Impact of Riverside Drains on Surface-Water and Ground Water Interactions in the Middle Rio Grande, New Mexico: Implications to the Sustainability of Native Cottonwoods (Populus deltoides ssp. wislizenii) and Native Species

Gerardo Rodriguez

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Impact of Riverside Drains on Surface-Water and Ground Water Interactions in the Middle Rio Grande, New Mexico:

Implications to the Sustainability of Native Cottonwoods (*Populus deltoides* ssp. *wislizenii*) and Native Species

By

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A Professional Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Water Resources Hydroscience Concentration Water Resource Program The University of New Mexico Albuquerque, New Mexico June 2021
Committee Approval

The Master of Water Resources Professional Project Report of Gerardo Rodriguez entitled *Impact of Agricultural Drains on Surface-Water Ground water Interactions in the Middle Rio Grande, New Mexico: Implications to the Sustainability of Native Cottonwoods (Populus deltoides wislizenii) and Native Species*, is approved by the committee:

_________________________   _______________
Chair       Date

_________________________   _______________
Committee member     Date

_________________________   _______________
Committee member     Date
Abstract

The Middle Rio Grande riparian zone, named the Bosque, provides cultural, aesthetic, environmental, recreational, and historical value to the residents of the Middle Rio Grande valley. Most of the Bosque has not experienced successful native cottonwood (*Populus deltoides* ssp. *wislizenii*) recruitment since the completion of the Cochiti reservoir and most of the Bosque cottonwood forest is senescing. This decline of the native species in the Bosque can be attributed to highly managed hydrology of the riparian zone. The levees and agricultural drains managed by the Middle Rio Grande Conservancy District (MRGCD), that borders both sides of the river, also affect the integrity of the Bosque. While the relationship between river stage and ground water level is well understood, the effects of the riverside drains on ground water level and bank storage are less understood. This study uses shallow monitoring well data and river stage data to evaluate the impact of the riverside drains on bank storage, ground water elevation, and the decline of bank storage. These factors affect cottonwood recruitment and native riparian integrity. The study compares the riverside drain on the east side of the San Juan Chama Drinking Water Project diversion dam to the riverside drain on the west, which is shallower, using time series analyses to evaluate the influence the riverside drain has on the native cottonwoods. Comparison of ground water depth measurement from monitoring wells on the west side of the river to those on the east side of the river, installed and monitored by the Bosque Ecosystem Monitoring Program (BEMP), indicate that the agricultural drain and, its induced artificial hydraulic gradient sloping away from the river, is causing the water table to drop below the 3 m at one site, ground water depth where the physiological condition of native cottonwood (decline, resulting in mortality in some individual trees. The agricultural drain has also increased the bank storage decline from a level that promotes optimal growth of cottonwood seedlings of 3 cm/day to a high of 20 cm/day occurring during a high water event in 2017 (Heller 2018).
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Introduction

In 1923, the Middle Rio Grande Conservancy District (MRGCD) was established to address the loss in agriculture acreage due to periodic flooding, a high water table, and increased soil salinity in the cultivated acreage in the Middle Rio Grande Valley (McDonald et al 1980). The MRGCD constructed flood control structures, drainage canals, levees, and irrigation canals along some of the 277,760 acres that contained within the district boundaries. The MRGCD had completed 95 percent of the above construction in approximately 10 years after its formation (Thompson 1986).

After the high water events in 1941 and 1942 the MRGCD partnered with the U.S. Army Corps of Engineers to install Kellner Jacks, also known as jetty jacks, for bank protection, flood protection and levee protection. Installation of the jetty jacks in the Middle Rio Grande started in 1952 and continued until 1959, (Grassel, 2002).

The most important structure that was constructed for flood control was the Cochiti Dam which was built by the US Army Corps of Engineers. The Construction of Cochiti Dam started in 1965 and the impoundment of water in Cochiti Lake began in 1973. Cochiti Dam replaced the Cochiti Diversion Dam which had previously had been used to divert water for irrigation purposes. The closing of Cochiti Diversion Dam and installation of jetty jacks & levees in the flood plain all but eliminated flooding in the river channel as well as stabilized the river channel. The consequence of the construction of flood control structures, Cochiti Dam, and other structures was a decrease in periodic flooding, decrease in the ground water table and an increase in salinity in the riparian zone. The untended consequence of the MRGCD construction...
was the reduction of flood plain plant communities, oxbow lakes and swamps and decreases in native cottonwood recruitment.

Today, southwestern riparian systems are among the most threatened ecosystems (Nilsson and Svedmark 2002), primarily due to the altered hydrology and flow regulation of the rivers. The altered hydrology of the riparian zone and flow regulation of rivers were enacted for the purposes of flood control, water supply, and hydropower production (Nilsson and Berggren 2000). The primary effect on riparian areas has been mediation of flows, reduced flood frequency, reduced lateral movement, and ultimately, the disconnection between the stream channel and the flood plain (Smith and Finch 2016). Cottonwoods depend on overbank flooding and scouring for the clearing of substrate for new stands and germination of seedlings (Mahoney and Rood 1998). Flow manipulations from dams, channelization, and diversions on the Rio Grande and other southwest streams have reduced or stopped the recruitment of a new cottonwood generation (Howe et al. 1991). Most riparian stands of cottonwoods in the Middle Rio Grande (MRG) are aging and progressing to later successional stages, a rarity in natural riparian regimes (Boggs and Weaver 1994).

In the MRG, the riparian area is named the Bosque. It has recreational and aesthetic value; residents use it for hiking, biking, swimming, and fishing and as a cool retreat in the hot summer months. What makes the Bosque so special is the tall canopy created by the native cottonwoods. Therefore, to maintain the Bosque, the cottonwoods’ recruitment and sustainability must be part of the Bosque management and restoration effort.
For this study, data were used from one of the first ground water elevation monitoring sites set up by the Bosque Ecosystem Monitoring Program (BEMP), the Alameda site. The Alameda site was installed in spring of 1997. Four additional sites were installed upstream of the Alameda site in 2008, when the San Juan Chama Drinking Water Diversion Project’s Dam was installed. These sites were installed at the request of the Albuquerque Bernalillo County Water Utility (ABCWU) in cooperation with BEMP to monitor the impact of the diversion dam on the riparian ground water levels. The additional monitoring wells were all installed with pressure transducers and data recording devices that monitored the ground water level every 30 minutes. In addition, wells’ ground water levels are measured by using Solinst steel level measuring tape. These measurements are taken once a month by BEMP volunteers or personnel. BEMP has 32 active sites, see figure .
Background & Previous Work

The Middle Rio Grande Conservancy District (MRGCD) was formed by judicial order in August 1925, after the state legislatures passed the Conservancy Act in 1923. The state legislature was responding to what was considered a period of devastation for the established agriculture economy when the number of irrigated hectares dropped from a high of 50,600 hectares in 1880 to 16,200 hectares by 1920 (Thomson 1986). The decrease resulted from ground water levels that created water-logged soils, seeped area, and alkali flats. Although land drainage was the paramount problem, other related problems were recognized as needing immediate attention. Among them were flooding, sedimentation of irrigation ditches and canals, and an erratic water supply. Channel aggradation increased the flood hazards. The local Chamber of Commerce in the early 1980’s considered the drainage and flooding as most important problem facing the economic development in the region so they supported the state legislature and the formation of the MRGCD. The local chamber of Commerce also influenced the way the district organized.

