Rio Grande Salinity Management Program: Preliminary Economic Impact Assessment

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DISCLAIMER

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Preliminary Economic Impact Assessment Report Contact

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EXECUTIVE SUMMARY

For purposes of this analysis, economic impacts from salinity were estimated for current users of surface water in the Rio Grande basin extending from San Acacia, New Mexico, continuing through the urbanized areas of Las Cruces, New Mexico and El Paso, Texas to Fort Quitman, Texas. This *study area* includes the agricultural areas of Socorro County New Mexico, the Elephant Butte Irrigation District in Sierra and Doña Ana Counties New Mexico, the El Paso County Water Improvement District #1 in El Paso County Texas, and the Hudspeth County Conservation and Reclamation District #1 in Texas. The urban areas included customers of El Paso Water Utilities (EPWU) and their bulk contract water supply customers of the lower valley. There are a number of other urban areas, but they do not use Rio Grande surface water.

High concentrations of dissolved solids (also expressed as salinity) in the Rio Grande basin, are a major concern for water resource managers and water users. The elevated salinity concentrations adversely impact agricultural production, residential, commercial and industrial water users, as well as have environmental consequences. Many sources contribute to the high concentrations of dissolved solids in this 270 mile reach of the Rio Grande. Contributing sources include discharge of subsurface saline groundwater, agricultural return flows, municipal wastewater discharges, and atmospheric deposition. The problems associated with high salinity take on greater importance as rapid urban growth increases water demand.

The Rio Grande Compact Commission, in collaboration with local water management entities, initiated a three state effort resulting in the creation of the *Rio Grande Salinity Management Coalition* (RGSMC) in January 2008. The RGSMC is composed of the Rio Grande Compact Commissioners from Colorado, New Mexico, and Texas, state water management agencies, local water utilities and irrigation districts, and university research organizations (see Appendix A for a list of Coalition members). The overall objectives of the RGSMC program are to better understand salinity concentrations, loading sources, and impacts in the Rio Grande basin from San Acacia, New Mexico to Fort Quitman, Texas, and to ultimately reduce salinity concentrations, increasing usable water supplies for agricultural, urban, and environmental purposes.

The focus of this initial phase of the RGSMC program is the compilation of existing salinity data and studies and development of baseline salinity and hydrologic information conducted by the Texas and New Mexico State Offices of the U.S. Geological Survey. This baseline information is documented in a separate report. A preliminary assessment of the economic impacts of salinity in the *study area* is the subject of this report.

The assessment process used for this study involved the review and evaluation of previous studies and impact assessment methods on agricultural and municipal salinity effects and economic damages in other areas. Applying the relationship between damages and saline concentrations (development of salinity-water use physical and economic impact functions), this study focused on acquisition and analysis of existing information on salinity concentrations and water use by economic sector in the *study area*.

Economic impacts attributable to salinity of Rio Grande water were estimated for residential, agricultural, municipal, and industrial uses within the *study area*. Impact issues addressed by this study include who is being affected and the types of economic impacts, the magnitude of economic damages overall and by user category, and threshold-effect levels for different types of water use. Economic impacts included reductions in agricultural yields, reduced appliance life, equipment replacement costs, and increased water use due to salinity (leaching) and associated increased costs.

This preliminary assessment of the economic impacts of salinity in the RGSMC *study area* is based on damage functions and calculation methods applied in previous studies in other areas and existing data and information for the *study area*. The use of previous studies and existing data is due in large part to the lack of region specific damage functions. Thus, the preliminary impact estimates in this study are preliminary and have significant limitations.

A number of additional economic impacts are not reflected in these estimates. Salinity damages that are not estimated in this preliminary study include: (1) higher value crop production that could be adopted with lower salinity (farmers have adapted over time by producing salt tolerant crops many of which are lower in value), (2) future urban growth and increasing urban use of surface water, (3) opportunity cost of not using all available water such as limitations on water reuse due to elevated salinity, (4) replacement cost of water when treatment plants shut down due to salinity concentration exceeding drinking standards, (5) environmental impacts, (6) agricultural and urban salinity damages during the low-flow season when no water is released from Rio Grande Project reservoirs, (7) variability in salinity concentrations and chemical components over the water delivery season, (8) damages from potential further increases in levels of salinity, and (9) Mexican and downstream impacts. Because these additional economic impacts are excluded from the preliminary assessment, the salinity damages estimated herein are an underestimate but provide insight on the extent of the problem.

Further, the estimated damages are for the current population and also do not account for other cities moving toward a greater use of Rio Grande water. The populations in Texas and New Mexico are projected to double within 50 years, while Ciudad Juárez is expecting to double its population within 20 years (Paso del Norte Water Task Force, 2001). Several cities in the region, including Hatch and Las Cruces, NM and Ciudad Juárez, MX, are planning for the use of Rio Grande surface water for municipal and industrial purposes. The future growth in population and increased use of Rio Grande water for urban supplies would result in higher economic impacts.

The total economic damage (cost) from Rio Grande salinity of those items included in this preliminary estimate is estimated to be about $10.2 million per year. Urban economic impacts account for 76% of total damages and agricultural damages account for the remaining 24% of total damages. The highest single category of damages is residential, 42% of the total, followed by agricultural, commercial, and urban landscape. The estimated economic damages are summarized in Table E-1 by dollar value and percent of total under different user categories. While most of the estimated damages are urban, damages in agriculture are significant.

Irrigated agricultural damages by study area location were estimated as follows: Socorro ($158k), Sierra ($166k), Doña Ana ($1,195k), El Paso ($667k), and Hudspeth ($239k). All of the urban, commercial, industrial, and landscape damages occur in El Paso.

Table E-1 Summary of economic damages from Rio Grande salinity by water user category

Type of Use	Damage	Percent
Agricultural (all counties)	$2,424,935	24%
Urban - El Paso County		
Residential	$4,300,712	42%
Landscape	$1,187,516	12%
Commercial/Other	$1,761,402	17%
Industrial/Large Users	$343,903	3%
Treatment Plants	$134,844	1%
Total	$10,153,312	100%

The economic benefits of reducing salinity were estimated for two scenarios (Table E-2). First, if a 200 mg/L TDS reduction in surface water salinity at the New Mexico/Texas stateline could be made, the economic benefit is estimated to be approximately $4.82 million per year with $4.76 million of the benefits accruing to El Paso County urban water users and $64k in Hudspeth County agriculture. Second, if a 200 mg/L TDS reduction in surface water salinity at San Acacia, NM could be made and continued through to Fort Quitman, TX, the economic benefit is estimated to be approximately $5.0 million per year with $4.76 million of the benefits accruing to El Paso County urban water users and $227k to Socorro, Sierra, Doña Ana and Hudspeth County agricultural users.

Table E-2 Summary of economic benefits of reducing Rio Grande salinity

Type of Use	Reduction at the NM/TX stateline	Reduction at San Acacia
Agricultural	$64,024	$226,766
Urban - El Paso County	$4,758,944	$4,758,944
Total	$4,822,968	$4,985,710

Recommendations to complete significant economic impact information gaps, which are believed to substantially underestimate impacts, and to refine the assessment analysis to improve evaluation of potential salinity management control alternatives are listed below:

1) Assess the economic damages in agriculture from the inability to grow higher value crops suitable to this climate and soils because of current salinity concentrations.

2) Estimate future economic damages resulting from the projected growth in population in the study area and associated increase in urban use of surface water.

3) Evaluate water supply opportunity costs of reduced reclaimed water use due to physical issues and consumer acceptance problems attributed to elevated salinity.

4) Estimate the water replacement cost impacts when treatment plants must be shut-down due to salinity exceeding drinking water standards.

5) Estimate economic damages to agriculture and urban use from salinity during the low-flow season when no water is released from Rio Grande Project reservoirs.

6) Revise and refine estimates of salinity damages as needed for the five main river reaches using the Phase 1 hydrologic salinity concentration results.

7) Evaluate the economic benefit of selected, screened salinity control management alternatives.

INTRODUCTION

Study Area

For purposes of this analysis, economic impacts from salinity were estimated for current users of surface water in the Rio Grande basin extending from San Acacia, New Mexico, continuing through the urbanized areas of Las Cruces, New Mexico and El Paso, Texas to Fort Quitman, Texas. Zones in this study area included the agricultural areas of Socorro County New Mexico, the Elephant Butte Irrigation District (EBID) in Sierra and Doña Ana Counties New Mexico, the El Paso Water Improvement District #1 (EPWID#1) in El Paso County Texas, and the Hudspeth County Conservation and Reclamation District #1 (HCCRD#1) in Texas that utilize Rio Grande surface water (Figure 1 and Table 1). The urban areas included customers of El Paso Water

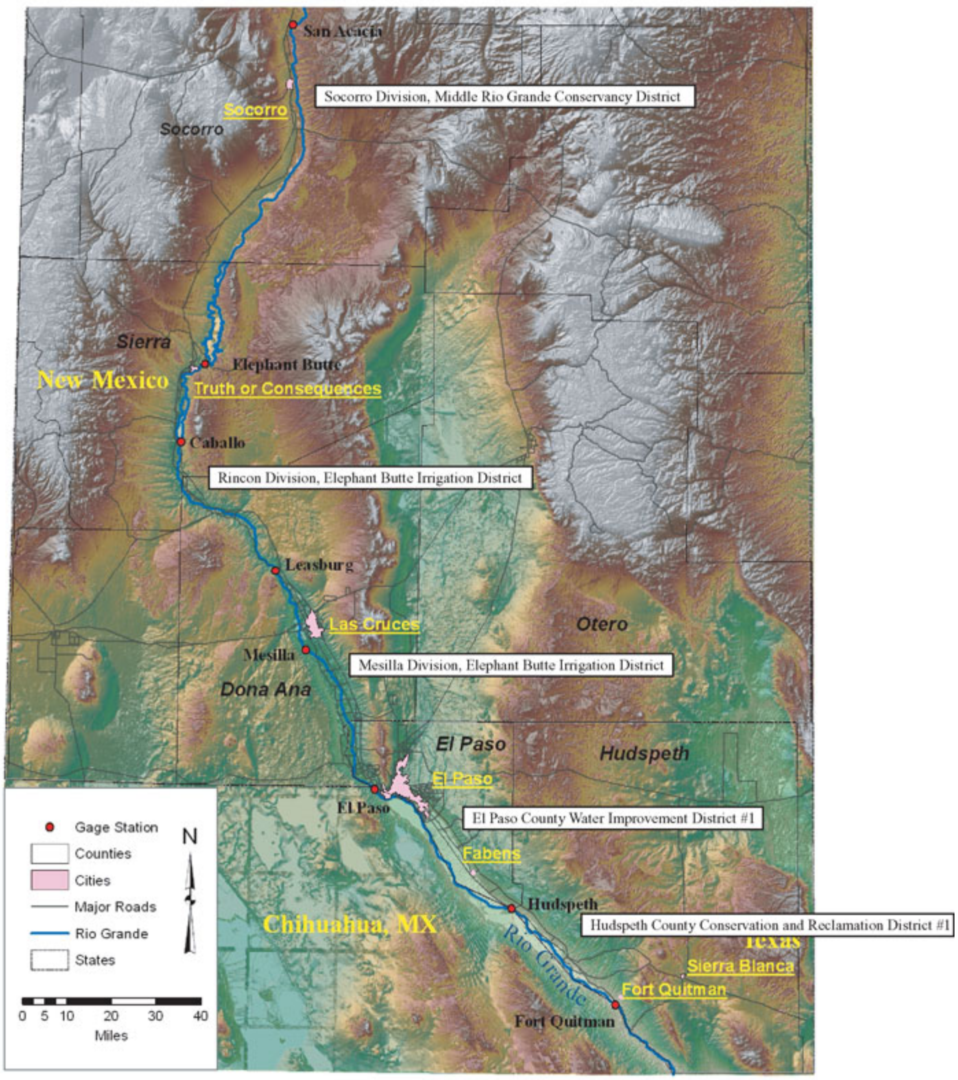

Figure 1 Study area showing selected gauge stations, communities, and agricultural areas.

Table 1 Study area damage estimate zones

Zones	State	Urban	Agriculture
Socorro County	NM	No	Yes
Sierra County	NM	No	Yes
Doña Ana County	NM	No	Yes
El Paso County	TX	Yes	Yes
Hudspeth County	TX	No	Yes

Utilities (EPWU) and their bulk contract water supply customers of the lower valley. There are a number of other urban areas, but they do not use Rio Grande surface water at the present time.

The Rio Grande depends on mountain snowpack runoff, upstream water diversions and reservoir releases, and urban and limited agricultural return flows. The river flows at San Acacia include releases of water from a number of upper basin reservoirs (Heron, El Vado, Abiquiu, and Cochiti). The river flows below Caballo Reservoir are controlled by the release of water from the two lower basin reservoirs (Elephant Butte and Caballo Reservoirs) (Figure 1). Flows below Caballo Reservoir are usually high during the irrigation season (typically March through mid-October) and very low, with no releases from the reservoirs, during the non-irrigation season (November through February). Flow at the Hudspeth canal heading fully depends on agricultural return flows from EPCWID#1 and municipal and wastewater treatment discharge in El Paso County. For a normal year, U.S. Bureau of Reclamation releases 790,000 acre-feet of water from the Elephant Butte and Caballo reservoirs in compliance of Rio Grande Compact, including 60,000 acre-feet of water for Mexico according to 1906 International Treaty between the United States and Mexico. After combining with groundwater inflows and other return flows, approximately 930,000 acre-feet of water is delivered at the river headings for agricultural and urban water use in the area.

Over 90% of river water is used for agriculture. There is approximately 15,600 acres of water rights land in the Socorro Division, irrigated with diverted river water at San Acacia. The Rio Grande Project, consisting of the river reach between Elephant Butte Reservoir and the El Paso-Hudspeth County line, has 159,650 acres of farmland with water rights (90,640 acres in the EBID in New Mexico and 69,010 acres in the EPWID#1 in Texas). The HCCRD#1 has about 18,000 acres of potentially irrigable farmland below El Paso County, but the amount of cropped acreage is often much lower because of a lack of sufficient water quantity and quality. In a full water supply year, EPWU diverts approximately 60,000 acre-feet of surface water for processing at two treatment plants. This accounts for approximately 50% of the current total annual urban water supply. Additional detail is provided in the hydrology and economic impact estimation sections.

The current population in the overall study area region is approximately 2.3 million of which approximately 700,000 are in El Paso County, TX, 100,000 in Doña Ana County, NM, and 1.5 million in Ciudad Juárez, Mexico (Fullerton and Molina 2009). The populations in Texas and New Mexico are projected to double within 50 years, while Ciudad Juárez is expecting to double its population within 20 years (Paso del Norte Water Task Force 2001). Several communities in the region, including Las Cruces, NM and Ciudad Juárez, MX, are planning to use Rio Grande surface water for municipal and industrial purposes. The future growth in population and increased use of Rio Grande water for urban supplies will result in greater economic impacts and make the management and reduction of salinity concentrations in the river increasingly important.

