THE "FORGOTTEN RIVER" OF THE RIO GRANDE/RIO BRAVO

INVESTIGATION INTO THE RECLAMATION OF

AN ARID RIPARIAN ECOSYSTEM

by

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This document provides a record of flows in the Rio Grande from 1889-1998 for the reach from Elephant Butte Dam down to Presidio/Ojinaga. Daily flow records have been compiled into Annual Flows, plus Average Annual Flows and Average Monthly Flows for various periods. This portion of the Rio Grande falls under the administration and operation of two Federal agencies, the Bureau of Reclamation and the International Boundary and Water Commission.

ABSTRACT

The 200 mile reach of the Rio Grande/Rio Bravo which extends from below El Paso to its confluence with the Rio Conchos at Presidio-Ojinaga is commonly referred to as the "forgotten river." The development of the Rio Grande Project with its dams and associated irrigation works has dramatically altered the natural hydrograph for this "forgotten" section of the Rio Grande. Various non-governmental organizations as well as the U. S. Department of Interior and the International Boundary and Water Commission have concerns about the ecologic condition of this river. Currently, the flows through the forgotten river are only one quarter of the annual quantity present prior to the construction of Elephant Butte Dam in 1915. Moreover, the peak flows which formerly occurred in late May and early June have been shifted to late September and early October. There are six gaging stations recording daily flows from Elephant Butte Dam to Presidio, Texas. The entrance into the forgotten river is measured at the Fort Quitman gaging station, while the exit of the forgotten river is recorded at the Presidio gaging station, three miles above the confluence with the Rio Conchos. Records of daily flows for these six stations are available on the International Boundary and Water Commission web site. For this report, data from these stations have been compiled, analyzed and summarized into annual averages, monthly averages, and historical hydrographs. Some type of storage and release structure could enhance ecosystem restoration efforts within this stretch of the river. This thesis investigates the feasibility of utilizing a Riparian Restoration Reservoir to mimic the natural flow patterns for this segment of the Rio Grande. By storing 30,000 acre-feet of these winter flows for release in June, a hydrographic flow regime could be produced which mirrors the annual flow pattern originally present in this reach of the Rio Grande. Any restoration effort in the forgotten river must also address issues other than water quantity, including the extensive invasive salt cedar intrusion along the riparian corridor, sedimentation, sediment transport attenuation and salinity levels in the river. Water quality information for this region is scant. Graphs of Total Dissolved Solids and Chloride Flux concentrations collected from1992-2000 are provided for this forgotten river. It can be concluded that the construction of a Riparian Restoration Reservoir is viable, and should be considered as an option when any restoration efforts are planned for the forgotten river sub-basin of the Rio Grande/Rio Bravo.

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THE "FORGOTTEN RIVER" OF THE RIO GRANDE/RIO BRAVO

Investigation into the Reclamation of an Arid Riparian Ecosystem

The "Forgotten River" is the epithet commonly used when referring to the 200-mile reach of the Rio Grande (Rio Bravo) which extends from below El Paso-Ciudad Juarez to its confluence with the Rio Conchos at Presidio-Ojinaga. In this sparsely populated area of the western Texas - Mexico border region, there is increasing concern over the condition of the Rio Grande ecosystem (23). Various environmental organizations are focusing their attentions on the health of this Rio Grande riparian corridor, including the World Wildlife Fund, the Environmental Defense Fund and the American Heritage Rivers group. In 1999, the Forgotten River Advisory Committee, composed of members from various non-governmental organizations, university staff, federal and state officials, and interested citizens, formed specifically to address the ecological degradation in this stretch of the Rio Grande. On a national scale, the entire Texas portion of the Rio Grande has been designated as one of fourteen American Heritage Rivers.

Public opinion about the Forgotten River is fraught with misinformation, myth, and spurious facts. There is widespread misperception that this segment of the Rio Grande is a dead-end, hydrologically disconnected from the Rio Conchos-Rio Grande river system below Presidio. The American Rivers group in 1997 designated the Rio Grande as one of the ten most degraded rivers in America. A proposal by the National Heritage Institute entitled "*Physical Assessment for Improved Management of Water Resources of the Bi-*

national Rio Grande Basin" conveys this idea explicitly: "The river section along the border from Fort Quitman to the Rio Conchos confluence sees no baseflow at all . . . it is a dead river in this reach." The facts however, present a much different picture of this so called "dead" and "forgotten" sliver of the Rio Grande.

