had experienced for over a century (Wozniak 1987). While the stability of this adaptation gradually disappeared, the technology of irrigation and

the methods of irrigation agriculture that were used changed very little for most farmers in the Rio Grande Valley until after the 1920s. The Anglo-Americans introduced changes in the New Mexican economy that altered settlement systems, land use patterns and the utilization of natural resources not only along the mainstream of the Rio Grande but also in the more marginal areas of the Middle Rio Grande Basin. Exploitation of minerals, grasslands, and forests as a part of the new, commercial economy of New Mexico opened portions of the ecosystems of the Middle Rio Grande Basin to more intensive use than the preceding subsistence economy had found possible or necessary.

However, the most immediate and profound impacts of the new economics of the Anglo-Americans came along the mainstream of the Rio Grande itself. By the early 1890s, serious problems had emerged in the irrigation agriculture of the Rio Grande Valley. Drought, which had struck sporadically in the 1880s, became acute in the early 1890s (Wortman 1971); by 1889 the Rio Grande below Albuquerque literally dried up for four months of the year. Stream flow had been seriously depleted by rapid development of irrigation agriculture in the San Luis Valley of Colorado; the effects on downstream users were dramatic and ultimately led to federal intervention (Follett 1896; Harper et al. 1943; Harroun 1898; Yeo 1910, 1928).

Ironically, at the same time that the Rio Grande was being seasonally depleted, lands in the middle Rio Grande Valley from Cochiti to San Marcial, especially between Bernalillo and La Joya, were becoming waterlogged and thus not amenable to cultivation (Clark 1987; Harper et al. 1943; Harroun 1898). Sedimentation in the Rio Grande resulting from decreased flows had caused the bed of the main channel to aggrade; as a result, the water table in many parts of the valley had begun to rise. Waterlogged lands had always been a problem near the Rio Grande itself owing to poor drainage and wasteful irrigation practices; under traditional agricultural methods, excess water in the acequias was simply dumped onto low-lying lands at the end of the acequia. Only a small percentage of ditches had facilities for returning the excess flow to the Rio Grande or delivering the water to downstream ditches. Each ditch system, of which there were dozens, was independent; no plan or organization to integrate the multitude of irrigation

systems in the middle Rio Grande Valley existed or was deemed necessary.

Though more urbanized and subject to outside influences than their neighbors to the north, residents of the middle Rio Grande Valley maintained patterns of agriculture that were remarkably traditional in the period before the 1920s (Harper et al. 1943). After the early 1880s and the arrival of the railroad, some commercial agriculture was introduced into the area around Albuquerque, Belen, and Socorro, but for the most part irrigation agriculture preserved its traditional orientation toward subsistence farming. At least 90 percent of the farmers were Hispanic or Puebloan, and approximately 90 percent of the irrigated acreage was farmed by them (Natural Resources Committee 1938). Nonetheless, irrigated acreage did expand in the middle Rio Grande Valley in the 1860s to early 1890s.

Beginning in the mid 1890s, droughts, sedimentation, aggradation of the main channel, salinization, seepage, and waterlogging caused an overall decline in irrigable acreage available in the middle Rio Grande region. The total amount of actual irrigated acreage remained relatively stable as previously uncultivated lands were brought into production to replace adversely affected acreage.

Much of the potentially irrigable acreage in the Middle Rio Grande Valley had been damaged by poor drainage and the rising water table and had been retired from production by the early twentieth century (Clark 1987; Dortignac 1956; Wortman 1971); this also resulted in the reemergence of the bosques in the Middle Rio Grande Valley. Thousands of acres were rendered unusable by the related problems of waterlogging and alkalization; at the same time floods were frequent and often devastating. The flood of 1874 destroyed almost every building between Alameda and Barelás (Carter 1953). In 1884, Tome, Valencia, and Belen were under water during the spring floods. The flood of 1886 wiped out part of the pueblo of Santo Domingo, and a new church had to be built. In 1904 most of the bridges on the Rio Grande were destroyed by a late summer flood. The spring flood of 1905 washed away the community of Tome.

As early as the 1890s, the desirability of reorganizing the middle Rio Grande Valley irrigation systems was recognized by a few individuals. The need for a unified and rationalized system of

irrigation and drainage was great, but such a development was hampered by misunderstanding and mistrust (Linford 1956). Local residents who were mostly Hispanic or Puebloan were naturally reluctant to surrender or assign water rights to private irrigation companies which were mainly Anglo-American enterprises in return for the promise of a more secure water supply in the future. Such a hesitancy was well founded; 90 percent of the private irrigation companies in the western United States went bankrupt—hardly a record to engender confidence in a privately sponsored reorganization of the middle Rio Grande Valley's irrigation systems (Wozniak 1987).