High concentrations of dissolved solids (also expressed as salinity) in the Rio Grande basin, extending from San Acacia, New Mexico, continuing through the urbanized areas of Las Cruces, New Mexico and El Paso, Texas to Fort Quitman, Texas, are a major concern for water resource managers and water users. The elevated salinity concentrations adversely impact agricultural production, residential, commercial and industrial water users and have environmental consequences. Many sources contribute to the high concentrations of dissolved solids in this 270 mile reach of the Rio Grande. Contributing sources include discharge of subsurface saline groundwater, agricultural return flows, municipal wastewater discharges, and atmospheric deposition. The problems associated with high salinity take on greater importance as rapid urban growth increases water demand and drives changing urban, agricultural, and environmental conditions and water uses. During the irrigation season, the average salinity concentration of the river water over 60 years varies from 500 mg/L at San Acacia, NM to 835 mg/L at the diversion point for agricultural and urban use in El Paso County, and increases to 1,172 mg/L at Hudspeth Canal heading.

The Rio Grande Salinity Management Coalition

The Rio Grande Compact Commission, in collaboration with state and local water management entities, initiated a three state effort resulting in the creation of the *Rio Grande Salinity Management Coalition* (RGSMC) in January 2008. The RGSMC is composed of the Rio Grande Compact Commissioners from Colorado, New Mexico and Texas, state water management agencies, local water utilities and irrigation districts, and university research organizations (see Appendix A for a list of Coalition members). The overall objectives of the RGSMC program are to better understand salinity concentrations, loading sources, and impacts in the Rio Grande basin from San Acacia, New Mexico to Fort Quitman, Texas with a basic understanding of the situation, then move to reducing salinity concentrations to increase usable water supplies for agricultural, urban, and environmental purposes. The Rio Grande Salinity Management Program is planned to be conducted in four phases described below.

Phase 1 - Salinity Assessment

- Compile and integrate salinity source information
- Develop a baseline salinity budget
- Determine critical data and information gaps needed to develop salinity management alternatives and assess benefits
- Develop preliminary estimates of the economic impacts of elevated salinity in the study area
- Develop phase 2 scope of work

Phase 2 - Develop Salinity Management Alternatives

- Alleviate information gaps, devise and install monitoring systems as needed
- Conduct a detailed assessment of environmental salinity impacts

- Conduct a detailed assessment of economic damages and benefits to residential, agricultural, municipal, and industrial sectors based on local conditions
- Develop and evaluate potential salinity management strategies
- Identify the most promising methods and locations for salinity control projects
- Conduct feasibility and cost analyses for identified salinity control projects
- Develop work scopes to conduct phases 3 and 4

Phase 3 – Conduct Pilot-scale Salinity Control Project Testing

- Implement feasible pilot-scale salinity control projects
- Monitor and evaluate pilot-scale salinity control and cost effectiveness
- Identify and develop implementation plans for projects determined to be effective
- Develop scope of work for phase 4 salinity control project implementation

Phase 4 – Expanded Scale Control Project Implementation, Monitoring and Evaluation

- Implement expanded scale salinity control projects found to be effective in pilot-scale tests
- Continuing monitoring and documentation of water quality improvements and salinity management benefits

The focus of the initial Phase 1 portion of the RGSMC program is the compilation of existing salinity data and studies and development of baseline salinity and hydrologic information conducted by the Texas and New Mexico State Offices of the U.S. Geological Survey (documented in a separate report). In addition, Phase 1 includes a preliminary assessment of the economic impacts of salinity in the study area, the subject of this report.

The Economic Assessment Process

The economic assessment process used for this study involved review and evaluation of previous studies. This included review of impact assessment methods for agricultural and municipal salinity effects and economic damages in these other regions. In addition, existing information on salinity concentrations and water use by economic sector in this study area were gathered and analyzed. This led to the development of salinity-water use physical and economic impact functions, and estimation of economic impacts by sector.

Impact issues addressed by this study include who is being affected and the types of economic impacts, the magnitude of economic impacts overall and by user category, and threshold-effect levels for different types of water use. Economic impacts include reductions in agricultural yields, reduced appliance life, equipment replacement costs, and increased water use due to salinity (leaching) and associated increased costs. Results of this and subsequent economic analyses will provide insight on what salinity reduction control measures are feasibly and could be pursued.

A first step in economic valuation of salinity impacts is the identification and quantification of physical impacts. The next step is economic valuation of these physical impacts. There are relatively few studies that have addressed the physical impacts or the valuation of salinity impacts. This section discusses types of salinity impacts and reviews previous literature on salinity damages with the focus on economic impact assessment and the methodologies used in this analysis. Not included in any studies are decisions by industry to not locate in a region due to the high salt concentration.

Types of Salinity Impacts

This preliminary assessment of the economic impacts of salinity in the study area is based on damage functions and calculation methods applied in previous studies in other areas and existing information. The use of previous studies and existing data is due in large part to the lack of region specific damage functions and information needed to conduct a more comprehensive and site specific analysis.

Thus the preliminary impact estimates in this Phase 1 study are just that, preliminary, and have significant limitations. The authors of this study believe the lack of information and limited preliminary assessment scope resulted in substantially underestimating actual salinity impacts in the region. It is important to note that because of the preliminary scope of this study a number of additional economic impacts are not reflected in the estimates developed in this study. Salinity damages not estimated in this preliminary study include: (1) higher value crop production that could be adopted with lower salinity, (2) future urban growth and increasing urban use of surface water, (3) opportunity cost of not using all available water such as limitations on water reuse due to elevated salinity, (4) replacement cost of water when treatment plants shut down due to TDS concentration, (5) environmental impacts, (6) salinity damages during the return/low-flow season when no water is released from Rio Grande Project reservoirs, (7) variability in salinity concentrations over the water delivery season, (8) damages from potential further increases in levels of salinity, (9) Mexican and downstream impacts, and (10) the issue of climate change and its implications on future surface water availability and salinity levels. Because these economic impacts were excluded from this preliminary assessment, the salinity damages estimated herein are an underestimate but provide insight on the extent of the problem. Recommendations to capture excluded or underestimated economic impacts are provided in the Conclusions and Recommendations section of this report.

The majority of salinity damage literature focuses on the impact on irrigated crop production. However a few studies have expanded analysis to larger portions of river basins and the effects on both agricultural and urban water users of increasing salinity in surface water. All of the studies classify the economic impact of water with elevated salinity levels into similar categories:

(1) reduced yields and increased water use for leaching salts in agriculture,
(2) reduced life of residential water-using appliances,
(3) commercial and industrial costs in various processes impaired by salinity in water,
(4) increased water use and costs to maintain urban landscapes,
(5) avoidance of salinity impacts by purchase of dispensed water or water softening systems,
(6) degradation of pipes, water delivery systems and water treatment facilities, and
(7) environmental impacts (analysis not performed in previous studies).

Agriculture has economic damages as a result of reduced crop yields, increased water application to leach salts out of the root zone from previous irrigation and inability to grow high value, less salinity tolerant crops. Residents incur costs in more frequent replacement of water-using household appliances and expenses associated with water softeners and even home based reverse osmosis systems. Commercial industry bears many of the same costs as residential, but with more intense damages given the high dollar value of equipment and associated volume of water use. Industry incurs increased costs to remove salts from the water used in manufacturing and damage to equipment. There are additional damages to urban landscapes such as home, business, park, and general vegetative cover. Local government facilities such as schools also incur damages. In short everywhere water is used, higher salinity concentration decreases the effectiveness of water application and decreases the useful life of appliances and plumbing that convey and use water.

Previous Economic Assessment Studies

There are two major studies that have focused on the physical and economic damages caused by elevated salinity levels in the Lower Colorado River, which serves as a water supply for extensive areas of Southern California, Nevada, and Arizona (Lohman et al. 1988) by the Milliken Chapman Research Group, Inc (cited hereafter as Milliken Chapman) and Metropolitan Water District of Southern California and U.S. Bureau of Reclamation, (MWD/USBR 1999). Another study, the Central Arizona Salinity Study (CASS) on the impacts of salinity from Central Arizona Project (Colorado River) and Salt River Project water, was completed in 2003. These studies follow a progression in that each analysis extensively employs the methodologies used in the previous study. Thus, the CASS analysis (the most recent) incorporates the work of MWD/USBR (1999) and Milliken Chapman (1988). In particular, a common basis of all three of these studies is the use of the original Milliken Chapman coefficients of urban municipal and industrial salinity physical damage of appliance and equipment estimates with relatively little modification. Summarizing the CASS (2003) study, the high salinity levels in river and groundwater used to supply urban systems cause detrimental economic impacts to residents, business (both commercial and industrial), local government facilities and agriculture.

The MWD/USBR work (1999) is an extensive study that included several aspects of salinity damage and an emphasis on MWD operations to blend different sources of water to achieve a water quality goal of 500 mg/L TDS delivered within its service territory. The MWD is the major provider of water for Southern California. MWD has two primary sources of water; the State Water Project (SWP) water imported from northern California and Colorado River Water (CRW). It acts as a "wholesale" supplier of water from these two sources. MWD accounts for 55% of the total water supply in the metropolitan areas of Southern California. The scope of the study reflects MWD's significant resources in analyzing their vast operations. The MWD study divides water delivery into 15 sub areas. Each sub area is characterized by its own blend and socio-economic characteristics. This does not mean that the MWD did not employ simplifying assumptions. For example, the study employs commercial and industrial ratios of water use to residential use to fill in the damage estimates for each sub area, but the overall scope makes this a definitive study. There are several significant results of the MWD study. First, the MWD study estimates a damage amount of $95 million dollars for every incremental increase of 100 mg/L TDS in source water. For the 2.45 million acre feet (MAF) total supplies from SWP and CRW at the time of the study, this amounted to an estimated damage of $0.386 per mg/L TDS per acre-foot from salinity. Second, the MWD incurs significant costs to achieve its 500 mg/L TDS goal and it is only possible about 70% of the time. A simple blend equation using 700 TDS for Colorado River water at 1.2 MAF and 275 mg/L TDS for the 1.2 MAF of State Water Project water indicates a resulting blend of 490 mg/L TDS, approximately the goal, but there are also considerable constraints and variability in supply and quality of both source waters. Because of this, MWD will often purposely not use a full allocation of less expensive Colorado River water to achieve the blend goal of water quality.

The Central Arizona Salinity Study (CASS 2003) employed the methodology and physical damage coefficients developed in the MWD/USBR analysis, but modified these for conditions in the Phoenix and Tucson metropolitan and surrounding areas. The CASS Technical Committee (the technical committee consisted of stakeholders, such as Arizona Department of Water Resources (ADWR), Arizona Department of Environmental Quality (ADEQ), consultants, private citizens, and various central Arizona communities) building on what MWD had accomplished, revised the model further by only focusing on central Arizona and incorporating factors inherent in or common to central Arizona.

As with MWD, the CASS study focused on the quality of surface water sources; Colorado River water delivered through the Central Arizona Project (CAP) and the waters from the Salt River Project (SRP) which includes the Salt and Verde Rivers (traditional sources of water for the Phoenix area along with groundwater). Though Tucson was included in the study, the impact of surface water salinity is minor as Tucson does not directly use CAP water (see below), rather the City injects CAP allocated water into aquifers for future recovery. At the time of the CASS study, Tucson was just beginning to use injected and mixed CAP and groundwater (CASS 2003, p. 5-6). The majority of damage in the CASS study comes from surface water delivered to the Phoenix metro area, (93% of total damages), and the remaining damages result from increases in salinity in agricultural use of CAP water. The CASS study estimated damages $28 million dollars per year in the Phoenix metro area for every incremental increase of 100 mg/L TDS. For the 1.4 MAF total supply of Central Arizona Project and Salt River Project water delivered to the Phoenix area, this translates to $0.198 per mg/L TDS damages per acre-foot from salinity.

The difference in damage estimates between the CASS and MWD studies ($0.198 per mg/L TDS per acre-foot versus $0.386 per mg/L TDS respectively) involves the amount of water used in agriculture and the types of crops grown in each area. Within the Phoenix metro area, 47% of total water supply is used in agriculture (CASS 2003, Table E-2). For the MWD service area, 14.7% of total water supplies are used in agriculture (MWD/USBR 1999, Technical Appendix 11, Table 1). In these areas, agriculture was found to have lower total damage costs associated with salinity than urban use.

MWD has considerable infrastructure costs to achieve TDS water quality blending goals. This attests to the priority that MWD attaches to providing water at or below 500 mg/L TDS. Urban water providers have experienced adverse and often unexpected consequences of replacing existing water supplies with new sources of differing salinity. This was the case with the Tucson water system. Because of limited groundwater resources and land subsidence, Tucson water officials actively sought and obtained Central Arizona Project (CAP) water from the Colorado River. The introduction of CAP water into the previously groundwater based Tucson system created serious unanticipated issues in the distribution system and with public acceptance. The new chemical mix precipitated out pipe scale resulting in brown water (harmless but unacceptable to Tucson residents) and there was public outcry regarding both water color and a different taste associated with the different salinity concentration of CAP water. The very costly solution implemented was to inject the CAP water into aquifers to replenish depleted groundwater supplies rather than use CAP water directly. The CAP water would then mix with the groundwater and hopefully have a more favorable mix of chemical characteristics.

For salinity damage estimation, these previous analyses used two approaches to deal with the difficulty in separating the distribution of different water sources and salinity concentrations. The CASS (2003) study calculated a blended TDS concentration based on relative weights of the aggregate amounts of sources water. The MWD/USBR (1999) study divided urban water use into sub areas served by different sources of water (area specific source water) and separately estimated damages to these regions by use category.

Any level of salinity can be considered an impairment of water quality, however previous studies have chosen to measure damage above a threshold level of salinity concentration through incremental changes of salinity in source water. As the focus of these studies was either the benefits of salinity reduction or the cost of further impairment of source water, both MWD and CASS used as a baseline existing salinity levels and damages at their own locations. Then, damages associated with either increased or decreased concentrations were estimated, usually in units of 100 mg/L TDS. The use of a baseline is mostly for methodological convenience, the underlying salinity damage equations all relate absolute damages levels to the level of TDS (Tihansky 1974, Black and Veatch 1967). The Milliken-Chapman study used 500 mg/L TDS as the baseline against which to measure salinity damage (Lohman et al. 1988). Selection of a baseline level is not as important as may first appear if the primary purpose is to estimate economic impacts or benefits of changes in salinity concentration. The overall damage functions used in all studies are remarkably linear, mostly due to a lack of information about physical damages in urban water uses over a range of salinity concentrations. Thus, with the available linear damage functions, incremental damage from a 100 mg/L increase or decrease in TDS is often, although not always, constant. One exception is costs that result from meeting goals or environmental regulations on salinity. The MWD/USBR study notes the extensive efforts of MWD to meet a goal of blended water of 500 mg/L TDS. Costs incurred to stay within a fixed limit may be nonlinear.

Agricultural impact thresholds were handled differently. Though the two reports used a baseline of zero damages at the existing salinity levels, the agricultural damage assessment, based on the amount of leached water required to mitigate salinity and the potential yield reduction, was proportional to the absolute amount of TDS in the water, i.e. was not calibrated to a baseline.

For this preliminary assessment of the economic damages of higher salinity concentrations in the Rio Grande, the methods employed in both the MWD and CASS studies were utilized along with as much local existing information. The following section describes the hydrology, salinity and water use conditions of the study area followed by sections that provide a more detailed discussion of the methodology used for the economic impact assessment, the results of the economic assessment impacts, and conclusions and recommendations.