HISTORICAL BACKGROUND

More than 1,800 miles in length, the Rio Grande is the fourth longest river in the United States. Its headwaters are situated in the southern Colorado Rockies surrounding the San Luis Valley. Flowing southward, the Rio Grande transects New Mexico from north to south, exiting through the Mesilla Valley into Texas. Below El Paso the river forms the international boundary between the U. S. and Mexico. This river has by tradition been divided into three major watershed basins: the Upper Rio Grande above Elephant Butte Dam, the Middle Rio Grande from Elephant Butte to Amistad Reservoir, and the Lower Valley from Del Rio, Texas to the Gulf of Mexico (20).

Prior to the advent of intensive irrigation and to construction of the Rio Grande Project, the Rio Grande below El Paso generally experienced biannual seasonal flows (13). From April through June, snow-melt runoff from southern Colorado and northern New Mexico delivered a majority of the annual flow. In the summer monsoon months of July to September, flash-floods from tributary arroyos provided substantial flows into the main river channel. Over the centuries, the climate of the Middle Rio Grande has experienced alternating wet and dry cycles lasting several decades (13, 20). These long cycles have sometimes been interrupted by acute periods of drought or flooding. Historical accounts from the last 350 years highlight some of these disparities (6).

An 1811 description by von Humboldt describes one such drought period: “The inhabitants of Paso del Norte have preserved recollection of a very extraordinary event which took place in 1752. The whole bed of the river became dry all of a sudden for more than thirty leagues above and twenty leagues below the Paso for several weeks,” about 130 miles in total (6). Conversely, during a notable wet period in 1598, the Spanish expedition led by Don Juan Oñate encountered a lush river valley at the Paso del Norte with wide marshes, an abundance of fish and fowl, and fresh flowing water (6).

Indigenous inhabitants of the region relied upon some flood irrigation to augment their subsistence living (7). Coronado’s expedition of 1540-42 into northern New Mexico estimated that more than 20,000 acres of land were under cultivation in the Upper Rio Grande, utilizing flood plains for farming (6). With the arrival of Spanish settlements in the 1600's, networks of acequias (irrigation canals) were developed on a small scale. From 1600 until the 1870's the level of irrigation remained relatively insignificant (2, 6, 10, 13).

Two centuries ago, the Mesilla Valley above El Paso was a broad flood plain nearly eight miles wide in places, covered with cottonwood bosques, sand bars and ephemeral meanders (13). The meandering Rio Grande was confined only by geography and powered by elevation gradients. Sediment transport often produced a wide sandy bottomed river which shifted across flood plains during seasonal changes in the river channels (11,13). Below El Paso, the river intermittently spilled out onto broad valley

plains before traveling through a succession of narrows. This region contained many oxbows, meanders and marsh lands during wetter periods (6, 7).

Following the Civil War, with increased settlement of the western U. S. and the construction of rail lines, the level of irrigation increased dramatically, especially along the Upper Rio Grande from Colorado to El Paso (2, 13). During the late 1800's irrigation farming in the San Luis Valley of southern Colorado erupted. From 1860 to 1890, more than 400,000 acres were put into production (2, 6). One direct result of this expansion was the diminution and even elimination of flows in the Rio Grande down to El Paso and Ciudad Juarez (Table 1), (4, 20). This extensive irrigation in southern Colorado led to the 1906 Treaty which settled Mexico’s suit against the U. S. over appropriation of Rio Grande water. Coupled with this heavy use of water by Colorado farmers came a period of sporadic flows through the Rio Grande (Figure 1). The cycles of flooding and drought made irrigation farming a difficult and tenuous task due to the unreliability of these flows. The first noted call for government intervention to stop flooding in this Upper Rio Grande basin may have been as early as 1874, following a severe flood in southern New Mexico which inundated and eradicated several small towns and farming communities (4).

