PROJECT SUMMARY

Sustainable Water Resources for Irrigated Agriculture in a Desert River Basin Facing Drought and Competing Demands: From Characterization to Solutions[1]

Background

In 2015, we embarked upon a long-term, multi-institutional, interdisciplinary research project on water resources sustainability in the Middle Rio Grande basin, defined by the portion of the basin from Elephant Butte Reservoir (EB) to the confluence with the Rio Conchos in Far West Texas/Northern Chihuahua. It is a highly managed system with little riparian habitat, a network of irrigation canals diverting water to agriculture, a network of drains to return unused water to the river, and at least three significant municipalities with a combined population of over 2 million (Las Cruces, New Mexico (NM), El Paso, Texas (TX), and Ciudad Juárez, Chihuahua, Mexico (CH)). The relevant aquifers in the project area that contain good quality water include the Mesilla (called Conejos Médanos in MX) and Hueco Bolsons, and the associated alluvial aquifer connected to the river. The river is the only source of surface water, and the two aquifers are the primary sources of fresh groundwater for users in NM, TX and CH. Our project is unique in that we included both the US and MX portions of the basin. The amount of surface water is dictated primarily by snowfall, snowmelt, and runoff in the upper portion of the basin, and collection and storage in EB Reservoir. The deeper Hueco Bolson and large portions of the Mesilla Bolson are primarily "fossil" deposits of water with little or no recharge. Thus, drawdown represents withdrawals against current and future reserves of freshwater, as well as growing risk of increasing salinity in those reserves.

The threat of warmer, drier climate is reducing water supplies from the river, while growing population and intensification of agriculture are increasing overall water demand. Thus, relatively cheap freshwater supplies are finite and dwindling due to a number of factors related to changing climate and growing demands. This scenario is being repeated not only in other river basins of the southwestern U.S., but also in other arid and semi-arid regions of the world that are dependent primarily on a desert river basin and its associated aquifers to meet the needs of irrigated agriculture, as well as growing urban populations. Thus, the core question is: **how can water be managed so that the three competing sectors—agricultural, urban, and environmental—can realize a sustainable future in this challenged water system?**

Our Approach

We took an interdisciplinary, stakeholder participatory approach in addressing this question. At the beginning of the project, we conducted over a dozen stakeholder meetings, engaging over 120 stakeholders to determine their important concerns/questions/issues regarding the future of water in our region. We obtained rich input from stakeholders regarding their concerns,

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management strategies, and desired futures. We summarize only their most important concerns/questions here:

- Prolonged drought and how to cope
- Urbanization/land use change/urban sprawl
- Soil and water salinization
- What will it take to realize more water conservation?

We focused the project on the future of water, not so much the past or even the present. Thus, simulation models were necessary to evaluate future scenarios. Our modelling approach was comprehensive, integrated, and interdisciplinary. We developed and/or evaluated a suite of models that performed at various spatial (from agricultural field to river basin) and temporal (from daily to decades) scales in order to address the important research questions of concern about future conditions and potential interventions that might alter future conditions. We considered conjunctive management of limited surface water and declining groundwater. We continued to incorporate stakeholder participation at every stage of the project.

Some of our important modelling tools/products that we either developed or improved for our use include:

- A basin-scale water balance simulation model
- A basin-scale hydroeconomic optimization model
- The small watershed- to field-scale model, Soil and Water Assessment Tool (SWAT), modified to include groundwater connections and salt fate and transport
- A field-scale salinity model
- A web-based user interface with the basin scale models, Sustainable Water through Integrated Modelling (SWIM)

This suite of models resulted in a modelling "toolbox" that provided the means to address many biophysical, economic, and policy related questions in an integrated fashion and at a range of spatial and temporal scales.

Our Findings

We summarize here our significant findings. For more detail and/or to review actual research results, consult our publication list or our full final report available online: https://water.cybershare.utep.edu/publications?ptype=prarticle

Status of Surface Water, Now and Into the Future

Over the past 20 years, reduced snowfall and snowmelt in the upper portions of the basin have resulted in much reduced water storage in EB Reservoir and prolonged drought for downstream users. The impact of drought, at times prolonged lasting several consecutive years, has been dramatic on EB Reservoir, resulting in much reduced surface area of the reservoir and a corresponding reduced storage volume for the majority of time.