The late 19th and early 20 century also witnessed the breakup of community land grants and the common lands (*ejido*) as an indirect consequence of land grant adjudications by the U.S. Surveyor General and the Court of Private Land Claims. Except for the construction of larger flour mills and the centralization of distribution networks as a result of railroad constructions, agriculture in the Middle Rio Grande Basin changed very little before the 1920s from its centuries old system of irrigation farming. Frustrated in that area by antiquated farming methods, Anglos were constantly advocating "modern" approaches to and techniques of farming.

In 1879, the long awaited railroad arrived in New Mexico. The railroads immediately superseded the limited trade on the Sante Fe Trail and were able to transport larger masses of goods more quickly than the old system of wagon transportation. Connections with the eastern United States spurred the growth of new industries in New Mexico, including the Middle Rio Grande Basin. These included the livestock industry in sheep and cattle, and natural resource extraction in minerals and lumber. The railroads also directly spurred population growth through employment in construction and operations; by 1920 over half of Albuquerque's male heads-of-households worked for the Santa Fe Railroad.

Physical resources deteriorated in the middle Rio Grande Valley from the 1890s to the mid 1920s (Harper et al. 1943). Water shortages resulting from drought and especially from over-exploitation of surface water for irrigation in the San Luis Valley were frequent throughout the period after the early 1880s (Conkling and Debler 1919; Follett

1896; Gault 1923; Hodges 1938; Yeo 1910). These shortages were often tragically combined with devastating floods (Carter 1953; Yeo 1943). Water shortages particularly affected the annual flows on the middle and lower Rio Grande, producing increased sedimentation and dramatic channel aggradation in the early twentieth century that choked the ditches (Clark 1987; Harper et al. 1943). The aggradation of the main stream channel increased the frequency and destructiveness of floods and also contributed to the waterlogging of arable lands in the middle and lower valley through lateral seepage and raised water tables (Burkholder 1928; National Resources Committee 1938). Waterlogging was frequently accompanied by salinization and alkali poisoning of soils (Conkling and Debler 1919; Harper et al. 1943). The changes in the hydrology of the valley were not the only causes of waterlogging and its accompanying effects on arable lands. Traditional irrigation practices in the middle valley encouraged and frequently were a primary immediate cause of arable acreage going out of production (Stewart 1936). The combined effect of all of these factors was a decline in irrigation agriculture in the middle Rio Grande Valley (Harper et al. 1943). Drought in the 1920s and 1930s had similar effects on the grasslands of the Middle Rio Grande Basin. Overgrazing reduced the cover grasses and contributed to serious soil erosion.

Concern over the deterioration of conditions in the middle Rio Grande Valley gradually grew in the 1920s (Burkholder 1928; Linford 1956). In 1921, the State Legislature created the Rio Grande Survey Commission, which was to study conditions in the middle valley in cooperation with the U.S. Reclamation Service (Hedke 1925). Finally in August, 1925, the Middle Rio Grande Conservancy District (MRGCD) was organized. By this time, two-thirds of the arable bottomlands within its boundaries were subject to seepage or were waterlogged (Burkholder 1928; Conkling and Debler 1919).

Over the next three years an official plan for reclamation, flood control, and irrigation was developed; the plan was presented in its final form by the chief engineer of the district, Joseph L. Burkholder, in 1928. The plan covered flood and river control, irrigation (especially diversion dams and main canals), drainage, water supply (a reser-

voir at El Vado), management of Indian lands belonging to five pueblos (Congressional legislation was needed in order to include Pueblo lands within the Middle Rio Grande Conservancy District), and sedimentation control (dealing with aggradation of the Rio Grande, channel shifts, lateral seepage, and waterlogged lands). In March, 1928, Congress authorized the Secretary of the Interior to enter into an agreement with the Middle Rio Grande Conservancy District for irrigation, drainage, and flood control on the lands of the pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta (Clark 1987). The MRGCD and its projects would transform Middle Rio Grande Basin agriculture in the 1920s, 1930s, 1940s and 1950s.

The arrival of modern irrigation technology not only meant a reorganization of the irrigation systems, a renovation of the facilities, and a rationalization of the structure of irrigation but also the infusion of outside influences and a tremendous escalation in the costs of irrigation (Wozniak 1987). Much of the latter impact was absorbed by the largesse of the federal government, which wrote off or massively subsidized the costs of irrigation agriculture in the Rio Grande Valley as it did in the rest of the arid American West. The changes in the character of irrigation agriculture in the middle Rio Grande Valley of New Mexico included:

- The appearance of modern surveyed ditch alignments to replace the old meandering systems;
- The construction of a small number of concrete diversion structures to replace the multitudes of primitive head works;
- Construction of large water storage structures to provide a virtually guaranteed source of water during the irrigation season; and
- The institution of operation and maintenance methods using heavy machinery to replace human beings with shovels.

Many of the old problems of flooding, sedimentation, waterlogging, alkali poisoning, and unreliable water supply were resolved or at least held in check, but they were replaced by new problems related particularly to finances, especially maintenance costs and reimbursement of construction costs. The new problems have proved to be much more intractable than the old ones (Wozniak 1987).

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