In El Paso and Juarez, farmers witnessed huge annual flows above one million acre-feet in 1891, 1897, 1903, 1905 (over 2 million acre-ft), 1906, 1907, 1911, 1912, and 1914; and only trickles of less than 100,000 acre-feet during 1894-96 (no flows recorded during this three-year period), 1899, and 1902 (Table 1), (2, 13, 20). Consequently, the farming communities affected by these unreliable flow conditions clamored for the U. S. government to dam and control the river (6, 13). The formation of the United States Bureau of Reclamation (Reclamation or USBR) in 1902 was part of the government's effort to regulate and manage the waters of the western United States. In 1905, the USBR was authorized to construct the Elephant Butte Dam as part of the Rio Grande Project for the purposes of storing water for use during drought years, providing for flood control from excessive runoffs, and for insuring the delivery of 60,000 acre-feet of water to Mexico at Ciudad Juarez as specified in the 1906 U. S. - Mexico Treaty (Reclamation Act of 1902 - Rio Grande Project Authorization 1905), (19).

CURRENT CONDITIONS

Since the construction of the Elephant Butte Dam in 1915, the character of the Rio Grande has dramatically altered. Surging spring runoffs from snow melt in the Upper Rio Grande Basin, Rio Chama Basin, Sangre DeCristo Mountains Basin, Jemez Basin, and the flash flood swells in summer months have been impounded, impeded and controlled. The energy within the Rio Grande and the transport of sediment have been significantly reduced (11). The impacts of Caballo Dam and downstream diversion dams have compounded this shift from a seasonally meandering wild river to a well-regulated irrigation project generally confined within constructed levees (Table 2), (19).

Today, the biannual peak flows in spring and summer have been replaced by a steadier and more consistent flow regime tied to the irrigation season (Tables 1 & 2). Typically, annual irrigation releases have begun in February and lasted through October.

As a direct result, the Rio Grande Project has produced a “forgotten” river below the El Paso Valley

devoid of large spring runoffs, though still subject to local flash flood events, especially during the summer (Figure 2).

*** Dams in the Middle Rio Grande Basin ***

Elephant Butte dam, completed in1915, is the second major dam constructed by Reclamation. The initial reservoir capacity was 2.6 million acre-feet and due to sedimentation now holds 2.1 million acre-feet. At this current declining rate of sedimentation the reservoir should remain viable (above 50% original capacity) for at least the next five centuries (8). In 1938 the Caballo Dam was completed, some 26 miles below Elephant Butte Dam, to allow for additional flood storage, to permit power generation at Elephant Butte beyond the end of the irrigation season and to provide for more efficient deliveries of project waters (19). Releases of Rio Grande Project waters are now measured at the outfall of the Caballo Reservoir (20).

The Rio Grande Project is solely an irrigation project. Two U. S. irrigation districts (Elephant Butte Irrigation District in New Mexico and El Paso County Water Improvement District No. 1 in El Paso) and the irrigation district in Juarez are the initial appropriated recipients of project water. The amount of water delivered annually is determined by the acreage expected to be in production and the available water stored in Elephant Butte and Caballo reservoirs. Several smaller diversion dams below Caballo were constructed to divert water within the Rio Grande Project: Percha Dam just 3 miles south of Caballo was finished in 1926, Leasburg Dam 63 miles below Percha Dam was constructed in 1905 and is the first Rio Grande Project dam, and the Mesilla Dam was

completed in 1929 (18). In the El Paso area are the American, International and Riverside Dams. In all, there are eight major appurtenances on the Rio Grande from Elephant Butte to Fort Quitman (19).

With the completion of Elephant Butte Dam in 1915, damages caused by flooding and crop losses due to insufficient water supplies were practically eliminated (15). The lowest release year for the Rio Grande Project was 1964 when only 220,000 acre-feet were released for irrigation compared to an average of 760,000 acre-feet for a full allotment year. Conversely, the largest release occurred in 1942 when 1,818,721 acre-feet spilled through the system. This compares with zero flows in 1894-1896 and more than 2,100,000 acre-feet in 1905 before the river was dammed (Figure 1 & Table 1).

The International Boundary and Water Commission (IBWC) is the lead Federal agency in charge of the Rio Grande along the border and manages the “forgotten” portion of the river as part of the Boundary Preservation Project. In 1970 the Boundary Treaty was signed by Mexico and the United States for the purpose of permanently marking the international boundary within the river by reducing the shifting of channels to preserve the character of the Rio Grande as the true U.S./ Mexico border (17).

Two other Projects directed by the IBWC have also significantly impacted the landscape of the Rio Grande. The Canalization Project from Percha Dam down to El Paso, and the Rectification Project from El Paso to the Little Box Canyon below Fort

Quitman, straightened the river and built levees for flood control. Together, these projects eliminated meanders and shortened the overall length of the Rio Grande by nearly 70 miles (20).