The MRGCD is governed by a board of directors which were initially appointed by judges from the second judicial District. The rational for judges to appoint the board was to remove political influence from the board. Public desire for more control over the MRGCD led to lawsuit, challenging the state constitutionality of a court-appointed board. Before the case could be heard, the state legislature passed a constitutional amendment in 1974 requiring all political subdivisions with taxing authority to have an elected governing body. Subsequent legislation mandated an elected board for the MRGCD.

The MRGCD extends south from Cochiti Dam to the northern Boundary of the Bosque Del Apache National Wildlife Refuge, 240 kilometers in length and varies from two to eight kilometers in with (fig 20). The district encompasses 112,463 hectares, including 11,540 hectares of Indian lands (Thompson 1986). By 1935 the MRGCD had dug 17 miles of new drainage and irrigation canals, and
incorporated another 124 miles of existing canal into the system. To protect against flooding nearly 200 miles of riverside levees and a system of jetties and checks alongside the river were installed. With the help the Congressional Flood Control Acts of 1944 and 1950 the district and the Army Corps of Engineers build Cochiti reservoir for flood control and replaced Cochiti diversion dam. Figure 21 show MRGCD gage schematic and the four districts and Figure 22 show a diagram of irrigation cannels and drainage ditches.

Figure 2. Middle Rio Grande Conservancy District Gage Schematic, From MRGCD.
The district was created to have three benefits: flood control, supply of irrigation water, and drainage. With the increase urbanization of Albuquerque and increase of ground water pumping for municipal water supply, the city has eliminated the need for subsurface drainage in the valley area. The district has two types of drains: riverside and Interior. The official engineering design called for riverside drains to be installed at a depth of approximately 2.5 meters and for interior drains at 3 meters. Interior drains are designed to lower the water table and to convey subsurface water from interior areas to riverside drains, which then return the water to the river. The drains also accept surface runoff from irrigation through waste way channels. The Albuquerque drain on the east side of the river measures 3.61 meters and the Lower Corrales drain measures 2.0. The Lower Corrales drain base flow is normally 5 cfs and rises to 12 cfs in the irrigation season (Figures 4 and 5). The time series plot of flow and ditch stage
for March through April 2021 and for the year 2020 show a stage height of 2 ft. and flow average of 60 cfs. The Albuquerque ditch stage height for 2020 was 5.5 ft. and flow average of 175 cfs (Figures 6).

From the time series plots of flow and stage height of the Lower Corrales riverside drain it can be concluded that the Lower Corrales ditch is not utilized very much, indicating that the district is not irrigating or draining many acres of agriculture land on the west side of the river. The conversion of agriculture land to urban development is show on Earth Timelapse video of Albuquerque from 1986 to 2020 (Google Earth Timelapse (Google, Landsat, Copernicus). The video clearly shows the green fields going to sand color to grid pattern of urban development. This is also occurring on the east side of the river but it is not as clear.


Figure 4. Lower Corrales drain stage height and flow for the year 2020.
Figure 5. Lower Corrales drain stage height and flow for the Month of March, MRGCD.

Figure 6. Albuquerque drains stage height and flow for the year 2020.
The third responsibility of the MRGCD is flood control, however with the opening of Cochiti reservoir in 1973 the river peak flows above 10,000 CFS have been eliminated and peak flows currently rarely exceed 6,000 CFS, Figure 19. Chochiti Dam primarily acts to reduce peak flows which reduce the chance of flooding and has a much smaller impact on low flows. Hence, the average annual flows have been less affected. The District new mission statement “The Middle Rio Grande Conservancy District operates, maintains and manages irrigation, drainage and river flood control in the middle Rio Grande Valley, promotes efficient and responsible water management, protects the environment, wildlife and endangered species in cooperation with other local, state and federal agencies, and provides multi-use recreational opportunities within the middle Rio Grande Valley” (https://www.mrgcd.com, mission statement, accessed on 4/20/2021).

Multiple investigations have been conducted regarding the interaction of ground water and surface water in the Albuquerque area. These investigations have been conducted by or in partnering with one or multiple organization listed; BEMP, University of New Mexico, New Mexico State University, Colorado School of Mines, USGS, U.S. Army Corp of Engineers, NM Interstate Stream Commission, Bureau of Reclamations, ABCWU, MRGCD and Middle Rio Grande Endangered Species Collaborative Program, just to name a few. Some of the investigations of surface water-ground water interaction in Middle Rio Grande (MRG), are summarized here. Heller (2018) utilized BEMP data to create a relational database. This database was used in conjunction with river hydrology to investigate ground water behavior in the MRG and its impact on bank storage, cottonwood recruitment, and native riparian integrity. Isaacson (2009) created a GIS model that combined ground water measurements and interpolated river water surfaces to produce comprehensive water surfaces for the entire riparian corridor. This river stage was analyzed to determine its effect on depth to ground water. Native and non-native riparian species have different tolerances for ground
water depth; the impact of different flow rates on the ability of species to survive is presented in the above study. Faiza (2011) also modeled surface water/ground water interaction at the Albuquerque Bio Park wetland near the Rio Grande. LeJuene (2008) used pressure transducers (PT) data from the BEMP diversion dam site to evaluate how river discharge, rain events, and diversion dam levels affect ground water levels. He found the soil at the site had high hydraulic conductivity and that ground water reacts rapidly to changing river stages. LeJuene also found that ground water levels are mainly a function of boundary conditions: river and riverside drains. Samson (2012) created a two-dimensional model (HYDRUS-2D), which was used to evaluate max bank storage and duration of bank storage under variant river flood stages. Samson concluded that the highly controlled or managed flow of the Middle Rio Grande has resulted in the diminished capacity of the riparian zone to store water for a prolonged period of time. Singh (1968) noted that the flow of water from the stream into the banks depends on the relative position of the stream stage and the ground water tables, the boundary condition, characteristics of the water-table profile, the hydraulic properties of the soil above the water table, the permeability of the soil-water interface of the bank, and the degree and intensity of stream-state fluctuation.

Worthington (2013) used data from eight selected locations along the Middle Rio Grande that had piezometers and surface water gages installed by U.S. Geological Survey. The PTs data were used to calculate horizontal and vertical ground water gradients as related to seasonal variations in surface-water discharge in the Rio Grande. The study showed that seasonal extremes of discharge significantly influence the direction and magnitude of ground water gradients in the Bosque. This study also looked at vertical and horizontal gradients at three
locations in the study area for changes due to the influence of municipal production well
pumpage from three of the nearest Albuquerque well fields. Worthington concluded that the
river level is the principal factor influencing ground water levels. Other contributing factors
include climate change, bosque vegetation, soil stratigraphy, riverside drains, irrigation ditches
and ground water pumping from shallow domestic wells near the river.

These studies provide valuable insight into the drivers of decreasing ground water tables
and the rapid decline of bank storage in the riparian zone in the MRG. By analyzing riverside
drains and their effect on the ground water tables and bank storage, this study generated an
improved understanding of the relationship between the river, the drains, and shallow ground
water that stakeholders, BEMP, and policy makers can use to make better informed decisions
on management and restoration regarding the Middle Rio Grande riparian zone, namely the
Bosque.