HYDROLOGY, SALINITY AND WATER USE

Physical and associated economic impacts from salinity concentrations of the Rio Grande were estimated for current users of surface water in the Study Area. These include agricultural and urban users from San Acacia, NM to Fort Quitman, TX (the southern termination point of the Rio Grande Compact). At this time agriculture is the only surface water user from San Acacia to Doña Ana County and the dominant user of surface water in El Paso and Hudspeth Counties. While there are plans to expand Rio Grande surface water use for urban supplies in the study area in the future, at present urban users are supplied by El Paso Water Utilities (EPWU) and bulk El Paso Water Utilities contract water supply customers in Far West Texas above Fort Quitman.

Study Area Water Allocation Compact, Treaty and Delivery Infrastructure

Management of the Upper Rio Grande is based on the three State 1938 Compact (allocation of water between Colorado, New Mexico and Texas), the 1906 Treaty between the U.S. and Mexico, and water allocation and operating rules under the Rio Grande Project contracts.

Signed in 1938, with Colorado, New Mexico, and Texas as parties and approved by Congress in 1939, the Rio Grande Compact apportions the waters of the Rio Grande above Ft. Quitman, Texas, among the three states. It provides for administration by a commission consisting of the state engineers of Colorado and New Mexico, a commissioner appointed by the Governor of Texas, and a representative of the United States.

The Compact sets forth the obligations of Colorado to deliver varying amounts of waters to New Mexico at the Colorado/New Mexico state line. The Compact as modified in 1948 sets forth New Mexico's obligation to deliver to Texas varying amounts of waters at Elephant Butte Reservoir. Given the variable climate, it provides for debits and credits to be carried over from year to year until extinguished under provisions of the compact. The Compact Commission requires the maintenance and operation of a series of stream gaging stations to determine the scheduled and actual delivery of water under the Compact.

Elephant Butte Reservoir completed in 1916, and Caballo Reservoir completed in 1938 have a combined storage capacity of 2.2 million acre-feet. The reservoirs were constructed to capture spring snowmelt flows and storage water released for agricultural irrigation season use. Releases are designed to conserve water supplies, resulting in reduced to little or no flow below the agricultural areas in El Paso in Texas, where there is no downstream obligation for water delivery. During the non-agricultural irrigation season, typically late October or November to February or early March, reservoir gates are closed and the flow of water in the river is from effluents of municipal treatment plants, groundwater inflows, agricultural return flows from drains, and runoffs from arroyos.

Flow in the Rio Grande between Caballo Reservoir in New Mexico and Fort Quitman in Texas is largely controlled by releases from Elephant Butte and Caballo Reservoirs. These two reservoirs and associated infrastructure of 5 diversion dams (Percha, Leasburg, Mesilla, American and

Riverside, of which the Riverside Dam was removed in 2003), 139 miles of canals, 457 miles of laterals, and 465 miles of drains are called the Rio Grande Project (Figure 1).

The Rio Grande Project was constructed by U.S. Bureau of Reclamation to provide surface water for agricultural irrigation in southern New Mexico and Far West Texas (El Paso County). The Rio Grande Project also provides water to comply with the 1906 treaty with Mexico in the amount of 60,000 acre-feet in a full supply year. Project lands occupy irrigable river bottom along the Rio Grande (U.S. Department of Interior, Bureau of Reclamation, 2007a). The Rio Grande Project has 159,650 acres of land with surface water rights (90,640 acres in the Elephant Butte Irrigation District in New Mexico and 69,010 acres in the El Paso County Water Improvement District #1 (EPCWID#1) in Texas). The Hudspeth County Conservation and Reclamation District #1, which is not part of the Rio Grande Project, has about 18,000 acres of potentially irrigable farmland below El Paso County and relies on agricultural return flow, municipal wastewater effluents and drainage water from the Rio Grande Project. Irrigated acreage actually in production in all three irrigation districts is less than the total amount of land with water rights and varies according to water supply availability, water quality and agricultural market conditions. Agricultural water use is discussed later.

Water in the Rio Grande Project was allocated 57% to farmers in the Elephant Butte Irrigation District in New Mexico and 43% to farmers in the El Paso County Water Improvement District No. 1 based on the proportion of total irrigable acreage within the project area. With the growth in El Paso City's population and urbanization of agricultural lands approximately 60,000 acre-feet of water per year have been converted to urban water use from EPCWID#1. In a full supply year 790,000 acre-feet of water are released from Elephant Butte and Caballo reservoirs including 60,000 acre-feet of water for Mexico in compliance of 1906 International Treaty. By combining with groundwater inflows, and other return flows, approximately 930,000 acre-feet of water is delivered at the river headings for agricultural and urban water use in the Rio Grande Project area. A new Rio Grande Project operating agreement was signed by Elephant Butte Irrigation District and El Paso County Water Improvement District #1 on February 14, 2008 and new procedures will be developed for allocating Project water supply to Elephant Butte Irrigation District and El Paso County Water Improvement District #1 (U.S. Department of Interior, Bureau of Reclamation, 2007b).

Characterization of the Rio Grande Flow

Upper Rio Grande flow is predominantly from spring run-off from snowpack in southern Colorado and northern New Mexico mountain ranges, which accounts for approximately 70% of river inflow. Monsoon season runoff from tributaries and arroyos, return flow from agricultural drains, effluents from wastewater treatment plants and groundwater inflows also contribute to the river flow. Rio Grande surface water is diverted into canals for agricultural irrigation or municipal water supplies. In this study, six monitoring stations were selected to represent water flows and salinity concentrations for the major river reaches and diversion points for water uses in the study area (shown in Figure 1). These stations and water uses for each section are listed below: (1) the gauge station at San Acacia above Elephant Butte Reservoir for agricultural use in Socorro County, NM, (2) the gauge station below Caballo Dam representing releases from Elephant Butte and Caballo Reservoirs for agricultural water use in that reach, (3) the gauge station at Leasburg, NM (a major agricultural diversion point), (4) the gauge station at Mesilla diversion dam (a major agricultural diversion point), (5) the gauge station at El Paso (Courchesne Bridge) just above the American Dam diversion (representing El Paso urban and El Paso County lower valley agricultural deliveries), and (6) the gauge station at Hudspeth Canal (representing agricultural deliveries to Hudspeth County).

Data Sources

Several flow and water quality data sources were evaluated and used in this analysis including: U.S. Geological stream gauge station data; U.S. Bureau of Reclamation historic records; data and reports (from 1934 to 1963) by L.V. Wilcox (1968), USDA Salinity Laboratory; data and reports (1969 to 1989) by S. Miyamoto (1995); Jerry Hugh Williams thesis (2001); and data developed for the El Paso-Las Cruces Sustainable Regional Water Project (Boyle and Parsons, 1996, 1998, 1999, 2000). All the raw data used in this report are complied in the U.S. Geological Survey (USGS) database and report (Moyer et al. 2009).

The monthly flow data were compiled for each year from 1908 through 2005 from U.S. Bureau of Reclamation, and Boyle and Parsons (1996). However, not all sites had data for all of these years. Monthly water quality data are based on data collected between 1934 through 1963 by Wilcox (1968) and data after 1963 compiled by Boyle and Parsons (1996) and Williams, 2001. Extensive gaps in observed water-quality data have occurred (Williams, 2001). Large amounts of water-quality data were collected from the Rio Grande at San Acacia, below Caballo Dam and Below Leasburg Dam, at El Paso from 1934 to 1963. Very limited water quality data from 1934 through 1947 are available for Hudspeth Canal heading. Since 1963, water-quality data have been collected sporadically. The extensive gaps in water-quality data and inconsistency in data available from site to site limit the ability to evaluate long-term changes in water-quality conditions.

International Boundary and Water Commission (IBWC) real-time flow data and Clean River Program water quality monitoring data, New Mexico Environment Department water quality monitoring data, Batsien (2009) and Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) project data from the University of Arizona were also reviewed. However, they were not used in this analysis due to inconsistency (different frequency and time) with the other data sources. Additional hydrologic and water quality data being compiled by USGS in a salinity database (Moyer et al. 2009) as a part of Phase 1 of the Rio Grande Project Salinity Assessment were not included because those data were still under development at the time of this study. Though not all the data compiled by USGS are used in this report, the results in this report are consistent with conclusions on flow and water quality as well as their spatial and temporal variations presented in the USGS report (Moyer et al. 2009). It is anticipated that better flow and salinity concentration information would allow improved economic impact estimates.

Study Area River Flow

Historic data show great spatial and temporal variations of both flow and TDS concentration. Statistical analyses were conducted for these six river reaches. Water flows in these reaches are summarized below.

The flow at San Acacia station is from the Upper Rio Grande basin flows and is high in late spring and early summer and low in later summer and fall as shown in Figure 2. This is because flow in this area depends on mountain snowpack runoff, upstream water diversions and reservoir releases, and urban and limited agricultural return flows. Flows at the river gauge stations, below Caballo Reservoir, Leasburg diversion dam, and the El Paso County Water Improvement District No. 1 diversion at the American Dam, are controlled by the release of water from Caballo Reservoir and the main reservoir, Elephant Butte Reservoir just above Caballo. Flows below Caballo are high during the irrigation season (typically March through mid-October) and very low, with no releases from the reservoirs, during the non-irrigation season (November through February) as shown in Figure 2. Flow at the Hudspeth canal heading depends on agricultural return flows from El Paso County Water Improvement District No. 1 and municipal and wastewater treatment discharge in El Paso County (Figure 2).

Within the Rio Grande Project area from Elephant Butte Reservoir to the El Paso County Water Improvement District No. 1, river water is diverted for agricultural irrigation and municipal uses primarily during the irrigation season. During the non-irrigation season, the river collects return flow as well as wastewater discharge along the way, as demonstrated by higher flows at El Paso station than those at Leasburg. Non-irrigation season river return flows are usually not of sufficient quality for urban use and limit the types and yields of agricultural crops.

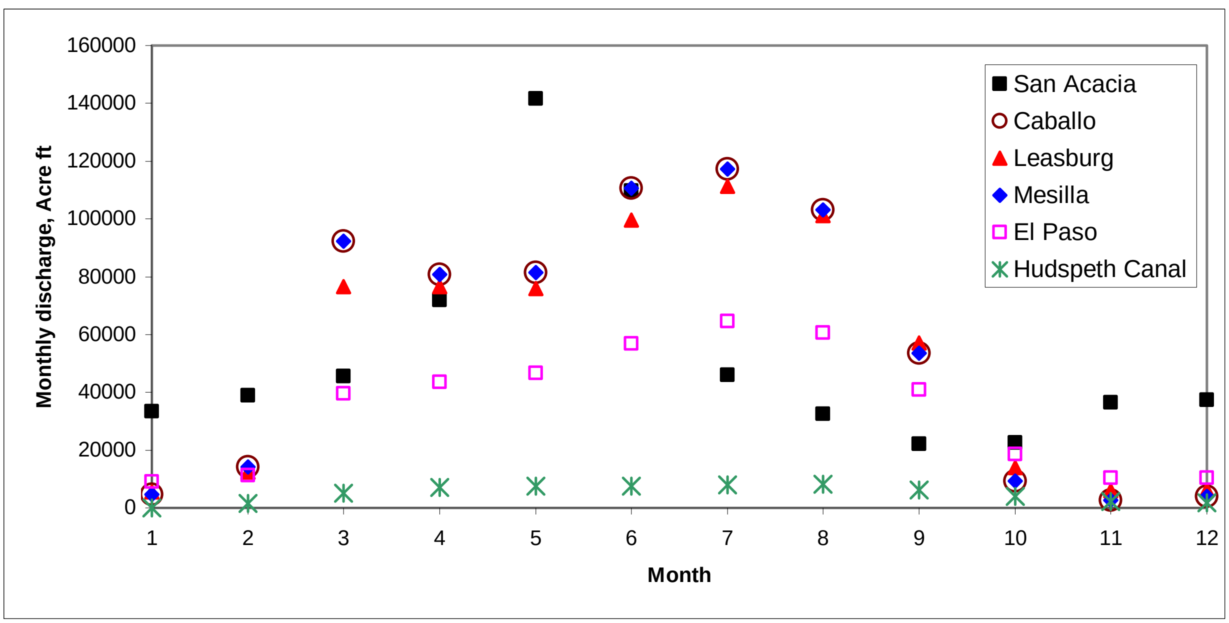

Figure 2 Average monthly discharges at selected gauge stations in the Study Area for the period of 1934 to 1993.

Spatial and Temporal Variation of TDS

The concentration of TDS in the Rio Grande increases as the river flows downstream. The salinity concentration varies widely depending on flow rate and other conditions. The river water quality at the San Acacia gauging station has been fairly stable, averaging between 400 to 500 mg/L except for elevated concentrations in August through October as shown in Figure 3. The increase in concentration is likely attributable to upstream water uses, such as return flow from agricultural irrigation, consumptive uses of river water by riparian vegetation and geologic conditions. The TDS concentration of river water at the gauge stations below Caballo, Leasburg, and El Paso is influenced by the release from the Caballo and Elephant Butte Reservoirs. TDS values are low during the irrigation season and high during non-irrigation season due to being controlled by poor quality return flows, wastewater effluents and groundwater inflows as shown in Figure 3. The TDS of the river water at the El Paso station is higher than those at upstream stations, which is attributed to poor quality of the return flows from drains, groundwater discharge and wastewater effluents. TDS at the Hudspeth canal heading is high, at 1,172 mg/L on average, even during the irrigation season (Figure 3). The results are consistent with conclusions of the USGS report (Moyer et al. 2009).

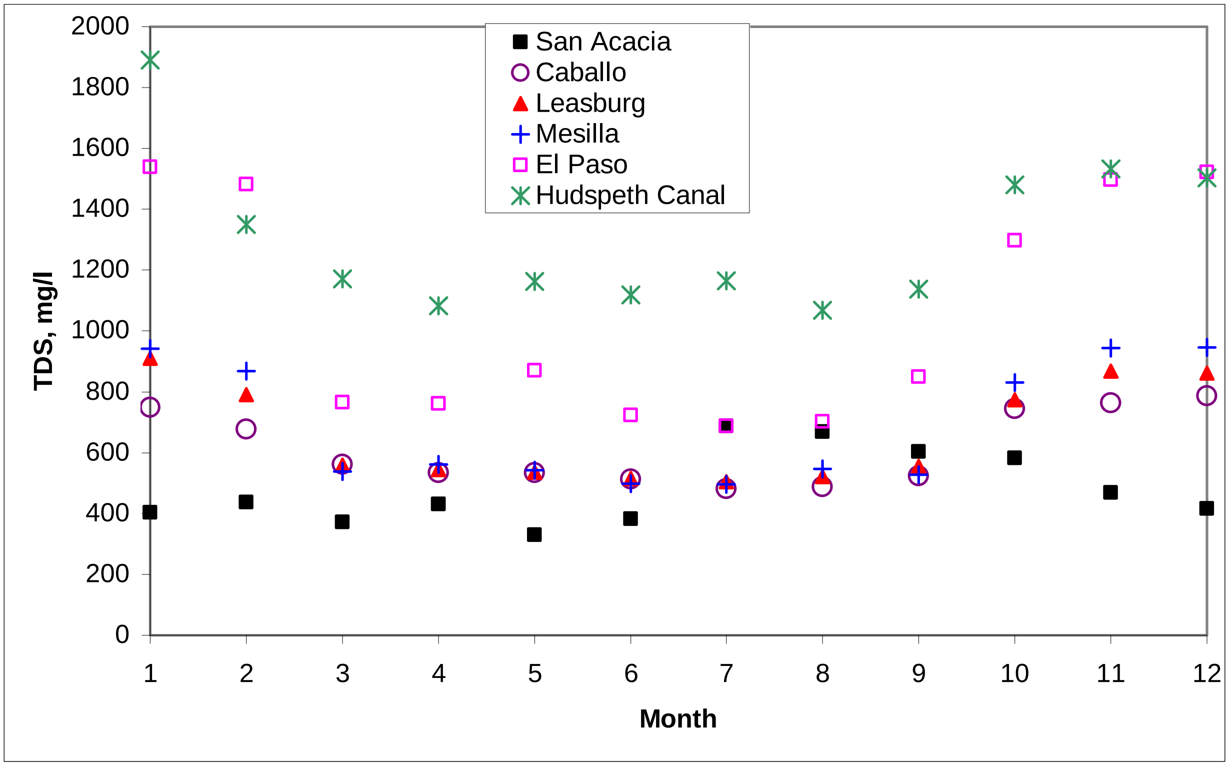

Figure 3 Average TDS of the river water for each month at different stations for the period of 1934 to 1993.