In summary, the Rio Grande has been controlled and regulated with the construction of dams and diversions to minimize the effects of severe flooding and to offset the lack of available water during periods of drought, thus providing a steady supply of irrigation waters. The net effect is a straighter, narrower river channel no longer susceptible to large springtime snow-melt runoffs. The transport of sediments has been drastically reduced and the pristine riparian corridor has been replaced with flood control levees and non-native tamarisk (10, 13). However, the continuous release of water from February to October has resulted in a river valley that is wetter, on average, over a considerably greater portion of each year. Essentially, the river has been slowed and diverted, allowing for nine months of irrigated agriculture annually since 1915. For the "forgotten" stretch of the Rio Grande, this has produced a narrow channel of saltier return flows from farmlands, of a much lesser quantity, spread out over the course of the entire year (13).

FLOWS IN THE FORGOTTEN RIVER

For purposes of performing a hydrographic analysis on this Forgotten River, the 60-year period from 1939 to 1998 will be emphasized (Figures 2 & 3). This time frame follows the completion of the Caballo Dam in 1938, and the full development of irrigation distribution and drainage networks. The IBWC Canalization and Rectification

Projects were initiated during this six-decade period as well. The driest two decades 1950-1970, as well as the last 20 years which were all full allocation years, also fall into this period. The amount of water flowing in the Rio Grande has been recorded at various

gaging stations, and data from these sites form the basis for this report (Tables 1 & 2).

For the nearly 400-mile length of the Rio Grand from Elephant Butte to Presidio there are currently six gaging stations in operation recording river flows on a daily basis. The Elephant Butte gage (08-3610.00) has been in operation since 1915 and is operated by Reclamation. The Caballo gage (08-3625.00) measures the outfall from Caballo Reservoir and has been operated by Reclamation since 1938. Ninety-eight miles below Caballo at the Courchesne Bridge is the El Paso gage (08-3640.00) currently operated by the United States Geologic Survey and it has been in nearly continuous operation since 1889. Eighty miles southeast of El Paso is the Fort Quitman gage (08-3705.00) operated by the International Boundary and Water Commission (IBWC) since 1923. One hundred twenty miles below Fort Quitman is the newest gage at Candelaria (08-3712.00), in operation since 1976 and operated by the IBWC. And the last gage on the “forgotten” stretch of the Rio Grande is the Presidio gage (08-3715.00) located a few miles upstream of the confluence of the Rio Grande and Rio Conchos also operated by the IBWC since 1900. The daily records from these stations have been compiled into annual and monthly averages to be used as the main body of data for this report (Tables 1 & 2).

Generally, as much as 60% of the water in the Upper Rio Grande Basin has been used up by the time the river is released from the Caballo reservoir (13). Large tracts of irrigation lands in Colorado and in the Middle Rio Grande Conservancy District in New Mexico, totaling more than 700,000 acres, account for a majority of this water “loss” (13, 22). Consumptive losses due to evapo-transpiration along the riparian corridor, ground water seepage and evaporative losses from the reservoirs make up the rest of the Rio Grande which never makes it to El Paso and beyond (15).

Over the last 60 years, the net amount of water coursing from Caballo Reservoir to Fort Quitman has decreased by approximately 80%. (Table 1). This percentage has changed in response to drought and wet conditions along the watershed (Figure 4). During the twenty five-year drought period of 1953 through 1977, as little as 6% of the flows remained in the river at Fort Quitman, while during the last 20 years, a relatively wetter period, this amount was nearly 28%. Therefore, in a typical year, the Rio Grande below El Paso experiences approximately 5-15% of the natural flows which would occur if the diversions for irrigation above El Paso were eliminated. However, the duration of these natural flows would also be much shorter than is now evident with water being released from Caballo Reservoir over a nine-month extended irrigation season.

Surprisingly, almost 93% of the flows recorded at Fort Quitman arrive at the Presidio gage 200 miles downstream through the “dead” and “forgotten” leg of the Rio Grande. Apparently the in-stream losses due to evapo-transpiration and seepage are nearly offset by baseflows and the summer rains which fall below El Paso. The annual hydrograph for the three gages in this part of the Rio Grande shows that in some years, the “forgotten” stretch is actually a gaining river (Figure 5).