**Study Area**

The study area for this project was selected due to the primary criterion of having
agricultural drains parallel to the Rio Grande on both sides of the river. The riverside drain on
the west side of the river is identified as the Lower Corrales drain and the riverside drain on the
east side of the river is identified as the Albuquerque drain. Both drains are managed and
maintained by the MRGCD. The secondary criterion was that the Albuquerque drain is two
meters deeper than the west side drain, the Lower Corrales drain (Fig 1). This project
investigated the interaction between the riverside drains ditches and the ground water in the
adjacent riparian zones that are part of the Rio Grande Valley State Park. The total reach of this project from Alameda Bridge to just north of Montano Bridge is 11 km in length, the length of the Lower Corrales drain. It encompasses parts of the Rio Grande Valley State Park from the Alameda Open Space to San Antonio Oxbow Overlook as well as the lower Corrales drain from Alameda Bridge to the point it drains into the river at Oxbow Bluff.

The study area also has a large number of ground water monitoring wells that are monitored by the Bosque Ecosystem Monitoring Program (BEMP)(Figure 1 and 2). Each set of monitoring wells is identified by a site number and an assigned name. The Alameda site was established in 1997, making it the oldest site; it is assigned site number 1. The other sites were installed in preparation of the San Juan Chama Drinking Water Project diversion dam operated by the Albuquerque Bernalillo County Water Utility Authority in North Albuquerque.
Calabacillas, site No. 11, site was installed in 2003, Minnow, site no. 12, was installed in 2002, Diversion, site no. 10, was installed in 2002, Bobcat, site no. 22, was installed in 2006 and Badger, site no. 21, was installed in 2006. Bobcat and Badger are north of the diversion dam and the other 4 sites are downstream of the diversion dam.
Figure 7. Image shows six study sites in the middle Rio Grande, New Mexico, including location of USGS streamflow gage.
Figure 8. Study area, Middle Rio Grande, New Mexico, including BEMP site, USGS streamflow gage and location Lower Corrales riverside drain flows into river.
**Study Period**

BEMP data for the Alameda site are available since 1997 and data for the Calabacillas site are available since 2003. Data for the Diversion site and the Minnow site are available since 2002 and Badger data is available since 2006 as are the data for Bobcat. For this project, the date range of 2007 through 2019 was used. BEMP data were exclusively used due to the fact that maintenance of the pressure transducer (PT) was not maintained and most of the sites in the study area have zero working pressure transducer. High river flow years occurred in 2017 and 2019 and, therefore, 2017 and 2019 were examined in closer detail, with a focus on the effect on the ground water depth to the rivers high stage. The flow and water elevation data for the lower Corrales drain and Albuquerque drain were analyzed for the period from 2007 through 2019.

**Data Source**

The Bosque Ecosystem Monitoring Program (BEMP) at UNM was begun in 1996 with National Science Foundation (NSF) Informal Science Education Program funding, and is jointly coordinated by the UNM Department of Biology and Bosque School in Albuquerque. “BEMP
has two main objectives. One is to involve citizen volunteers (mainly K-12 students) and site representatives (mainly their teachers) in monitoring key variables that reflect bosque ecosystem structure, functioning” (Eichhorst et al., 2001, pg. 1) and the second is to collect environmental data and make this information available to resource agencies that deal with the Rio Grande Bosque (Eichhorst et al. 2001).

It is generally acknowledged by ecologists that long-term environmental conditions cannot be documented effectively without long-term monitoring of selected abiotic and biotic variables. Long-term data for the Rio Grande flows and river stage are recorded by the United States Geological Survey (USGS), and precipitation is monitored by the National Oceanic and Atmospheric Administration, (NOAA). Prior to creation of BEMP, long-term data sets that record the ecosystem changes in the Bosque were limited or non-existent. BEMP filled the long-term data record need, by engaging local high school students. BEMP student volunteers, with oversight of BEMP staff, go out once a month to each site to collect ground water depth, litterfall, and rain gage measurements. Selection and analysis of BEMP monitored variables are based on many years of UNM Bosque research. (Eichhorst et al. 2001)

Each site is configured with five ground water monitoring wells spaced 40 ± 0.2 meters apart in a cross pattern with cross-axis facing east, west and the other cross-axis facing north and south. Each well is designated by its relative location to the site transect; east well, west well; center well, south, and north well (Fig 2). The wells in the study area were equipped with pressure transducers, which record temperature-corrected absolute pressure head in units of length, every 30 minutes. All but one of the pressure transducers has stopped working due to
lack of maintenance, so only ground water elevation data collected manually by BEMP were used for this project.

Figure 9. a. Typical Layout of a BEMP site. b. Diagram of monitoring well.


Rio Grande and Riverside Agriculture Drain Channels Flows and Water Stage

USGS river stage and streamflow data were retrieved from http://waterdata.usgs.gov to compare Rio Grande discharge and gage height to observed ground water behavior in the study area sites. Two gages were selected on the Rio Grande that was closest to the study area. USGS 08329918
Rio Grande at Alameda Bridge in Alameda was selected first because of its proximity to the study area, the gage is approximately 400 meters upstream from the Albuquerque Bernalillo County Water Utility Authority diversion dam. According to Isaacson 2009, this gage is can give inaccurate measurement due to several issues; first a very long vegetated island exists in the middle of the river stretching 280 meters upstream from the bridge. The island splits the channel in two with the potential of different water surface elevations in each. Additionally, the Upper Corrales Main Drain (operated by the MRGCD) empties into the Rio Grande 24 meters upstream of the old Alameda Bridge. The vegetated island prevents this inflow from being included in the Alameda measurement further making this and undesirable site for a stream gage. The gage data that were used for this study was USGS 08330000 Rio Grande at Albuquerque located at the central bridge.

The Lower Corrales agriculture drain parallels the river on the west side of the river approximately 200 meters west of the Rio Grande’s west bank. The Albuquerque agriculture drain also parallels the river on the east side of the river and it is also 200 meters of the east side bank of the river at the study sites. The agriculture drain flow data and water stage were retrieved from www.usbr.gov/uc/albuq/water/ETtoolbox/rg/PROD/gage/archive/gage/. The gage for the Lower Corrales drain is identified as LCRDR and is located at the start of Coors Bosque Trails (Figure 3). The gage for the Albuquerque drain is identified as ARSDR and is located by the Alameda Bridge.
All BEMP sites in the study area have been professionally surveyed, including elevation, using the NAVD88 datum. Water elevations were recorded in meters used in this project to describe the shallow aquifer, but elevation above sea level is used in some instances, particularly when constructing transects profiles. Manual surveys of the Minnow and Diversion sites were taken, using a Leica Disto D5
laser measuring tool and Firecore 16 ft. Aluminum grade rod (Table 1). The goal of the survey was to measure the Lower Corrales drain elevation and width as well as the Albuquerque drains and compare them to the transit profile created by Heller, 2018. Heller used LiDAR data retrieved from [http://earthexplorer.usgs.gov](http://earthexplorer.usgs.gov). LiDAR data were collected in 2010, and are available for the Minnow, Diversion and Badger sites. Minnow and Diversion sites were chosen for conducting manual transect measurements due to their being the center two sites, Minnow on the West side of the river and Diversion on the East side of the river.