We evaluated many future climate scenarios ranging from very wet to very dry and developed an innovative technique for adjusting the modeled (natural) flows to account for upstream water management. Looking at what climate scientists consider to be more likely future scenarios (mostly warmer and thus drier), it is clear that the trend of prolonged drought and dwindling supplies of surface water are likely to continue and even worsen into the foreseeable future (the next 50 years). In the future scenarios that we evaluated, EB reservoir will meet demand for only about 20% of the time under the likely warmer, drier scenario, and will not meet demand at any time during the period of simulation (50 years) under the very dry scenario. For irrigators in the Middle Rio Grande Basin (the largest and almost exclusive use of surface water in the region), the deficit in surface water availability will likely be replaced with groundwater.

Status of Groundwater, Now and Into the Future

Since irrigators will use groundwater to make up surface water deficits while continuing to expand pecan production, and the large cities in the region, who depend primarily on groundwater, will continue to grow, the Mesilla and Hueco Bolsons will be significantly depleted under the dry and very dry scenarios. Results for the Hueco Bolson show a dropping water level in the aquifer of about 3 ft/yr or 1 m/yr. Similar results were found in Mexico, where the rate of drop or depletion is 1.4 m/yr for "business as usual" and 9.4 m/yr if pumping rates increase by 50%. Furthermore, groundwater will migrate to areas of depletion, causing overall drops in the water elevation in general, and deterioration of water quality due to intrusion of brackish water. Since Ciudad Juárez is the biggest user, net movement of fresh groundwater is currently from the US to MX. It is possible that the freshwater in the Hueco Bolson, (approximately 10 to 15 million ac-ft) will be completely depleted within the next 50 years under the dry and very dry scenarios that we evaluated. The Mesilla Bolson, with an estimated 50 to 75 million ac-ft, has a longer life but perhaps still within this century.

Implications for Agriculture

Agriculture has changed markedly over the past 30 years in the region, primarily characterized by significant increases in pecan production and less production of less profitable annual crops, especially cotton. This has significant implications for water management and sustainable agriculture in the region. Pecans are perennials and represent a significant capital investment. They require water every year just to keep them alive, much less to optimize production. This makes cropping strategies for the region much less flexible. Our results show that if we were to experience a prolonged drought of 8-10 years, for example, current irrigation methods/limits would fail to meet the needs of pecans unless all other crops are removed from production in order to save pecan orchards.

As surface water for irrigation continues to dwindle, more use of groundwater will be required. As the aquifers in the region are depleted and water levels fall, it will become more and more expensive to pump groundwater, and the salinity of the groundwater that is being pumped will increase as saline water encroaches. This is clearly an unsustainable situation.

We evaluated a number of potential solutions to this increasingly dire situation. These solutions can be generally categorized as one or more of the following types of actions, described and briefly discussed below:

- Alternative sources of water - Use of treated wastewater is already in use for irrigation in our region. Another significant alternative source would be brackish water. Using our models, we evaluated pecan water use for two future dry conditions: a) irrigation with river water, fresh groundwater, and desalinated groundwater; this exemplifies a dry period where surface water is generally inadequate, and there is heavy reliance on groundwater, but desalination is available to treat saline groundwater for agricultural use; and b) irrigation with river water and fresh groundwater only; this exemplifies a dry period where surface water is generally inadequate, and there is heavy reliance on groundwater, which is also becoming more saline and thus its use is becoming more constrained. These results show that as groundwater becomes more saline in the future due to intrusion or upwelling of brackish groundwater, agricultural productivity will be decreased unless saline groundwater can be treated or replaced with alternate sources, either of which will be much more costly than present-day water supplies. We conducted a cost analysis of desalination in agriculture. Though technically feasible, the cost remains prohibitive for economically viable agriculture. Imported water is also of interest to irrigators but would be cost prohibitive at this time.
- Alternative methods of irrigation – Flood irrigation remains the predominant form of irrigation in our region. In terms of water use efficiency, flood irrigation is generally in the range of 65-70%. Most of the unused 30-35% percolates below the root zone, with about 5-10% being lost to evaporation. We have evaluated several improved irrigation methods including surge irrigation and drip irrigation. Drip irrigation can improve efficiency to 80-90% but has a significant capital cost. Furthermore, many irrigators are reluctant to adopt high efficiency irrigation methods such as drip irrigation because of salinity concerns. We compared rootzone salinity under four types of irrigation systems with irrigation water having an electrical conductivity (EC) of 1 dS/m. Results show that flood irrigation resulted in higher salinity in the root zone compared to drip or surge irrigation. The subsurface drip study is from a turf field and shows adverse impacts because salts accumulate at the drip line and migrate to the soil surface due to high evaporation, concentrating salinity at the soil surface. Surge or surface drip irrigation shows a lot of promise for decreasing total water use, especially when using groundwater as the source. Flood irrigation using surface water is not as efficient in terms of crop production, but the water "lost" to percolation is actually recharging the groundwater.
- Improved irrigation water management - A time-based method of scheduling irrigation is followed by most irrigators in our region and is based on simply counting the number of days since the last irrigation. By using evapotranspiration (ET)-based irrigation scheduling, our results show that at least two irrigations per season can be saved without reductions in yield. For example, with an estimated 15,000 acres under pecans in the El Paso County irrigation district and 5 inch/irrigation, 2 fewer irrigations translate into a potential water savings of 12,500 ac-ft per year. Furthermore, 2 fewer irrigations did not affect pecan nut yields. We also evaluated a novel irrigation management technique referred to as "partial rootzone deficit" (PRD) irrigation, where half of the tree root zone receives water but not the other half and alternates between each irrigation application so that much less total water is used. Nut yield was not improved by PRD but, in the second year of the study, individual nut weight was improved with early season deficit irrigation. These data suggest that 25% reduction irrigation water application during the early part of the growing season can have positive impacts on nut quality of drip irrigated pecan. PRD generally reduced leaf stomatal conductance and photosynthesis. But, in the second year of the study, early season water