The average monthly hydrographs before and after the construction of the Elephant

Butte dam indicate that the peak flow months have shifted by nearly three months to later in the season as a result of storing and releasing water for irrigation purposes (Figures 2 & 6). Prior to 1915, the peak flow in El Paso averaged nearly 220,000 acre-ft in the month of May. After the completion of Elephant Butte Dam the peak month shifted to July, with an average flow of 63,700 acre-feet for the last 60 years. Similarly, the peak flow at Presidio prior to 1915 occurred in July with an average of just under 160,000 acre-feet, and during the last 60-year period, the peak month has been October with an average flow of 17,700 feet, a reduction in peak flow of almost 90%. Thus the peak period of spring runoff flow has been delayed by three months for the Forgotten River, and markedly diminished in quantity. Prior to 1915, the annual average amount of water reaching Presidio equaled 573,700 acre-feet. Over the last 85 years, following the completion of the Elephant Butte Dam, the annual average amount of water has been reduced by 77% to 131,800 acre-feet.

This change in flow patterns through the Forgotten River has critically reduced the river's capacity for sediment transport (11). Additionally, the resulting river system now experiences a higher proportion of arroyo inputs into the total flow through the Forgotten River (13,17). These monsoonal flood events deliver huge amounts of sediment into the main river channel, a river now lacking the velocity and quantity of flow to effectively transport these loads (11). Consequently, enormous sediment bars reside at the mouths of the arroyos which previously were transported by the river for dispersion in downstream flood plains (17). Today, there are sections of the Forgotten River which are aggraded, having a river bed higher than the surrounding flood plain (11, 17).

RIVER RESTORATION, REHABILITATION, or RECLAMATION

While there does exist a remnant riparian corridor throughout the forgotten reach of the Rio Grande, indisputably, the ecological health of this system has been severely degraded (13, 17). Given the current situation resulting from the last 85 years of managing the Rio Grande Project, those (23) concerned with the health of this river system are asking the question: "What can be done to better manage this "forgotten" stretch of the Rio Grande and can it be restored in any way to a more natural condition?" The Stream Corridor Restoration guide book (16) from the Federal Interagency Stream Restoration Working Group provides the following definition for restoration: "Restoration is a complex endeavor that begins by recognizing natural or human-induced disturbances that are damaging the structure and functions of the ecosystem or preventing its recovery to a sustainable condition. It requires an understanding of the structure and functions of stream corridor ecosystems and the physical, chemical and biological processes that shape them." What is commonly referred to as "restoration" is in fact one of three distinct processes: restoration, rehabilitation, or reclamation:

(1) Restoration is the reestablishment of the structure and function of ecosystems. Ecological restoration is the process of returning an ecosystem as closely as possible to pristine conditions. For the Rio Grande this would mean the decommissioning of

Elephant Butte and removal of the other seven downstream dams.

(2) Rehabilitation is defined as making the land useful again after a disturbance(s). This process involves the recovery of ecosystem functions by establishing geologically and hydrologically stable landscapes. One aspect of rehabilitation could be the abandonment of irrigation farming along the Rio Grande.

(3) Reclamation includes activities intended to change the biophysical capacity of an ecosystem. The resulting ecosystem is different from the ecosystem existing prior to recovery. Often the goal of reclamation is an attempt to create an ecosystem which mimics or reflects the undisturbed character of a river system (16).

Using these definitions as guidelines, restoration and rehabilitation of the "forgotten" stretch of the Rio Grande are not possible given the present political, economic and social constraints for maintaining the Elephant Butte Dam. Therefore, the only viable restoration mode for enhancing the health of this river is some type of reclamation effort designed to reproduce or mimic a more natural hydrographic flow pattern.

The Bureau of Reclamation and the Army Corps of Engineers have an extensive history of dam construction, and are only now dealing with some of the inevitable after-affects which result from damming rivers (16, 20, 21). Usually, the effects that dams have on fish populations, sediment transport, and flood control are dramatic and obvious. Often, hydro-power plants require down-stream dams to help regulate the outlet flows from these facilities (16, 21). The Forgotten River could be an opportunity to carry this idea one step further; to construct a dam for the purposes of re-establishing spring run-off flows in a river depleted by irrigation systems and upstream dams. This concept will be referred to as the Riparian Restoration Reservoir (Restoration Reservoir); a catch-and-release system constructed to enhance river flows and habitat.