Statistical Analysis of Flow, TDS and Salt Load

Statistical analyses were performed on river flow rates and TDS concentrations at San Acacia, Caballo, Leasburg, Mesilla, El Paso, and Hudspeth Canal gauge stations. Flow and water quality data were divided into two seasons corresponding with typical Rio Grande Project water deliveries for agricultural and urban uses. The agricultural irrigation season extends from March through October, while the non-agricultural irrigation season is from November through February. During the non-agricultural irrigation season, the reservoir gates are closed and there is no release of water from the Rio Grande Project reservoirs to the river. During this time the only flow in the river from Caballo Dam, New Mexico to Fort Quitman, Texas is from agricultural irrigation return flows, urban wastewater treatment effluents, discharge of deep saline brines and shallow groundwater, and very limited winter precipitation. While these return flows are important, elevated salinity concentrations restrict agricultural and urban uses of this water. By far the majority of Rio Grande Project water use (88-96% of the annual total depending on location) is during the agricultural irrigation season. It is important to note that deliveries and damages from Rio Grande (Rio Bravo) salinity from water use in Mexico are excluded from this preliminary assessment.

Statistical Analysis Results

The preliminary statistical analysis results of the river flow and TDS at six gauge stations are summarized in Table 2. The average, maximum and minimum annual, seasonal and monthly flow rates and TDS were calculated for each station. These stations were selected for use in the preliminary economic assessment based on the major areas and types of water use, relatively uniform salinity concentrations within the river reaches between stations, and availability and reliability of data. The average salinity concentrations for the irrigation season at each gauge station were used in the economic impact assessment. The raw data availability at each gauge station is also noted in Table 2.

Station at San Acacia

The San Acacia gauge is about 78 miles north of the gauge below Elephant Butte Reservoir and is the highest upstream point of the region covered by this study. Agricultural irrigation is currently the only use of the Rio Grande surface water from the San Acacia gauge station. Recreation and environmental (wildlife and fish) water uses were not accounted for in this study.

The Rio Grande flow at San Acacia during the irrigation season varies between 3,645 and 2,444,801 acre-feet with an average flow of 486,643 acre-feet, which accounts for 77% of its annual average discharge of 631,553 acre-feet. Its average discharge during the non-irrigation season is 144,910 acre-feet, which accounts for 23% of its average annual discharge (Table 2).

The Rio Grande water TDS at San Acacia, during the irrigation season, varies between 125 and 2,140 mg/L with an average TDS of 500 mg/L. TDS during the non-irrigation season varies between 204 and 720 mg/L, with an average TDS of 435 mg/L (Table 2). High TDS during the irrigation season is expected to be due to groundwater discharge from Albuquerque basin.

Station below Caballo Dam

Caballo Dam is the lower of the two Rio Grande Project reservoirs. The Rio Grande flow below Caballo Dam during the irrigation season varies from 205,789 to 1,696,350 acre-feet with an average flow of 646,445 acre-feet, which accounts for 96% of its annual average flow of 672,013 acre-feet. Its flow during the non-irrigation season varies from 65 to 459,323 acre-feet with an average flow of 25,568 acre-feet, which accounts for only 4% of its total annual average flow (Table 2).

Table 2 Statistical analysis of flow rate, TDS, and salt load at selected Rio Grande stations

Station		Period	Volume (acre-feet)			TDS (mg/L)		
			Max	Min	Average	Max	Min	Average
San Acacia	Cumulative	Annual	2,838,027	5,210	631,553	2,140	125	486
	Cumulative	Irrigation season[1]	2,444,801	3,645	486,643 (77%)	2,140	125	**500**
	Cumulative	Non-irrigation season[2]	547,319	131	144,910 (23%)	720	204	435
		Month	309,000	0	12,058	2,140	125	485
		Raw data	Jan 1941 to Dec 1955 and Jan 1959 to Dec 2005			Jan 1944 to Dec 1955 and Jan 1967 to Dec 2003		
Caballo	Cumulative	Annual	17,958,590	206,082	672,013	1,146	310	612
	Cumulative	Irrigation season	1,696,350	205,789	646,445 (96%)	1,146	310	**550**
	Cumulative	Non-irrigation season	459,323	65	25,568 (4%)	1,139	340	749
		Month	412,400	6	56,160	1,146	310	612
		Raw data	Jan 1940 to Dec 1998			Jan 1940 to Dec 1966 & Jan 1980 to Dec 1993		
Leasburg	Cumulative	Annual	1,764,110	167,631	632,954	1,330	294	676
	Cumulative	Irrigation season	1,657,250	165,485	603,532 (95%)	1,242	294	**568**
	Cumulative	Non-irrigation season	460,752	0	29,422 (5%)	1,330	382	862
		Month	401,790	0	48,440	1,330	294	676
		Raw data	Jan 1934 to Dec 1995			Jan 1934 to Dec 1953, Jan 1958 to Dec 1963, & Jan 1980 to Dec 1995		
Mesilla	Cumulative	Annual	897,686	143,837	397,425	1,742	198	665
	Cumulative	Irrigation season	656,454	222,871	349,110 (88%)	1,507	198	**577**
	Cumulative	Non-irrigation season	425,103	10,813	48,315 (12%)	1,742	328	953
		Month	187,111	0	22,413	1,054	169	665
		Raw data	Jan 1986 to Dec 1991, Jan 1993 to Dec 2000, & Jan 2002 to Dec 2003			Jan 1980 to Dec 1991 & Jan 1993 to Dec 1994		
El Paso	Cumulative	Annual	1,539,000	57,481	411,853	3,832	370	1054
	Cumulative	Irrigation season	1,427,400	56,601	371,048 (90%)	3,199	394	**835**
	Cumulative	Non-irrigation season	481,728	791	40,805 (10%)	3,832	370	1,516
		Month	337,000	136	29,814	3,832	370	1054
		Raw data	Jan 1934 to Dec 1999			Jan 1934 to Dec 1993		
Hudspeth canal	Cumulative	Annual	80,290	38,980	60,298	2,287	507	1,253
	Cumulative	Irrigation season[1]	73,100	45,450	55,139 (91%)	2,251	507	**1,172**
	Cumulative	Non-irrigation season[2]	10,190	1,080	5,159 (9%)	2,287	655	1,477
		Month	11,580	0	4,915	2,287	507	1,253
		Raw data	Jan 1934 to Dec 1947			Jan 1934 to Dec 1947		

Notes: 1. Irrigation season is March through October. 2. Non-irrigation season is November through February.

The Rio Grande water TDS below Caballo Dam during the irrigation season varies from 310 to 1,146 mg/L with an average TDS of 550 mg/L, which can be compared to its median of 510 mg/L. TDS during the non-irrigation season varies between 340 and 1,139 mg/L with an average TDS of 749 mg/L, which is 199 mg/L higher than the TDS average during the irrigation season (Table 2). Water quality during the non-irrigation season is higher in TDS than during the irrigation season because, the majority of water during the non-irrigation season is probably from discharge of high salinity groundwater

Station below Leasburg Dam

The Rio Grande flow at Leasburg during the irrigation season varies between 165,485 and 1,657,250 acre-feet with an average flow volume of 603,532 acre-feet, which accounts for 95% of its annual average flow of 632,954 acre-feet. Its flow during the non-irrigation season ranges from 0 to 460,753 acre-feet with an average flow of 29,422 acre-feet, which accounts for only 5% of its average annual flow (Table 2).

The Rio Grande water TDS at Leasburg during the irrigation season varies between 294 and 1,242 mg/L with an average TDS of 568 mg/L, which can be compared to its median of 562 mg/L. Its TDS during the non-irrigation season varies between 382 and 1,330 mg/L with an average TDS of 862 mg/L, which is 294 mg/L higher than its average TDS during the irrigation season (Table 2). Water quality during the non-irrigation season has a higher TDS than that during the irrigation season because the majority of water during the non-irrigation season is return flow including groundwater discharge.

Station below Mesilla Dam

The river water is diverted above the Mesilla Dam through Westside and Eastside Canals for agricultural irrigation. The Rio Grande flow below Mesilla Dam during the irrigation season varies between 222,871 and 656,454 acre-feet with an average flow of 349,110 acre-feet, which accounts for 88% of its annual average flow of 397,425 acre-feet. Its flow during the non-irrigation season ranges from 10,813 to 425,103 acre-feet with an average flow volume of 48,315 acre-feet, which accounts for 12% of its average annual flow (Table 2).

The Rio Grande water TDS at Mesilla during the irrigation season is between 198 and 1,507 mg/L with an average TDS of 577 mg/L, which can be compared to its median of 551 mg/L. Its TDS during the non-irrigation season is between 328 and 1,742 mg/L, with an average TDS of 953 mg/L, which is 376 mg/L higher than its average TDS during the irrigation season (Table 2).

Station at El Paso

The Gage Station at El Paso is located at Courchesne Bridge (Figure 1). Water flow through the El Paso Station is used for agricultural irrigation in the Lower El Paso Valley and Mexico, and also for urban water supply for El Paso during the irrigation season when TDS and sulfate concentrations remain within drinking water limits, which are 1,000 mg/L TDS and 250 mg/L sulfate (EPA, 2009). The EPWU uses 300 mg/L as limit of sulfate (EPWU 2007).

The Rio Grande flow at El Paso during the irrigation season varies between 56,601 and 1,427,400 acre-feet with an average flow of 371,048 acre-feet, which accounts for 90% of its average annual flow of 411,853 acre-feet. Its flow during the non-irrigation season varies between 791 and 481,728 acre-feet with an average flow of 40,805 acre-feet, which accounts for 10% of its above annual average flow (Table 2).

The Rio Grande water TDS at El Paso during the irrigation season varies between 394 and 3,199 mg/L with an average TDS of 835 mg/L, which can be compared to its median of 819 mg/L. TDS during the non-irrigation season ranges from 370 from 3,832 mg/L with an average TDS of 1,516 mg/L, which is 681 mg/L higher than its average TDS during the irrigation season (Table 2). There is a 10% exceedance of TDS over 1,000 mg/L usually occurring at the beginning or end of the irrigation season, which could result in shutdown of the water treatment plants. During the non-irrigation season, TDS exceeds the 1,000 mg/L drinking water secondary limit much of the time.

Station at Hudspeth Canal Heading

The Gage station at Hudspeth Canal Heading monitors operation spills from El Paso County (Figure 1). Monthly flow and TDS data were complied from January 1934 to December 1947 without gaps. During that time period return flows from upstream may also flow through the Rio Grande after passing the Riverside Dam. After 1999, almost all of the return flows during the non-irrigation season were diverted through the American Canal Extension, flowing through Riverside Canal and Franklin Canal, eventually flowing into the Hudspeth Canal and returning to the Rio Grande above Fort Quitman, Texas. Agricultural irrigation is the only water use below the Hudspeth Canal Heading Station.

The total flow of the Hudspeth Canal during the irrigation season varies between 45,450 and 73,100 acre-feet with an average flow of 55,139 acre-feet, which accounts for 91% of its annual average flow of 60,298 acre-feet. Its flow during the non-irrigation season varies from 1,080 and 10,190 acre-feet with an average flow volume of 5,159 acre-feet, which accounts for 9% of its above annual average flow volume (Table 2).

The Hudspeth Canal water TDS during the irrigation season is between 507 and 2,251 mg/L with an average TDS of 1,172 mg/L. Its TDS during the non-irrigation season is between 655 and 2,287 mg/L with an average TDS of 1,477 mg/L, which is 303 mg/L higher than its average TDS during the irrigation season (Table 2). The TDS exceeded 1,000 mg/L approximately 60% of time during the irrigation season.

Water Use

Currently over 90% of Rio Grande water is used for agricultural irrigation in the Study Area. Surface water is used primarily for agricultural production at Socorro County (San Acacia), Rincon Valley, Mesilla Basin (Leasburg-Mesilla), and Hudspeth County. In El Paso County, surface water is used for both agricultural and municipal and industrial uses.

Agricultural Irrigation
Alfalfa is the dominant crop grown in Socorro County, New Mexico. Below Caballo in Sierra, Doña Ana and El Paso Counties, cotton, pecans and alfalfa are the major crops grown. In Hudspeth County cotton is the predominant crop. The crop acreages by counties are summarized in Table 3.

Table 3 Crop acreage by crop; Socorro, Sierra, Dona Counties, NM, El Paso and Hudspeth Counties, TX

	Socorro	Sierra	Doña Ana	El Paso	Hudspeth
Alfalfa	13,070	2,900	11,659	3,339	1,444
Barley	0	0	44	0	0
Berries	0	0	0	0	0
Chile	400	1,500	2,526	232	675
Corn	1,446	730	6,580	0	1,100
Cotton	0	110	13,128	22,592	10,141
Fruit/Orchard	30	30	13	0	0
Grapes	80	350	44	0	0
Other hay	400	0	0	854	0
Lettuce	0	10	1,193	167	0
Melons	20	0	37	0	0
Misc field	20	0	664	0	0
Misc sg	1,000	0	1,203	2,672	100
Misc veg	100	0	1,042	0	0
Nursery stock	0	0	21	0	0
Oil seed	0	0	0	0	0
Onions	0	600	3,167	927	0
Pasture	6,565	750	689	0	0
Peanuts	0	0	0	0	0
Pecans	0	380	18,587	10,525	0
Pistacios	0	3	0	0	0
Potatoes	0	260	0	0	0
Dry beans	0	0	0	0	0
Rye	40	180	0	0	0
Sod	0	0	0	0	0
Sorghum	0	0	134	0	0
Sugarbeets	0	0	0	0	0
Wheat	400	300	563	0	0
Total	23,571	8,103	61,294	41,308	13,460

Source: NM Office of State Engineer, Michelsen et al. 2009

Acreages within EBID were assigned by county. However Sierra County approximately matches up with the Caballo Dam diversion, while Doña Ana matches approximately with the Leasburg Dam and Mesilla Dam diversions. The water right acreage in Rincon Valley of EBID, Sierra County, New Mexico is 18,104 acres, while the Leasburg and Mesilla Dam diversions cover a total of 72,527 acres of water rights land in Doña Ana County, New Mexico and 10,834 acres in El Paso County, Texas. A total of 58,176 acres of water rights lands in located in the lower El Paso Valley. There is only 18,000 acres of water rights land in Hudspeth Texas.