deficit improved leaf gas exchange during the late growing season. Results show potential for this water management technique, especially in times of limited water availability.

- Improved salinity management - As groundwater becomes saltier, soil salinity builds up over time. Gypsum as a soil amendment improves the leaching of salt in soil because calcium sulfate is very effective at replacing sodium chloride. Using a "sulfur burner" is also effective in converting elemental sulfur to sulfate (through oxidation)which will form calcium sulfate in soil and, in turn, leach sodium salts from soil. This was shown to be an effective treatment for reducing salt in soil.
- Alternative crops – We evaluated several alternative crops to pecan, such as other perennials like pistachio, pomegranate, and switchgrass, and annuals such as energy sorghum, forage sorghum, and canola. Though these crops are generally adapted to our region, under current conditions they cannot compete economically with pecan.

<u>Implications for Urban Centers</u>
The urban centers are the biggest users of groundwater in the region. As groundwater sources are depleted, alternative sources will have to be "tapped" to meet growing demand, resulting in increased cost of water to residents. In 2020, the cost of water for residents in El Paso was on the average only 1.3% of their annual income. In 2070, it is projected to be 4.4%. The greatest consumptive use in the urban environment, and thus the greatest opportunity for conservation, is outdoor vegetation and evaporation from bare soil. Reducing landscaping uses of water would be an effective way to reduce urban demand. Furthermore, urban centers can improve water sustainability and resiliency by reusing municipal wastewater, especially for drinking water supplies. Direct potable reuse of wastewater could reduce the amount of fresh groundwater pumping by cities, though it is a very expensive alternative.

<u>Implications for Environmental Uses</u>
Historically, almost no surface water has been allocated to serve environmental needs in the region, and environmental uses of water remain one of the greatest deficiencies in water policy. The U.S. Boundary and Water Commission (IBWC) has proposed periodic pulse flows in times of ample supply to flood riparian areas to encourage riparian vegetation. We evaluated the water requirements for pulse flows every 5-10 years. This strategy would require relatively small amounts of water, amounting to generally less than 2% of the total annual flow in any one year.

Our Conclusions and Recommendations

1. "Business as usual" is not sustainable in the Middle Rio Grande Basin; water management across all sectors and jurisdictions must be improved to realize a more sustainable future.
2. Both for agriculture and urban uses, several alternatives are possible, but all are costly, some more than others. Water will become more expensive for all users as these alternatives are implemented.
3. On a larger regional and jurisdictional scale, a new approach is called for, one based on "adaptive cooperation", among sectors and across jurisdictions. Adaptive cooperation is needed across four important themes: a) information sharing, b) conservation, c) greater development and use of alternative water sources (*e.g.*, brackish groundwater desalination and municipal wastewater reuse), and d) new limits to water allocation/withdrawals coupled with more flexibility in uses.