From 1938 to 1998, more than 80,000 acre-feet flowed past Fort Quitman, on average, from October through May (Table 2). Depending upon the site selected for construction of this Restoration Reservoir, a storage pool of up to 30,000 acre-ft may be feasible. A reservoir of this size would also allow for a portion of the flows to pass through the system during the winter months.

During the last sixty years, the highest flows recorded at the Fort Quitman gage were in late September, 1941. The peak occurred on September 22, when in one day, 13238.5 acre-feet (6,600 cfs) roared into the “forgotten” corridor of the Rio Grande. This flood event produced a peak flow of 7705 acre-feet eight days later on September 30, at the Presidio gage. The greatest flow ever recorded at Presidio happened on June 13-14, 1905 when over 27,000 acre-ft were recorded for both days, an average velocity of 13,500 cubic feet per second (cfs.) (21).

For purposes of a general discussion, a Riparian Restoration Reservoir holding 30,000 acre-feet of water will be evaluated (Table 3). One cubic foot per second is equal to 1.98 or two acre-feet of water per day. At 30,000 acre-feet, a variety of release rates are possible. A release of 1000 cubic feet per second would last for 15 days, while a release of 3000 cubic feet per second would run for 5 days. In actuality, any release of such a large amount of water would require a gradual increase and decrease in flows, a ramping up and deceleration of releases. For example, 30,000 acre-feet could be released over a two-week period with an initial flow of 1000 cfs. for 2 days, followed by a 2 day release of 2000 cfs., with a 2-3 day peak release of 3000 cfs., to be mirrored by a similar pattern of decreased flows. The resulting hydrograph for the Forgotten River would be significantly altered from the existing system (Figure 7). The peak flows would be shifted from early fall, back to late spring-early summer as was the case prior to the construction of the Elephant Butte Dam.

The physiography (Table 4) of the Forgotten River consists of a series of 11 narrow canyons that are less than 650 feet in width, and vary in length from 0.3 to 9 miles. These canyons are separated by broader valleys ranging from 0.6 to 74 miles in length and are from 1 to 2 miles wide. Within this watershed a total of 101 arroyos draining 3,200 square miles discharge into the Rio Grande. The overall slope from Fort Quitman to Haciendita, just upstream of Presidio is a drop of 850 feet over 190 miles (S = 0.00085) (11).

Caballo Reservoir is a suitable model for evaporative losses as it is a shallow warm-water body similar to any potential storage facility to be constructed within the Forgotten River. Thus, the evaporative losses expected from the construction of a Riparian Restoration Reservoir can be determined using data collected at Caballo Reservoir (21). The annual average evaporation rate for Presidio is equal to 108 inches which compares favorably with the evaporation rate of 112 inches measured at Caballo Reservoir (Table 5). The annual evaporation loss at Caballo Reservoir is 0.1278 acre-feet of evaporation per total acre-feet in storage. The Riparian Restoration Reservoir might only be used to store water during the months of October through May. Total evaporation equals 57.58 inches for this period, or 53% of the annual total. Therefore, the evaporative losses expected at the Restoration Reservoir will be around 0.07 acre-feet of evaporation per acre-foot of storage. For a reservoir of 10,000 acre-feet only 680 acre-feet would evaporate, and similarly, a 30,000 acre-feet reservoir would lose 2,040 acre-feet. Given the average flow during the non-irrigation season of over 80,000 acre-feet, evaporation from a Riparian Reservoir should not be considered as a major water loss. When factoring for the average slope of the area, and the slope of the watershed away from the river channel; the site selected for this reservoir might only require a dam 40 feet in height (Table 6).

OTHER ISSUES: Salt Cedar, Salinity, and Sediment Transport

There are several key issues which must be addressed prior to the construction of a Riparian Restoration Reservoir. Chief among them, is the extensive mono-culture invasive tamarisk (*Tamarix ramosissima, T. chinensis, and T. aphylla*) forest which covers most of the riparian corridor.

Tamarisks, or Salt Cedars, thrive in arid conditions and out-compete native species like cottonwoods and willows (10). Tamarisks were introduced into this area as early as the 1930's for purposes of bank stabilization and erosion control (10, 14). The flood of late 1942 produced the first spilling at Elephant Butte Dam and consequently hastened the spread of tamarisk seeds from Caballo to Presidio and below. This 1942 flooding was the primary accelerant for tamarisk invasions below El Paso (10, 17). Unlike the native cottonwoods which only seed in the springtime to take advantage of runoff flows, tamarisks seed indiscriminately throughout most of the year (10, 14). A riparian zone infested with tamarisk is affected in three distinct ways: (1) Tamarisks rapidly consume water, drawing down water tables and reducing flows in waterways; (2) Tamarisks promote sedimentation which reduces the depth and width of river channels; and (3) Tamarisk stands are poorly suited for supporting many species of native wildlife, decimating the abundance and diversity of riparian flora and fauna (14).