Table 1.1 Tool list used to measure transect profiles, and water depth at monitoring wells.

<table>
<thead>
<tr>
<th>Tool No.</th>
<th>Tool Name/Mfr.</th>
<th>Tool Model No.</th>
<th>Tool Serial No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leica Disto D5</td>
<td>Disto D5</td>
<td>391811247</td>
</tr>
<tr>
<td>2</td>
<td>Firecore</td>
<td>FS125 16ft. Aluminum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade rod</td>
<td>Grade rod</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Solinst Water Level Meter</td>
<td>Model 101 P7</td>
<td></td>
</tr>
</tbody>
</table>

**Study Sites**

When the planning for the San Juan Chama Drinking Water Project diversion dam began, the Albuquerque Bernalillo County Water Utility Authority partnered with BEMP to install five monitoring sites bracketing the diversion dam. Bobcat installed in 2006 is upstream of the dam on the west side of the river and Badger installed in 2006 is upstream of the dam on the east side of the river. The Minnow site, installed in 2003, is approximately 80 meters downstream from the diversion dam on the west side of the river and Diversion, installed in 2002, is 70 meters downstream of the diversion dam on the east side of the river (measurements were taken from Google Maps). The Calabacillas site was installed in 2003 and is on the west side of the river, 1.3 km downstream from the Alameda Bridge. The Alameda site was installed in 1997 and is 1.1 km downstream from the Alameda Bridge on the east side of the river.
Figure 11. Map and imagery of study site and transect line.
**Data validation and utility**

BEMP staff and student volunteers collect manual readings of depth to ground water at each site, monthly. Depths to water in wells were measured by using a steel tape, and electric tape. The standard USGS procedure for water-level measurement is done by using a steel tape (Sweet and other, 1990), which is generally considered accurate to plus or minus 0.01 ft. (Sweet and others, 1990, Dalton and other, 1991). This measuring method can lead to two types of errors; mechanical and human error. Mechanical errors are wearing of the tape and the probe, kinks in the tape, and stretching of the tape with increased depth can reduce the accuracy to plus or minus 0.1 ft. (Barcelona and others, 1985; Dalton and others, 1991). Human error includes incorrectly reading the tape of the Solinst water level instrument, incorrectly recording the reading on the BEMP form, and inputting the data into the

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Center Location – approximate (Google Maps Link)</th>
<th>Ditch Measurement location (Google Maps Link)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Badger</td>
<td><a href="https://goo.gl/maps/ETmhbs5yxYoHfEooBA">https://goo.gl/maps/ETmhbs5yxYoHfEooBA</a></td>
<td></td>
</tr>
<tr>
<td>Diversion</td>
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<td><a href="https://goo.gl/maps/xKhjghhk">https://goo.gl/maps/xKhjghhk</a></td>
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<tr>
<td>Alameda</td>
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<td>dVaaUxbbA</td>
</tr>
<tr>
<td>Bobcat</td>
<td><a href="https://goo.gl/maps/WhV7Hd1PdFzaLVKWA">https://goo.gl/maps/WhV7Hd1PdFzaLVKWA</a></td>
<td></td>
</tr>
<tr>
<td>Minnow</td>
<td><a href="https://goo.gl/maps/MyYNtmBjFtdCmcMQ8">https://goo.gl/maps/MyYNtmBjFtdCmcMQ8</a></td>
<td><a href="https://goo.gl/maps/bMTyFiQ">https://goo.gl/maps/bMTyFiQ</a></td>
</tr>
<tr>
<td>Calabacillas</td>
<td><a href="https://goo.gl/maps/3aeX3Pl7GwTKAq7">https://goo.gl/maps/3aeX3Pl7GwTKAq7</a></td>
<td>pRmphTA</td>
</tr>
</tbody>
</table>
database incorrectly, constantly changing volunteers, who require repeated training, could also lead to errors. BEMP maintains a low error rate by maintaining quality assurance/quality control protocols.

Vandalism to the well casing can also affect the data.

The BEMP ground water depth monthly data were compared to pressure transducer data from the same well, from sites that had working pressure transducers. The comparison was done on data from the Diversion site by Keller in 2001 (Figure 5). Comparing time series plots of depth to ground water from both datasets illuminated how well the two measurements corresponded. The similarity between the two datasets can be characterized as highly similar.

Euclidean distance is a common technique for describing or quantifying the similarity between two time series. It is expressed as the square root of the sum of squared difference between two associated points, or summing the ordered point-to-point distance between them. As it is a summation normally meant to compare time series of equal length, Euclidean distance was normalized in this study by dividing by n,

$$NED = \frac{\sqrt{\sum(x_i - y_i)^2}}{n}$$

where $x_i$ and $y_i$ are depth to ground water measurements for each coinciding measurement, as measured by the PTs and by monthly BEMP readings, and n is the number of matched pairs. Also, the proportion of matched differences with an absolute value under 5 cm ($P_{<|5|}$), were measured. For the most similar dataset $P_{<|5|}=1$, and for the least similar dataset has $P_{<|5|}=0.17$. Most datasets have $P_{<|5|}>0.8$ and almost half have $P_{<|5|}>0.9$. 
From these analyses, it was concluded that, with few exceptions, most of the BEMP data are accurate and useable (Heller, 2018).

![Figure 12. Comparison of Pressure Transduce data from Diversion to BEMP Monthly data for the Diversion site (Keller 2018).](image)

**Analysis**

**Methods**

Analysis of the study area began by plotting the Rio Grande streamflow and river height, as measured by the USGS stream gage, to identify the date & time of high-water events (Fig 6). By combining the Rio Grande river stage plots and the ground water depth plots by site, the connection of the Rio Grande river stage to the ground water depth of the Bosque can be observed. The objective of this study is to analyze the impacts of the riverside drains on the Bosque abiotic factors; ground water depth, ground water recession, and biotic factor like Bosque litterfall. The drains define the western edge and eastern edge of the study area and Alameda Bridge defining the North edge and the
Calabacillas Alameda transect defining the south edge of the study area. The effects of the diversion dam on the ground water elevation in the study area were also analyzed.

The elevation of the lower Corrales drain was compared to the elevation of the Albuquerque drain to determine the difference in water surface elevation and correlate that to the difference in ground water depth measured, in corresponding BEMP sites, on the western site and eastern site of the river. The elevations, measured manually, were compared to those created using LiDAR data for accuracy.

![Discharge Rio Grande at Alameda (cfs)](image)

Figure 13. Rio Grande river discharge from USGS gage 08329918 Rio Grande at Alameda Bridge at Alameda, Albuquerque, NM.
Figure 14. Map of MRGCD riverside drain ditches, USGS National Hydrography Dataset.