Urban (El Paso) Supplies

The El Paso Water Utilities treats Rio Grande water for municipal use at the Canal Plant and Jonathan Rogers Plant. In a full water supply season, 50,000 to 60,000 acre-feet of river water is supplied for urban water use. This is approximately 50% of the total annual water supplied by El Paso Water Utilities. River water is delivered to the treatment plants by the El Paso County Water Improvement District No. 1. The water remains in lined canals essentially from the American Diversion Dam, which is located approximately 1.7 miles below the El Paso Station, to the treatment plants. Because of return flow and treated wastewater discharge, there is small increase in the average salinity concentration of water delivered to the lower Jonathan Rogers Water Treatment Plant. The salinity of the delivered water for each plant is shown in Table 4 and Table 5.

Table 4 EPWU delivered water historical salinity concentration (TDS, mg/L) at Canal Plant

	FY02-03	FY03-04	FY04-05	FY05-06	FY06-07	FY07-08	FY08-09
Minimum	605	665	575	455	467	577	450
Maximum	914	1020	895	742	1060	995	973
Average	698	**779**	684	573	642	680	627
Shut-down (days)		87	92				

Table 5 EPWU delivered water historical salinity concentration (TDS, mg/L) at J. Rogers Plant

	FY02-03	FY03-04	FY04-05	FY05-06	FY06-07	FY07-08	FY08-09
Minimum	577	689	615	447	506	603	493
Maximum	884	902	940	814	979	928	912
Average	707	**786**	726	623	681	711	654
Shut-down (days)		80	74				

For low flow years (2003-04 and 2004-05), salinity concentration of delivered water is higher than during normal flow years. During these dry years, the plants were shut down between 74 and 92 days because of lack of water and/or poor quality (high sulfate concentration) of water at both the beginning (March) and end (October) of irrigation season. This required EPWU to use alternative water sources. At that time, this was increased groundwater pumping. In some cases there were wells with well-head reverse osmosis units to bring the groundwater to drinking water standards. This is just one more example of impacts and costs of salinity. It should be noted that average salinity of water at El Paso station was used in salinity impact assessment in this preliminary study.

ECONOMIC IMPACT ASSESSMENT METHODOLOGY

This section outlines the methodology used to estimate salinity damages in the Study Area from the use of Rio Grande water. This preliminary assessment employs the methodology of the CASS analysis adjusted to Rio Grande Study Area conditions. The estimation methodology used for agricultural and urban damages are discussed. Urban damages are subdivided into residential, commercial industrial and urban landscape categories. The methodology, for agriculture, is similar to the CASS study, but is more detailed in accounting for crop yield reduction and salinity leaching costs. For the urban sector, the methodology uses CASS damage coefficients which are applied to Study Area demographics and conditions. Damages are estimated in 2007 dollars. The major methodological assumptions used are (1) TDS measurements of delivered surface water are used to estimate the current impact of salinity changes and associated damages and (2) a baseline salinity damage threshold value of 500 mg/L was selected as a point at which urban damages are estimated. Agricultural damages were estimated for the continuum of salinity impact but exclude damages from the inability to produce higher value, less salinity tolerant crops, a substantial and economically significant impact of water salinity concentrations.

For purposes of this analysis, damages from salinity were estimated for current users of surface water in the Study Area which includes the Rio Grande Project, the northern adjacent county of Socorro New Mexico and the southern Hudspeth County Conservation and Reclamation District #1 (technically not a part of the Rio Grande Project). Urban use includes customers of El Paso Water Utilities including their bulk contract customers of the lower valley and for agriculture. Salinity damages are estimated for Socorro, Doña Ana, and Sierra Counties in New Mexico and El Paso and Hudspeth Counties in Texas. Categories for estimating damages by sub area are listed in Table 6.

Table 6 Study Area damage estimates

Zones	State	Urban	Agriculture
Socorro County	NM	No	Yes
Sierra County	NM	No	Yes
Doña Ana County	NM	No	Yes
El Paso County	TX	Yes	Yes
Hudspeth County	TX	No	Yes

Agricultural Impacts

Two major economic impacts that salinity has on agriculture are reduced crop yields and the additional water associated with leaching accumulated salts from the plant root zone. The most widely cited analyses of the effects of salinity on crop production are Maas E.V. and Hoffman G.J. (1977) and the comprehensive FAO study by Ayers, R.S. and D.W. Westcott, (1989). These authors have developed a system of equations to estimate yield reduction and additional water required for leaching based on a series of crop specific coefficients. The basic soil salinity equation developed by Maas and Hoffman is as follows:

(1) $ECs = .2\ ECw(1+1/LF)$;

where: ECs is the electrical conductivity of water in the soil profile (ds/m),
ECw is electrical conductivity of irrigation water (ds/m), and
LF is the leaching fraction (percent).

Ayers and Westcott relate soil salinity to yield reduction in the following empirical equation:

(2) $Y = 100 - b(ECs - a)$,

where: Y is relative yield (100% max),
ECs is soil salinity (ds/m), and
a, b are crop specific coefficients.

Soil and irrigation salinity are measured in electrical conductivity, which is actually only a partial measure of total dissolved solids (the dissolved salt component). TDS is related to conductivity (ds/m) by general association. Gratten (2002) developed the following equation for conductivity to TDS.

(3) $TDS = 640 \times ECw$ for $ECw < 5$ ds/m and $TDS < 3200$

The Maas and Hoffman (1977) and Ayers and Westcott (1989) equations were developed for general irrigation conditions similar to the Rio Grande area. Actual salinity and irrigation requirements are more complex and result from a series of dynamic and steady state physical and chemical interactions. Soil type and condition, irrigation efficiency, irrigation timing and technology all interact in irrigation. A more extensive model that incorporates field uniformity and irrigation technology was developed by Dinar and Letey (1996). To use such a model would require a much more extensive analysis than presented here.

The extra water for leaching to maintain an economical yield depends on the water demand by the crop. The area is characterized by high evapotranspiration rates. For purposes of this analysis, actual evapotranspiration demand (ET) is used as measure for crop water demand.

(4) $ET = K_0 \times PET$,

(5) $Lw = ET/(1-LF) - ET$

where Lw is amount of leach water (inches)
PET is potential evapotranspiration and
K_0 is ground cover coefficient specific to each crop.

ET was estimated for each crop in the Elephant Butte Irrigation District by Sammis et al. (1984). Using the Ayers and Westcott (1989) model of yield and leaching, the leaching fractions are obtained as shown in Table 7 which is required above ET (see equations 4 and 5) to maintain a 100% yield for major crops in the Study Area at different salinity levels.

Table 7 Required leaching fraction for maximum yield

TDS (mg/L)	Alfalfa	Chile	Pecans	Cotton
500	9%	11%	7%	2%
600	10%	13%	9%	3%
700	12%	16%	11%	3%
800	14%	18%	12%	4%
900	16%	21%	13%	4%
1000	18%	24%	15%	5%

Equations 1 through 5 are applied to develop the amount of leaching water needed to obtain maximum yield. To derive actual costs to irrigated agriculture of increasing salinity requires additional information on (1) cropping acreages, maximum crop water demand, cost and returns of crops and the cost of delivered irrigation water.

Cropping acreages by crop type were developed for Socorro, Sierra and Doña Ana Counties in New Mexico and El Paso and Hudspeth Counties in Texas. For New Mexico, crop acreages were obtained from the New Mexico Department of Agriculture (2000). Crop acreage for El Paso and Hudspeth Counties in Texas was derived from data in Michelsen et al. 2009. Estimates of economic damage from yield loses employed NM Cooperative Extension Crop Costs and Returns Estimates for Farm and Ranches (2007, http://costsandreturns.nmsu.edu). Net returns per acre after operating expenses were used to estimate dollar losses attributable to salinity. Data for Texas Counties was derived from Texas AgriLife Extension, Texas Crop and Livestock Budgets, 2007, District 6 (http://agecoext.tamu.edu/resources/crop-livestock-budgets.html). As reporting for District 6 does not include all of crops grown in El Paso (such as pecans) and Hudspeth Counties, New Mexico crop budgets were used for those crop budgets not covered in District 6 report. Crop prices used in the damage estimates were based on data in 2007.

Texas crop acreages are based on 2005 data in all counties except Hudspeth. In Hudspeth County, crop acreage is quite variable depending on the amount of available water. The irrigation district, Hudspeth County Conservation and Reclamation District #1, only has access to residual or return flow water from upstream users thus the amount of water is variable and lately has been characterized by reduced flow. Irrigated acreage in the Hudspeth County Conservation and Reclamation District adjusts to the water supply available and has varied from 14,000+ acres in 2001 to 8,900 acres in 2007. To assess damages from salinity (not reduced flow), crop acreage was based on data in 2000, corresponding to the year with a full water allocation.

Economic costs of salinity are calculated for the cropping pattern in each county using the value of yield losses and the cost of extra water required due to leaching. There is an economic tradeoff between yield loss and the cost of additional water. The analysis develops an optimal leaching fraction (minimum total cost of yield losses and additional water) for each irrigation district or county. This is a more extensive methodology than used in the Central Arizona Salinity Study, which only used the cost of the leaching fraction. Above certain thresholds of soil salinity, no amount of leaching water will restore maximum yield. Because of the differential impact on yields, salinity has an additional cost that is reflected through crop selection. Onions and lettuce (important crops in EBID) have thresholds at approximately 800 – 900 mg/L TDS in irrigation water. This may explain why these crops are not significantly produced in EPCWID#1 or HCCRD#1. Cotton on the other hand has a relatively high threshold and given enough leaching water can produce high yields. In HCCRD #1, where water quality is above 1,000 mg/L TDS, cotton is the major crop. Alfalfa can be produced there but at a cost of a very high leaching fraction (excess of 25%). In fact, there is an economic tradeoff between the cost of leaching water and yield loss. Very few authors except for Dinar and Letey (1996) have noted that more leaching reduces cost of yield losses but at the expense of more water. In the results section, optimal leaching fractions are developed for each district.

The cost of water for leaching agricultural crops is calculated at the price for purchasing an additional (marginal) acre foot of water within each irrigation district. These prices do not include fixed irrigation district charges but are only the variable cost of additional water. For Hudspeth County, water costs per acre foot are difficult to characterize by one number since the variable charge per acre foot of water is set by dividing remaining district costs by the quantity of water delivered, and the quantity of water delivered varies from year to year. A typical price is $17 per acre foot of water with recent prices ranging from $15 to $20 per acre foot (personal communication, Jim Ed Miller, President of HCCRD #1), The cost of additional water used to leach a field is shown in Table 8.

Table 8 Marginal cost of water used for leaching

New Mexico Agriculture		Cost per Acre-foot
Socorro County Agriculture		$ 9
EBID	Sierra	$ 40
	Doña Ana (average at Leasburg and Mesilla)	$ 40
Texas Agriculture		
EPCWIP#1		$ 27
HCCRD #1		$ 17

Another approach to estimating economic losses is to compare net income (returns to land) on a farm wide basis as salinity increases (Ejeta et al., 2005). The basic climatic conditions of EBID, EPCWID#1 and HCCRD #1 are similar, though there is an increase in growing season length from north to south. However, per acre net returns on a farm basis decrease at least from EBID down river (see King and Maitland, 2003). Crop selection is directly affected by increasing salinity. Producers in HCCRD #1 are constrained to mostly cotton, a relatively low net return (crop) relative to other crops that can be grown with better water quality (such as EBID). Though other factors may be involved, salinity increases and water availability are major contributing sources of economic loss in agriculture. To fully assess these economic impacts, more extensive analysis beyond the scope of this preliminary analysis is required. This would include estimating cropping patterns at reduced salinity levels which would suggest higher value crops.

Urban Municipal and Industrial Impacts

In this analysis, only residential and other urban damages are considered for El Paso City and County. This is because within the Study Area of this analysis, this is the only urban area currently using Rio Grande surface water. Surface water in El Paso County is delivered by El Paso Water Utilities (EPWU). Other urban areas such as the Las Cruces metropolitan area will eventually use surface water as a part of sustainable sources of supply and, hence, will also be affected by Rio Grande salinity in the future. A more complete analysis would consider damages from both current and future users of surface water, including growth in population and impacts over time. This preliminary economic assessment provides estimates of salinity damages for the current population and infrastructure conditions for a single year. The types of urban impacts from salinity considered in the analysis are (1) residential, (2) urban landscape, (3) commercial, (4) industrial, and (5) surface water treatment.

For urban water, separating surface water salinity damages from groundwater sources means tracking the distribution of water sources by EPWU. Salinity damages are proportional to the duration of exposure, so that if an area had surface water 60% of the year, surface water would account for 60% of the annual damages at a given concentration of salinity. A distribution map of source water to El Paso metropolitan area is shown in Figure 4. During the irrigation season (7 months corresponding to the release period for waters from Elephant Butte Dam), the majority of the city is served by surface water from the two surface water treatment plants, the Canal (Robertson\Umbenhauer) Plant and Jonathan Rogers Plant, respectively 40 and 60 MGD capacity. If surface water were the total urban supply during the irrigation season, damage from salinity would amount to 58.3% (7/12) of annual damage estimates associated with that salinity level.

Actual supplies of surface water to El Paso during the irrigation season are somewhat less than total water demand, in that there are two areas not entirely supplied by surface water (Figure 4). The upper valley on the west side is supplied by Mesilla Basin wells and some sections of the east side receive both surface water, groundwater and desalinated groundwater from the Kay Bailey Hutchison Reverse Osmosis plant (the desalination plant supplies blended water of about 640 mg/L TDS). The number of accounts served by the individual surface water and groundwater plants is not known and varies depending on the quantity of water supplied by each source. An alternative approach used to estimate urban surface water use is an annual equivalent (AE) supply. Surface water accounted for 54% of total annual supplies (58,141 acre-feet surface water / 106,684 acre-feet total water delivered, EPWU 2007) to urban users. The annual equivalent supply of surface water would be 54% of the 160,474 residential accounts thus 87,476 of all households were assumed to be supplied Rio Grande surface water on an annual equivalent basis. The same surface water percent was applied to commercial and industrial water use. Based on analysis presented in the hydrology section, surface water to EPWU averages 835 mg/L during the irrigations season.