Studies by USBR have demonstrated that the evapo-transpiration rate for tamarisk can be 50% greater than for native cottonwoods (10, 14, 21). Unfortunately, elimination of tamarisk has proven to be a formidable task, as burning only produces a higher density of new sprouts, flooding requires nearly two years of innundation for an effective kill, and root plowing is only temporarily effective. Herbicides are currently being used in other riparian systems, most notably in the Texas section of the Pecos River, and have proven to be the most cost effective and efficient means of removing salt cedar. Tamarisk eating beetles (*Diorhabda elongata*) are also being introduced to selected areas across the western states. Wide-scale application of these beetles will depend upon the results of these initial tests (14).

Compounding this situation are the dwindling populations of Southwestern willow flycatchers (*Empidonax trailii extimus*) , currently listed as an endangered species by the Fish and Wildlife Service. The critical habitat designation has specified that tamarisk thickets provide suitable habitat favored by the fly catcher and removal of tamarisk now requires coordination with the Fish and Wildlife Service to ensure the survivability of this threatened bird (17, 20).

Other invasive species which may pose a threat to this area in the near future include the Arundo reed (*Arundo donax*), and hydrilla, which are aggressively migrating upstream from the Lower Rio Grande Basin and have now entered the reach above Amistad Reservoir, below Big Bend National Park (23).

The well established tamarisk forest which permeates the Forgotten River has certainly deposited and concentrated salts along the river banks. Dense stands of tamarisks within the riparian corridor prodigiously pull water from the river into the banks as these plants grow and transpire. Elimination of these invasive halophyllic plants, could produce an influx of salts from bank storage back into the Rio Grande during flood events (5).

Water quality information indicates that the overall Total Dissolved Solids (TDS) content of the river decreases from Fort Quitman to Presidio (Table 7). Whether this is due primarily to the tributary inflows or the contribution of base flows has not been determined. A report by the Texas Water Resources Institute "Flow, Salts, and Trace Elements in the Rio Grande: A Review" examined the flow-weighted annual salinity in the river from 1969 through 1989 (5). An estimated 403,000 metric tons of salt entered the Forgotten River at Fort Quitman annually over this 20 year period. The Texas Clean Rivers Program has been collecting water quality samples in this reach since 1992. The concentrations of chlorides, TDS, and sulfates show a general decrease in salt content as the Rio Grande courses from Fort Quitman to Presidio (Figure 8).

How the release of a large amount of water from a Restoration Reservoir over a relatively short time period would affect the salinity levels at the mouth of the Forgotten River in Presidio is unknown. The initial flushing may wash a considerable amount of salts down the river. This could produce a plug of salty water that would be detrimental to irrigators utilizing the flows above Presidio.

Eventually, the salts collected by the tamarisk will be washed out when flood flows return. In 1942, over 1,175,00 acre-feet flowed through the Forgotten River hastening the spread of tamarisk, and in 1987, the 890,000 acre-feet of water which flowed washed much of the accumulated salts out of the system and into the Amistad Reservoir (5).

Sediment Transport - Any appurtenance placed across a river affects the transport of sediments. The low velocity of flows in the Forgotten River has created a build-up of sediments at the mouths of arroyos and in the valley segments between the narrower canyons (11, 17). A Restoration Reservoir would assist in transporting sediments below the dam, however sediment deposition would occur upstream as the river slows when entering the reservoir. By allowing a portion of the flows to pass through the reservoir, and not completely closing the dam, some sedimentation could be off-set. A bottom-gate structure that passes water through the bottom of the storage pool is one possible method of transporting sediments through the reservoir. The selection of a site for this type of structure would also require the analysis of backwater effects on flow and upstream depositional rates. Channel morphology and sediment transport are two critical issues requiring a more thorough investigation prior to any restoration effort for the Forgotten River (11, 12).