*Transect Elevation profile*

The transect elevations were manually measured at the Minnow and Diversion sites. These sites are in the middle of the study area and, since the profile of the riverside agriculture drains does not change significantly throughout its reach, these sites were considered a good representative of the entire profile of the agriculture drainage ditches. Multiple points were measured in the drainage ditches, with the focus on the elevation of the ditch and profile of the ditch. Measurements, along the transect created between Minnow and Diversion, were mostly limited to the west well, center well and east well
and distance and height of the river bank. The distance for the north and south monitoring well were measured to check placement distance.
Figure 15. Minnow site W-E transect topographic profile, using manual measurements. Land surface elevation approximate 1518 meters (4980 ft).

Figure 16. Minnow site W-E transect topographic profile using LiDAR data (Heller 2018).
Figure 17. Diversion site E-W transect topographic profile, generated with manual measurements by author. Land surface elevation approximate 1518 meters (4980 ft).

Figure 18. Diversion site E-W transect topographic profile generated using LiDAR data (Heller 2018).
The manual measured elevation of the Lower Corrales ditch, when compared against the elevation generated by LiDAR, matches very closely, ± 0.5 percent of Y scale, and gives a high certainty of the accuracy of the manual measured profile of the Minnow and Diversion ditches. The difference in bottom elevation of the Lower Corrales ditch and the Albuquerque ditch is two-meter, with the Albuquerque ditch being deeper.

**Hydraulic gradient and effect of the diversion dam**

To better compare and measure ground water depth, ground water recession, and the hydraulic gradient generated by riverside drains, and determine if the BEMP ground water elevation data would show any effects of the diversion dam on the study sites of the study area, all the west side sites were plotted against all the east side sites (Figure 12). For closer analysis, two corresponding sites (sites on west – east transect) were plotted (Figure 13, Figure 14 and Figure 15). Analysis of the east ground water elevation plot and west well elevation plot line on the Bobcat and Badger plots against the same plots parameters of Minnow, Diversion, Calabacillas and Alameda, reveals that the Bobcat ground water depth for the east well depth and west well depth are trending straight across the time line, 2003 – 2020. By comparison, the Minnow, Diversion, Calabacillas and Alameda plots show a dip in the water depth trend-line around 2008 which is the year that the diversion dam came into operation (figure 12). This graph also shows how the west bank ground water elevation is higher for all the west side ground water wells, clearly showing the hydraulic gradient sloping from the river to the riverside drain. The east side sites plots also show the same trend but here the west side ground water average depth is higher for all the east sites as the east side well is the furthest from the river. This clearly indicates the direction
of the hydraulic gradient and the magnitude of the hydraulic gradient. Table 3 shows the hydraulic gradient for each site.

Figure 19. Plot east well depth to groundwater compared to west well depth to groundwater of all west side sites and east side sites. Site 22 is Bobcat, Site 21 is Badger, Site 12 is Minnow, Site 10 is Diversion, Site 11 is Calabacillas, and site 1 named Alameda. Y axis is in centimeters (cm)
Table 3. Ground water elevation average and hydraulic gradient slope.

<table>
<thead>
<tr>
<th>Site no.</th>
<th>Site name</th>
<th>East Wells ground water elevation Average (m)</th>
<th>West Wells ground water elevation Average (m)</th>
<th>Hydraulic Gradient (∆h/∆L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Bobcat</td>
<td>0.95</td>
<td>1.40</td>
<td>0.005625</td>
</tr>
<tr>
<td>12</td>
<td>Minnow</td>
<td>1.50</td>
<td>1.75</td>
<td>0.003125</td>
</tr>
<tr>
<td>11</td>
<td>Calabacillas</td>
<td>1.50</td>
<td>1.75</td>
<td>0.003125</td>
</tr>
<tr>
<td>21</td>
<td>Badger</td>
<td>2.80</td>
<td>1.70</td>
<td>0.01375</td>
</tr>
<tr>
<td>10</td>
<td>Diversion</td>
<td>2.75</td>
<td>2.00</td>
<td>0.009375</td>
</tr>
<tr>
<td>1</td>
<td>Alameda</td>
<td>3.25</td>
<td>2.25</td>
<td>0.0125</td>
</tr>
</tbody>
</table>

All the east side sites have a larger hydraulic gradient than their correspondent west side sites. The hydraulic gradient is 63 percent larger at the Badger site than the Bobcat site and Diversion is 67 percent larger than Minnow with the difference between Calabacillas and Alameda 97 percent. The large hydraulic gradient increase in the east side site is expected due to the increased depth of the Albuquerque agriculture ditch compared to the Lower Corrales ditch. The Albuquerque ditch is 1.7 times deeper.

In order to correlate ground water elevation to the stage of the river and the riverside drains at each site, ground water including Bobcat vs. Badger, Minnow vs. Diversion, and Calabacillas vs. Alameda, were created with the of Rio Grande stage added. This shows how the ground water elevation fluctuations are influenced by the Rio Grande stage, and also how the ground water elevation declines as quickly as the river discharge. The plot of Bobcat vs. Badger shows the positive effect of the DGW diversion dam. The trend line of the ground water depth for Bobcat shows an increasing trend in ground water depth or the depth of the ground water at Bobcat has decreased. The raised ground water table is due to the diversion dam keeping the river stage high. Also, the Lower Corrales ditch is lower on the west side. The Corresponding Badger site trend line shows steady ground water levels and the difference here is that the Albuquerque drainage ditch has a greater depth than the Lower Corrales.
(Figure 13). The time series plots of Minnow vs. Diversion and Calabacillas vs. Alameda shows a similar trend line of ground water depth increasing slightly. Overall, the time series plots show all the west side sites having shallower ground water depth compared to the east side sites.
Figure 20. Top Chart Bobcat West, Center, and East Well, 2007 – 2019. Rio Grande stage height for USGS 0830000 Rio Grande nr Central, NM, from 2007 to 2019. Bottom chart Badger
Figure 23. Alameda west, center and east well, 2019 High River flow event.
Figure 24. Figure shows the annual autumn cottonwood leaf litterfall. A clear split between the east and west side BEMP sites is visible in both the leaf litterfall and depth to ground water data.
Figure 25. Annual cottonwood leaf litterfall at Alameda site and Calabacillas site.

Figure 26. Annual cottonwood leaf litterfall at Minnow site and Diversion site.
Figure 27. Annual cottonwood leaf litterfall at Bobcat site and Badger site.

Yearly Litterfall Analysis

Litterfall is the collection of plant debris, (leaves, twigs, seeds) that falls naturally. The litterfall is collected in 13 inch diameter tubs that are strategically placed according to BEMP designation. Assessing litterfall can help to quantify gross measures of forest productivity, ecosystem health and native versus exotic species composition (Eichhorst, et al, 2009). Analyzing the time series plots of the
annual cottonwood leaf litterfall at the, Calabacillas and Alameda, Minnow and Diversion and Bobcat and Badger sites, it can clearly be determined, from the trend of the cottonwood leaf litter that the cottonwoods are more productive (litterfall g/m²), on the sites on the west side of the river than the sites on the east side of the river. Figure 26 shows the Minnow site being more productive than the Diversion site year after year except for the year 2020. The same trend is repeated on the Bobcat and Badger series plots showing the annual cottonwood leaf litterfall (figure 27). From 2007 to 2015, the cottonwood leaf litter trend increased, but starting in 2015, there was a large decrease of both leaf and woody litter. The drastic decrease in 2015 is potentially due to stress from the low river stage in the 5 years starting around 2010. The bar plot, however, shows the Badger site is decreasing much faster. Again, Badger is on the east side of the river with the large hydraulic gradient slope due to the Albuquerque drain (Figure 17).