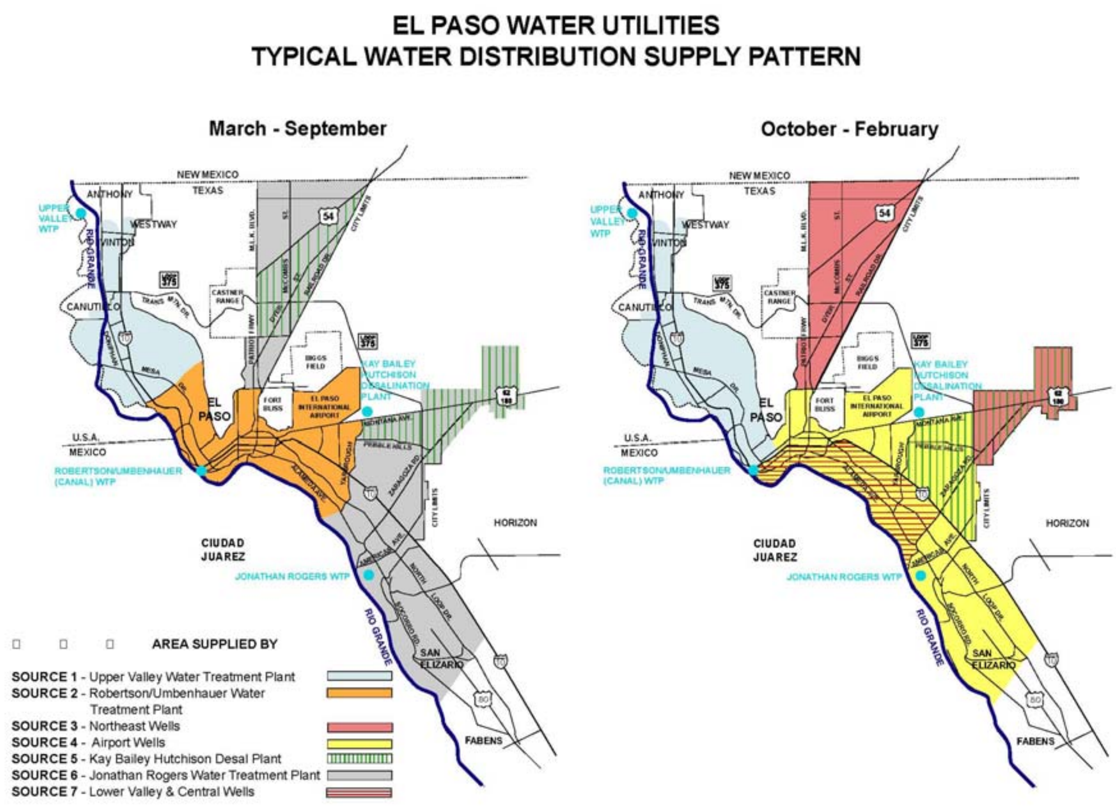

Figure 4 El Paso Water Utilities typical water distribution supply pattern.

Source: El Paso Water Utilities, 2009.

Residential Impacts

Damages to residential water users employs the CASS methodology, adjusted to 2007 demographics in the El Paso Water Utilities service area and the lower valley of El Paso County, which gets their bulk water from EPWU. Two types of residential salinity impacts are considered, reduced life of water using appliances and plumbing and household operating costs incurred to avoid damages or impacts (water softening and the purchase of bottled water). Damage functions for residents are based on a series of equations developed by Tihansky (1974) that were also used in the MWD and CASS reports. The equations from the CASS (2003) report were used to estimate the reduction in the expected life of water using appliance due to salinity (Table 9).

Application of the methodology provides an estimate of the life span ($Y = Y_i(TDS)$) of the appliances (indexed by i) with the baseline TDS value of 500 for the delivered water quality of EPWU. Economic costs are measured as the change in straight-line annual depreciation for the two life span estimates as follows

(6) $$D_h = \sum^{i=6} P_i \times C_i \times (Y_i(TDS) - Y_i(500)),$$

where D_h is the damage per household,
P_i is the percent of household with appliance I, and
C_i is the cost of appliance i (2007).

Table 9 Economic impacts of reduced life of water using appliances and plumbing

Appliance/Plumbing Item	Percent of Residences with Appliance	Cost	Life Span in Years (y) as a Function of TDS in mg/L
Water Heater	100%	$302.45	$Y_1 = 14.63 - 0.013 * TDS + 0.689(10^{-5}) * TDS^2 – 0.11(10^{-8}) * TDS^3$
Faucet	100%	$408.59	$Y_2 = 11.55 - 0.00305 * TDS$
Garbage Disposal	43%	$109.61	$Y_3 = 9.23 - 0.00387 * TDS + 1.13(10^{-6}) * TDS^2$
Clothes Washer	95%	$629.20	$Y_4 = 14.42 - 0.011 * TDS + 0.46(10^{-5}) * TDS^2$
Dish Washer	60%	$431.98	$Y_5 = 14.42 - 0.011 * TDS + 0.46(10^{-5}) * TDS^2$
Evaporative Coolers	80%	$1159.00	$Y_6 = 20 / exp(0.0001761 * TDS)$

Source: CASS, Appendix J

The percent of residents with specific appliances was developed for the CASS study by a national survey from the Association of Home Appliance Manufactures. The only modification for this study was to data on evaporative coolers. The Las Cruces Utilities Department conducted an informal survey of households and estimated 80% of residences used evaporative coolers (Personal communication, Joshua Rosenblatt, Water Conservation Officer, Las Cruces Utilities). The same percentage was applied to the El Paso area. The cost of the appliances is based on the CASS original values. The consumer price index for durable goods (Department Store Index) has remained relative unchanged. The CPI durable goods index is also at approximately the same level in 2007 as it was in 2000 – the time of the reported values in the CASS analysis. CASS was subsequently published in 2003 with updated aggregated numbers to consumer prices for durable goods. This report further adjusted damages estimates according to the consumer price index for durable goods to 2007.

Additional residential economic impacts involve avoidance costs. Water softening systems and purchasing bottled water are both included from the CASS (2003) study as shown in Table 10 Residential damages to households are the sum of appliance costs and avoidance costs. Salinity damages were estimated for surface water quality of 835 mg/L TDS for the annual equivalent number of households served by surface water. Damages are estimated above a threshold level of 500 mg/L TDS.

Table 10 Economic costs of avoidance of salinity impacts by purchase of dispensed water, home filtration systems, and water softeners (2000 Price Level)

Avoidance Method	Annual Cost	Unit or Cost (y) as a Function of TDS in mg/L
Bottled Water	$135.93	y = 61.1 + 0.00323 * TDS {y = % of households using bottled water}
Water Softener	$319.30	$Y = 6.758 + 0.007 * TDS + 3.01(10^{-6}) * TDS^2 + 2.2(10^{-10}) * TDS^3$ {y = % of households using water softening devices}

Source: CASS Appendix J, Table E-7

Urban Landscape Impacts

Although salinity in agriculture is readily acknowledged, urban areas have similar economic losses in reduced landscape amenity value and costs. There is no doubt that lawns and trees provide economic value to urban residents, simply note the costs that residents choose to incur to establish and maintain landscapes. Approximately 50 percent of the water consumed in western cities is used outdoors, and most of that is for irrigation. Though most homeowners may not be aware that salts accumulate in the root zone and eventually impact landscaping, they may subconsciously water the wilting sections of the landscape caused by salinity and inadvertently flush water below the root zone, an intuitive leaching fraction. The extra water comes at a cost, particularly since urban treated water is more expensive than untreated irrigation water. The literature on the urban landscape cost of salinity is relatively sparse with most analysis done in Australia on saline water logging (Wilson, 2002). Miyamoto (Salt Tolerance of Landscape Plants Common in the Southwest, 2008) specifically addresses salt tolerance of common landscape plants. He develops a threshold of 3 ds/m (1,920 mg/L) of soil salinity for damages to most landscape plants. Working backwards from this threshold, it is possible to derive a leaching fraction for various TDS levels of landscape water from the municipal utility. Miyamto estimates ET to be 48 inches for landscapes (Landscape Irrigation with water of elevated Salinity, 2007). This estimate, combined with equations 1 through 5 above, can be used to derive the amount of additional water required to maintain landscape appearance. The cost of additional leaching water is the cost attributable to salinity.

EPWU delivers 36 million Ccf (100 cubic feet) or 82,645 acre-feet to households, schools, churches, and commercial use. For households, 50% is assumed to go to outdoor use, schools 50%, churches 50%, and commercial 32% (CASS), resulting in 16.3 million Ccf (37,420 acre-feet) assumed to go to outdoor use. Only a small fraction of this water is attributable to leaching of salts domestic delivered water is much more expensive than untreated agricultural irrigation water. The EPWU residential rate is $3.40 per Ccf for the second tier water rate (EPWU web Site, water rates, 2007). Because water use is higher in the landscape irrigation season, the second tier (or even higher rate) is most relevant to outdoor use. Thus, even a small increase in the leaching fraction can involve considerable economic loss.

Reclaimed water for golf courses and parks is not included in the analysis. Reclaimed water is typically 900 – 1,200 mg/L TDS (Miyamoto, 2008), however, impacts are highly dependent on soil type, water table height, irrigation management and use of the landscape. There are also potential opportunity costs associated with reclaimed water. Use of reclaimed water off-sets the need for and cost of additional sources of water. However, consumers are unwilling to use all of the reuse water available, in large part because of the elevated salinity. These costs are not included in the preliminary economic impact estimates.

Commercial Impacts

The methodology used to estimate commercial damages is based on functional (use) categories for commercial water. Water use by the commercial sector is subdivided into the following categories; sanitary, cooling, irrigation, kitchen, laundry and other. The effect that salinity and its associated hardness have on the commercial sector of society is measured by estimating its effect in each of these categories. CASS used MWD data on the percentage distribution of water use by function and assumed that Southern California would be very similar to Central Arizona. This assumption is extended to El Paso. MWD also developed cost estimates per acre-foot per mg/L TDS for each of the functional categories of commercial water use. These estimates are indicated in Table 11.

Table 11 Cost of salinity damage by commercial water use by function

Use Category	Sanitary	Cooling	Kitchen	Laundry	Others
AE Surface water use					
Percentage of Commercial Use	29%	12%	7%	8%	12%
Distributed Use (acre-feet)	5,251	2,173	1,268	1,449	2,173
TDS Function ($/AF per mg/L)	$0.26	$0.69	$0.43	$0.85	$0.29

Source: CASS, Table E-10.

1. Percentages do not add to 100% because landscaped water (32%) is accounted in subsequent section

2. Use is derived by multiplying percent of use times total commercial water use in EPWU

Because there was a very modest change in the producer price index from 2000 (used in the CASS study) to 2007, the original cost estimates were retained for this study. Commercial irrigation salinity costs are excluded from this estimate and included in the urban landscape damages results as indicated earlier.

Industrial Impacts

Methodology employed in previous studies estimates industrial damages from salinity by separating industrial use by standard industrial classification code (SIC code), function of water use within each industry type by water process and then estimating costs by multiplying process use by unit costs for each function (engineering estimates). The methodology is outlined in the following steps:

1. The water use by the industrial sector was calculated by first obtaining the number of industrial establishments in each SIC code along with respective employment. Information on El Paso's industry and the number of employees along with the amount of water use per employee was gathered from the 2002 Economic Census Data

reported by the U.S. Census Bureau (2002 Economic Census Manufacturing El Paso County, TX). This data was used to derive annual use in acre-feet per year for each industry sector and the summation across all sectors (total industrial use).

2. The use by sector was then scaled back so that the aggregate use from census data matched EPWU industrial and large water users' consumption in 2007. The scaling was needed because the Census data over estimated reported El Paso industrial water use. Industrial water use was further scaled back for annual equivalent use of surface water. EPWU industrial and larger water uses (non government) were 1,276 thousand Ccf in 2007. This amounts to 2,937 acre-feet. The annual equivalent surface water use would be 1,600 acre-feet. Water use by industrial sector scaled to match EPWU industrial surface water use by SIC code is listed in Table 12.

3. Aggregate costs were then totaled across all sectors.

Table 12 Industry water use in El Paso County by SIC Code

			Scaled water use per employee	Annual use	Annual use
Industry	Establish.	Employees	gallons/day/employee	Gallons/yr	Ac-ft/yr
Food mfg	63	1,445	112	40,366,436	124
Beverage mfg	0	0	201	0	0
Textile product mills	14	1500	49	18,486,563	57
Apparel mfg	44	5,722	4	5,372,958	16
Leather product mfg	25	886	124	27,523,812	84
Paper mfg	17	952	340	80,974,978	249
Chemical mfg	3	1,200	285	85,355,100	262
Plastics & rubber prod	33	4,858	98	118,793,281	365
Nonmetallic mineral	28	567	59	8,318,953	26
Primary metal mfg	13	2,000	142	71,129,250	218
Fabricated metal prod	90	1,498	38	14,417,876	44
Machinery mfg	0	0	56	0	0
Comp & electronic	23	2,019	36	17,931,496	55
Electrical equip.	20	2,258	36	20,054,145	62
Transportation equip	15	775	47	9,096,563	28
Furniture prod. Mfg	34	593	24	3,503,370	11
Total	422	26,273			1,600

4. As noted with the commercial damage estimates, there was a very modest change in the producer price index from 2000 used in the CASS study to 2007 and the original cost estimates were retained for this study.

5. The total use by industry sector was partitioned by function into the following use categories; process water, boiler water, cooling water, sanitation and irrigation water (assumed to have zero impact from salinity) for each industry.
6. As with commercial, each of the use categories have a cost estimate associated with it (per acre-feet per TDS, Table 13).

Table 13 Industrial water use impact functions

Impact Functions	Process Water Demineraliza-tion	Process Water Softening	Process Water Minor	Cooling Towers	Boiler Feed	Sanitation & Irrigation
($/af per mg/L)	$1.53	$0.65	$0.00	$0.30	$1.09	$0.00

Source: CASS, Table E-7.

Surface Water Treatment Plants Impacts

Both MWD and CASS studies estimated salinity damages to water treatment plants. El Paso has two surface water treatments plants (Canal and Rogers) that are adversely affected by salinity. There are two categories of costs; (1) degradation of pipes and other components of the plants and (2) replacement water costs that are incurred during periods when the plants cannot operate because of high salinity levels of surface source water (because of EPA standards the plants must shut down when water exceeds 1,000 mg/L TDS). Estimation of replacement costs requires information on frequency of water quality exceedance, quantity of water requiring replacement and the source(s) and cost of water replacement. Insufficient data were available to estimate the cost of replacement water. Thus, the damage estimates are based on degradation treatment plant components. Also omitted because of lack of information are damages to the utility water distribution system, such as shortened life from mineralization on distribution pipes and valves and increased maintenance costs.

The methodology for treatment plant damage is similar to the estimate methodology used for residential appliances. Increased salinity decreases the useful life of the treatment plants and increases the annual replacement costs ($plant x 1/L) where $plant is the replacement cost of the plant and L is useful life of plant. Replacement costs for the Canal and Rogers plants were 2007 estimates of capital costs derived from analysis of expansion options for the Rogers Plant. (Texas Water Development Board, Supporting Documentation 2005 Far West Texas Water Plan, Appendix B, Table B-4). Life span of treatment plants employed an equation developed by Tihansky (1974). The expected life of a water facility can be expressed by the following formula:

(7) Expected life in years (L) = 30.83 – (0.0033 * TDS)

As the treatment plants only operate during the summer months and use direct surface water, damage estimates are based on the salinity level on the Rio Grande. Though the Canal plant has slightly lower salinity levels than the Roger plant, the same TDS of the surface inflow were used for the respective plants. Damages are measured from a 500 mg/L TDS baseline. Damage to the surface plants was estimated based on the duration of feed water (58%) during the year and the respective feed quality at the input sources.