CONCLUSION

The Rio Grande from Fort Quitman to Presidio may be forgotten but it is certainly not gone. At its confluence with the Rio Conchos, the Rio Grande has over the last 40 years contributed 125,000 acre-feet annually. This amounts to approximately one-sixth of the total flows in the Rio Grande/Rio Bravo beyond Presidio-Ojinaga (Table 8).

Presently, the most practical and viable method for restoring the riparian corridor of the Forgotten River may very well be the construction of a Restoration Reservoir. This could provide a means of re-establishing a hydrograph which mimics the spring run-off flow regime present before the completion of the Elephant Butte Dam. Such a reservoir would restore energy to the river system, and promote the recruitment of native plant species by inundating flood plains during the late spring when the Rio Grande traditionally reaches it’s maximum rate of over-bank flows. Downstream, the riparian flora and fauna of the Big Bend Parks would also benefit from the reintroduction of late spring flows.

Proposed development of a Riparian Restoration Reservoir faces several major obstacles. The International Boundary and Water Commission has been authorized to construct one more dam along the Rio Grande, but has yet to receive any appropriations to do so. Mexico must address a myriad of issues along its border with Texas, and restoration of the environment along a portion of unpopulated desert is a low priority. Physically, the remoteness of this section of river means that accessibility is a challenge. The lands along the Texas side of the Forgotten River are a checkerboard of private ranches and state-owned sections. And finally, ongoing funds would be required to properly operate and maintain the reservoir. The political, financial, and physical realities of this concept make actualizing such a reservoir unlikely. However, the political landscape is changing, and more emphasis is being placed on the health of our nation's rivers and the stewardship of our riparian zones (23). As the pressure grows for removing more dams from our rivers, the construction of riparian restoration reservoirs may present a tenable, albeit paradoxical solution to all interested parties. The Forgotten River reach of the Rio Grande could become a case-study for this kind of project.

The Rio Grande Alliance issued a "State of the River" paper in 2000 which proposes restoration of the Forgotten River through the release of discharge peaks of 3,500 cfs lasting 3-5 days, or approximately 35,000 acre-feet using Rio Grande Project water (22). Any release of waters from project storage would have to meet the requirements specified in the Colorado-New Mexico-Texas interstate compact, the contractual agreements between Reclamation and the irrigation districts, and could even require a change in the Congressional Authorization governing the Rio Grande Project (19). A flow of 3,000 cfs entering the Forgotten River would require a higher release at Elephant Butte Dam. In late May-early June, the irrigation deliveries often exceed 2,500 cfs, and an additional 3,500 cfs would be difficult to manage. Flooding occurs in some portions of the Mesilla Valley when flows reach 5,000 cfs.

It is hoped that the information presented in this thesis will heighten interest in any restoration efforts along Forgotten River reach of the Rio Grande. While several ideas are being debated on what might be the best method or scheme for restoring the ecology and health of the river, the concept covered in this thesis - the construction of a Restoration Reservoir - was selected on the basis of practicality and legality. This type of project would not require the transfer of any waters from existing users, and would ultimately let the water already existing in the system do the work of restoring the Rio Grande. Such an expensive, massive, and bi-national project is open to criticism from those who believe that the last thing the Rio Grande needs is another dam. Nonetheless, anyone investigating this part of the Rio Grande should at least become aware of the notion of building a dam for the sake of a river, and not for utilitarian purposes of irrigation, power production, or municipal uses. Should this idea eventually be pursued, the next logical step would be a full scale Feasibility Study for the restoration of the riparian corridor along this Forgotten River sub-basin of the Rio Grande/Rio Bravo.

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22. Rio Grande Restoration: *http://www.riogranderestoration.org/*

23. Various *Non-Governmental Organizations* have expressed an interest in the state of the Rio Grande and the Forgotten River through attendance at meetings, conferences personal contact and with the formation of the Forgotten River Advisory Committee. These groups include, but are not limited to: The Environmental Defense Fund, the Sierra Club, the World Wildlife Fund, the Southwest Environmental Center, the Rio Grande/Rio Bravo Coalition, the Rio Grande Alliance, the Texas Center for Policy Studies, the Public Policy Information Fund of Texas, the World Heritage Institute, the Wild and Scenic Rivers, the Consortium of the Rio Grande, and the American Heritage Rivers

Acknowledgment - The term "*Forgotten River*" was first coined by Steve Harris of the Rio Grande Alliance. Thank-you "Uncle River"

APPENDIX A

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