Discussion

The San Juan Chama Drinking Water Project diversion dam (DWP) has raised the ground water elevation at Bobcat and Badger. Bobcat’s time series plot of the west well ground water elevation and east well ground water depth have a trend line that slopes up, an indication of decreasing elevation of ground water at this site. The Badger site time series plot also indicates a positive influence from the DWP diversion dam. The trend line does not decrease but stays level indicating stabilization of the ground water depth. The time series plots of the Minnow and Diversion sites show the negative effect of the DWP diversion dam, with a noticeable dip in the time series plots of ground water elevation at the Minnow, Diversion and Calabacillas after the year 2008, the year the DWP diversion dam came online. The Alameda site dip is not as pronounced, indicating the decrease influence of the DWP diversion dam on sites further downstream from the dam (Figure 12).
All of the monitoring wells throughout the study area and study period were observed to have highly variable depths to ground water, and were strongly correlated to Rio Grande discharge. All the sites’ ground water levels respond quickly to changes in river discharge, with the ground water depth decreasing with the rise of river flow during the same time period. On the other side of the peak, we observe the rapid decreasing of river discharge and rapid increasing of ground water depth during the same period. This is an indication of how strongly the ground water elevation is connected to the river’s stage. The strongest driver of the ground water elevation is the high discharge events that happen in late April early May, the start of the irrigation season. In a naturally flowing river this period would correspond with spring snowmelt, and flooding of the riparian area. On the Rio Grande, high discharge events over 10,000 (CFS) have not occurred since 1973 which corresponds with the Cochiti Reservoir coming online (Figure 19).

![Figure 28. Rio Grande peak flow USGS gage 8330000 at Central Bridge](image)
In 2017, a high discharge event occurred. We observed from the time series plots of ground water depth at the Diversion site, that the measured depth at the west well, which is 14 meters from the river channel, raised 1.75 meters, while ground water depth at the east well, which is 94 meters from the river channel, only rose 1 meter during the same event. At the Minnow site directly across the stream channel from Diversion site, the pattern is similar. Ground water depth measurement rose over one meter at the east well, which is 90 meters from river channel, during the 2017 high stage even. The west well, which is 170 meters from the river channel, during this period only rose 50 cm. Considering that the riparian floodplain extends from the river channel to the agricultural drains levee, which is only 170 meters from the river channel, the river high discharge event only raised ground water depths in over half of the riparian zone.

Another high discharge event occurred in 2019 and we observed the same ground water response. The hydrograph from the Minnow and Diversion site monitoring wells, show 50 percent higher water tables at the wells close to the river channel then the wells further from the river channel, (Figure 16). Hydrographs show that the strongest driver for the fluctuations are the artificial hydraulic gradient generated by the drainage ditches that parallel the river on the east and west side of the river. Hydraulic gradient has both a magnitude and direction and table 3, shows the calculated hydraulic gradient for each site, the direction of the hydraulic gradient follows the east west transect on the Minnow and Diversion site, with the direction of the hydraulic gradient on Minnow site following the transect from the river west to the drainage ditch and at the Diversion site the direction of the hydraulic gradient following the transect from the river east to the drainage ditch. The velocity of ground water flow is proportional to the magnitude of the hydraulic gradient and the hydraulic conductivity of the aquifer.
The effect of the riverside drains on ground water depth can clearly be seen by the comparison of the west side sites to the East side sites. Badger, Diversion and Alameda east well measurements all are at the 3 meter depth, with the west well measurements coming in at less than 2 meters. Cottonwood trees experience crown dieback when depth of ground water is greater than three meters, and susceptible to mortality of ground water depths greater than five meters (Horton, et al, 2001). Image 1 shows typical cottonwood stands on the Diversion side with crown dieback, image 2 shows typical healthier cottonwood stands on the Minnow side. Photographs were taken April 14, 2021.

![Image 1. Typical cottonwood stands on Diversion site, showing crown dieback.](image-url)
The hydraulic gradient has both a magnitude and direction. Ground water velocity is proportional to the hydraulic gradient and the hydraulic conductivity of the aquifer. The hydraulic gradient is 63 to 97 percent larger on the sites east side of the river than the west side sites. The direction of flow on the west side is from the west river bank to the Lower Corrales riverside drain and on the east side sites the direction of ground water flow is from the river bank east to the Albuquerque riverside drain. From the ground water receding rates after high discharge events of the river are found to be 5 cm/day at Minnow and 16 cm/day at Diversion it can be induced that the hydraulic conductivity at these two sites is very high. This is confirmed by the type of soils found inside the levee next to the Rio Grande within the study area. The Brazito soil layer ranges from sand to clay, with the dominant
components being sand, and sandy loam and the Vinton surface layer range from sand to clay (USDA, 1977).

Comparing litterfall BEMP data by site also show the adverse effect of the riverside drains on the health of the vegetation in the Bosque.

This project has demonstrated the adverse effects the agriculture drain ditches have on the Bosque native riparian forest; drop in ground water depth due to the induced hydraulic gradient, the high rate of ground water recession, reduce lateral movement of water during overbank flooding. These parameters plus the Rio Grande flow regulation has prevent and will prevent future cottonwood recruitment and push forward the existing living riparian cottonwood stands into later successional stages, a rarity in natural riparian regimes.

**Conclusion**

Why Do We Need To Preserve the Cottonwood Bosque Forest?

The Bosque’s benefits to its residents are cultural, aesthetic, recreational, environmental, and social. Preserving the cottonwood Bosque forest will help sustain and enhance these benefits. The re-greening (saving the Bosque cottonwood), substantially cool the borderlands, and contribute to ameliorating the local climate (Beehler, B, Glassberg, J.). This would benefit the local fish, bird, mammal and butterfly populations at a time when they all face existential threat. Moreover, the green corridor would become a destination for lovers of nature and the outdoors, from around the world. It would be an asset to Albuquerque, attracting new businesses and residents to the city who are seeking open spaces and nature walks, all within easy access from a major thoroughfare or accessible by bike.
There is also accumulating evidence that any activity performed outdoors or in view of a natural environment can have positive effects on quality of life. Cognitive function, particularly in children (including sustained attention and interest and improved problem solving), can be improved by having access to a nearby natural environment (McCurdy, Winterbottom, Mehta, & Roberts, 2010; Wells, 2000).

This project has shown how the riverside drains that were constructed nearly 100 years ago, have adversely affected the riparian forest at the study site. The initial function of the drainage ditches has been diminished along certain runs of their length, with the conversion of agricultural land to urban development, the lowering of the water table by city pumping, and the reduction of available water in the water shed due to global warming climate change. The money spent by MRGCD for the construction and maintenance of agriculture drainage ditches, agriculture irrigation canals, and later Cochiti dam was to improve economic development in the valley in the early 20th century. Solutions that were implemented 96 years ago, under different conditions than today, are no longer applicable or helpful. In light of current physical, environmental, and social values, those past solutions are not working today and we can change them to better serve society.