The review and application of methods from other regions for estimating salinity damages in the Study Area is by design a rough approximation. The composition of the water is not considered for the Study Area and how it would change damages to agriculture, urban and industrial users. However this preliminary estimate of economic damages attributable to salinity maximizes the application of previous studies by applying the relationships, coefficients and measurements to the existing conditions for the Study Area. This provides a cost efficient and timely estimate for decisions makers. Certainly the estimates would be significantly improved by developing baseline data for the Study Area. The estimated damages fro the *Study Area* from salinity following the methods discuss above follow.

ASSESSMENT OF ECONOMIC IMPACTS

Salinity concentrations in the Rio Grande were analyzed in detail as described in the U.S.G.S report. While salinity concentrations at a given location can vary significantly during the irrigation season and from year to year, it is impossible to calculate the large number of salinity concentration permutations. Therefore, the long-term irrigation season average level of salinity is used in this preliminary assessment to estimate a base-line of economic impacts. The irrigation season average salinity levels were summarized in Table 14 for sub-areas along six main reaches of the Rio Grande that represent major water diversion and use points. These are the salinity concentrations used for the preliminary base-line estimate of economic impacts. It should be noted that the average TDS concentration at Leasburg and Mesilla gage stations was used for Doña Ana County and EPCWID#1 upper valley because there was not acreage split by diversion.

Table 14 TDS of surface water in each sub-area

New Mexico Agriculture		TDS (mg/L)
Socorro County Agriculture		500
EBID	Sierra	550
	Doña Ana (average at Leasburg and Mesilla)	573
El Paso Urban		835
	Mesilla Basin	
	Hueco Bolson	
	Rio Grande Surface Water	835
Texas Agriculture		
EPCWID#1 Lower Valley		835
Hudspeth County		1,172

Agriculture Impact Estimates

Using the methodology described above, the estimated annual dollar losses from less yield and increased leaching water cost incurred in the production of current agricultural crops due to salinity in each county with delivered surface water from the Rio Grande are shown in Table 15 through Table 19. Losses are based on delivered surface water salinity concentrations from Table 14. For each diversion point, the damages are estimated by crop and the existing cropping pattern.

Table 15 Dollar losses to Socorro agriculture from salinity

	Alfalfa	Chile	Pecans	Onions	Lettuce	Small grains	Corn	Cotton	Pasture Other hay
Net returns per acre	$475.00	$930.57	$ 469.00	$78.00	$396.00	$(49.00)	$307.00	$8.10	$(80.00)
Yield loss ($)	3.71	75.07	-	11.44	41.63	-	7.20	-	-
AET (in)	60.00	39.00	45.60	37.44	22.44	18.00	30.00	31.20	31.20
Leach W. (in)	5.22	3.39	3.97	3.26	1.95	1.57	2.61	2.71	2.71
Leaching costs ($)	3.80	2.47	2.89	2.37	1.42	1.14	1.90	1.98	1.98
Total ($)	7.52	77.55	2.89	13.81	43.05	1.14	9.10	1.98	1.98
Distribution of Crop acreage	55.4%	1.7%	0.3%	0.4%	0.0%	6.3%	6.1%	0.0%	29.6%
Salinity Cost per acre	$6.77		Total Acres	23,401			Total Damages	$158,376	
Delivered TDS level	500 mg/L								
Dollar cost of delivered water	$9								

Table 16 Dollar losses to Sierra agriculture from salinity

	Alfalfa	Chile	Pecans	Onions	Lettuce	Small grains	Corn	Cotton	Pasture Other hay
Net returns per acre	$475	$931	$469	$78	$396	($49)	$307	$8.10	($80)
Yield loss ($)	-	-	-	4.77	14.37	-	-	-	-
AET (in)	60.00	39.00	45.60	37.44	22.44	18.00	30.00	31.20	31.20
Leach W. (in)	8.18	5.32	6.22	5.11	3.06	2.45	4.09	4.25	4.25
Leaching costs ($)	27.27	17.73	20.73	17.02	10.2	8.18	13.64	14.18	14.18
Total ($)	27.27	17.73	20.73	21.79	24.57	8.18	13.64	14.18	14.18
Distribution of Crop acreage	35.80%	18.50%	9.00%	10.60%	0.10%	6.30%	9.00%	1.40%	9.30%
Salinity Cost per acre	$20.50		Total Acres	8,103			Total Damages		$166,143
Delivered TDS level	550 mg/L								
Dollar cost of delivered water	$9								

Table 17 Dollar losses to Doña Ana agriculture from salinity

	Alfalfa	Chile	Pecans	Onions	Lettuce	Small grains	Corn	Cotton	Pasture Other hay
Net returns per acre	$475	$931	$469	$78	$396	($49)	$307	$8.10	($80)
Yield loss ($)	-	8.99	-	5.91	19.02	-	-	-	-
AET (in)	60.00	39.00	45.60	37.44	22.44	18.00	30.00	31.20	31.20
Leach W. (in)	8.18	5.32	6.22	5.11	3.06	2.45	4.09	4.25	4.25
Leaching costs ($)	27.27	17.73	20.73	17.02	10.2	8.18	13.64	14.18	14.18
Total ($)	27.27	17.73	20.73	17.02	10.2	8.18	13.64	14.18	14.18
Distribution of Crop acreage	19.00%	4.10%	30.40%	6.90%	1.90%	3.30%	10.70%	21.40%	2.20%
Salinity Cost per acre	$19.81	Total Acres		60,312	Total Damages			$1,195,034	
Delivered TDS level	573 mg/L								
Dollar cost of delivered water	$40								

Table 18 Dollar losses to El Paso County agriculture from salinity

	Alfalfa	Chile	Pecans	Onions	Lettuce	Small grains	Corn	Cotton	Pasture Other hay
Net returns per acre	$475	$931	$469	$78	$396	($49)	$307	$8.10	($80)
Yield loss ($)	4.23	77.39	-	11.63	42.42	-	7.55	-	-
AET (in)	60.00	39.00	45.60	37.44	22.44	18.00	30.00	31.20	31.20
Leach W. (in)	9.77	6.35	7.42	6.09	3.65	2.93	4.88	5.08	5.08
Leaching costs ($)	24.42	15.87	18.56	15.24	9.13	7.33	12.21	12.7	12.7
Total ($)	28.65	93.26	18.56	26.87	51.55	7.33	19.76	12.7	12.7
Distribution of Crop acreage	8.10%	0.60%	25.50%	2.20%	0.50%	6.30%	0.00%	54.70%	2.10%
Salinity Cost per acre	$16.14		Total Acres	41,308			Total Damages		$666,522
Delivered TDS level	835 mg/L								
Dollar cost of delivered water	$30								

Table 19 Dollar losses to Hudspeth agriculture from salinity

	Alfalfa	Chile	Pecans	Onions	Lettuce	Small grains	Corn	Cotton	Pasture Other hay
Net returns per acre	$475	$931	$469	$78	$396	($49)	$307	$8.10	($80)
Yield loss ($)	-	29.03	-	7.59	25.87	-	0.07	-	-
AET (in)	60.00	39.00	45.60	37.44	22.44	18.00	30.00	31.20	31.20
Leach W. (in)	20.00	13.00	15.20	12.48	7.48	6.00	10.00	10.40	10.40
Leaching costs ($)	28.33	18.42	21.53	17.68	10.6	8.5	14.17	14.73	14.73
Total ($)	28.33	47.44	21.53	25.27	36.47	8.5	14.24	14.73	14.73
Distribution of Crop acreage	11%	5%	0%	0%	0%	1%	8%	75%	0%
Salinity Cost per acre	$17.75		Total Acres	13,460			Total Damages		$238,860
Delivered TDS level	1,172 mg/L								
Dollar cost of delivered water	$17								

Total losses to agriculture in the Study Area are summarized in Table 20.

Table 20 Agricultural damages from TDS in surface water of the Rio Grande

Sub-areas	Socorro	Sierra	Doña Ana	El Paso	Hudspeth
Acreage	23,401	8,103	60,312	41,308	13,460
TDS (mg/L)	500	550	573	835	1,172
Average net return per acre	$ 273	$ 411	$ 316	$ 167	$ 128
Percentage yield loss	0.8%	0.7%	0.7%	0.5%	0.2%
$ cost from loss yield (acre)	$ 3.82	$ 0.52	$ 1.15	$ 1.28	$ 1.46
Leaching fraction	8%	12%	12%	14%	25%
Water for leaching (aft)	0.34	0.50	0.47	0.50	0.96
$ cost of leaching	$ 2.95	$ 19.98	$ 18.67	$14.86	$ 16.28
Total $ loss per acre	$ 6.77	$20.50	$ 19.81	$16.14	$ 17.75
Total $ loss all acres	$158,376	$166,143	$ 1,195,034	$666,522	$238,860
Total Acreages	146,584				
Total Agricultural Losses	$2,424,935				

Total agricultural losses from salinity for the Study Area total over $2.4 million. However, the estimate for total damage losses in irrigated agriculture does not include the significant reduction in potential revenue from restricted, existing crop production patterns that could be attributable to increases in salinity. For example, El Paso and Hudspeth Counties have average per acre net returns of $167 and $128 respectively compared to $411 for Sierra County, a difference of approximately $250 per acre. Given the fixed cropping pattern assumed in the analysis, estimated salinity damages amount to $16.50 per acre, far less than the $250 potential loss net revenue. There is no climatic reason Hudspeth and El Paso Counties could not duplicate the cropping pattern and yield of EBID, The difference in returns results from the constraint salinity imposes on production of higher value crops grown in the Mesilla Valley. A more extensive analysis is needed to quantity the losses from constrained cropping patterns.

Urban M&I Impact Estimates

Residential Impact

For Rio Grande surface water, Table 21 indicates per household residential damage and aggregate costs in 2007 for residents within the city limits from 835 mg/L salinity which is above the 500 mg/L TDS baseline. EPWU serves additional residential customers through wholesale supplies to the lower valley and other bulk water users. Per household damages from Table 21 were applied to residential units served by wholesale water from EPWU. Water heaters and clothes washers incur the greatest damage from salinity. Total residential damages are indicated in Table 22 and amount to $4,300,712, with El Paso City residents incurring about $4 million of these damages.

Table 21 Appliance depreciation costs (reservoir delivery season)

	Percent of Residents	Unit Cost	Baseline Life Span	Delivered Salinity Span	Annual Cost Difference	Weighted cost
Water Heaters	100%	$302.45	9.7	7.9	$6.97	$6.97
Faucets	100%	$408.59	10.0	9.0	$4.63	$4.63
Garbage Disposal	43%	$109.61	7.6	6.8	$1.69	$0.73
Clothes Washer	95%	$626.20	10.1	8.4	$12.00	$11.40
Dish Washer	60%	$431.98	10.1	8.4	$8.28	$4.97
Evaporative Coolers	80%	$1,159.00	18.3	17.3	$3.85	$3.08
					Cost per household	$31.78
Surface water TDS	835					
EP Households	160,474					
Surface water percent	54.5%				Seasonal Cost	$31.78
Annual Equivalent # of Households	87,455				El Paso Household Damages	$2,779,433

Non appliance costs

		Annual Cost per Household	Change in % Households Baseline	Delivered	Cost per Household
Bottled water		$ 135.93	62.7%	63.8%	$1.47
Water Softeners		$ 319.30	11.0%	14.8%	$12.12
				Cost per household	$13.60
Seasonal TDS (mg/L)	835				
EP Households	160,474				
Surface water percent	54.5%			Seasonal Cost	$13.60
Annual Equivalent # of Households	87,455			El Paso Household Damages	$1,189,005
Total cost per household					$45.38
Total damages					$3,968,439

Table 22 Household damages from TDS, urban water supply in El Paso County

	Res. Accts.	AE Accts	TDS (mg/L)	Per Residence $	Total Damages
City of El Paso	160,474	87,456	835	$45.38	$3,968,439
Hacienda del Norte	220	120	835	$45.38	$5,440
Homestead	1,230	670	835	$45.38	$30,417
Lower valley Water district	12,000	6,540	835	$45.38	$296,416
	173,924	94,786			$4,300,712

Urban Landscape Impact

Elevated salinity concentrations requires additional water to maintain urban landscape soil salinity at acceptable levels (EC < 3.0 ds/m or TDS <1,920 mg/L). Measured against a 500 TDS baseline, El Paso delivered surface water with a salinity of 835 mg/L TDS during irrigation season. At this level, water demand for urban landscapes required an additional 3.95% of total outdoor water use. When applied to 8.8 million Ccf (hundred cubic feet) or 20,202 acre-feet for outdoor use at $3.40 per Ccf (current EPWU rates for water above 1.5 times average winter consumption), this amounts to $2,199,000 in salinity damages (Table 23). Over 75% of the total is related to residential landscapes.

Table 23 Cost of salinity damage to urban landscape from additional use of water in leaching

Category	Class Volume[1]	Outdoor Use	Outdoor Use[2]	% Water Leaching[3]	Ccf used for Leaching	$/Ccf	Cost of Leaching
	Aft	Percent	Ccf				
Residential	31,211	50%	6,777,061	3.95%	267,808	$3.40	$910,546
Schools	1,911	50%	414,977	3.95%	16,399	$3.40	$55,755
Churches	209	50%	45,359	3.95%	1,792	$3.40	$6,094
Commercial	11,521	32%	1,601,116	3.95%	63,271	$3.40	$215,121
Subtotal	44,852		8,838,513		349,269		$1,187,516

1. These volumes are adjusted to Annual Equivalent (p27) to represent surface water supply use.
2. Outdoor use is converted to Ccf for consistency with EPWU billing.
3. Required additional water measured above a 500 mg/L baseline; applied to outdoor water use.

Commercial Impact

The damages from salinity by customer class (schools and churches are included in commercial damages) are shown in Table 24. These damage estimates do not include water for irrigation (accounted under urban landscape). Total salinity damages to the commercial sector are

$1,760,000 for salinity concentration above the baseline. In this case the schools, churches and government combined account for only about 35% of the total commercial damages.

Table 24 Salinity damages for commercial, school, church and misc. government use

Category	Volume (1,000 CcF)	Volume		Cost	
		Acre-feet	AE acre-feet[1]	$/per acre-foot	Total Cost
Commercial	9,266	21,336	11,628	$97.28	$1,131,098
Schools	1,537	3,539	1,929	$97.28	$187,621
Churches	168	387	211	$97.28	$20,508
Gov (not military)	3,420	7,875	4,292	$97.28	$417,478
	14,391	33,137	18,059	$97.28	$1,756,705

1. Annual Equivalent

Industrial Impact

Estimation of industrial damages followed the CASS methodology by classifying water use by industrial function and associating impact costs of salinity with each use or function (such as cooling). As with other urban water uses, industrial damages were estimated for the reservoir release season average of 835 mg/L TDS. Total damages were $343,900 for the sector, a relatively small proportion of total salinity damages across the Study Area.

Treatment Plants Impact

The final category of estimated salinity damages was for the two surface water treatments plants, The Robetson/Umbenhauer Water Treatment Plant (also called the Canal Street Water Treatment Plant) and Jonathan Rogers Water Treatment Plant, with respective capacities of 40 and 60 million gallons per day (MGD). Based on previous studies, elevated salinity decreases the useful life of water supply treatment plants. From a baseline salinity concentration of 500 mg/L TDS, facility equipment replacement changes from a period of 29 years to a replacement period of 28 years at 835 mg/L TDS. Replacement costs are estimated at $41 million for the Canal plant and $59 million for the Rogers treatment plant. Prorated based on the change in replacement time, damage to the two plants was estimated at $134,834 which is a small proportion of total salinity damages. However, this does not include other impacts such as reduced life and increased maintenance costs to water utility distribution systems. It should be noted that replacement of distribution mains is considered a formidable future cost (Environmental Protection Agency, *Drinking Water Infrastructure Needs Survey and Assessment: Third Report to Congress*, June 2005).