To save the Bosque in the middle reach of the Rio Grande, I propose that the Lower Corrales drainage ditch be re-engineered by the MRGCD from Alameda Bridge to where it drains into the river by Oxbow North Bluff. The ditch would be required to be partially filled to eliminate the artificial gradient that it creates from the river to the ditch on the west side to raise the ground water level to sustainable level for the cottonwood and still maintain some level of flood protection. The Albuquerque drain could also be re-engineered to decrease the hydraulic gradient and raise the groundwater elevation on the east of the river. This would produce a higher water table and therefore more ground water storage, which would help watersheds ride out long stretches of drought.
The abandoning of the Lower Corrales drainage ditch would not fix the issue of cottonwood recruitment because for successful cottonwood recruitment a few parameters are required: 1. the creation of suitable recruitment sites by floodwater run-off. Cottonwood “seeds germinate almost exclusively on the freshly deposited, exposed alluvium left by receding floodwaters” (Mahoney 1991, pg. 3). The availability of this type of moist, exposed habitat during 6 to 8 weeks after seed dispersal is crucial because of the limited period of seed viability. 2. Flood water scrubbing riparian debris from the Bosque ground to expose moist alluvium. 3. A ground water recession rate of less than 4 cm/day. “Root growth of young cottonwood seedlings is very rapid, with an average growth rate of 4 to 12 mm, and a trunk growth rate of 13.5 mm per day” (Taylor 2000, pg. 3). Because the upper layers of the moist alluvium dry rapidly with the onset of warmer summer temperatures, rapid root growth is essential in order to keep up with water recession rate. With the construction of the Cochiti Reservoir, natural high peak flows and the timing and peak flows have been all but eliminated which prohibits the recruitment of the native cottonwood (*Populus fremontii*).

Given the current political polarization around the issue, a conversation about saving the Bosque cottonwood by abandoning a section of the Lower Corrales ditch and modifying the depth of the Albuquerque ditch would be a very difficult conversation to initiate even in light of the available data showing the negative effects and documentation of the adverse effect the drainage ditches have on the native riparian forest. The idea for a possible new approach to starting the conversation comes from a study entitled “Personal Experience Bridge Moral and Political Divides Better than Facts” (Kubin, Emily, et al.). New research suggests a solution can be found in stories, not statistics. People have greater respect for those they disagree with when they communicate their position from a place of personal experience, not facts and figures. To communicate to all the stakeholders including the New Mexico State Legislature, Albuquerque City Council, MRGCD, BEMP and the general public, the changes that are
required to save the Bosque, a conversation needs to start with an examination of the way in which the public personally experiences the Bosque.

The following picture gallery is a small representation of the public’s experience with the Bosque.

Image 3. Families experiencing the Bosque trails, Bosque Trails.
Image 4. Families experiencing the Bosque trails near Montano Bridge, (left image). People walking on Ditch trail, (right image).

Image 5. People walking and riding bicycle on Ditch trail (left image). People fishing off Ditch trail.
The Google time-lapse video, hyperlink on pg. 44, clearly shows the conversion of agricultural land to urban use. The video shows that the west side conversion from agriculture to urban development is more dramatic than on the east side of the river, reducing the amount of irrigation required and also the usage of the riverside drainage ditches, this is shown in figures 22, 23 and 24. We have also shown the adverse effect of the agriculture ditches by artificially lowering the depth of the ground water table in the riparian zone which directly affects the health of the native riparian forest. A survey in 1926 found that the depth to ground water, through 78 percent of the valley, ranged from 0 to 1.2 meters (Thomson, 1998). BEMP data show that the ground water depth on the east side study area is at or reaching 3 meters, which is the reason the cottonwoods on the east side of river are distressed with crown dieback (Image 1). On the west side, the ground water depth in the riparian zone is 2 meters or less, and the cottonwoods are visibly healthier, (Image 2). Studies have shown that native
cottonwood recruitment will not occur under the current management of the river but we can maintain the current cottonwood forest by abandoning or modifying ditches that are underutilized. This will be expensive and require extensive engineering work as the network of ditches that MRGCD manages is very extensive and they are all connected. But the MRGCD budget for Fiscal year 2020 was $23,204,105 with Bernalillo County covering 70% of the budget, therefore the MRGCD has the budget and some of the personnel to conduct the engineering study required to abandon or modify the drainage ditches that adversely affect the cottonwood forest. With reduced economic benefit from agriculture in Bernalillo County, caused by the increase in urbanization, two of the three functions, that is drainage and irrigation, that MRGCD was formed to supply the citizens of the Middle Rio Grande Valley, have been reduced. Therefore, rethinking the way tax money is spent by the MRGCD needs to be discussed with more money allotted to save the Bosque cottonwood forest. Tax funds used to save the cottonwoods wood be offset by increased tax base generated from new businesses and residents attracted to the area by Bosque cottonwood forest.
Table 4. MRGCD Budget for fiscal year 2021

### FY21 Detailed Budgeted Revenues by Category

<table>
<thead>
<tr>
<th>Description</th>
<th>FY20 Budget</th>
<th>FY21 Request</th>
<th>Incr (Decr) FY21 Over FY20</th>
<th>% Change</th>
<th>Recurring</th>
<th>Non-recurring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandoval Co ADV Collections</td>
<td>$1,779,270</td>
<td>$1,814,856</td>
<td>$35,586</td>
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<td>$1,814,856</td>
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<td>Bernallio Co ADV Collections</td>
<td>12,714,414</td>
<td>12,966,702</td>
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<td>Valencia Co ADV Collections</td>
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<td>71,462</td>
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<tr>
<td>Soccoro Co ADV Collections</td>
<td>518,481</td>
<td>515,000</td>
<td>(3,481)</td>
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<td><strong>Total ADV Collections</strong></td>
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<td><strong>Total WSC Collections</strong></td>
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<tr>
<td>BIA Pueblos</td>
<td>721,843</td>
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<tr>
<td>La Joya Acquisite Agreement</td>
<td>2,550</td>
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<td>-</td>
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<td>Alameda/Riverside Drain Agreement</td>
<td>245,118</td>
<td>250,000</td>
<td>4,882</td>
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<td>Corps of Engr repayment of ABQ West</td>
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<td></td>
<td></td>
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<td><strong>Total Contracts</strong></td>
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<td>Partners for Fish &amp; Wildlife Program</td>
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<td>NFWF Sub-Grant</td>
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<tr>
<td>NFWF Water Leasing Pilot Program</td>
<td>787,900</td>
<td>787,900</td>
<td>100.00%</td>
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<tr>
<td>BOR Drought Grant - Resiliency</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>BOR Drought Grant - Soccoro Main Hub</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>DHSEM - Administrative Cost on Belen</td>
<td>135,000</td>
<td>135,000</td>
<td>100.00%</td>
<td>-</td>
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<td></td>
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<tr>
<td><strong>Total Grants</strong></td>
<td>130,000</td>
<td>927,900</td>
<td>813.77%</td>
<td>-</td>
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<tr>
<td>Int on Assessments - Sandoval County</td>
<td>60,000</td>
<td>50,000</td>
<td>(10,000)</td>
<td>-16.67%</td>
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<td></td>
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<tr>
<td>Int on Assessments - Bernallio County</td>
<td>135,000</td>
<td>130,000</td>
<td>(5,000)</td>
<td>-3.70%</td>
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<tr>
<td>Int on Assessments - Valencia County</td>
<td>35,000</td>
<td>30,000</td>
<td>(5,000)</td>
<td>-14.29%</td>
<td>30,000</td>
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<tr>
<td>Int on Assessments - Soccoro County</td>
<td>20,000</td>
<td>22,500</td>
<td>2,500</td>
<td>12.50%</td>
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<tr>
<td>Int on Investment Accounts</td>
<td>400,000</td>
<td>250,000</td>
<td>(150,000)</td>
<td>-37.50%</td>
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<tr>
<td><strong>Total Interest</strong></td>
<td>650,000</td>
<td>482,500</td>
<td>(167,500)</td>
<td>-26.77%</td>
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<tr>
<td>Leaseback Fees</td>
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<td>5,000</td>
<td>-</td>
<td>0.00%</td>
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<tr>
<td>Water Bank and Losaltlack Admin Fees</td>
<td>15,000</td>
<td>20,000</td>
<td>5,000</td>
<td>33.33%</td>
<td>20,000</td>
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<tr>
<td>Water Bank Lease Fees</td>
<td>225,000</td>
<td>225,000</td>
<td>-</td>
<td>0.00%</td>
<td>225,000</td>
<td></td>
</tr>
<tr>
<td>Fuel Rebates</td>
<td>-</td>
<td>1,500</td>
<td>1,500</td>
<td>100.00%</td>
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<tr>
<td>Bosque Access Fees</td>
<td>25,000</td>
<td>25,000</td>
<td>-</td>
<td>0.00%</td>
<td>25,000</td>
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<tr>
<td>Film License Revenues</td>
<td>10,000</td>
<td>7,500</td>
<td>(2,500)</td>
<td>-25.00%</td>
<td>7,500</td>
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<tr>
<td>Turnout Installations</td>
<td>35,000</td>
<td>42,750</td>
<td>7,750</td>
<td>22.14%</td>
<td>42,750</td>
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<tr>
<td>Map Sales</td>
<td>1,500</td>
<td>1,750</td>
<td>250</td>
<td>16.67%</td>
<td>1,750</td>
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<tr>
<td>Scrap Sales</td>
<td>7,000</td>
<td>6,000</td>
<td>(1,000)</td>
<td>-14.29%</td>
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<tr>
<td>License Application Fees</td>
<td>25,500</td>
<td>30,000</td>
<td>4,500</td>
<td>17.89%</td>
<td>30,000</td>
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<tr>
<td>Construction Special Use License</td>
<td>-</td>
<td>2,500</td>
<td>2,500</td>
<td>100.00%</td>
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<tr>
<td>Pump-In Water License</td>
<td>-</td>
<td>2,000</td>
<td>2,000</td>
<td>100.00%</td>
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<tr>
<td>Commercial Boating License</td>
<td>-</td>
<td>750</td>
<td>750</td>
<td>100.00%</td>
<td>750</td>
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<tr>
<td>Turnout Application Fee</td>
<td>-</td>
<td>1,500</td>
<td>1,500</td>
<td>100.00%</td>
<td>1,500</td>
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<tr>
<td>Gain/(Loss) on Asset Disposal</td>
<td>20,000</td>
<td>25,000</td>
<td>5,000</td>
<td>25.00%</td>
<td>25,000</td>
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<tr>
<td>Asset Disposal Not Capitalized</td>
<td>-</td>
<td>500</td>
<td>500</td>
<td>100.00%</td>
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</tbody>
</table>
### MIDDLE RIO GRANDE CONSERVANCY DISTRICT

**FY21 Detailed Budgeted Revenues by Category**

<table>
<thead>
<tr>
<th>Description</th>
<th>FY20 Budget</th>
<th>FY21 Request</th>
<th>Incr (Decr) FY21 Over FY20</th>
<th>% Change</th>
<th>Recurring</th>
<th>Non-recurring</th>
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<tbody>
<tr>
<td>District Water Bank - WSC Fees</td>
<td>145,000</td>
<td>150,000</td>
<td>5,000</td>
<td>3.48%</td>
<td>150,000</td>
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<tr>
<td>Other Non-Contract Revenue</td>
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<td>-</td>
<td>0.00%</td>
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<td></td>
</tr>
<tr>
<td><strong>Total Other Revenues</strong></td>
<td><strong>542,000</strong></td>
<td><strong>582,850</strong></td>
<td><strong>40,850</strong></td>
<td><strong>7.54%</strong></td>
<td><strong>582,850</strong></td>
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</tr>
<tr>
<td>Other Financing Sources (Loan from NMFA)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.00%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total Other Financing Sources</strong></td>
<td><strong>-</strong></td>
<td><strong>-</strong></td>
<td><strong>-</strong></td>
<td><strong>0.00%</strong></td>
<td><strong>-</strong></td>
<td><strong>-</strong></td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td><strong>$ 23,204,105</strong></td>
<td><strong>$ 24,278,001</strong></td>
<td><strong>$ 1,073,886</strong></td>
<td><strong>4.63%</strong></td>
<td><strong>$ 23,350,191</strong></td>
<td><strong>$ 927,000</strong></td>
</tr>
</tbody>
</table>
Future work

BEMP has collected 25 years of ground water depth data, by its large network of citizen scientists. This data will be the foundation for future studies and actions. Several ideas for future use of the BEMP data are listed below.

- Model the relationship among the drainage ditches, ground water behavior, and Rio Grande streamflow. This could be used to redesign the drainage ditches to raise and maintain the ground water levels within the riparian zone and preserve the native cottonwoods in a sustainable manner.

- Conduct a study of the economic benefits that would be generated by the increased tax base from businesses and residents attracted to the amenities of the Bosque compared to the tax money that would be spent to support the work of the MRGCD to sustain a healthy Bosque.

- Install and maintain pressure transducer in all the BEMP sites to increase the frequency of ground water elevation data that BEMP collects. BEMP data of ground water depth is taken monthly, while ground water data from pressure transducers can be measured every 15 minutes to 30 minutes. Also pressure transducers can measure the ground water temperature at the same time. This will provide more insight as to how the ground water reacts to the changing conditions of the river flow as well as to climate change.

- A study of the method of pole planting the native cottonwood trees in the riparian area to replace trees that are at the cessation stage. This will require an innovative solution o to water the trees until their root system grows enough to reach the water table. Solar energy could be
used to power pumps that would transport water to newly planted trees. A potential water source could be the recycled water from the Albuquerque wastewater treatment plant.
References


*Bosque Del Apache NWR Albuquerque.*

*BOSQUE ECOSYSTEM MONITORING PROGRAM (BEMP) SITE MONITORING REPORT for 2019 2019 ANNUAL SITE MONITORING TECHNICAL REPORT Bosque Ecosystem Monitoring Program (BEMP).*


Eichhorst, Kim, et al. *Bosque Ecosystem Monitoring Program (BEMP)*.


Harner, Mary J., and Jack A. Stanford. “DIFFERENCES in COTTONWOOD GROWTH
between a LOSING and a GAINING REACH of an ALLUVIAL FLOODPLAIN.”

Ecology, vol. 84, no. 6, June 2003, pp. 1453–1458,