Summary of Damages

The total salinity damages in the *study area* for long-term average salinity concentration levels by category of water user are shown in Table 25.

Table 25 Summary of economic damages from Rio Grande salinity by water user category

Type of Use	Damage	Percent
Agricultural	$ 2,424,935	24%
Urban - El Paso County		
Residential	$ 4,301,050	42%
Landscape	$ 1,187,516	12%
Commercial/Other	$ 1,761,402	17%
Industrial/Large Users	$ 343,903	3%
Treatment Plants	$ 134,844	1%
	$ 10,153,650	100%

Most damages are urban (76% of the total), though damages in agriculture are significant. The highest category of damages is residential (42% of the total) followed by agricultural, urban landscape and commercial. As a reminder, these are preliminary estimates of annual damages from Rio Grande salinity in the study area assuming a current situation relative to population, water use distribution, and cropping patterns.

Incremental Damages and Potential Benefits of Reducing Salinity

By reducing the salinity of the delivered water, there would be benefits derived by extending the life of appliances, reduced leaching water use in agriculture and urban landscapes, improved yields, and additional benefits (not indicated in this analysis) from the potential of using higher valued crops and increased useful life of urban distribution mains. To estimate the incremental benefits (reduced damages) for a 200 mg/L TDS decrease (an increase would have the opposite negative effect (cost) at major points along the river, two different change points were considered; from San Acacia, NM downstream to Fort Quitman, TX and from the NM-TX Stateline downstream to Fort Quitman, TX. These changes in salinity concentrations are hypothetical. The estimated incremental benefits for a 200 mg/L TDS decrease in salinity concentrations throughout the Study Area (San Acacia downstream to Hudspeth County) are shown in Table 26 and Figure 5.

A 200 mg/L TDS reduction in salinity concentrations in Rio Grande water in the entire Study Area is estimated to result in $5.0 million in benefit from the reduction in damages from surface water salinity. Based on the preliminary estimates of salinity damages which exclude a number of types of other damages, approximately 80% of the benefits of the reduction would accrue to urban users in El Paso County.

If a reduction of salinity of 200 mg/L TDS can be achieved at the NM-TX Stateline (El Paso County), the damages would be reduced for the areas downstream but would not affect the areas upstream. The incremental changes in damages and benefits of a 200 mg/L TDS decrease at El Paso County and downstream to Fort Quitman are shown in Table 27 and Figure 5. A 200 mg/L TDS reduction in salinity concentrations in Rio Grande water at the NM-TX Stateline is estimated to result in $4.8 million in benefit from the reduction in damages from surface water salinity.

Table 26 Incremental changes in damages for a 200 mg/L TDS decrease from San Acacia, NM downstream to Fort Quitman, TX

	All Users	Urban Users
Damages at Current Salinity Levels	$10,153,650	$7,728,715
Damages with a 200 mg/LTDS decrease	$5,167,940	$2,969,771
Benefit of reducing salinity	$4,985,710	$4,758,944
Dollar per acre-foot benefit per mg/L TDS[1]	$0.05	$0.42

1. Per unit benefit based on full Rio Grande Project allocation deliveries.

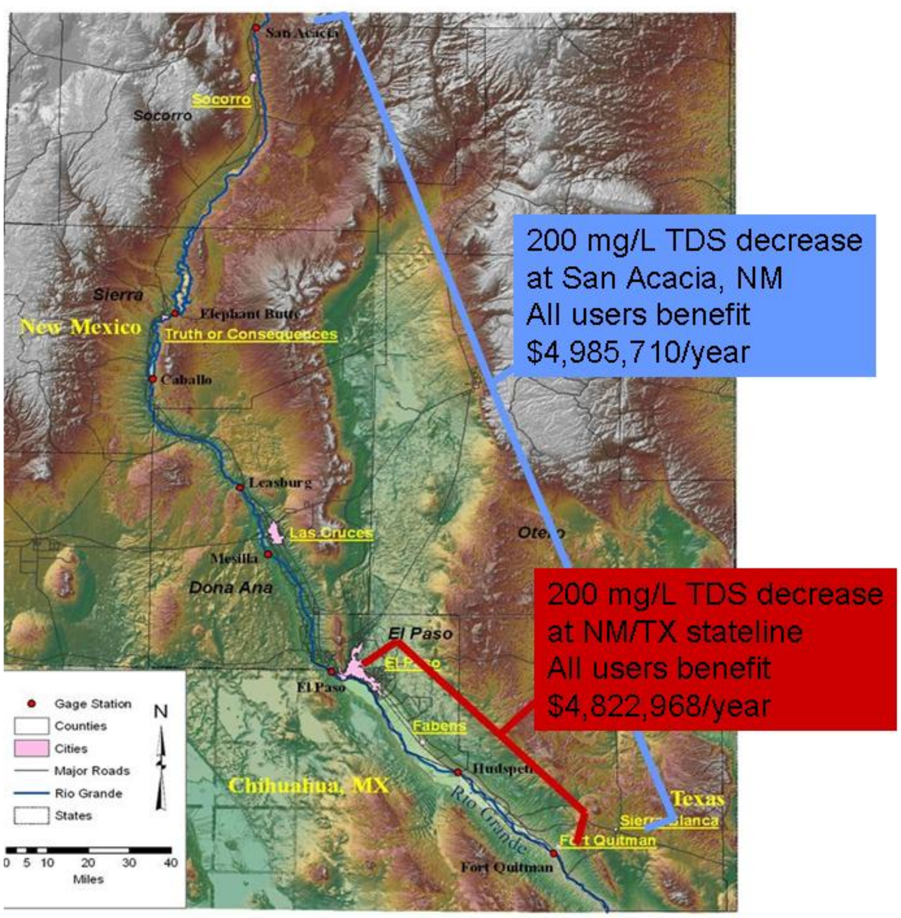

Figure 5 Summary of benefits of incremental 200 mg/L TDS decrease in salinity.

Applying the economic assessment impact functions for a reduction in salinity concentration provides a damage estimate per mg/L TDS per acre-foot of $0.04, which is considerably below the $0.198 CASS estimate and the $0.386 estimate for MWD. But a closer evaluation indicates the reason for the difference; Rio Grande water is more intensively allocated to agriculture than water in the Phoenix or Southern California study areas. Damages to agriculture per mg/L TDS acre-foot are less than urban damages. The last column indicates incremental damages and benefits of a reduction in salinity to the urban sector with the current quantity of surface water diverted by EPWU. The $0.33 damage per mg/L TDS per acre-foot is similar to the urban damages estimated for the Southern California metro area. Again note that this is a low estimate of damages in this Study Area for many reasons including: current cropping patterns are limited by salinity, future urban growth and increases in urban surface water use, water reuse limitations due to salinity, and exclusion of environmental impacts, off-season surface water use, Mexican and downstream impacts.

Table 27 Incremental changes in damages for a 200 mg/L TDS decrease from NM/TX Stateline downstream to Fort Quitman, TX

	All Users	Urban Users
Damages at Current Salinity Levels	$10,153,650	$7,728,715
Damages with a 200 mg/LTDS decrease	$5,330,682	$2,969,771
Benefit of reducing salinity	$4,822,968	$4,758,944
Dollar per acre-foot benefit per mg/L TDS[1]	$0.05	$0.42

1. Per unit benefit based on full Rio Grande Project allocation deliveries.

CONCLUSIONS AND RECOMMENDATIONS

In this first phase of the Rio Grande Project Salinity Management Program, a preliminary assessment of the economic impacts of salinity in the Rio Grande was conducted, including a review of literature of salinity impact assessments and estimation of economic impacts using existing, applicable physical and economic damage coefficients applied to current Study Area characteristics and information. Annual damages attributable to salinity were estimated for irrigated agriculture, and El Paso County, residential, landscape, commercial/other, industrial/large users, and drinking water treatment plants, the only community currently supplying Rio Grande water for urban use in the Study Area.

Economic Impacts of Rio Grande Salinity

Irrigated agricultural damages were estimated for the current cropping pattern individual crop yield loss due to salinity as well as extra costs associated with leaching of salts from the soil profile. Losses were estimated as reduction in net returns for the producer and are as follows: Socorro ($158k), Sierra ($166k), Doña Ana ($1,195k), El Paso ($667k), and Hudspeth ($239k). The total annual damages estimated across the entire Study Area for irrigated agriculture is $2.4 million.

Residential damages were estimated on a household basis and included appliances plus purchase of bottled water for consumption. For a household, the clothes washer had the greatest cost due to salinity of $11.40. Per household, the cost across all appliances is estimated to be $31.78. For all households in El Paso using surface water the total damages to appliances are $2.8 million. In addition to appliances damages, the household cost for bottled water and water softeners is estimated at $13.60 per household or $1.2 million for the city. The total household cost due to salinity in El Paso is an estimated $4.0 million By including Hacienda del Norte, Homestead and Lower valley Water District the total household costs of salinity are $4.3 million. This translates to $45.38 per household per year.

Urban landscapes are damaged by salinity the in a manner similar to agricultural crops. To offset these damages, it is assumed that urban landscapes will be protected via leaching. This means that the cost of the extra water necessary to leach the salts from the soil represent the cost of salinity. By far the largest category for landscape is residential where the cost of leaching water is an estimated $0.9 million. For residential, schools, churches and commercial, the total cost of salinity related to landscapes is $1.18 million.

Commercial damages from salinity (excluding the landscapes covered above) are estimated at $1.8 million. This includes functional use categories of sanitary, cooling, kitchen, laundry and other. Similarly, industrial damages of salinity are $344k. A last classification for estimating damages is for water treatment plants. Basically when salinity exceeds the safe drinking water standards then the treatment plants cease operation and alternative water supplies have to be used at a higher cost. The cost for this alternative water is $135 k.

This suggests that the total economic damage (cost) from Rio Grande salinity of those items included in this preliminary estimate is about $10.2 million per year. Recall above, several types of losses are not included. However, with this preliminary analysis, at least some of the benefits of reducing salinity can be estimated. For example, for a 200 mg/L TDS reduction in surface water salinity at the New Mexico/Texas stateline the benefits using existing information are estimated to be approximately $4.82 million per year with $4.76 million of the benefits accruing to urban water users in El Paso County. If a 200 mg/L TDS reduction in surface water salinity at San Acacia, NM can be made, the economic benefit is estimated to be approximately $5.0 million per year with $4.76 million of the benefits accruing to El Paso County urban water users and $227k to Socorro, Sierra, Doña Ana and Hudspeth County agricultural users.

Several salinity management alternatives and locations to reduce salinity concentration will be considered in Phase 2. The economic impacts of changes in salinity are non-linear with changes in salinity concentration. The economic benefits of management alternatives will therefore vary depending on the amount and location of salinity reduction.

Preliminary Assessment Limitations and Recommendations

Because of the preliminary scope of this study a number of additional economic impacts are not reflected in these estimates. Salinity damages not estimated in this preliminary study include: (1) higher value crop production that could be adopted with lower salinity, (2) future urban growth and increasing urban use of surface water, (3) opportunity cost of not using all available water such as limitations on water reuse due to elevated salinity, (4) replacement cost of water when treatment plants shut down due to TDS concentration exceeding drinking standards, (5) environmental impacts, (6) salinity damages during the return/low-flow season when no water is released from Rio Grande Project reservoirs, (7) variability in salinity concentrations and chemical components over the water delivery season, (8) damages from potential further increases in levels of salinity and (9) Mexican and downstream impacts. Because these additional economic impacts are excluded from the preliminary assessment, the salinity damages estimated herein are an underestimate but provide insight on the extent of the problem.

Some of the larger underestimated or excluded damages are the impacts on agricultural production, future growth in population and planned increases in urban use of Rio Grande surface water. Results from this preliminary assessment of economic damages suggest that agriculture accounts for about 22 percent of the total, even with approximately 90 percent of the surface water going to irrigation of agricultural lands. However, this is certainly an underestimate in part due to using current agricultural crop production patterns. Because of Rio Grande salinity concentrations, farmers cannot produce higher value, salinity vulnerable crops and must instead grow salt tolerant crops, many of which are lower in value. The preliminary assessment economic impact estimates do not include the reduction in agricultural income from the inability to produce higher value crops because of the salinity concentration.

Further, the estimated damages are for the current population and also do not account for other cities moving more toward use of Rio Grande water. The populations in Texas and New Mexico are projected to double within 50 years, while Ciudad Juarez is expecting to double its population within 20 years (Paso del Norte Water Task Force, 2001). Several cities in the region, including Las Cruces, NM and Ciudad Juarez, MX, are planning for the use Rio Grande surface water for municipal and industrial purposes. The future growth in population and increased use of Rio Grande water for urban supplies would result in much higher economic impacts and make the reduction and management of salinity concentration in the river increasingly important. The issue of global climate change presents a further dynamic factor that may have dramatic implications on water availability, allocation and salinity levels with associated damages.

The following are recommendations to fill-in significant economic impact information gaps, which are believed to substantially underestimate impacts and to refine the assessment analysis to improve evaluation of potential salinity management control alternatives in Phase 2 of the Rio Grande Project Salinity Management Program.

1) Assess the economic damages in agriculture from the inability to grow higher value crops suitable to this climate and soils because of current salinity concentrations.

2) Estimate future economic damages resulting from the projected growth in population in the study area and associated increase in urban use of surface water.

3) Evaluate water supply opportunity costs of reduced reclaimed water use due to physical issues and consumer acceptance problems attributed to elevated salinity.

4) Estimate the water replacement cost impacts when treatment plants must be shut-down due to salinity exceeding drinking water standards.

5) Estimate economic damages to agriculture and urban use from salinity during the low-flow season when no water is released from Rio Grande Project reservoirs.

6) Revise and refine estimates of salinity damages as needed for the five main river reaches using the Phase 1 hydrologic salinity concentration results.

7) Evaluate the economic benefit of selected, screened salinity control management alternatives.

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APPENDIX A

Rio Grande Project Salinity Management Coalition Program Members

Rio Grande Compact Commission
Texas Commissioner
New Mexico Commissioner
Colorado Commissioner

State Water Management Agencies
Texas Commission on Environmental Quality
Texas Water Development Board
New Mexico Interstate Stream Commission
New Mexico Environment Department
Colorado Division of Water Resources

Local Water Utilities and Irrigation Districts
El Paso Water Utilities
Las Cruces Utilities Department
Elephant Butte Irrigation District
El Paso County Water Improvement District No. 1
Hudspeth County Conservation and Reclamation District #1

University Research Organizations
New Mexico State University, Water Resources Research Institute
Texas A&M University, Texas AgriLife Research and Extension Center at El Paso
University of Texas at El Paso, Center for Environmental Resource Management

Other State and Federal Agencies
New Mexico Department of Agriculture
US Bureau of Reclamation
US Geological Survey, New Mexico and Texas Water Science Centers